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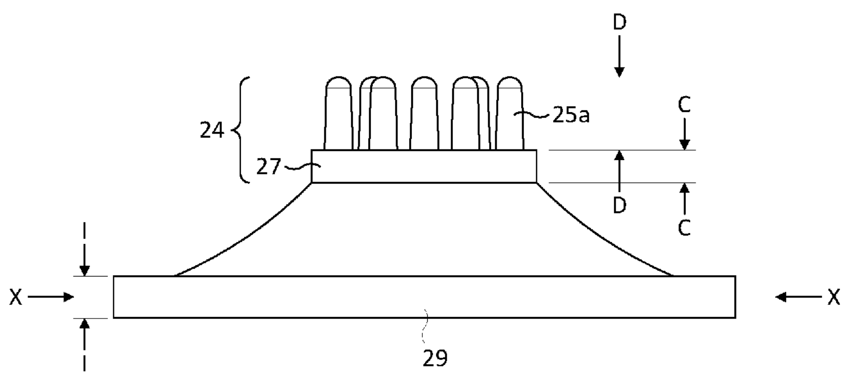

FIG. 3C

(57) Abstract: An EEG sensor comprising conductive contact means and a diaphragm (22). The diaphragm (22) is for mounting on a mounting means having a cavity. The contact means (20) is disposed on the diaphragm (22) for electrical contact with a scalp. The diaphragm is mountable on the mounting means (18) to deform to locate the contact means in the cavity (26, 28) further to an impact force on the contact means towards the cavity. The EEG sensor may form part of an EEG sensor assembly. A plurality of such assemblies may be incorporated in a helmet. The contact means mount and/or the contact portion may be conductive and/or may be formed of polymer-based or silicone-based material.

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EEG SENSOR, ASSEMBLY INCLUDING AN EEG SENSOR AND METHOD OF MANUFACTURE

Field of the Invention

The invention relates to an EEG sensor and to a EEG sensor assembly including such a sensor, particularly for a helmet. The invention also relates to a helmet comprising a plurality of such sensor assemblies, and to a method of manufacture of such a sensor.

Background to the Invention

Use of electroencephalography (EEG) to monitor electrical activity in a brain is well known. EEG measures voltage fluctuations resulting from ionic current within neurons of the brain. Headsets having multiple EEG sensors are well known.

It may be wanted to monitor electrical activity during sport, but use of such headsets during some sporting activities, where there is possibility of hard impact of a wearer's head, is dangerous. Electrodes may embed in the head on impact of the helmet with an external object or person. For example, a known patent publication, EP3219255A1, discloses electrodes formed of metal and mounted on springs for use in headsets, but it is highly undesirable to include such hard metal objects in a helmet due to the risk of such impact. Also, a helmet including such electrodes may not comply with regulations of official sporting bodies. It is an object of the present invention to address these issues.

Summary of the Invention

In accordance with a first aspect of the present invention, there is provided an EEG sensor comprising a conductive contact means and a contact means mount. The contact means is attached to the contact means mount for electrical contact with a scalp. The contact means mount is mountable on a mounting means having a cavity. The contact means mount is configured to deform such that, when so mounted, the contact means locates in the cavity further to an impact force on the contact means towards the cavity.

Where such an impact force is applied by a scalp to the contact means, the contact means is pushed to a position in the cavity so that the scalp is protected from embedding of the contact means. During normal use of the EEG sensor in which electrical activity at the scalp is to be detected, the contact means is projected to press against the scalp.

The contact means mount may be in the form of a diaphragm. This enables the design to be thinner than prior art designs with coil springs, which is particularly important when the EEG sensor is to be incorporated in a helmet.

The contact means mount may be formed of a single piece of material. This, amongst other features, enables a simpler, more reliable design than is known from the prior art. The contact means mount may be moulded.

The contact means mount may have at least one surface for mounting on the mounting means and have a portion on which the contact means is mounted. The contact means mount may be shaped so that when the at least one surface is mounted on the mounting means the portion is further away from a remote end of the cavity than the at least one surface.

The at least one surface may be mountable on the mounting means so that the contact means mount extends across the cavity. The contact means mount is configured to resiliently deform.

The contact means mount may extend between the mounting means and the contact means. The single piece of material may also be mounted on the mounting means to extend across the cavity. The contact means mount may be mounted on the mounting means at outer portions thereof, for example at an outer periphery of the contact means mount.

The portion of the contact means mount on which the contact means is mounted may be a central portion. Material of the contact means mount may extend convexly from the central portion to the outer portions.

The contact means mount may be shaped to actively move the contact means into the cavity after being deformed to a predetermined extent by the impact force. This means that, rather than resistance to location of the contact means into the cavity increasing in dependence on extent of deformation, after the predetermined extent of deformation the contact means mount moves the contact means into the cavity due to its shape and resilient character.

Although not essential, the Shore A hardness of the contact means may be less than about 95. The contact means may have a Shore A hardness in a range from about 60 and about 90. The Shore A hardness of the contact means mount may be less than about 65. The contact means mount may have a Shore A hardness in a range from about 30 to about 60. The hardness of the contact means mount is such that the risk of it embedding in a scalp is low or non-existent.

The contact means mount may be conductive. The EEG sensor may further comprise coupling means for electrically coupling the contact means mount to signal processing circuitry.

At least one of the contact means and the contact means mount may be formed of a polymer-based or silicone-based material. The material may include conductive pieces to make the material conductive. The conductive pieces may comprise chopped carbon fibres. The contact means mount may be formed of a polymer-based material and said material may be formed in a process in which a mixture of polyurethane and conductive pieces is cured. The conductive pieces may comprise about 4% to about 9% of the mixture.

There may be provided an EEG sensor assembly comprising the EEG sensor and the mounting means. A thickness of the mounting means under an impact force is at least sufficient to accommodate the contact means. The mounting means may be compressible for impact absorption.

The mounting means may provide a mounting surface on which the contact means mount is mounted, wherein the mounting surface is disposed to face the scalp.

In the EEG sensor assembly, the mounting means may comprise a mounting layer and a cushioning layer. The mounting surface may be on the mounting layer. The cushioning layer may be attached to the mounting layer, have a contact surface facing the scalp and be arranged to expose the mounting surface on which the contact means mount is mounted. The cushioning layer may provide a hole that forms part of the cavity and the contact means may project towards the scalp via the hole.

According to a second aspect of the present invention, there is provided a method of making a contact means mount for an EEG sensor, comprising: moulding a predetermined material to a shape to form the contact means mount, curing the material and joining the cured material to a conductive contact means, the contact means being for contact against a scalp, wherein the contact means mount is mountable on a mounting means having a cavity and is configured to deform such that, when so mounted, the contact means locates in the cavity further to an impact force on the contact means towards the cavity. The contact means mount may be a diaphragm.

There may be provided a method of making an EEG sensor comprising this method and further comprising: moulding a predetermined a further material to a shape to form the contact means.. .

The contact means mount may have a mounting plane and be configured to project the contact means away from the plane. The contact means mount may be configured to flex/deform further to an impact event on the contact means towards or through the plane.

The method may further comprising attaching the contact means mount to the mounting means such that the contact means mount projects the contact means away from the cavity and such that the contact means mount can flex further to impact on the contact means towards the cavity so that the contact means is located in the cavity.

The contact means may be located in a mould with the material. In this case the material may be partially or wholly cured in the mould with the contact means such that the material and the contact means bond. The further material of the contact means may be located in a mould with the contact means material when the further material is partially or fully cured.

The contact means and the contact means mount may be formed of polymer-based or silicone based material. Where the contact means and the contact means mount are formed of polymer-based material, they may be formed by curing a mixture of polyurethane and conductive pieces. The conductive pieces comprise chopped carbon fibres. The conductive pieces may comprise about 4% to about 9% of the mixture.

The Shore A hardness of the contact means mount may be less than about 65. Preferably, the contact means has Shore A hardness in a range from about 60 and about 90. Preferably, the contact means mount has Shore A hardness in a range from about 30 to about 60.
The EEG sensor made according to the second aspect may include any of the features set out above in relation to the first aspect.

According to a third aspect of the present invention, there is a contact means mount for an EEG sensor, comprising a diaphragm, the diaphragm enabling fixing thereto of a conductive contact means for electrical contact with a scalp, wherein the diaphragm is mountable on a mounting means having a cavity and is configured to deform such that, when so mounted, the contact means locates in the cavity further to an impact force on the contact means towards the cavity. The contact means mount may include any of the features set out above in relation to the first and second aspects attributed to the contact means mount.

Brief Description of the Figures

For better understanding of the present invention, embodiments will now be described, by way of example only, with reference to the accompanying Figures in which:

Figure 1 is an illustrative cross-sectional view of a helmet including a sensor assembly in accordance with an embodiment of the invention;

Figure 2 is an illustrative view of parts of the sensor assembly;

Figures 3A, 3B and 3C are respectively perspective, plan and side views of a variant sensor that may be included in the sensor assembly illustrated in Figure 1;

Figure 4A and 4B are respectively underside and cross-sectional views of a plurality of the sensor assemblies having mounting and cushioning layers each formed of respective single piece of material; and

Figures 5 is a diagram of elements of signal processing circuity for use with sensor assemblies in a helmet.

The Figures are to aid in understanding of the present invention and parts shown therein are not necessarily to scale.

Detailed Description of Embodiments

Like parts are indicated with like reference numerals throughout.

Embodiments of the invention relate to an EEG sensor and a sensor assembly including such a sensor, for a helmet, configured to avoid harm being caused by the sensor to a scalp of a wearer when an impact event occurs. Embodiments of the invention may specifically relate to a contact means mount for such a sensor.

Referring to Figure 1, in an embodiment of the invention a helmet 10 comprises a body 12, a visor 14, a sensor assembly, signal processing circuitry and a housing 16. The body 12 has an aperture 19 therethrough and a coaxial cable 17 extends from the sensor assembly to the signal processing circuitry through the aperture 19.

The helmet 10 is illustrated in Figure 1 as comprising only a single sensor assembly for ease of illustration, but embodiments of the invention typically comprise a plurality of such assemblies in an array. A plurality of coaxial cables 17 may extend from the signal processing circuitry to such a plurality of sensor assemblies through the aperture 19. Alternatively, there may be a plurality of spaced apertures 19, each allowing a respective coaxial cable 17 to extend from the signal processing circuity to a respective sensor assembly.

Referring also to Figure 2, the sensor assembly includes a mounting layer 18, a cushioning layer 20 and an EEG sensor. The sensor comprises a flexible, conductive contact portion mount in the form of a diaphragm 22, and a conductive contact means for contact with a scalp 21 in the form of contact portion 24. The sensor can conduct electrical signals carrying information on electrical activity at the scalp 21.

A first surface of the mounting layer 18 is attached to the body 12 by an adhesive, or in variant embodiments by other suitable means such as a mechanical fixing. The mounting layer 18 is formed of a material that may resiliently compress to absorb impact in an impact event and is preferably flexible for ease of attachment of the mounting layer 18 onto the body 12, such as a rubber material. In variant embodiments, the mounting layer 18 may alternatively be formed of an inflexible material, and may be moulded to conform with the shape of an interior surface of the body 12, so that flexibility is not needed for mounting. In other variant embodiments, the mounting layer 18 may be substantially incompressible. In one such embodiment the mounting layer 18 may be integrally formed with the body 12 of the helmet 10, in which case the mounting layer 18 is formed of the same hard material as the body 12. The mounting layer 18 and at least some of the body 12 may be 3D printed.

The cushioning layer 20 is disposed between the mounting layer 18 and the scalp 21. The cushioning layer 20 is attached to the mounting layer 18 by an adhesive, or in variant embodiments by other suitable means such as a mechanical fixing. A contact surface 23 of the cushioning layer 20 is for location against the scalp 21. The cushioning layer 20 is formed of a resiliently compressible material, for example a foam material. Preferably, the material of the cushioning layer 20 is more compressible than the material of the mounting layer 18. In an example, a thickness of the mounting layer 18 indicated at A-A is 4mm and a thickness of the cushioning layer 20 indicated at B-B is 4mm. In variant embodiments, these thicknesses may have different values and may be different from each other. A wearer may require a larger helmet than usual to accommodate such a compressible layer and the mounting layer 18.

An impact event occurs when the wearer is involved in a crash or other impact, where an impact force is exerted by the scalp 21 on the contact portion 24, pushing the contact portion 24 towards the mounting layer 18. Such a force may be exerted from the contact portion 24 pushing on the scalp 21, or from the scalp 21 pushing on the contact portion 24. The impact force is greater than forces exerted by the scalp 21 on the contact portion 24 during normal, non-impact event movements that occur while wearing the helmet, that is, the impact force is greater than a predetermined force that is greater than such forces.

A wearer of the helmet 10 may wear a balaclava and in this case the contact portion 24 is configured to penetrate through the balaclava. References herein to contact with the scalp or to an impact force exerted by the scalp should be understood to encompass where a balaclava or like material is located between the helmet 10 and the scalp 21.

The helmet 10 has a particular orientation in which it is typically used and in such an orientation the contact portion 24 is projected generally downwardly towards the scalp 21 of the wearer. The terms “underside”, “downwardly” and like terms as used herein are to be understood accordingly. This is despite the contact portion 24 in Figure 3A projecting upwardly.

In the example sensor illustrated in Figure 2, the contact portion 24 has a base 27 and a plurality of prongs 25 projecting from the base 27. The diaphragm 22 has a central portion and an outer portion in the form of an annular outer periphery 29 with material extending between the central portion 31 and the outer periphery 29. The central portion of the diaphragm is fixed to the base 27. The prongs 25 are intended for dry contact with a scalp, but in variant embodiments a scalp 21 may be coated with a conductive paste to enhance electrical contact. The prongs 25 are preferably splayed to improve contact with the scalp 21. The diaphragm includes a peripheral portion 29 and is fixed to a mounting surface (indicated at 33 in Figures 4A and 4B) of the mounting layer 20 so that the diaphragm extends across the recess 26.

Referring also to Figures 3A, 3B and 3C, in an example sensor that is a variant on that shown in Figure 2 the contact portion 24a also comprises a plurality of prongs 25a projecting from a base 27. In the example shown, the base 27 is about 1mm in thickness, indicated at C-C and the prongs 25a have a height, indicated at D-D of about 2mm. The base 27 is not however limited to being made of any particular thickness and the prongs 25a are not limited to being any particular height. For example the prongs 25a may be from about 1mm to 6mm in height. The prongs may be compressible; for example a prong of height 5mm may be compressible to 3mm during an impact event. The prongs 25a may be compressible through their compressibility and/or by virtue of their deformability. While seven prongs 25a are shown in the Figures, embodiments are not limited to any particular number of prongs.

Also, the base 27 may have diameter, indicated at E-E, of about 11mm, the diaphragm 22 may have a diameter of 30mm, indicated at F-F, and the diameter of the diaphragm 22 excluding the outer periphery 29 may be 24mm, indicated at G-G, Embodiments are not limited to these dimensions. All these dimensions may be varied, for example in view of desired characteristics of the sensor and materials used in the sensor.

Material of the outer periphery 29 may be thicker than the material between the outer periphery 29 and the central portion 31 for lateral rigidity. The thickness of the outer periphery 29, indicated at I-I, may be 2mm for example. The contact portion 24 is fixed to the central portion 31. An underside surface of the diaphragm 22 extends convexly between the periphery 29 of the diaphragm 22 and the central portion 31. The diaphragm 22 is shaped and disposed to project the prongs 25a towards the scalp and to bias the prongs 25 against the scalp 21.

Referring to Figures 4A and 4B, the mounting layer 18 and the cushioning layer 20 together provide a cavity from which the contact portion 24 projects. The cavity comprises a cylindrical recess 26 in the mounting layer 18 and a cylindrical hole 28 through the cushioning layer 20. The recess 26 has a lesser diameter than the hole 28 and the recess 26 and the hole 28 are aligned. Thus, an annular surface portion 33 of the mounting layer 18 is exposed.

A surface of the outer periphery 29 of the diaphragm 22 and the annular surface portion 33 each have hook and loop material 30 (indicated at in Figure 1) fixed thereon enabling mutual attachment and detachment. Thus, the diaphragm 22 is mounted in the hole 28 on the annular surface portion 33 of the mounting layer 18. In variant embodiments, the hole 28 is not cylindrical, but is otherwise shaped to expose a surface portion on the mounting layer 18 on which the diaphragm 22 is mounted.

A portion of the hook and loop material 30 (illustrated in Figure 1) covering a section of the annular surface portion 33 is electrically conductive, whereas the rest is substantially not electrically conductive. In variant embodiments, the surface of the outer periphery 29 of the diaphragm 22 may be otherwise fixed to the surface portion 33, detachably or permanently. For example, the outer periphery 29 of the diaphragm may be adhered to the annular surface portion 29 using an adhesive, where at least a portion of the adhesive is a conductive adhesive, or by other suitable mechanical or chemical means.

A cable loop (not shown) is electrically coupled to the conductive portion of the hook and loop material 30 on the annular surface portion 33. The coaxial cable 19 is electrically coupled to the cable loop, such that the coaxial cable 19 can receive signals via the cable loop 35 and the conductive portion of the hook and loop material.

Alternative means to electrically couple the diaphragm 22 to the coaxial cable 19 may be provided in variant embodiments. The diaphragm 22 has a first side disposed to face the scalp 21 in use. Such means are preferably electrically coupled to the second side of the diaphragm, such that, in the event of impact, the diaphragm 22 is between the electrical coupling means and the scalp 21. For example, a wire may simply be affixed to the diaphragm 22 at the second side thereof.

Absent force on the contact portion 24, the diaphragm 22 is configured to project the contact portion 24 to a fully projected position in which the central portion 31 of the diaphragm 22 extends out of the cushioning layer 20, away from a remote end of the cavity and beyond the contact surface 23.

The diaphragm 22 and the contact portion 24 are configured to enable the contact portion 24 to be partially depressed due to normal, non-impact event movements of the wearer's head and due to curves of the wearer's head. The diaphragm 22 is configured to flex under an impact force such that the contact portion 24 is pushed through a plane X-X of the outer periphery 29 of the diaphragm 22, through the hole 28, into the recess 26.

Although not essential in all embodiments, the diaphragm 22 is configured to invert to enable this. In other words, the diaphragm 22 is shaped to actively move the contact portion 24 into the recess 26 after being deformed to a predetermine extent by the impact force. In alternative embodiments, the diaphragm 22 may be configured to depress without inversion.

The material of the mounting layer 18 is such that it cannot compress to greater than a predetermined extent during an impact event. When compressed to this extent, the recess 26 is sufficiently high as to contain the contact portion 24 in a protected position in which it cannot embed in the scalp 21. In some embodiment, the material of both the mounting layer 18 and the cushioning layer 20 are such that they cannot compress together to greater than a predetermined extent during an impact event. When compressed to this extent, the recess 26 and the hole 28 are sufficiently high as to contain the contact portion 24 in the protected position in which embedding in the scalp 21 is not possible.

In variant embodiments, each of the cushioning layer 20 and the mounting layer 18 may be formed of multiple laminated layers. Embodiments of the invention are not limited to any particular construction of the mounting layer 18 and the cushioning layer 20. These layers provide a mounting means for the diaphragm 22 and maintain a thickness in an impact event such that the contact portion 24 is prevented from embedding in the scalp 21. They also preferably compress for comfort of the wearer.

In Figures 4A and 4B, an array of five sensor assemblies are arranged for location in the helmet 10 to detect electrical activity at different portions of the scalp 21. Each of the mounting and cushioning layers 18, 20 for all of the five sensor assemblies 20 is preferably formed of single piece of material. In embodiments, there may be greater than or fewer than five sensors assemblies in the array.

Referring also to Figure 5, the signal processing circuitry comprises a Brain Computer Interface (BCI) board 37 and a circuit board 39 for cable management. The BCI board 37 has a microcontroller 34, and a storage device 44 and a Bluetooth communications module 46 both operatively coupled to the microcontroller 34. The BCI board may include Analogue to Digital (ADC) converters and signal amplifiers (not shown) arranged to process signals received from the sensors. The microcontroller 34 comprises a processor, a memory, a clock, and input/output interfaces operatively connected by a bus. In addition, the signal processing circuity includes a battery 38 and a recharge port 40, both operatively coupled to the microcontroller 34. Computer program codes are stored in the memory which, when executed by the processor, result in the microcontroller 34 performing the steps ascribed to it herein. The BCI board 37 is configured to receive signals from each sensor via the cables 19, to process the signals and to write EEG data to the storage device 44 or transmit the EEG data over Bluetooth ®.

The storage device 44 may comprise any kind of computer readable storage medium(s). The storage device 44 may be, by way of non-exhaustive example be one or more of: a hard disk, an erasable programmable read-only memory (EPROM or Flash memory), an SD card, an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store data.

The communications module 46 may alternatively or additionally be configured for communication using a suitable short range radio communications technology other than Bluetooth®, such as Wi-Fi®, or for communication with a remote device using a cellular communications network. The communications module 46 may be otherwise configured for transmission using alternative communications technologies.

In operation of the sensor assembly, before an impact event, the diaphragm 22 is shaped so that the contact portion 24 is projected in a projected position, to bias against the scalp 21. The diaphragm 22 and the contact portion 24 may deform during normal, non-impact movements, such that the contact portion 24 is partially depressed but remains projecting from the hole 28. The resilient nature of the diaphragm 22 and the contact portion 24 also permit small lateral and rotational movements of the scalp 21 without the contact portion 24 significantly moving from a particular contact position on the scalp 21. Electrical signals from the scalp 21 are conducted through the contact portion 24, the diaphragm 22, the conductive section of the hook and look material 30, through the coaxial cable 19, to the signal processing circuitry 15, where they are stored and/or transmitted under the control of the microcontroller 23.

When an impact event occurs, the contact portion 24 is pushed and the cushioning layer 20 is compressed. The diaphragm 22 is deformed such that the contact portion 24 passes an inversion threshold position. The diaphragm 22 then inverts to move the contact portion 24 into the recess 26. The diaphragm 22 may return to its normal position in which the contact portion 24 is projected due to its own resilience after the impact force has been removed, or the helmet 10 may be removed and the diaphragm 22 returned to its normal position using one or more tools.

In variant embodiments, the diaphragm 22 may be electrically non-conductive. In this case, an electrical coupling is provided between the cable contact and the contact portion 24, for example a wire.

The contact portion 24 is preferably formed of a single piece of a first material. Alternatively, the contact portion may be formed from two or more pieces formed all from the first material or from different materials which may or may not include the first material, such two or more pieces being attached together by mechanical or chemical attachment means, for example by a mechanical fixing or an adhesive.

The diaphragm 22 is preferably formed of a single piece of a second material. Alternatively, the diaphragm 22 may be formed from two or more pieces formed all from the second material or from different materials which may or may not include the first material, such two or more pieces being attached together by mechanical or chemical attachment means, for example by a mechanical fixing or an. The first and second material may be the same material or different materials.

In an example manufacturing process, the diaphragm 22 and contact portion 24 are formed in multiple steps. In a first step the contact portion 24 is formed in a first mould of the first material and cured. In a second step, diaphragm 22 is also formed in a second mould of the second material and cured. The base of the cured contact portion 24 and the cured diaphragm 22 are then adhered together or otherwise affixed by chemical or mechanical means. Optionally, a conducting layer, for example of silver, may be applied between the contact portion 4 and the diaphragm 22 for improved conductivity between the two parts. In a variant process, in the second step the cured contact portion 24 and the second material are located together in a variant second mould and the diaphragm 22 is formed against the contact portion 24 and chemically bonded to it. In this process case the contact portion may be only partially cured (i.e. be tacky) when located in the second mould and the contact portion 24 and the diaphragm 22 may be fully cured together.

The first material is such that the Shore A hardness when the first material is cured is at least about 55 and is less than about 90. Preferably, the cured first material has a Shore A hardness of at least about 60 and less than about 90. In alternative embodiments, the contact portion 24 may be formed of a material having a Shore A hardness greater than 90, such as a conductive metal.

The second material is such that the Shore A hardness when the second material is cured is at least about 25 and is less than about 65. Preferably, the cured second material has a Shore A hardness of at least about 30 and less than about 60.

The word “about” with reference to Shore hardness should be understood as meaning 0.5 above or below the stated value.

The cured materials from which the diaphragm 22 and the contact portion 24 are formed are conductive and based on polyurethane. In alternative embodiments, other polymer-based materials may be used instead, for example silicone. Other suitable conductive and resiliently deformable materials may be known to persons skilled in the art and embodiments of the invention are not limited to use of particular materials.

In example processes, the first material is a mixture of polyurethane 60 shore (Shore A) or polyurethane 90 shore (Shore A), and chopped carbon fibre pieces, where the chopped carbon fibre pieces constitutes about 6% of the mixture by weight. The second material may be, for example, a mixture of PU30 Shore (Shore A) and carbon fibres, which may be chopped or unchopped. Where the second material includes chopped carbon fibres, the size of the chopped pieces in the first material may be less than in the second material. Before mixing the carbon fibre pieces may be soaked in alcohol.

In an alternative process, the contact portion 24 and the diaphragm 22 are formed together in a single mould from the same material. In an example, the material may be a mixture of polyurethane 60 shore, and chopped carbon fibre, where the chopped carbon fibre is about 6% of the mixture. In tests using the example materials, the sensor 20 and diaphragm when made from the same material had better conductivity but lower flexibility than when made in the two-step process.

In variant embodiments, to render the contact portion 24 and/or the diaphragm 22 conductive, suitably small pieces of carbon nanotubes and/or graphene fibres may be used instead of or in addition to chopped carbon fibre, for example. Other additives may be used in other variant embodiments. Fine conductive metal fibres, for example of silver, may be included without detracting from the resilient flexibility of the contact portion 24 and/or the diaphragm 22. Alternatively, the contact portion 24 and the diaphragm 22 may not include any metal. In variant embodiments in which the contact portion 24 and/or the diaphragm 22 is formed of silicone-based material, any of the above mentioned additives, including chopped carbon fibre, carbon nanotubes and/or graphene may be used. The silicone based material may be silicone RTV 240 or Silicone RTV 133.

In alternative embodiments, the contact portion 24 and/or the diaphragm 22 may be formed using alternative manufacturing methods. One or both may not be formed in a mould. For example, one or both may be 3D printed and materials selected suitable for 3D printing.

Embodiments of the invention relate to use of the sensor assemblies described above in helmets. Such helmets may be for use in sport, for example in motorsports involving vehicles or motorbikes. Such helmets may be for use when cycling, football, hockey, baseball, softball, skateboarding, inline skating, skiing, snowboarding, hang-gliding and parachuting for example. Helmets may be used in many other sports. Embodiments are also not limited to use in helmets for sport. Helmets including such sensor assemblies may usefully be worn during non-sporting activities, for example by soldiers and pilots.

During normal use of the sensor, that is, when the contact portion 24 is biased against the scalp and in which there is not an impact event, the contact portion 24 is in a spaced relationship from the surface of the periphery 29 that attaches to the surface portion 33 of the mounting layer 18, in a manner orthogonal with respect to the mounting surface 18. The surface of the peripheral portion 29 defines a mounting plane spaced from the mounting surface 33.

Various modifications may be made to the embodiments and variants thereon described above within the scope of the claims, as will be clear to the person skilled in the art.

Embodiments of the invention are not limited to a diaphragm 22 that has a circular outer periphery. The diaphragm may be otherwise shaped. For example, the diaphragm may be rectangular. Embodiments are also not limited to the diaphragm being attached to the mounting layer 18 around the entirety of its circumference. For example, where the diaphragm is rectangular, the diaphragm may be attached at one pair of parallel sides thereof. The diaphragm may be fixed to the mounting layer 18 only to such an extent that its function can be performed in projecting the contact portion 20 and enabling movement of the contact portion 20 into the cavity further to an impact event.

The surface or surfaces of the peripheral portion 29 of the diaphragm 22 that attach to the surface portion 33 of the mounting layer 18 are preferably in a mounting plane, although this is not essential to all embodiments. Instead the mounting layer 18 may provide a stepped mounting surface and a variant diaphragm may include surfaces in different planes for mounting on such a stepped mounting surface. Embodiments of the invention are not limited to any particular configuration of mounting layer 18 and diaphragm 22 configured to mount on such a mounting layer 18.

Embodiments of the invention are also not limited to a diaphragm 22 that covers the whole of the opening of the cavity in the mounting layer 18. The diaphragm may extend partially over the opening of the cavity. The diaphragm may be in the form of a strip that extends partially or wholly across the cavity. Such a strip may or may not retain the contact portion 20 projected away from an opening to the cavity.

In this disclosure, unless stated to the contrary, the disclosure of alternative values for the upper or lower limit of the permitted range of a parameter, coupled with an indication that one of said values is more highly preferred than the other, is to be construed as an implied statement that each intermediate value of said parameter, lying between the more preferred and the less preferred of said alternatives, is itself preferred to said less preferred value and also to each value lying between said less preferred value and said intermediate value.

Unless otherwise stated, all individual features and/or steps of all embodiments described herein are disclosed in isolation and any combination of two or more such features is also disclosed, to the extent that such features or steps or combinations of features and/or steps are capable of being carried out based on the present specification as a whole in the light of the common general knowledge of a person skilled in the art, irrespective of whether such features or steps or combinations of features and/or steps solve any problems disclosed herein.

CLAIMS

1. An EEG sensor comprising:
conductive contact means;
a diaphragm, the contact means attached to the diaphragm for electrical contact with a scalp, wherein the diaphragm is mountable on a mounting means having a cavity and is configured to deform such that, when so mounted, the contact means locates in the cavity further to an impact force on the contact means towards the cavity.

2. The EEG sensor of claim 1, wherein the at least one surface is mountable on the mounting means so that the diaphragm extends across the cavity.

3. The EEG sensor of claim 1 or claim 2, wherein the Shore A hardness of the diaphragm is less than about 65.

4. The EEG sensor of any one of the preceding claims, wherein the diaphragm is configured to resiliently deform.

5. The EEG sensor of any one of the preceding claims, wherein the diaphragm is formed of a single piece of material.

6. The EEG sensor of any one of the preceding claims, wherein the diaphragm is conductive.

7. The EEG sensor of claim 6, further comprising signal carrying means electrically coupled to the diaphragm, wherein a first side of the diaphragm is for facing a scalp, and wherein the signal carrying means is electrically coupled to the diaphragm at a second side of the diaphragm opposite the first side.

8. The EEG sensor of any one of the preceding claims, wherein the diaphragm has at least one surface for mounting on the mounting means and has a portion on which the contact means is mounted, wherein the diaphragm is shaped so that when the at least one surface is mounted on the mounting means the portion is further away from a remote end of the cavity than the at least one surface.

9. The EEG sensor of any one of the preceding claims, wherein the diaphragm has an outer portion having the at least one surface.

10. The EEG sensor of claim 9, wherein the portion is a central portion and the contact means projects from the central portion of the diaphragm.

11. The EEG sensor of claim 10, wherein material of the diaphragm extends convexly from the central portion to the outer portion.

12. The EEG sensor of any one of the preceding claims, wherein the diaphragm is arranged to actively move the contact means into the cavity after being flexed to a predetermined extent by the impact force.

13. The EEG sensor of any one of the preceding claims, wherein at least one of the contact means and the diaphragm is formed of a polymer-based or silicone-based material.

14. The sensor of claim 13, wherein the diaphragm is formed of a polymer-based material and said material is formed in a process in which a mixture of polyurethane and conductive fibres is cured.

15. The EEG sensor of claim 14, wherein the conductive fibres comprise about 4% to about 9% of the mixture.

16. The EEG sensor of any one of the preceding claims, wherein the diaphragm has shore hardness in a range from about 30 to about 60.

17. The EEH sensor of any one of the preceding claims, wherein the at least one surface of the diaphragm forms a mounting plane, wherein the diaphragm is configured to deform further to the impact force on the contact means such that the contact means passes through the mounting plane

18. An EEG sensor assembly comprising:

the EEG sensor of any one of the preceding claims;

the mounting means, wherein a thickness of the mounting means under the impact force is at least sufficient to accommodate the contact means further to flexing of the diaphragm under the same impact force.

19. The EEG sensor assembly of claim 16, wherein the mounting means is compressible for impact absorption.

20. The EEG sensor assembly of claim 16 or claim 17, wherein the mounting means provides a mounting surface on which the at least one surface of the diaphragm is mounted, wherein the mounting surface is disposed to face the scalp.

21. The EEG sensor assembly of any one of claims 18 to 20,

wherein the mounting means comprises a mounting layer and a cushioning layer, wherein the mounting surface is on the mounting layer,

wherein the cushioning layer is attached to the mounting layer, has a contact surface facing the scalp and is arranged to expose the mounting surface,

wherein the cushioning layer defines a hole that forms part of the cavity, wherein the contact means is projected towards the scalp via the hole.

22. The EEG sensor assembly of claim 21, wherein the diaphragm, the contact means and the mounting means are configured to cooperate such that the impact force on the contact surface and the contact means compresses at least the cushioning layer and pushes the contact means into the cavity so as not to project from said contact surface.

23. A helmet comprising a plurality of sensor assemblies each in accordance with any one of claims 18 to 22, wherein the mounting means is attached to an interior surface of a body of the helmet.

24. A method of making a contact means mount for an EEG sensor, comprising:

moulding a predetermined material to form a diaphragm, curing the material, and joining the cured material to a conductive contact means, the contact means being for contact against a scalp, wherein the diaphragm is mountable on a mounting means having a cavity and is configured to deform such that, when so mounted, the contact means locates in the cavity further to an impact force on the contact means towards the cavity.

25. The method of claim 24, wherein the Shore A hardness of the diaphragm is less than about 65.

26. A method of making an EEG sensor comprising:

the method of claim 24 or claim 25;

moulding a predetermined further material to form the contact means and curing the further material; and fixing the further material when the further material is at least partially cured to the material.

27. The method of claim 26, wherein the at least partially cured further material of the contact means is located in a mould with the material, wherein the material is cured in the mould with the at least partially cured further material of the contact means such that the material and the further material bond.

28. A contact means mount for an EEG sensor, comprising a diaphragm, the diaphragm enabling fixing thereto of a conductive contact means for electrical contact with a scalp, wherein the diaphragm is mountable on a mounting means having a cavity and is configured to deform such that, when so mounted, the contact means locates in the cavity further to an impact force on the contact means towards the cavity.

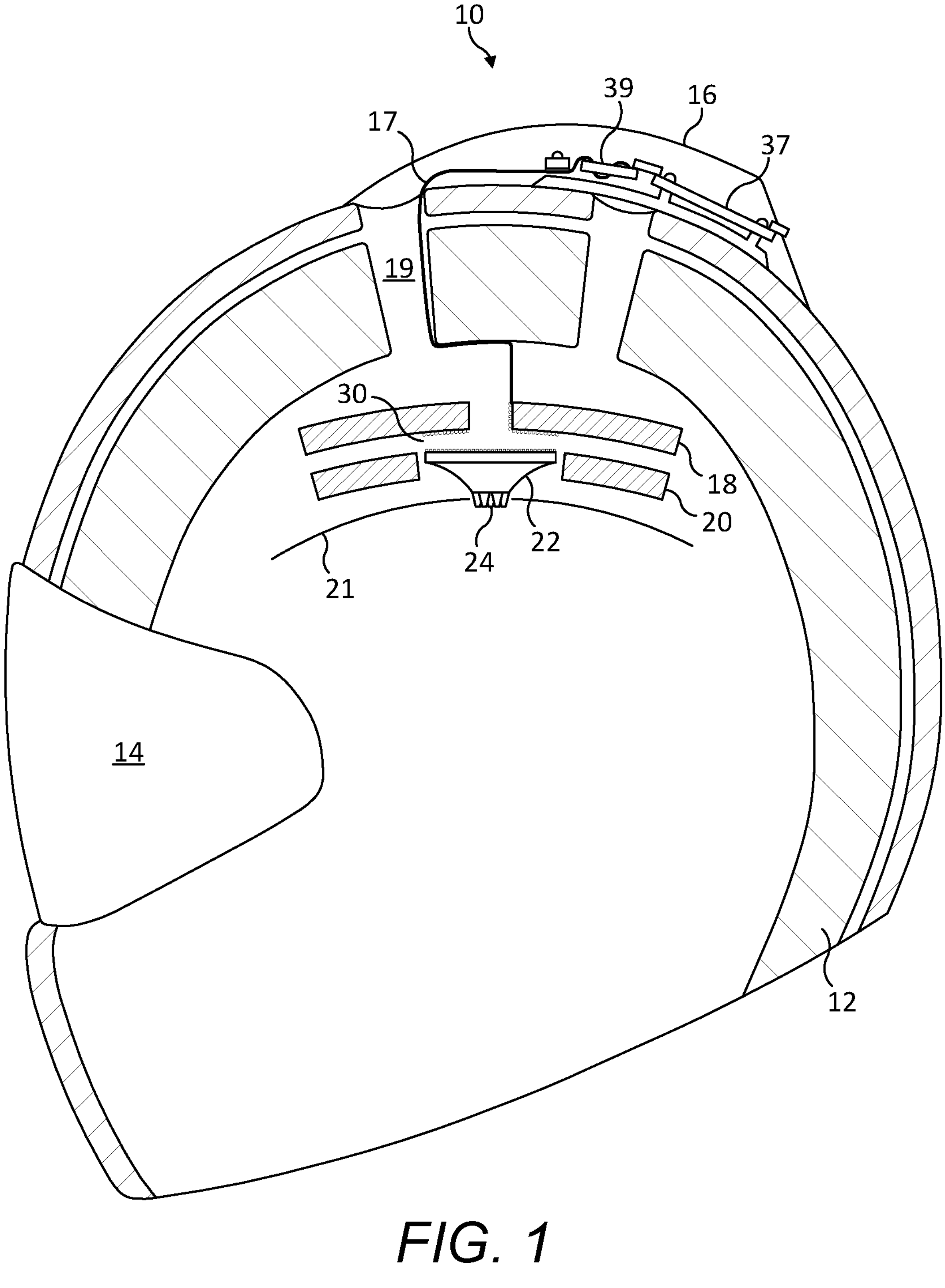

FIG. 1

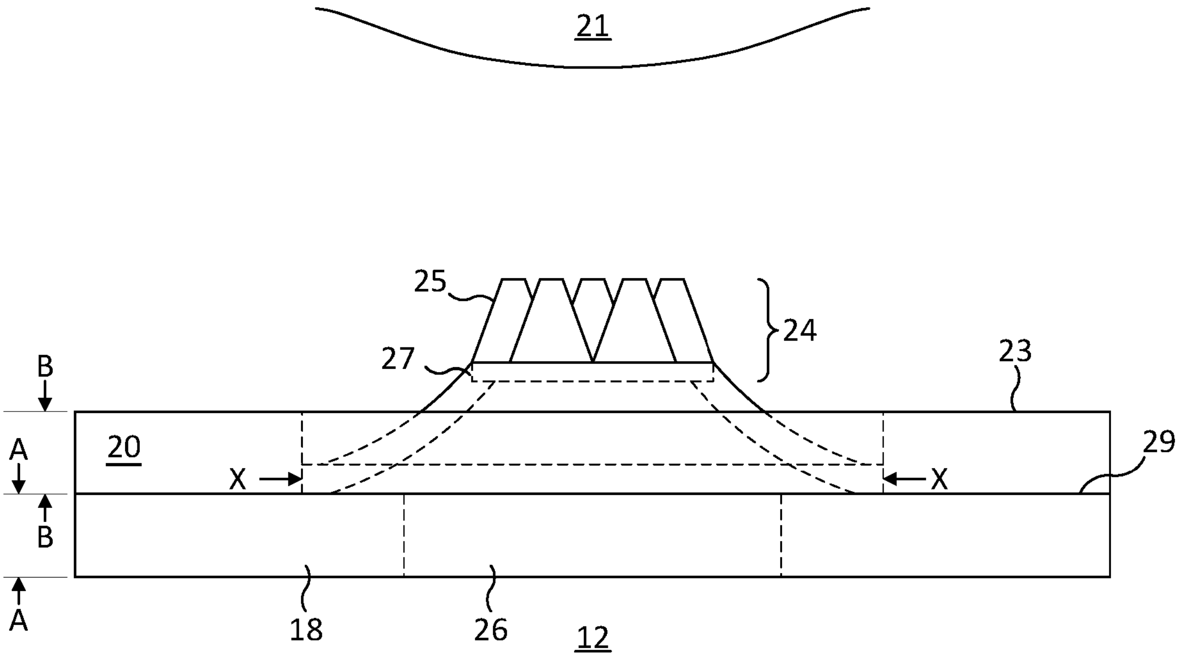

FIG. 2

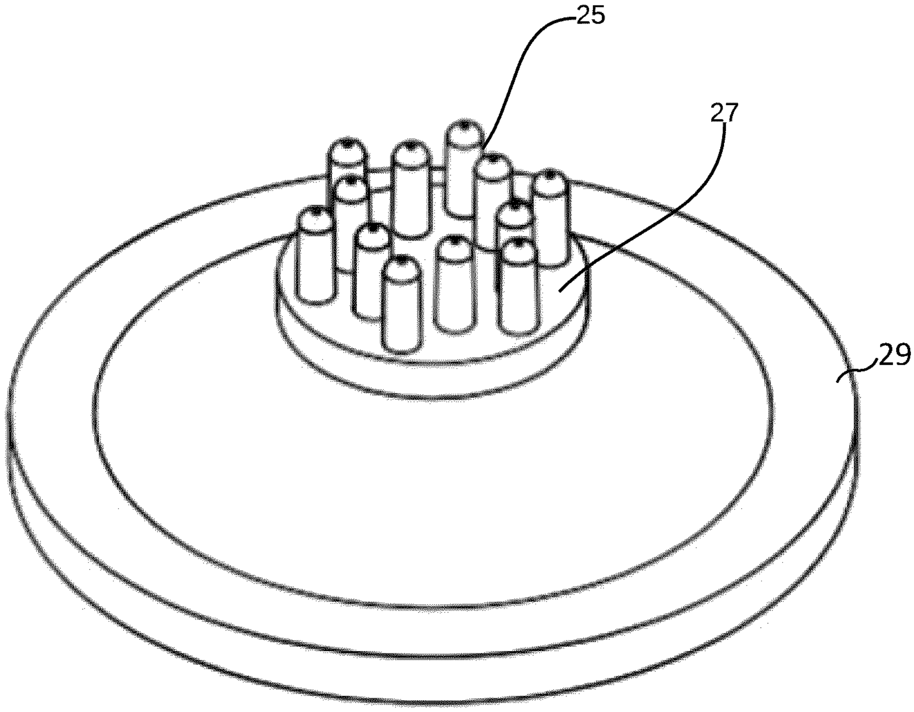

FIG. 3A

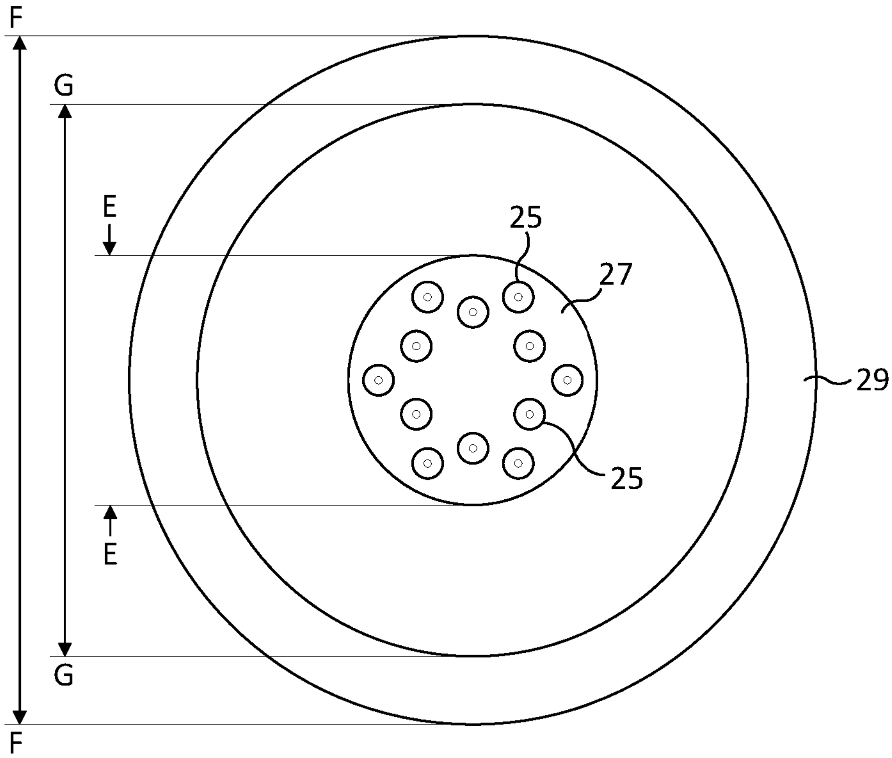

FIG. 3B

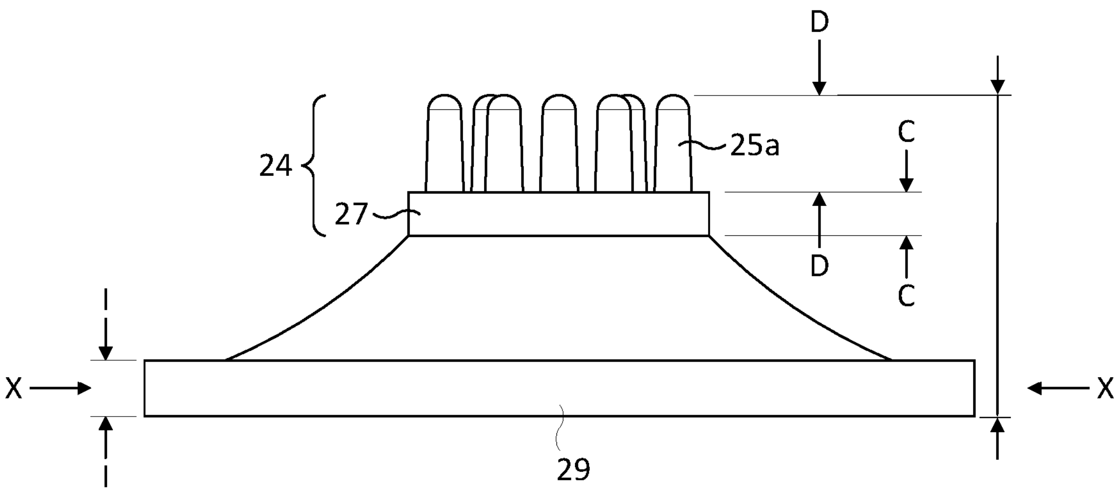

FIG. 3C

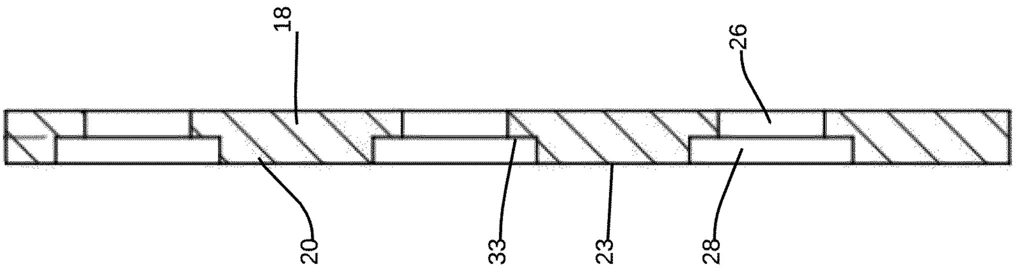

FIG. 4B

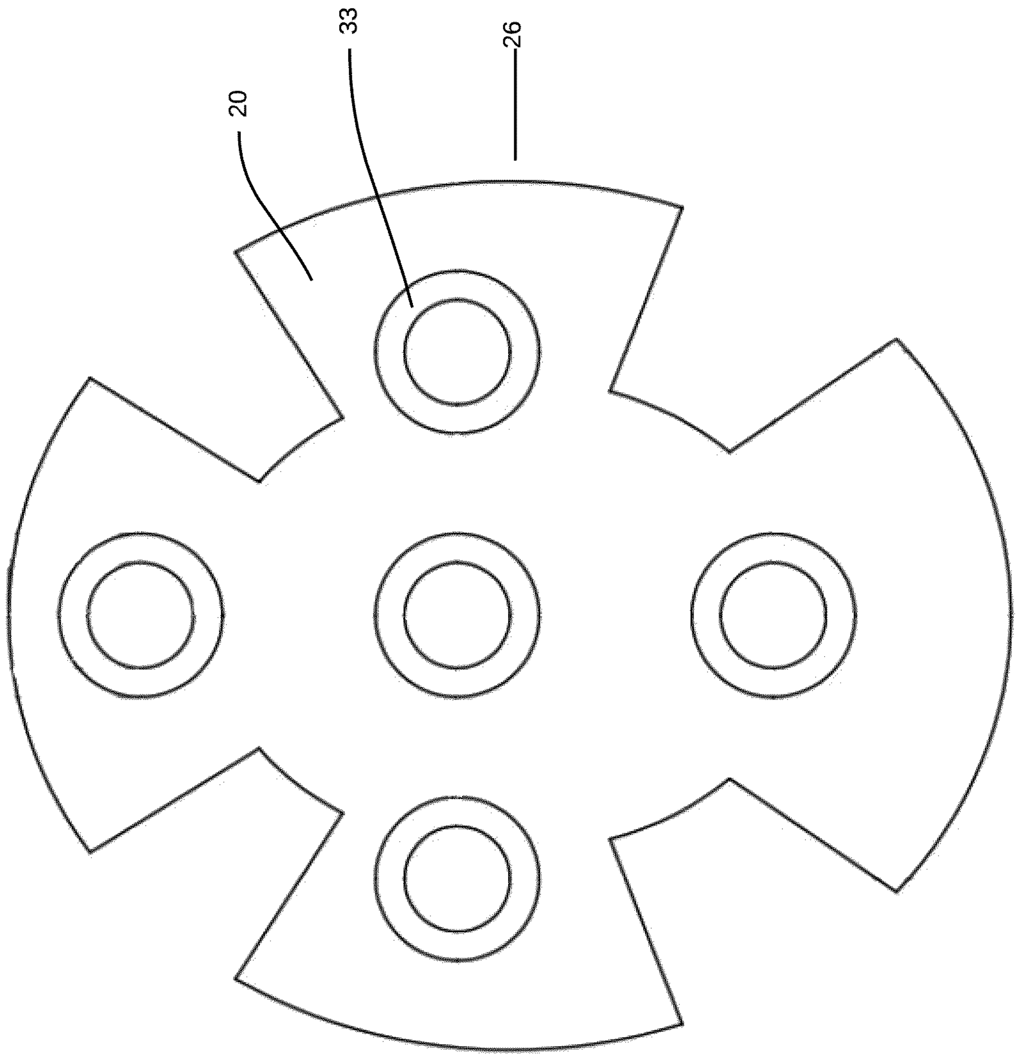

FIG. 4A

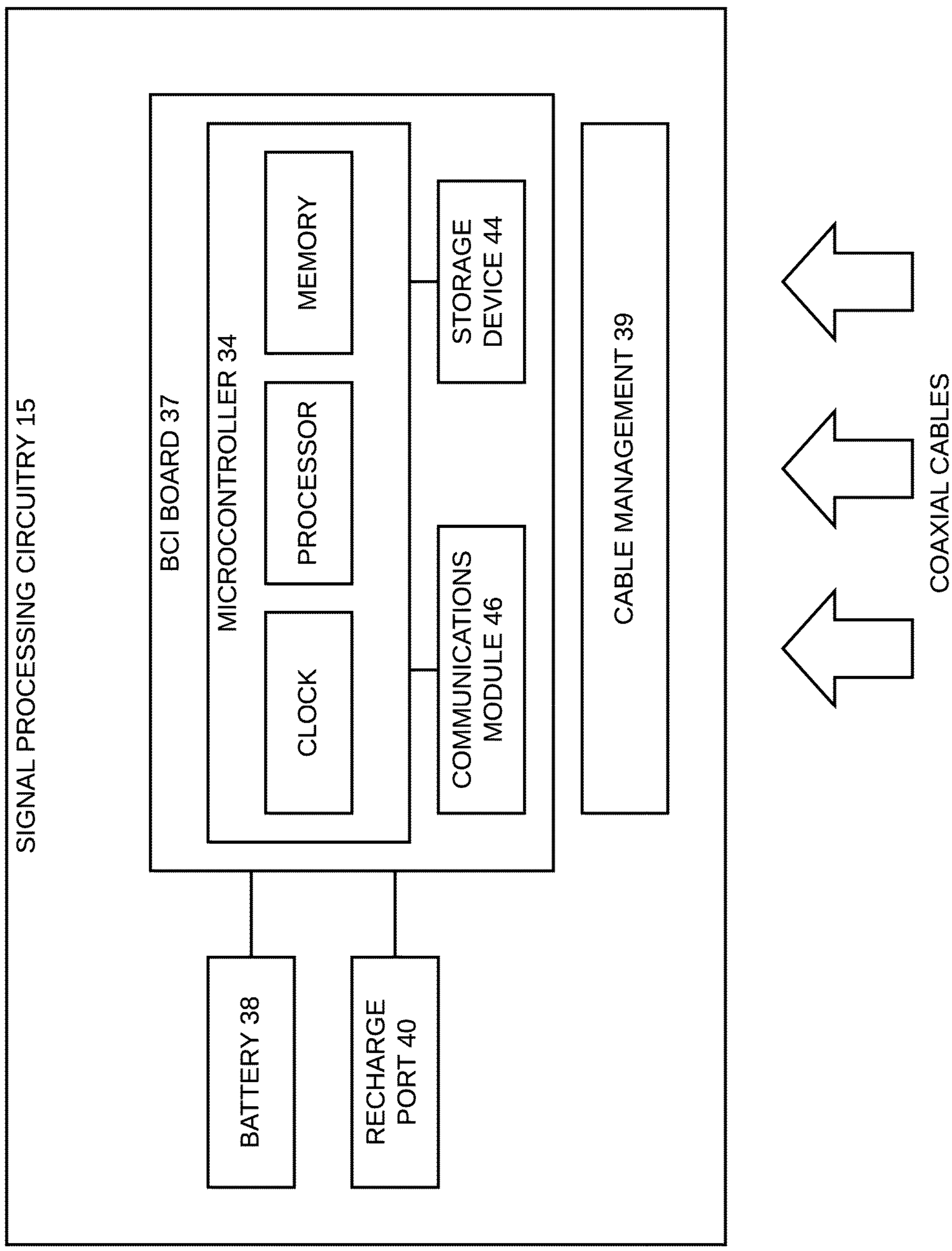
SIGNAL PROCESSING CIRCUITRY 15
BCI BOARD 37
MICROCONTROLLER 34
CLOCK
PROCESSOR
MEMORY
COMMUNICATIONS MODULE 46
STORAGE DEVICE 44
CABLE MANAGEMENT 39
BATTERY 38
RECHARGE PORT 40
COAXIAL CABLES

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/067585

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/251 A61B5/291 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

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.
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Y	column 2, line 47 - line 61	24-27
A	column 7, line 23 - column 8, line 22; figures 8-9	23
X	US 2013/066185 A1 (KERTH TREVOR [US] ET AL) 14 March 2013 (2013-03-14)	1-22,28
A	paragraphs [0005], [0013], [0044] - [0046], [0051]; figures 1,2,8	23-27
X	US 2018/092599 A1 (KERTH TREVOR AUSTIN [GB] ET AL) 5 April 2018 (2018-04-05)	1-22,28
Y	paragraphs [0052] - [0059]; figures 8-10	23
A		24-27

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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 :

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"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
14 October 2021	22/10/2021

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	Dydenko, Igor

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	WO 2017/112368 A1 (3M INNOVATIVE PROPERTIES CO [US]) 29 June 2017 (2017-06-29) page 8, line 4 - page 10, line 19	24-27
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A	pages 8-13; figures 1-7	1,24
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2

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Information on patent family members

International application No
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