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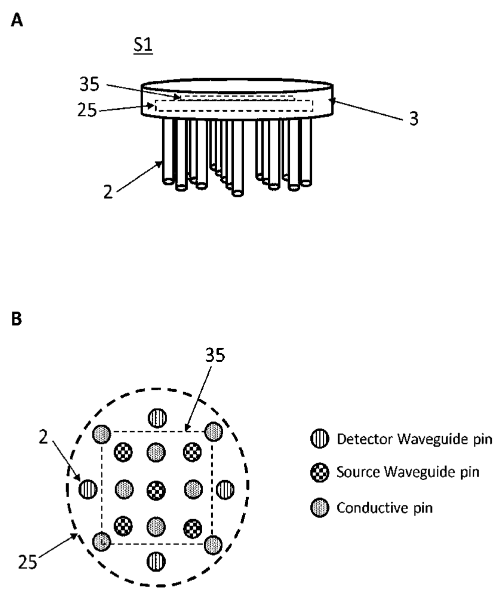
(54) SENSOR, SYSTEM AND HOLDER ARRANGEMENT FOR BIOSIGNAL ACTIVITY MEASUREMENT

(57) A sensor module (S1) for biosignal activity measurement, comprising a main electrode base (3) and a plurality of pins (2) protruding from that main electrode base, configured such that, when applied on a subject, the pins (2) make contact or are in close proximity to the subject's skin, and wherein the electrode base (3) comprises electronic circuitry for biosignal measurement, said electronic circuitry being connected to said plurality of pins (2); and the plurality of pins (2) comprise a number of electrically conductive pins and at least one source waveguide pin configured for light emitting purposes and/or at least one detector waveguide pin configured for light detection purposes.

Figure 2



EP 3 184 043 A1

Description

Technical Field

[0001] The present invention relates generally to non-invasive biosignal activity measurement sensors and systems, including for example, brain activity measurement sensors and systems, such as electroencephalogram (EEG) and near infrared spectroscopy (NIRS) sensors and systems for brain activity measurements.

Background

[0002] There is currently an interest for the development of portable, lightweight an non-invasive biosignal activity measurement systems for monitoring biosignals and more specifically the neurophysiological activity of subjects in operational, clinical and research environments. For example, the simultaneous use of electroencephalographic (EEG) acquisition with functional near infrared spectroscopy (fNIRS) has been shown advantageous in order to provide a better understanding of the mechanisms involved in cerebral activation, since such techniques provide complementary information from the brain in terms of temporal and spatial resolution.

[0003] Patent application US 2014/0018640 A1, for example, describes a holder set and a brain function measuring device capable of executing measurements by an optical bioinstrumentation device (e.g. fNIRS) and by a an electroencephalograph (EEG) at the same time.

[0004] Report document "Concurrent EEG and NIRS tomographic imaging based on wearable electro-optodes", by Tzyy-Ping Jung et al., University of California - San Diego La Jolla, 13-04-2014, describes a dual-modality neuroimaging system with EEG/NIRS electrodes, known as electro-optodes, that allow non-invasive and non-intrusive acquisition of EEG and fNIR signals. The developed brain activity sensor combines the capability of simultaneously recording both EEG and fNIRS signals from the same site by integrating both EEG electrode and NIR probe into one electro-optode.

Summary

[0005] The present invention provides for a new and advantageous sensor module that can be applied, for example, to dual-modality EEG and fNIRS brain activity measurement.

[0006] The scope of the invention is defined by the claims.

[0007] According to an exemplary embodiment, there is provided a sensor module for biosignal activity measurement, comprising a main electrode base and a plurality of pins protruding from that main electrode base, configured such that, when applied on a subject, the pins make contact or are in close proximity to the subject's skin, and wherein the electrode base comprises electronic circuitry for biosignal measurement, said electronic circuitry being connected to said plurality of pins; and the plurality of pins comprise pins that can conduct both light and electricity.

[0008] According to an exemplary embodiment, the plurality of pins comprise an outer electrically conductive surface or layer with an inner waveguide core.

[0009] According to an exemplary embodiment, the outer electrically conductive layer is a conductive mesh.

[0010] According to an exemplary embodiment, the conductive mesh comprises a woven fabric, comprising a plurality of conductive wires or fibres designed for being flexible and ensuring conductivity of the pins.

[0011] According to an exemplary embodiment, the inner core comprises a transparent silicone.

[0012] According to an exemplary embodiment, the plurality of pins comprise a material that can conduct both light and electricity.

[0013] According to another exemplary embodiment, there is provided a compact EEG and fNIRS sensor for brain activity measurement that advantageously avoids the need for long connecting light fibres, costly lasers and large power supplies. According to an embodiment, the proposed EEG and fNIRS sensor may be integrated in a holder arrangement and communicate wirelessly with other sensors and/or system control modules, which allows for wearable applications and comfort during long term use. Also according to an embodiment, the EEG and fNIRS sensor may advantageously consume low power and be cheaper to implement.

[0014] According to an embodiment, there is provided a compact EEG and fNIRS sensor for brain activity measurement that advantageously can acquire fNIRS and EEG signals simultaneously, from the same brain region. Furthermore, according to an embodiment, the sensor module comprises a plurality of flexible pins for electrical conduction and/or light guidance that advantageously adapts to the scalp of a subject and allows for better quality measurements, where hair may block the light path. The pins advantageously separate de hair and provide optical isolation.

[0015] According to an exemplary embodiment, there is provided a sensor module for brain activity measurement, comprising a main electrode base and a plurality of pins protruding from that main electrode base, configured such that, when applied on a subject, the pins make contact or are in close proximity to the subject's skin, and wherein the electrode base comprises electronic circuitry for NIRS and EEG measurement, said electronic circuitry being connected to said plurality of pins; and the plurality of pins comprise a number of electrically conductive pins and at least one source waveguide pin configured for light emitting purposes and/or at least one detector waveguide pin configured for light detection purposes.

[0016] According to an exemplary embodiment, the electrical conductive pins are connected to EEG measurement circuitry and the at least one source and/or detector waveguide pins are connected to NIRS measurement circuitry.

[0017] According to an exemplary embodiment, the EEG and NIRS measurement circuitry is integrated in an ASIC located on a PCBA inside or connected to the electrode base.

[0018] According to an exemplary embodiment, the NIRS measurement circuitry comprises at least one light emitting circuit including a LED and at least one light detection circuit including a photo detector.

[0019] According to an exemplary embodiment, the photo detector is a Silicon Avalanche photo diode (SiAPD).

[0020] According to an exemplary embodiment, the NIRS measurement circuitry is configured for controlling the light emitting and detection circuits such as to create a plurality of source-detection pairs.

[0021] According to an exemplary embodiment, the plurality of pins comprise pins that can conduct both light and electricity and can be configured for EEG and/or NIRS measurement.

[0022] According to an exemplary embodiment, the plurality of pins comprise an outer electrically conductive surface or layer with an inner waveguide core.

[0023] According to an exemplary embodiment, the outer electrically conductive layer is a conductive mesh.

[0024] According to an exemplary embodiment, the conductive mesh comprises a woven fabric, comprising a plurality of conductive wires or fibres designed for being flexible and ensuring conductivity of the pins.

[0025] According to an exemplary embodiment, the inner core comprises a transparent silicone.

[0026] According to an exemplary embodiment, the plurality of pins comprise a material that can conduct both light and electricity.

[0027] The description also relates to an electrode holder for holding a plurality of sensors for biosignal activity measurement according to embodiments herein described.

[0028] The description also relates to a system comprising a plurality of sensors for biosignal activity measurement according embodiments herein described.

[0029] According to an exemplary embodiment, the system further comprises a control module configured for controlling activity and/or receiving measurements from the plurality of sensor modules.

[0030] According to an exemplary embodiment, the control module is further configured for controlling the light emitting and detection circuits of different sensor modules such as to create a plurality of source-detection pairs between light emitting circuits and light detection circuits located in different sensor modules.

[0031] Certain objects and advantages of various new and inventive aspects have been described above. It is to be understood that not necessarily all such objects or advantages may be achieved in accordance with any particular embodiment of the present invention as described in the claims. Those skilled in the art will recognize that the solution as described in the claims may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages without necessarily achieving other objects or advantages.

Brief description of the drawings

[0032] The above and other aspects of the sensor and system for brain activity measurement according to the present invention will be shown and explained with reference to the non-restrictive example embodiments described hereinafter.

Figure 1 shows a schematic of a system, a sensor holder set and a sensor module for biosignal activity measurement according to an exemplary embodiment.

Figures 2A and 2B show a perspective and bottom view of a sensor module for biosignal activity measurement according to a first exemplary embodiment.

Figure 3 shows a bottom view of a sensor module for biosignal activity measurement according to a second exemplary embodiment.

Figure 4 shows a bottom view of a sensor module for biosignal activity measurement according to a third exemplary embodiment.

Figure 5 shows another perspective view of a sensor module for biosignal activity measurement according to a fourth exemplary embodiment.

Detailed description

[0033] In the following, in the description of exemplary embodiments, various features may be 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 is however not to be interpreted as the invention requiring more features than the ones expressly recited in the independent claims. Furthermore, combinations of features of different embodiments and obvious known alternative structural means are meant to be within the scope of the present description, as would be clearly understood and derived by those skilled in the art at the time of the invention. Additionally, in some examples, well-known methods, structures and techniques have not been shown in detail in order not to obscure the conciseness of the description.

[0034] **Figure 1** shows a schematic of a system **100**, a sensor holder arrangement **15** and a sensor module **S1** for biosignal activity measurement, such as brain activity measurement, according to an exemplary embodiment. The system **100** for biosignal activity measurement comprises a holder arrangement **15** so designed, configured and manufactured to be placed over the subject's head and to structurally hold a plurality of sensor modules **S1 to S9** for brain activity measurement. The system **100** comprises a control module **CM** configured for controlling and/or receiving all the measurements from the plurality of sensor modules **S1 to S9.** Said control module **CM** may be located outside the sensor holder arrangement, but may be also located, or at least some control functions, in the sensor holder arrangement **15.** The plurality of sensor modules **S1 to S9** may communicate between them and/or with the control module **CM** by means of electrical wired connections or wireless transmission. According to an embodiment, said control module **CM** may also perform signal processing techniques in order to quantify and/or improve the signal quality of the measurements received.

[0035] According to an exemplary embodiment, each sensor module, such as **S1** in the figure, comprises a printed circuit board assembly (PCBA) **25,** an application-specific integrated circuit (ASIC) **35,** light emitting circuits **L1 to L4** and light detection circuits **P1 to P5**. According to an exemplary embodiment, the ASIC **35** is mounted on the PCBA **25**. According to an embodiment, the light emitting circuits **L1 to L4** and the light detection circuits **P1 to P5** are placed on the PCBA outside the ASIC. According to an exemplary embodiment, the light emitting circuits **L1 to L4** comprise a light-emitting diode (LED) and the light detection circuits **P1 to P5** comprise a photo detector such as a Silicon Avalanche photo diode (SiAPD). According to an exemplary embodiment, the ASIC uses low power and comprises high performance transimpedance amplifiers (TIA) which advantageously reduces the size of NIRS sensing arrangement.

[0036] According to an embodiment, the ASIC comprises further electronic circuitry configured for modulating the light emitting sources (e.g. TDMA, CDMA) and for controlling the light emitting and detection circuits such as to create a plurality of source-detection pairs. According to an exemplary embodiment, the sensor module **S1** is configured and operated such that at least one of said plurality of source-detection pairs presents a distance of at least 2 cm between the light source and the light detector, which advantageously would make one sensor module useful for fNIRS measurements. According to an exemplary embodiment, the ASIC **35** controls the light emitting sources according to compressive sampling (CS) techniques in order to further reduce power consumption. According to an exemplary embodiment, different sensor modules **S1 to S9** are located at different locations of the subject's head and the system **100** is configured for controlling the light emitting and detection circuits of different sensor modules such as to create a plurality of source-detection pairs, which advantageously increases the depth of the optical path.

[0037] According to an exemplary embodiment, the PCBA **25** has a circular shape with a diameter in a range between 3 and 4 cm. According to an exemplary embodiment the sensor module **S1** further comprises biopotential sensing means and electronic circuitry for EEG measurements and the ASIC 35 comprises processing means for processing EEG and fNIRS signals.

[0038] It is understood that and according to an exemplary embodiment, the sensor modules **S1 to S9** may not be isolated in different PCBAs, but their sensing circuitry be located in one large PCBA made of a flexible material that is integrated in the holder arrangement **15**.

[0039] **Figure 2A** shows a perspective view of a dual modality sensor module **S1** for biosignal activity measurement according to a first exemplary embodiment. The sensor module **S1** comprises a main electrode body or base **3** and a plurality of pins **2** protruding from that main electrode base. The main electrode body or base **3** may serve both to hold the pins **2**, the PCBA **25** and the ASIC **35** and to protect the PCBA and ASIC. According to an exemplary embodiment, the sensor module **S1** comprises pins **2** with separate functionality. According to an exemplary embodiment the sensor module **S1** comprises: at least one source waveguide pin configured for light emitting purposes, at least one detector waveguide pin configured for light receiving/detection purposes, and a plurality of electrically conductive pins. According to an exemplary embodiment the sensor module **S1** comprises 17 pins: 4 detector waveguide pins, 5 source waveguide pins and 8 conductive pins, as is illustrated in **Figure 2B**. According to an exemplary embodiment the at least one detector waveguide pin is connected to a photo detector present on the PCBA **25**, and the plurality of conductive pins are connected to light detection and biopotential circuitry respectively, integrated in the ASIC **35** and the at least one source waveguide pin is connected to light emitting circuitry present on the PCBA **25**.

[0040] According to an embodiment, the ASIC **35** comprises circuitry for modulating the light emitting sources (e.g. TDMA, CDMA) and for controlling the light emitting and detection circuits such as to create a plurality of source-detection pairs. According to an exemplary embodiment, the sensor module **S1** is configured and operated such that at least one of said plurality of source-detection pairs presents a distance of at least 2 cm between the light source and the light detector, which advantageously would make one sensor module useful for fNIRS measurements. According to an exemplary embodiment the ASIC 35 comprises circuitry and processing means for processing EEG and fNIRS signals.

[0041] According to an embodiment, the plurality of pins **2** protrude in the direction of the measurement surface or skin when the sensor module **S1** is applied on the subject, e.g. an area of the subject's skin, for measurement purposes. The plurality of pins **2** are further configured to be flexible, which is advantageous to move away hair and provide direct contact to the subject's scalp.

[0042] According to an exemplary embodiment, the sensor module **S1** may incorporate the optical recording functionality along with the existing bio-potential recording.

[0043] **Figure 3** shows a bottom view of a dual modality sensor module for biosignal activity measurement according to a second exemplary embodiment. In this exemplary embodiment, the sensor module **S1** comprises a main electrode body or base **3** and a plurality of pins **2** protruding from that main electrode base as in **Figure**

2A and 2B, but the sensor module **S1** comprises a plurality of pins with dual functionality, that is, such plurality of pins can conduct both light and electricity. According to an exemplary embodiment, the pins **2** comprise an electrically conductive surface or outer layer material **40** with an inner waveguide core **50** or a core of a material that acts as a waveguide. According to an exemplary embodiment the pins may be made by a core transparent silicone wrapped in a conductive fabric. According to an exemplary embodiment, the electrically conductive surface or fabric may be a conductive mesh.

[0044] According to an exemplary embodiment, the dual modality sensor module comprises circuitry, for example in the ASIC **35** or PCB **25**, for configuring the dual modality pins for biosignal measurement, e.g. EEG and/or NIRS and/or other biosignals, such as ECG or PPG. It is understood that not all the pins of the sensor module shall be dual modality pins, but the sensor module may comprise both dual modality pins and single functionality or specialized pins.

[0045] **Figure 4** shows a bottom view of a dual modality sensor module for biosignal activity measurement according to another exemplary embodiment. In this exemplary embodiment, the sensor module **S1** comprises a main electrode body or base **3** and a plurality of pins **2** protruding from that main electrode base as in **Figure 2A and 2B**, and the sensor module **S1** comprises a plurality of pins with dual functionality, that is, such plurality of pins can conduct both light and electricity, but in this embodiment the pins are made from a material that both guides light and in electrically conductive. According to an embodiment the pins are made from an optically transparent silicone with added small metal or carbon particles.

[0046] **Figure 5** shows another perspective view of an EEG and NIRS sensor module for brain activity measurement according to a forth exemplary embodiment comprising the PCBA with ASIC and the electrodes with optical and electrical conductors.

Claims

1. A sensor module (S1) for brain activity measurement, comprising a main electrode base (3) and a plurality of pins (2) protruding from that main electrode base, configured such that, when applied on a subject, the pins (2) make contact or are in close proximity to the subject's skin, and wherein
   the electrode base (3) comprises electronic circuitry for NIRS and EEG measurement, said electronic circuitry being connected to said plurality of pins (2); and
   the plurality of pins (2) comprise a number of electrically conductive pins and at least one source waveguide pin configured for light emitting purposes and/or at least one detector waveguide pin configured for light detection purposes.

2. A sensor module (S1) for brain activity measurement according to any preceding claim wherein the electrical conductive pins are connected to EEG measurement circuitry and the at least one source and/or detector waveguide pins are connected to NIRS measurement circuitry.

3. A sensor module (S1) for brain activity measurement according to any preceding claim, wherein the NIRS measurement circuitry comprises at least one light emitting circuit (L1 to L4) including a LED and at least one light detection circuit (P1 to P5) including a photo detector.

4. A sensor module (S1) for brain activity measurement according to claim 3 wherein the photo detector is a Silicon Avalanche photo diode (SiAPD).

5. A sensor module (S1) for brain activity measurement according to any preceding claim, wherein the NIRS measurement circuitry is configured for controlling the light emitting and detection circuits such as to create a plurality of source-detection pairs.

6. A sensor module (S1) for brain activity measurement according to any preceding claim, wherein the plurality of pins (2) comprise pins that can conduct both light and electricity and can be configured for EEG and/or NIRS measurement.

7. A sensor module (S1) for brain activity measurement according to claim 6, wherein said plurality of pins (2) comprise an outer electrically conductive surface or layer (40) with an inner waveguide core (50).

8. A sensor module (S1) for brain activity measurement according to claim 7, wherein the outer electrically conductive layer (40) is a conductive mesh.

9. A sensor module (S1) for brain activity measurement according to claim 8, wherein the conductive mesh comprises a woven fabric, comprising a plurality of conductive wires or fibres designed for being flexible and ensuring conductivity of the pins.

10. A sensor module (S1) for brain activity measurement according to any of claims 7 to claim 9, wherein the inner core (50) comprises a transparent silicone.

11. A sensor module (S1) for brain activity measurement according to claim 6,
    wherein said plurality of pins (2) comprise a material that can conduct both light and electricity.

12. A sensor module (S1) for biosignal activity measurement, comprising a main
    electrode base (3) and a plurality of pins (2) protruding from that main electrode base, configured such

that, when applied on a subject, the pins (2) make contact or are in close proximity to the subject's skin, and wherein

the electrode base (3) comprises electronic circuitry for biosignal measurement, said electronic circuitry being connected to said plurality of pins (2); and
the plurality of pins (2) comprise pins that can conduct both light and electricity.

13. A holder arrangement (15) configured for being applied on a subject and
comprising at least one sensor module (S1) for brain activity measurement according to any of the preceding claims.

14. A system (100) for biosignal activity measurement comprising a plurality of
sensor modules (S1 to S9) for brain activity measurement according to any of claims 1 to 12.

15. A system (100) for biosignal activity measurement according to claim 14 further comprising a control module (CM) configured for controlling activity and/or receiving measurements from the plurality of sensor modules (S1 to S9).

Figure 1

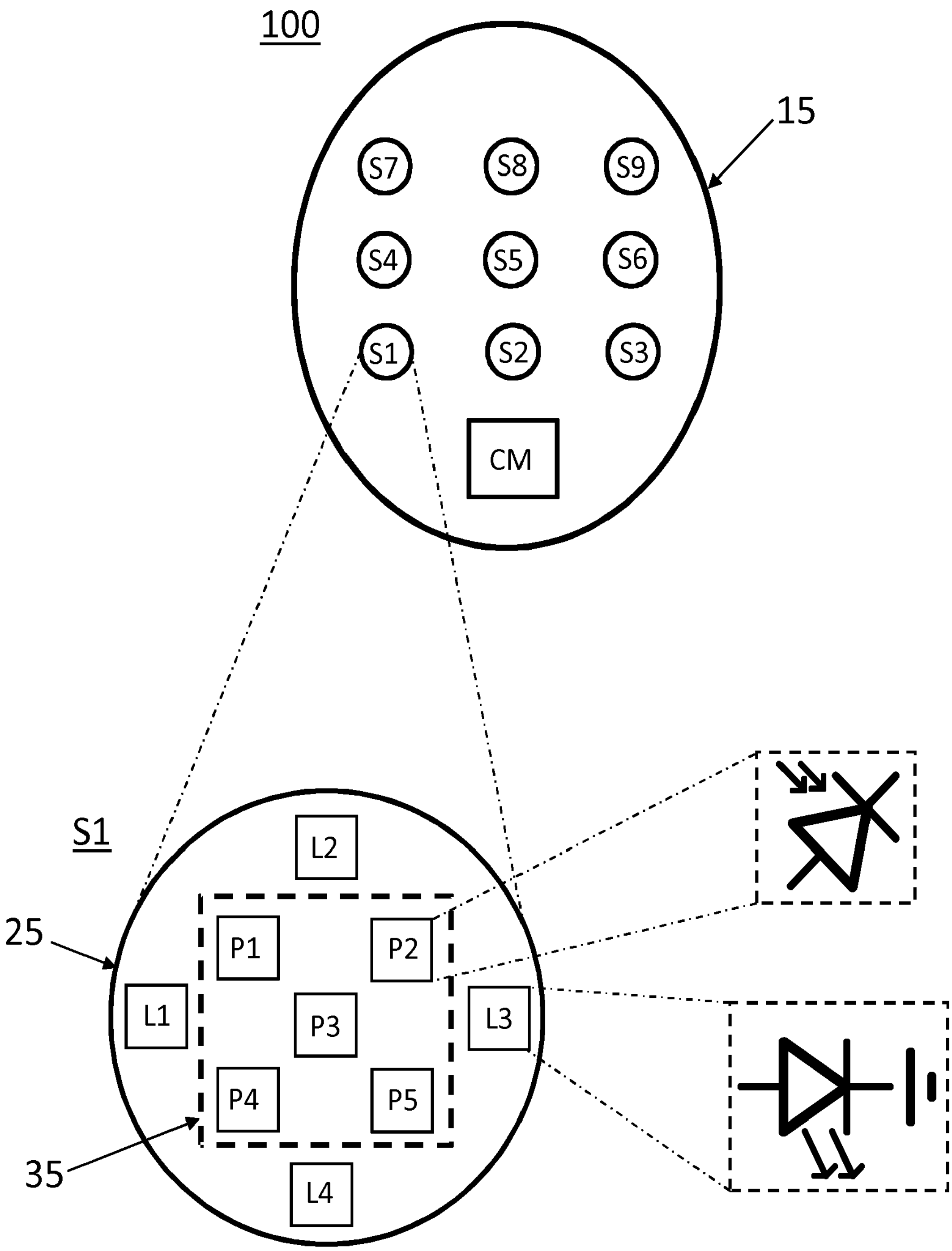


Figure 2

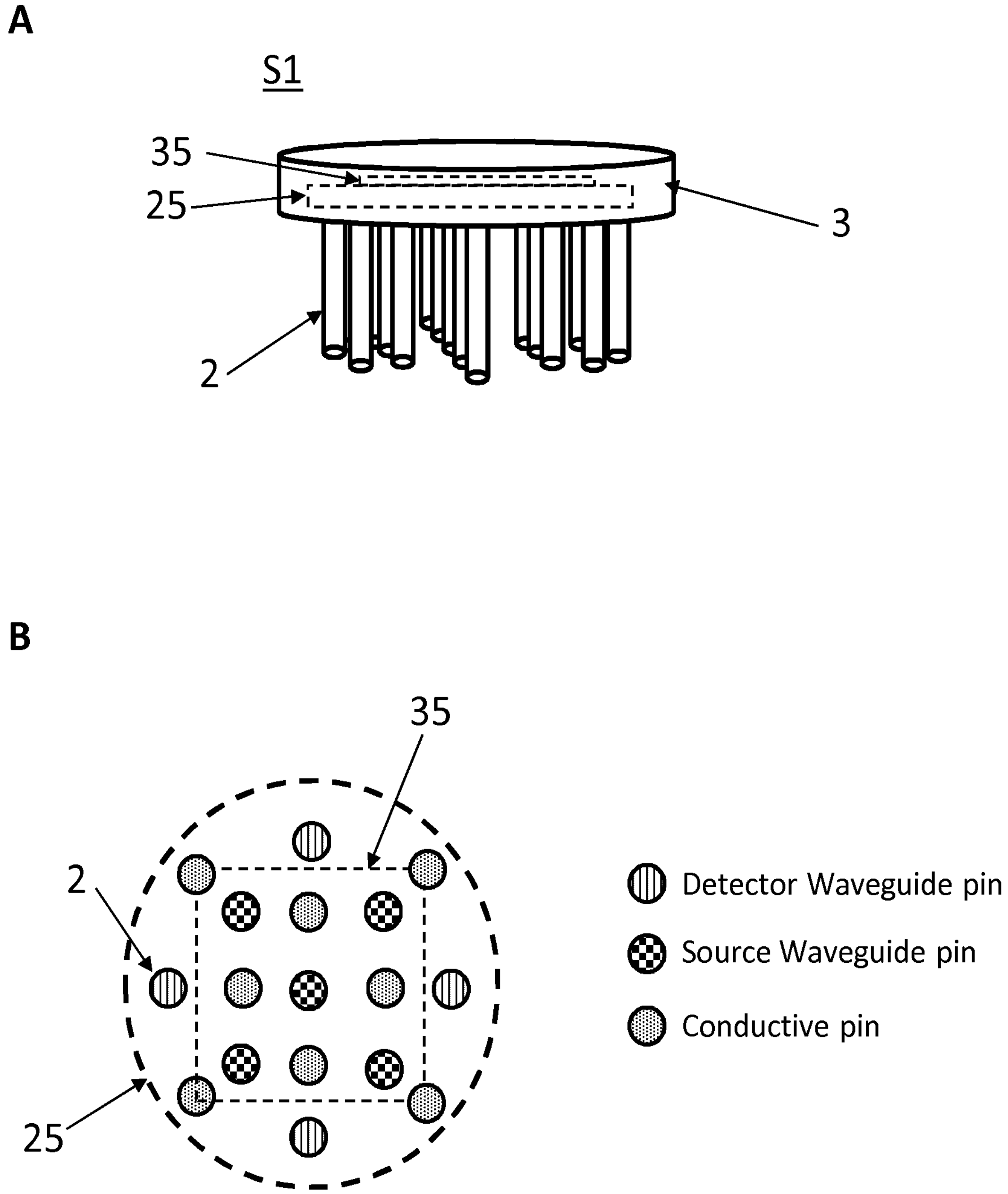

A
S1
35
25
3
2
B
35
2
25
Detector Waveguide pin
Source Waveguide pin
Conductive pin

Figure 3

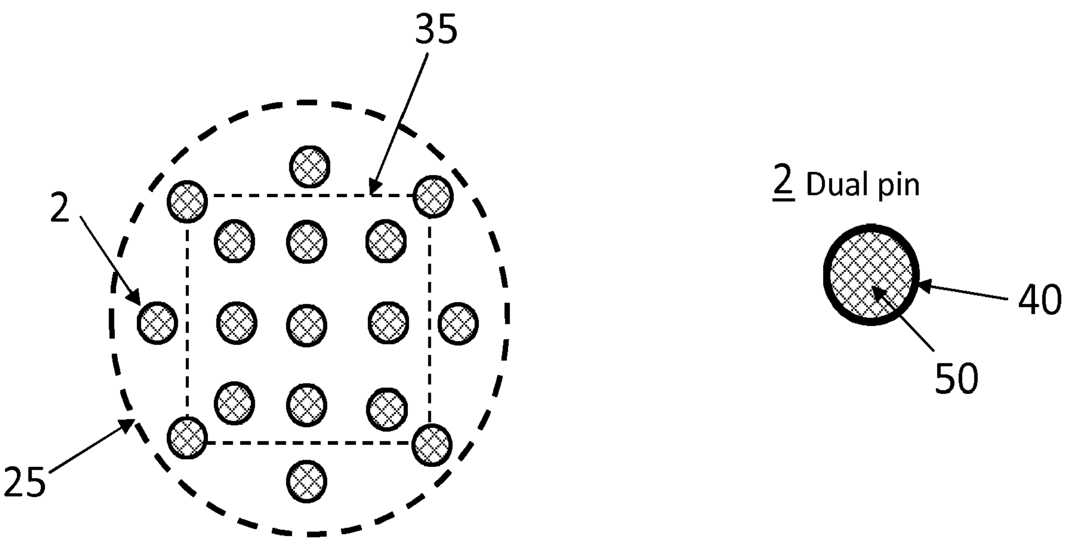


Figure 4

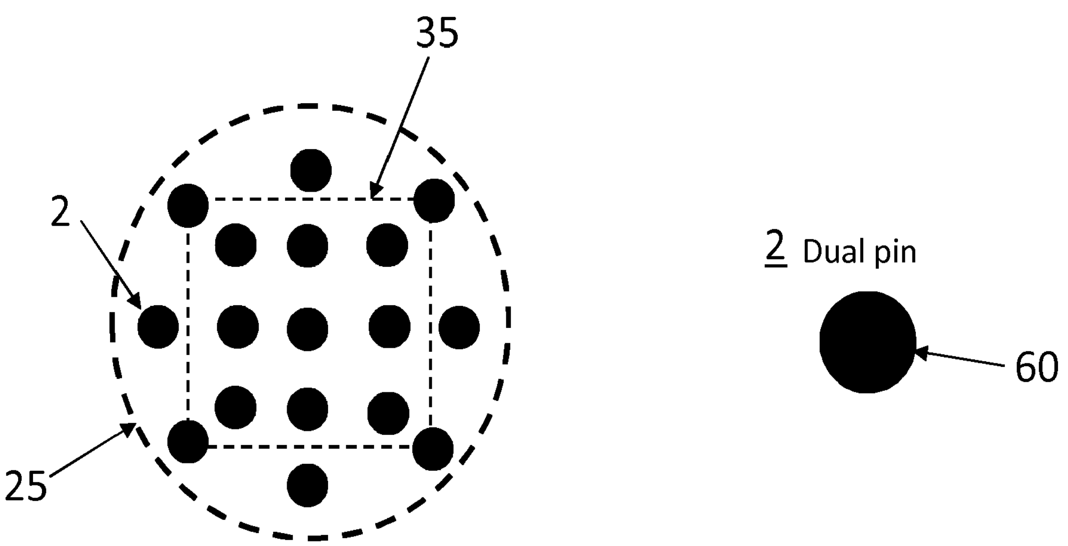
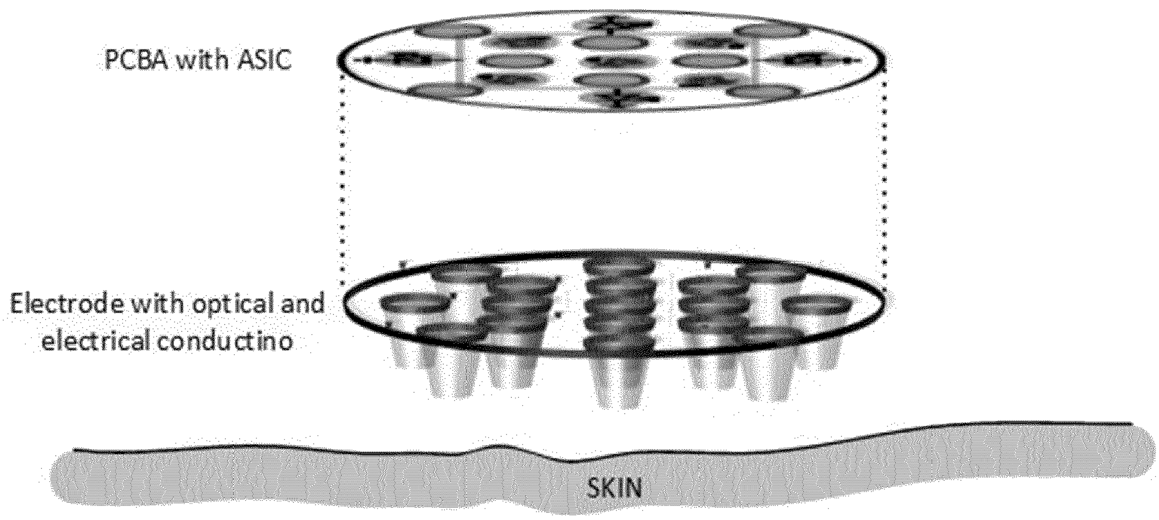


Figure 5


PCBA with ASIC
Electrode with optical and
electrical conductino
SKIN

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EUROPEAN SEARCH REPORT

Application Number
EP 16 20 4491

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	MOHAMAD SAWAN ET AL: "Wireless Recording Systems: From Noninvasive EEG-NIRS to Invasive EEG Devices", IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS, IEEE, US, vol. 7, no. 2, 1 April 2013 (2013-04-01), pages 186-195, XP011507013, ISSN: 1932-4545, DOI: 10.1109/TBCAS.2013.2255595 * see items "A. Noninvasive Studies" on pages 187, 188.; figures 1-3 * -----	1-15	INV. A61B5/0408 A61B5/00 A61B5/0478
X	ALMAJIDY RAND K ET AL: "Novel near infrared sensors for hybrid BCI applications", PROGRESS IN BIOMEDICAL OPTICS AND IMAGING, SPIE - INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING, BELLINGHAM, WA, US, vol. 9536, 14 July 2015 (2015-07-14), pages 95361H-95361H, XP060056545, ISSN: 1605-7422, DOI: 10.1117/12.2182066 ISBN: 978-1-5106-0027-0 * abstract * * See item "2. METHODOLOGY; 2.1 The sensor module". * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) A61B
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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
The Hague	8 May 2017	Dhervé, Gwenaëlle

CATEGORY OF CITED DOCUMENTS

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A	WO 2015/143031 A1 (NEUROTOPIA INC [US]) 24 September 2015 (2015-09-24) * page 8, line 21 - page 9, line 8; figure 18 *	1	
A	COOPER R J ET AL: "Design and evaluation of a probe for simultaneous EEG and near-infrared imaging of cortical activation; Design and evaluation of a probe for simultaneous EEG and NIR imaging of cortical activation", PHYSICS IN MEDICINE AND BIOLOGY, INSTITUTE OF PHYSICS PUBLISHING, BRISTOL GB, vol. 54, no. 7, 7 April 2009 (2009-04-07), pages 2093-2102, XP020149910, ISSN: 0031-9155 * See item "2. Methods, 2.1. Opto-electrode probe". *	6-12	TECHNICAL FIELDS SEARCHED (IPC)

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A	DUFOUR SUZIE ET AL: "Optrodes for combined optogenetics and electrophysiology in live animals", NEUROPHOTONICS, SOCIETY OF PHOTO-OPTICAL INSTRUMENTATION ENGINEERS, 1000 20TH ST. BELLINGHAM WA 98225-6705 USA, vol. 2, no. 3, 1 July 2015 (2015-07-01), page 31205, XP060072808, ISSN: 2329-423X, DOI: 10.1117/1.NPH.2.3.031205 [retrieved on 2015-07-02] * see, in item "4. Combining Light Delivery with Electrographic Recordings: Optrodes Designs", the items "4.1 Preliminary Designs" and "4.4 Optrodes in Freely Behaving Animals" * -----	6-12	
A	S-T LIN ET AL: "Flexible optitrode for localized light delivery and electrical recording", OPTICS LETTERS, OPTICAL SOCIETY OF AMERICA, vol. 37, no. 11, 1 June 2012 (2012-06-01), pages 1781-1783, XP001575801, ISSN: 0146-9592, DOI: 10.1364/OL.37.001781 [retrieved on 2012-05-16] * the whole document * -----	6-12	TECHNICAL FIELDS SEARCHED (IPC)

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015143031 A1	24-09-2015	NONE	

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20140018640 A1 **[0003]**

Non-patent literature cited in the description

- **TZYY-PING JUNG et al.** Concurrent EEG and NIRS tomographic imaging based on wearable electro-optodes. University of California, 13 April 2014 **[0004]**

专利名称(译)	用于生物信号活动测量的传感器，系统和支架布置		
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摘要(译)

一种用于生物信号活动测量的传感器模块（S1），包括主电极基座（3）和从该主电极基座突出的多个销（2），其构造成使得当施加在对象上时，销（2）使得接触或接近受试者的皮肤，并且其中电极基座（3）包括用于生物信号测量的电子电路，所述电子电路连接到所述多个销（2）;多个引脚（2）包括多个导电引脚和至少一个配置用于发光目的的源波导管和/或至少一个配置用于光检测目的的检测器波导管。