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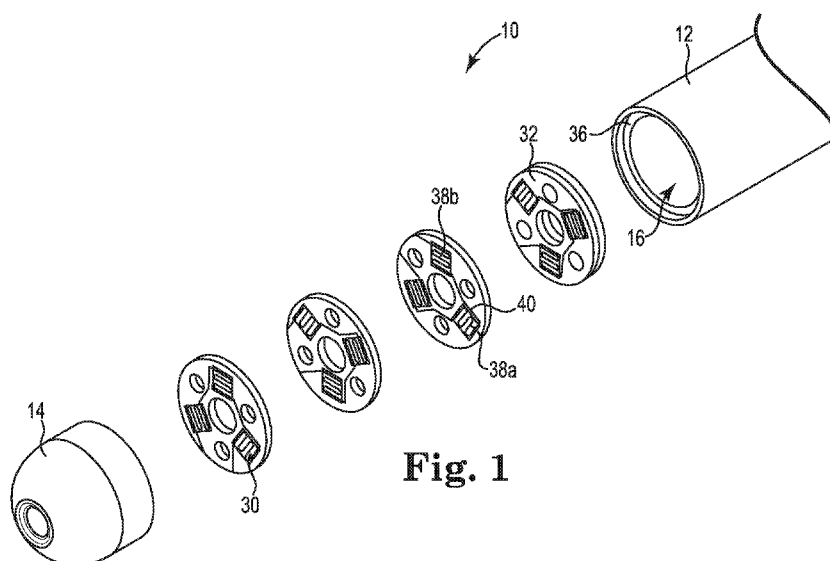
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[Continued on next page]

(54) Title: MODULAR DISC ARRAY FOR MINIMALLY INVASIVE MEDICAL DEVICE

**Fig. 1**

(57) Abstract: In certain embodiments, an apparatus includes a stacked array of discs electrically coupled together where each disc includes an electrical component. In certain embodiments, a minimally-invasive medical device includes a stack of transducer platforms positioned within the minimally-invasive medical device. Each platform includes a plurality of electrical components.



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- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

MODULAR DISC ARRAY FOR MINIMALLY INVASIVE MEDICAL DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Provisional Application No. 62/274,352, filed January 3, 2016, which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present invention relates to medical devices and methods for positioning electrical components within medical devices.

BACKGROUND

[0003] Minimally-invasive medical devices like catheters are devices inserted into patients to assist with or perform medical procedures and diagnostics.

SUMMARY

[0004] In Example 1, an apparatus includes a stacked array of discs electrically coupled together where each disc includes an electrical component.

[0005] In Example 2, the apparatus of Example 1, wherein the electrical component is a sensor.

[0006] In Example 3, the apparatus of any of Examples 1–2, wherein each of the discs includes multiple sensors.

[0007] In Example 4, the apparatus of any of Examples 2–3, wherein the sensors include magnetoresistive elements.

[0008] In Example 5, the apparatus of any of Examples 2–4, wherein each sensor is configured to sense magnetic fields in a direction different than the other sensors.

[0009] In Example 6, the apparatus of any of Examples 1–5, wherein one of the discs includes at least two different types of sensors.

[0010] In Example 7, the apparatus of any of Examples 1–6, wherein one disc includes sensors having magnetoresistive elements and another disc includes temperature sensors.

[0011] In Example 8, the apparatus of any of Examples 2–7, wherein the sensors are mounted to a substrate of each disc.

[0012] In Example 9, the apparatus of any of Examples 2–7, wherein the sensors are embedded in each disc.

[0013] In Example 10, the apparatus of any of Examples 1–9, wherein the disc includes optical components.

[0014] In Example 11, the apparatus of any of Examples 1–10, wherein each disc includes a plurality of electrical components.

[0015] In Example 12, the apparatus of any of Examples 1–11, wherein the stacked disc array includes four discs.

[0016] In Example 13, a minimally-invasive medical device includes a body forming an aperture. The device also includes a plurality of transducer platforms positioned within the aperture and electrically coupled together. Each platform includes an electrical component. At least one of the platforms facilitates electrical communication between the other plurality of platforms and off-platform electrical components associated with the minimally-invasive medical device.

[0017] In Example 14, the device of Example 13, wherein the electrical component is a transducer.

[0018] In Example 15, the device of any of Examples 13–14, wherein the platforms are one of square-shaped, disc-shaped, and hexagon-shaped.

[0019] In Example 16, a minimally-invasive medical device includes a stack of discs positioned at a distal end of the minimally-invasive medical device. Each disc includes a plurality of electrical components.

[0020] In Example 17, the device of Example 16, wherein the discs are electrically or optically coupled to each other.

[0021] In Example 18, the device of any of Examples 16–17, wherein at least some of the plurality of electrical components are transducers.

[0022] In Example 19, the device of Example 18, wherein at least some of the transducers include magnetoresistive elements.

[0023] In Example 20, the device of any of Examples 18–19, wherein at least some of the transducers are temperature sensors.

[0024] In Example 21, the device of any of Examples 18–19, wherein each transducer is configured to sense magnetic fields in a direction different than the other transducers.

[0025] In Example 22, the device of any of Examples 16–21, further including a cap and body forming an aperture housing the stack of discs.

[0026] In Example 23, the device of Example 22, further including a retainer that physically couples the discs, cap, and body together.

[0027] In Example 24, the device of Example 23, wherein the retainer extends through center apertures formed in each of the discs.

[0028] In Example 25, the device of any of Examples 16–24, wherein each disc includes a plurality of protrusions that are sized to fit into holes defined by an adjacent disc.

[0029] In Example 26, the device of any of Examples 16–25, wherein the plurality of electrical components are mounted to a disc's substrate.

[0030] In Example 27, the device of any of Examples 16–26, wherein the plurality of electrical components are embedded in each disc.

[0031] In Example 28, the device of any of Examples 16–27, wherein the discs comprise silicon.

[0032] In Example 29, the device of any of Examples 16–28, wherein the plurality of electrical components includes at least one of the following: a battery, capacitor, amplifier, analog-to-digital converter, signal processor, wireless communicator, radiofrequency ablator, or cryo-ablators.

[0033] In Example 30, the device of any of Examples 16–29, wherein the plurality of electrical components are electrically coupled to each other.

[0034] In Example 31, the device of any of Examples 16–29, wherein each electrical component is independently electrically coupled to a most proximal disc of the stack.

[0035] In Example 32, the device of any of Examples 16–31, wherein a most proximal disc of the stack facilitates electrical communication between the stack of discs and off-disc electrical components associated with the medical device.

[0036] In Example 33, a catheter includes a plurality of sensing structures coupled together and positioned within the catheter. Each sensing structure includes a plurality of sensors having a transducer.

[0037] In Example 34, the catheter of Example 33, wherein the plurality of sensing structure are positioned within a hollow cavity formed by the catheter and at a distal end of the catheter.

[0038] In Example 35, the catheter of any of Examples 33–34, wherein the sensing structures are disc-shaped and stacked together.

[0039] While multiple embodiments are disclosed, still other embodiments of the present invention will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the invention. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] FIG. 1 shows a partial exploded view of a distal portion of a medical device, in accordance with certain embodiments of the present disclosure.

[0041] FIG. 2 shows a partial exploded view of a top portion of a medical device, in accordance with certain embodiments of the present disclosure.

[0042] FIG. 3a shows a partial view of an assembled medical device, in accordance with certain embodiments of the present disclosure.

[0043] FIG. 3b shows a partial section view of the assembled medical device of FIG. 3a and an array of discs positioned within the device, in accordance with certain embodiments of the present disclosure.

[0044] FIG. 3c shows a top view of one of the discs in the array of FIG. 3b, in accordance with certain embodiments of the present disclosure.

[0045] While the invention is amenable to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and are described in detail below. The intention, however, is not to limit the invention to the particular embodiments described. On the contrary, the invention is intended to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

[0046] Minimally-invasive medical devices can be provisioned with various electrical components such as transducers to enhance functionality. Because medical devices are used for a wide variety of procedures, a device's desired range of functionality may vary from device to device. For example, catheters may benefit when provisioned with magnetic field sensors, which can assist with tracking and navigating catheters during medical procedures. Irrigated catheters—which use a fluid to control the catheter's temperature—may further benefit when additionally provisioned with temperature sensors. However, because the size of devices like catheters is limited, fitting additional components like transducers into devices can be challenging. Features of the present disclosure are accordingly directed to methods and devices for positioning electrical components within medical devices.

[0047] Figures 1 and 2 show partial exploded views of a tip 10 of a medical device such as a catheter. Although a catheter is used as an example, the present disclosure is applicable to a wide variety of medical devices. The catheter includes a body 12 and cap 14 that form a center aperture 16. The cap 14 is coupled to the body 12 by a retaining structure 18 shown in FIG. 2. An array of discs 20 is positioned and maintained within the center aperture 16. Each disc is shown as having a central opening 22, multiple holes 24 around the central opening 22, and multiple protrusions 26. The central opening 22 permits the retainer 18 to extend through the stacked array of discs 20 to secure the cap 14 and discs 20 to the body 12. The protrusions 26 help

secure a position of one disc in relation to a disc positioned immediately adjacent. As shown in figures 1 and 2, the protrusions 26 of one disc are aligned with holes 24 of an adjacent disc such that, when the discs are stacked together, the protrusions 26 fit into the holes 24. Each protrusion 26 is shown extending from another protrusion 28, which adjacent discs rest upon when stacked to create a space between the discs for positioning electrical components 30. As will be described below in more detail, the discs' electrical components 30 can be used to perform a variety of functions by using components such as transducers and sensors.

[0048] The array architecture permits modularity, which enables a wide variety of configurations of discs or platforms and respective electrical components and connections. Although discs are shown and described, components like transducers can be positioned on differently-shaped platforms. For example, an individual platform within an array of platforms could be shaped as a square, hexagon, etc. The configuration shown in figures 1 and 2 includes four discs that are stacked upon one another and positioned and retained within a medical device once assembled. Each disc is shown having a central opening 22 that aligns with a central opening of the other discs in the array. Each disc also has three holes 24 that are offset from holes of an immediately-adjacent disc. The three discs positioned nearest the cap 14 have protrusions 26 on the bottom side of each disc. When assembled, the protrusions 26 of each disc fit into the holes 24 of the disc positioned immediately below. Bottom disc 32 is shown as having a rim 34 that rests upon a lip 36 in the body 12 though the bottom disc 32 could also have protrusions or other features that fit into holes or other features on the body 12.

[0049] Each disc is shown having electrical components 30 positioned on a top side of the disc. One type of electrical component could include a sensor and, more specifically, a magnetoresistive sensor. Magnetoresistive sensors can include giant- or tunneling-magnetoresistive elements, which sense magnetic fields. As mentioned above, magnetic field sensors like magnetoresistive sensors can assist with tracking and navigating medical devices during medical procedures. The discs in figures 1 and 2 are shown having three groupings 38 of sensors. Each group 38 could be configured to

sense magnetic fields in a particular direction. For example, the first group 38a of sensors could sense magnetic fields in a direction perpendicular to a top surface of the disc while the second group 38b could sense magnetic fields in a parallel direction and so on.

[0050] The sensors 38 are shown as being electrically connected in series with traces 40 extending to the first and third groups from a side of the disc. The traces of one disc can be electrically connected to the traces of the other discs. The bottom disc 32 can function as an electrical and communications bus that facilitates signal communication and powering of the other discs. For example, the bottom disc 32 can receive signals from the other discs and transfer those signals to off-disc electronics of the catheter for further processing and mapping of the sensed magnetic fields. The bottom disc 32 may include electrical connectors on a bottom side of the disc for electrically coupling the disc array 20 with other electronics of the catheter.

[0051] As mentioned above, the array of structures permit modularity enabling a wide variety of configurations of discs and platforms and respective electrical components and connections. Figures 1 and 2 show an example of just one of many uses and configurations of the disc array. For example, fewer or more than four discs can be used in an array; and fewer or more sensors could be used on an individual disc. More discs and sensors could be added if additional sensing capabilities were desired. For example, if space in a radial direction was limited, a larger number of smaller-diameter discs could be used. Discs could have a different number of holes and protrusions or even different features, like pins or adhesives, that secure one disc to another. Instead of a central opening, discs could utilize other openings or notches that enable retainers or other features to extend through the discs. For example, medical devices like catheters may be irrigated such that lines of fluid may be directed to a tip of the device; and medical devices implementing ablation may require additional electrical signals to be sent to a tip of the device. The discs can be configured to permit such features to extend through the discs to reach desired areas of the device.

[0052] A wide variety of types and combinations of electrical components can be utilized on the modular arrays. Moreover, the modular arrays can utilize optical

components like waveguides and magneto-optic transducers. In addition to the previously mentioned magnetoresistive sensors, embodiments can include discs can be provisioned with sensors that measure temperature, force, acceleration, ultrasound, flow, pressure, position, radiation levels, and other parameters. For example, discs could include temperature sensors like thermistors that may be useful for measuring temperature of irrigated medical devices where temperature control is desired. Discs could be provisioned with other electrical components to be used to function as batteries, capacitors, amplifiers, analog-to-digital converters, signal processors, wireless communicators, radiofrequency ablaters, cryo-ablaters, and others. An individual disc could include more than one type of electrical component or sensor. An individual disc could include only magnetoresistive sensors while another disc in the array could include only temperature sensors.

[0053] Electrical components can be positioned in a wide variety of ways. For example, the disc itself could be made of silicon so electrical components may be integral with or embedded in the disc. Discs could include substrates on which electrical components like integrated circuits are mounted to. For example, the substrate could be made of glass, and sensors and supporting sensor circuitry could be embedded in a layer of aluminum oxide or other suitable materials positioned on top of the substrate. Sensor coil configurations may be deposited on a substrate and embedded in a disc.

[0054] Discs and electrical components can be electrically connected in a variety of ways. For example, discs and electrical components could be connected using wires, traces, vias, ball-grid arrays, flex circuitry, spring contacts, wafer-to-wafer bonding, and other methods to communicate electrical signals to and from each other. For disc-to-disc electrical communication, the protrusions 26 could include conductive material that physically couples with conductive materials contained in an adjacent disc's hole 24 to electrically couple the two discs. Signals of the electrical components of each disc can be combined or kept independent of other signals. Another example of disc-to-disc electrical communication includes using a flex circuit that directs various electrical signals of the discs towards the bottom disc. Moreover, optical components such as magneto-optic transducers positioned on discs can be optically coupled together.

[0055] FIG. 3a shows a side view of a distal end of an assembled medical device 100 having a body 102 and cap 104. FIG. 3b shows a partial section view of the assembled medical device and an array of discs positioned within the device. FIG. 3c shows a top view of one of the discs in the array. The body 102 and cap 104 form an aperture where the discs are positioned. A retaining structure 106 integral with the cap 104 extends through three stacked discs 108 through a central opening 110 of each disc 108. Although the discs 108 are shown as being generally parallel with each other, discs may be canted such that electrical components 112 are oriented in a specific direction or angle. Additionally, electrical components 112 themselves could be oriented or positioned in a variety of positions on a disc 108. Although electrical components 112 are shown positioned on a top side of the disc 108, the disclosure is not limited to such positions. The electrical components 112 are electrically connected with traces 114 that extend from component to component and down a side of the disc 108. Signals of the electrical components could also be transmitted through the disc or other suitable electrical transmitting configurations like vias or flex circuits. Although the medical device 100 is shown as having a body 102 and cap 104 with discs positioned within the medical device, a disc could be a most distal part of the medical device. For example, a most distal disc could be arranged to form a central aperture along with the body to house other discs. Such a disc may be arranged to position an array of ultrasound transducers. Moreover, the array of discs can be positioned at various points within the medical device and not necessarily at a distal end.

[0056] Various modifications and additions can be made to the exemplary embodiments discussed without departing from the scope of the present invention. For example, while the embodiments described above refer to particular features, environments, and applications, the scope of this invention also includes embodiments having different combinations of features and embodiments that do not include all of the described features. Accordingly, the scope of the present invention is intended to embrace all such alternatives, modifications, and variations as fall within the scope of the claims, together with all equivalents thereof.

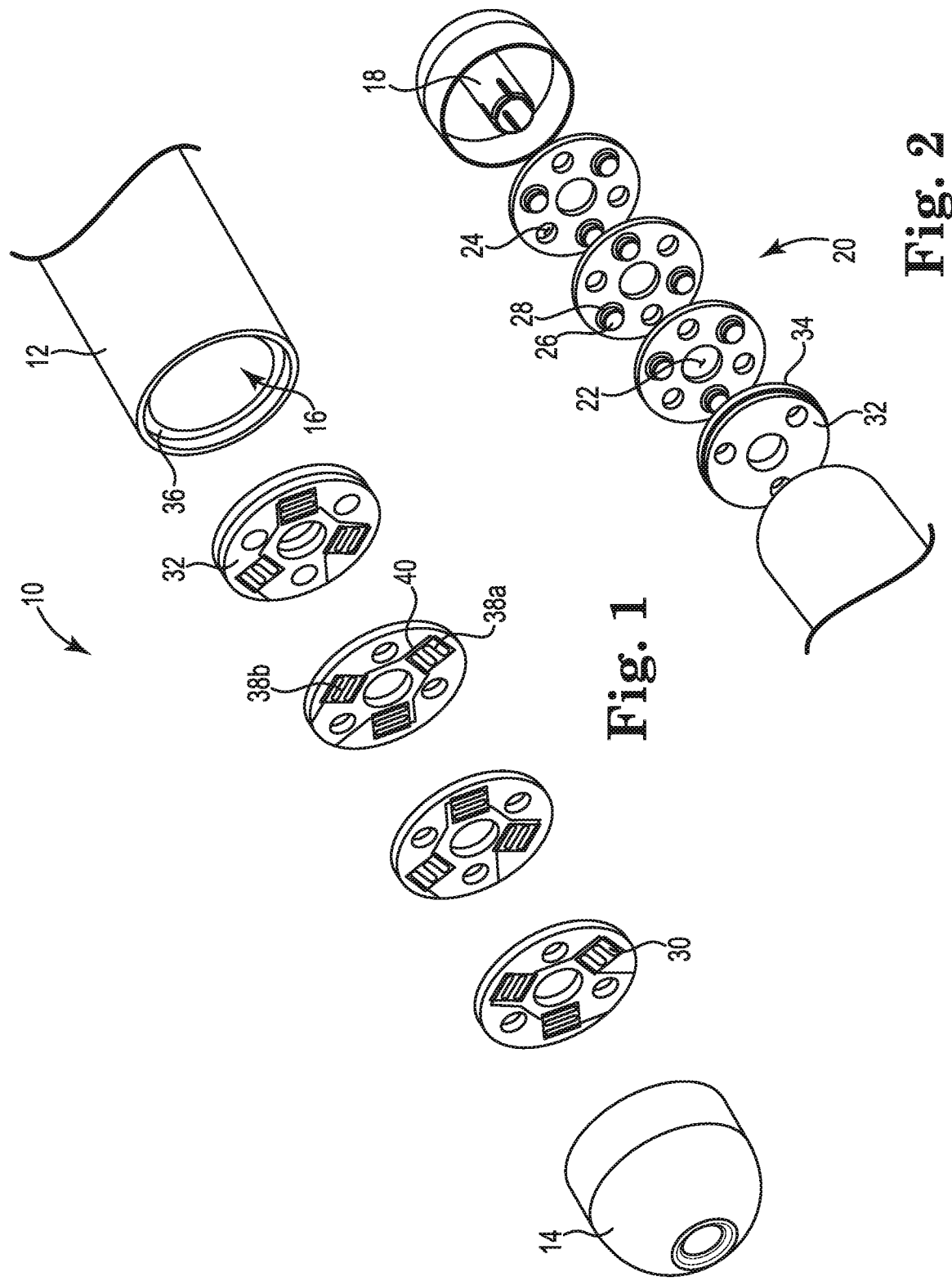
CLAIMS

We claim:

1. An apparatus comprising:

a stacked array of discs electrically coupled together, each disc including an electrical component.
2. The apparatus of claim 1, wherein the electrical component is a sensor.
3. The apparatus of claim 2, wherein each of the discs includes multiple sensors.
4. The apparatus of claim 3, wherein the sensors include magnetoresistive elements.
5. The apparatus of claim 4, wherein each sensor is configured to sense magnetic fields in a direction different than the other sensors.
6. The apparatus of claim 3, wherein one of the discs includes at least two different types of sensors.
7. The apparatus of claim 3, wherein one disc includes sensors having magnetoresistive elements and another disc includes temperature sensors.
8. The apparatus of any of claims 2–7, wherein the sensors are mounted to a substrate of each disc.
9. The apparatus of any of claims 2–7, wherein the sensors are embedded in each disc.
10. The apparatus of claim 9, wherein the disc includes optical components.

11. The apparatus of any of claims 1–10, wherein each disc includes a plurality of electrical components.
12. The apparatus of any of claims 1–11, wherein the stacked disc array includes four discs.
13. A minimally-invasive medical device comprising:
 - a body forming an aperture;
 - a plurality of transducer platforms positioned within the aperture and electrically coupled together, each platform including an electrical component; and
 - wherein at least one of the platforms facilitates electrical communication between the other plurality of platforms and off-platform electrical components associated with the minimally-invasive medical device.
14. The minimally-invasive medical device of claim 13, wherein the electrical component is a transducer.
15. The minimally-invasive medical device of any of claims 13–14, wherein the platforms are one of square-shaped, disc-shaped, and hexagon-shaped.



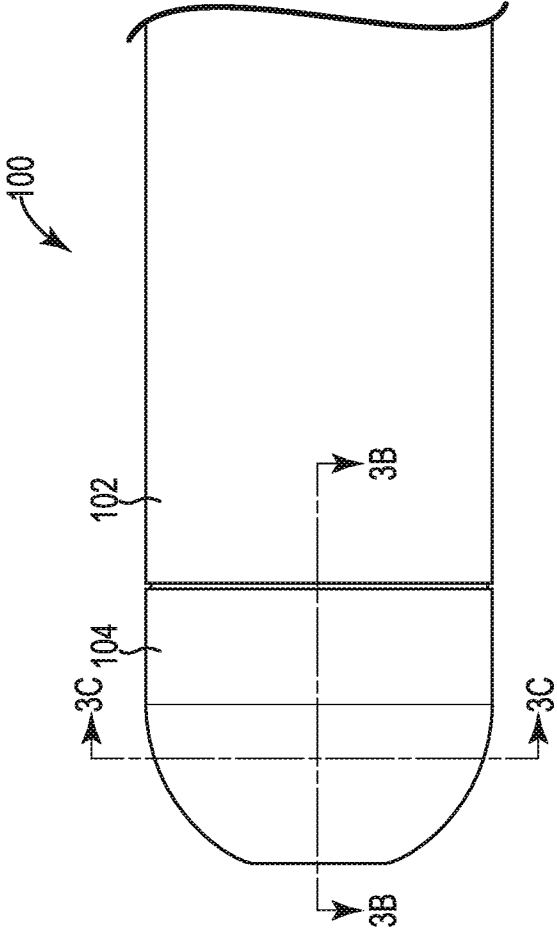


Fig. 3A

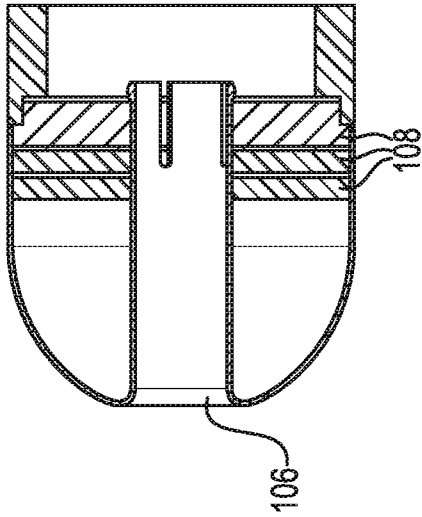


Fig. 3B

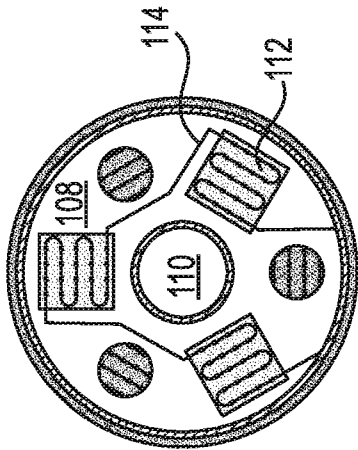


Fig. 3C

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/012001

A. CLASSIFICATION OF SUBJECT MATTER

INV. A61B5/06 G01R33/09 A61M25/095
ADD. A61B5/01

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)
G01R

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	JENS HÖFFLIN ET AL: "Electrifying the disk: a modular rotating platform for wireless power and data transmission for Lab on a disk application", LAB ON A CHIP, vol. 15, no. 12, 4 May 2015 (2015-05-04), pages 2584-2587, XP055357295, ISSN: 1473-0197, DOI: 10.1039/C5LC00138B page 2586, column 2, lines 3-8 figures 1a, 1b ----- -/--	1,11,12



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

31 March 2017

Date of mailing of the international search report

30/05/2017

Name and mailing address of the ISA/

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Authorized officer

Mecking, Nikolai

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/012001

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	TOOLEY C R ET AL: "The Magnetospheric Multiscale Constellation", SPACE SCIENCE REVIEWS, REIDEL, DORDRECHT, NL, vol. 199, no. 1, 24 November 2015 (2015-11-24), pages 23-76, XP036097411, ISSN: 0038-6308, DOI: 10.1007/S11214-015-0220-5 [retrieved on 2015-11-24] pages 52-54 figures 2,5-8,18,31 -----	1-12
X	WO 2013/120184 A1 (MICROPHARMA LTD [CA]) 22 August 2013 (2013-08-22) paragraphs [0120], [0252] - [0257]; figures 4,11A-11C -----	1-4,6-12
X	US 3 349 259 A (KISTLER WALTER P) 24 October 1967 (1967-10-24) column 3, lines 65-68; figure 1 -----	1,2,8,9, 11,12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/012001

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-12

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-12

An apparatus comprising: a stacked array of discs electrically coupled together, each disc including an electrical component.

2. claims: 13-15

A minimally-invasive medical device comprising: a body forming an aperture;a plurality of transducer platforms positioned within the aperture and electrically coupled together, each platform including an electrical component; and wherein at least one of the platforms facilitates electrical communication between the other plurality of platforms and off-platform electrical components associated with the minimally-invasive medical device.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/012001

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2013120184	A1	22-08-2013	EP 2819584 A1 07-01-2015
			HK 1204900 A1 11-12-2015
			US 2015011874 A1 08-01-2015
			WO 2013120184 A1 22-08-2013

US 3349259	A	24-10-1967	NONE
