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(54) **Title**: TORQUE COIL WITH BRAGG GRATING

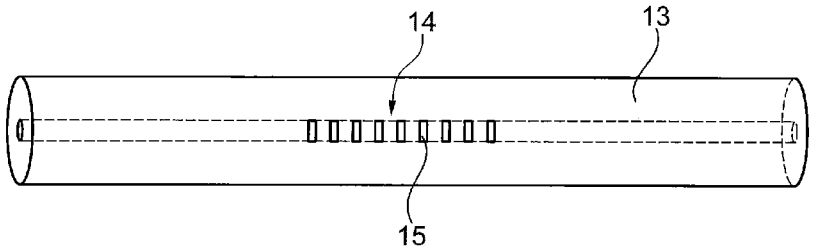


Fig. 3

(57) **Abstract**: One aspect relates to a torque coil, a detection system including such torque coil, and a method for forming such torque coil. The torque coil includes a wound inner wire layer and a wound outer wire layer. The outer wire layer is wound over the inner wire layer. A wire of the outer wire layer is an optical fiber and the optical fiber includes a Bragg grating. The Bragg grating includes grating structures and the Bragg grating is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures.

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TORQUE COIL WITH BRAGG GRATING

Background

One aspect relates to a torque coil, a detection system including such torque coil, and a method for forming such torque coil.

Medical devices as e.g. catheters may be guided through body lumens and blood vessels. For example, WO 2014/025402 A2 discloses an implantable medical device lead with a lead body including a lumen extending from a proximal end of the lead body to a distal end of the lead body, and a helically coiled conductor including one or more filars extending through the lumen and including a plurality of turns. The implantable medical device lead further includes an insulative coating on at least one of the one or more filars, the insulative coating circumferentially covering the outer surface of the at least one of the one or more filars, and at least one cohesive structure formed between adjacent turns of the helically coiled conductor. The at least one cohesive structure includes portions of the insulative coating on the at least one of the one or more filars and is configured to interconnect adjacent turns of the helically coiled conductor.

When being guided through body lumens or blood vessels, catheters may also be used for measuring specific properties of the surrounding tissue.

However, there may be a need to provide an improved device, such as a torque coil for measuring properties of the surrounding tissue that is easy to handle.

It should be noted that the aspects of the embodiments described in the following apply also to the torque coil, the detection system including a torque coil, and the method for forming a torque coil.

Brief Description of the Drawings

Exemplary embodiments of the invention will be described in the following with reference to the accompanying drawings:

Figure 1 shows a schematic drawing of an example of a detection system according to one embodiment.

Figure 2 shows schematically and exemplarily an embodiment of a torque coil according to one embodiment.

Figure 3 shows schematically and exemplarily an embodiment of an optical fiber.

Figure 4 shows schematically and exemplarily another embodiment of a torque coil according to one embodiment.

Figure 5 shows basic steps of an example of a method for forming a torque coil according to one embodiment.

Detailed Description

In the following Detailed Description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. In this regard, directional terminology, such as "top," "bottom," "front," "back," "leading," "trailing," etc., is used with reference to the orientation of the Figure(s) being described. Because components of embodiments of the invention can be positioned in a number of different orientations, the directional terminology is used for purposes of illustration and is in no way limiting. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the invention is defined by the appended claims.

According to one embodiment, a torque coil is presented. The torque coil includes a wound inner wire layer and a wound outer wire layer. The outer wire

layer is wound over the inner wire layer. This means the inner wire layer is within the outer wire layer.

A wire of the outer wire layer is an optical fiber and the optical fiber includes a Bragg grating. The Bragg grating includes grating structures and the Bragg grating is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures.

The term "torque coil" may be understood as a tube made of at least one wound wire defining an inner lumen. The torque coil thereby forms a flexible tube for torque transmission, torque response and/or torque control. The torque coil may be flexible enough to be guided through blood vessels or body lumens and may be stiff enough to be pushed also through complex anatomies and e.g. calcified lesions without buckling.

A wound wire layer may be understood as a wire wound to form a tube. The wire may be helically wound. The wire may be wound in a constricted state, and thereby, provide the torque coil with stored energy. Here, the torque coil is made of at least two wound wire layers. The inner wire layer and the outer wire layer can be wound in the left or right hand direction. Torque is transferred best in the direction opposite of the wind direction.

The Bragg grating forms a fiber Bragg grating which is a type of distributed Bragg reflector constructed in a short segment of the optical fiber that reflects particular wavelengths of light and transmits all others. This is achieved by creating a periodic variation in a refractive index of a fiber core of the fiber, which generates a wavelength-specific dielectric mirror. The fiber Bragg grating can be used as an inline optical filter to block certain wavelengths or as a wavelength-specific reflector.

A predefined wavelength range may be between 0.1 – 10 μm.

The torque coil according to one embodiment can be used for example as catheter body with integrated optical sensing. The Bragg grating may reflect a predefined wavelength range based on a mutual distance of the grating structures change. A sensing or detecting of changes of the reflected wavelength range may allow e.g. a determination of a change of a mechanical condition or a

temperature of the torque coil and/or its surroundings. A change of a mechanical condition may be a change of a pressure which may be used to e.g. identify a severity of a lesion by measuring a pressure gradient between a proximal and a distal end of the lesion (so-called flow fracture reserve (FFR) measurement). A change of temperature may be detected and used to control a temperature of tissue surrounding the e.g. electrophysiological catheter body during e.g. an ablation of the tissue. The torque coil according to one embodiment with the integrated optical sensing allows a sensing without electrical wires used for e.g. conventional mechanical and/or electrical sensor systems and without additional space requirements of e.g. a conventional temperature sensor system. Further, the controllability of the torque coil within e.g. a blood vessel is not degraded by the integrated optical sensing in contrast to conventional sensor systems added to torque coils. For example, the torque coil according to one embodiment may have good flexibility, pushability and/or retrievability properties, which are not influenced by a sensing system. These properties may be varied along a length of the torque coil and may further be customized. Additionally, an inner lumen of the torque coil according to one embodiment is not occupied by a conventional sensor system and is therefore free for e.g. a guide wire to guide the torque coil through e.g. a highly calcified lesion. As a result, the torque coil according to one embodiment is easy to handle.

The torque coil according to one embodiment can for example be used to identify cancer cells in minimal invasive interventional oncology. The Bragg grating may then be provided with a coating, for example, a biomarker coating, to which specific molecules of e.g. cancer cells may adhere and thereby change the reflected wavelength range of the optical fiber. The reflected wavelength range may be further processed by spectral imaging methods as e.g. Surface Plasmon Resonance spectroscopy, Raman spectroscopy, Hyperspectral imaging and the like.

In an example, the optical fiber includes at least an additional Bragg grating. The additional Bragg grating may be configured for reflecting an additional predefined wavelength range based on a mutual distance of the grating

structures of the additional Bragg grating. The Bragg grating and/or the additional Bragg grating may be arranged at a distal end of the torque coil. The Bragg grating and/or the additional Bragg grating may also be arranged at different positions of the torque coil to allow simultaneous measurements at different positions within e.g. a body lumen.

In an example, the Bragg grating and/or the additional Bragg grating is/are arranged perpendicular to a longitudinal direction of the optical fiber to detect e.g. physical changes of the optical fiber.

The Bragg grating and/or the additional Bragg grating may also be tilted with respect to the longitudinal direction of the optical fiber so that light may be reflected to an outer surface of the optical fiber, may be reflected by the outer surface back into the optical fiber and may then be detected and further processed for e.g. interventional oncology. In an example, the Bragg grating and/or the additional Bragg grating is/are arranged with an angle between 20° and 70° relative to a longitudinal direction of the optical fiber. The Bragg grating and/or the additional Bragg grating may also be arranged with an angle between 40° and 50° relative to a longitudinal direction of the optical fiber.

In an example, the torque coil further includes an intermediate wire layer. The intermediate wire layer may be wound over the inner wire layer and the outer wire layer may be wound over the intermediate wire layer. By means of the intermediate wire layer, a three layered coil is formed which may be stiffener than a two layered coil and/or may allow a bidirectional or dual directional torque transmission, torque response and torque control. There may be still one or more further intermediate wire layers arranged between the inner wire layer and the outer wire layer to form a multi layered coil.

In an example, the inner wire layer is wound with a pitch in a first direction and the intermediate wire layer is wound with a pitch in a second direction reverse to the first direction. In an example, only the inner wire layer and the outer wire layer are wound with the same pitch. In an example, only the intermediate wire layer and the outer wire layer are wound with the same pitch. In another example, only the intermediate wire layer and the inner wire layer are

wound with the same pitch. Reverse winding of at least two wire layers may provide additional stability to the torque coil. Further, the torque coil may then be rotated clockwise and counterclockwise without collapsing or winding open with the rotation.

In all layers, the pitch may be varied along the length of the torque coil to provide e.g. a varying stiffness of the torque coil. Further, in all wire layers, the surface of the layer may be (nearly) closed or open, which means there may be gaps or (nearly) no gaps between adjacent filars or filar portions of the wire layer.

All wires of all wire layers may be made of metal, except for the optical fiber, which may be made of a plastic material, as e.g. PMMA, a glass material, as e.g. acrylic glass, or the like. A cover, such as a polymer cover, may surround at least one, and one embodiment, the outer wire layer to secure the wire layer.

According to one embodiment, also a detection system is presented. The detection system includes a torque coil as described above and a detection unit. The detection unit is configured for detecting a change of the reflected wavelength range. The change of the reflected wavelength range may be based on a change of a mutual distance of grating structures of a Bragg grating in the torque coil. The change of the mutual distance of the grating structures may be based on a change of a length of the torque coil and/or an optical fiber of the torque coil. The change of the length may be based on a change of a mechanical condition or a temperature of the torque coil and/or the optical fiber.

In an example, the detection unit is further configured for determining a change of a mechanical condition based on the change of the reflected wavelength range. The mechanical condition may be a pressure, a strain, a force, or the like.

In an example, the detection unit is further configured for determining a change of temperature based on the change of the reflected wavelength range.

In an example, the detection unit is further configured for determining a change in a spectrum based on the change of the reflected wavelength range. The

change of spectrum may be used for spectral imaging to identify e.g. cancer cells.

According to one embodiment, also a method for forming a torque coil is presented. It includes the following steps, not necessarily in this order:

a) winding an inner wire layer, and

b) winding an outer wire layer over the inner wire layer.

A wire of the outer wire layer is an optical fiber and the optical fiber includes a Bragg grating. The Bragg grating includes grating structures and the Bragg grating is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures.

The Bragg grating may be created by providing a systematic (periodic or aperiodic) variation of a refractive index into a core of the optical fiber by means of e.g. an UV laser.

The method for forming a torque coil may further include a step of winding an intermediate wire layer over the inner wire layer before winding the outer wire layer over the intermediate wire layer.

In one embodiment, a torque coil comprises a wound inner wire layer, and a wound outer wire layer. The outer wire layer is wound over the inner wire layer, a wire of the outer wire layer comprises an optical fiber, the optical fiber comprises a Bragg grating, the Bragg grating comprises grating structures, and the Bragg grating is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures.

In one embodiment, with any of the torque coils previously described, the optical fiber comprises at least an additional Bragg grating that is configured for reflecting an additional predefined wavelength range based on a mutual distance of the grating structures of the additional Bragg grating.

In one embodiment, with any of the torque coils previously described, the Bragg grating and/or additional Bragg grating is arranged perpendicular to a longitudinal direction of the optical fiber.

In one embodiment, with any of the torque coils previously described, the Bragg grating and/or additional Bragg grating is arranged with an angle between 20° and 70° relative to a longitudinal direction of the optical fiber.

In one embodiment, any of the torque coils previously described further comprises an intermediate wire layer, wherein the intermediate wire layer is wound over the inner wire layer and the outer wire layer is wound over the intermediate wire layer.

In one embodiment, with any of the torque coils previously described, the inner wire layer is wound with a pitch in a first direction and the intermediate wire layer is wound with a pitch in a second direction reverse to the first direction.

In one embodiment, with any of the torque coils previously described, the inner wire layer and the outer wire layer are wound with the same pitch.

In one embodiment, a detection system comprises a torque coil comprising a wound inner wire layer and a wound outer wire layer. The outer wire layer is wound over the inner wire layer, a wire of the outer wire layer is an optical fiber, the optical fiber comprises a Bragg grating, the Bragg grating comprises grating structures, and the Bragg grating is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures. The system further includes a detection unit. The detection unit is configured for detecting a change of the reflected wavelength range.

In one embodiment, with any of the detection system previously described, the detection unit is further configured for determining a change of a mechanical condition based on the change of the reflected wavelength range.

In one embodiment, with any of the detection systems previously described, the detection unit is further configured for determining a change of temperature based on the change of the reflected wavelength range.

In one embodiment, with any of the detection systems previously described, the detection unit is further configured for determining a change in a spectrum based on the change of the reflected wavelength range.

In one embodiment, a method for forming a torque coil comprises winding an inner wire layer, and winding an outer wire layer over the inner wire layer. A wire of the outer wire layer is an optical fiber, the optical fiber comprises a Bragg grating, the Bragg grating comprises grating structures, and the Bragg grating is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures.

In one embodiment, with any of the methods previously described, the Bragg grating is arranged perpendicular to a longitudinal direction of the optical fiber.

In one embodiment, with any of the methods previously described, the Bragg grating is arranged with an angle between 20° and 70° relative to a longitudinal direction of the optical fiber.

In one embodiment, any of the methods previously described, further comprises winding an intermediate wire layer over the inner wire layer and winding the outer wire layer is wound over the intermediate wire layer.

In one embodiment, any of the methods previously described, further comprises winding the inner wire layer with a pitch in a first direction and winging the intermediate wire layer with a pitch in a second direction reverse to the first direction.

It shall be understood that the the torque coil, the detection system including such torque coil, and the method for forming such torque coil, according to the independent claims have similar and/or identical embodiments, for example, as defined in the dependent claims. It shall be understood further that an embodiment can also be any combination of the dependent claims with the respective independent claim.

Figure 1 shows schematically and exemplarily an embodiment of a detection system 1 according to one embodiment. The detection system 1 includes a torque coil 10 and a detection unit 20. The torque coil 10 is a tube made of wound wires. The torque coil 10 thereby forms a flexible tube for torque transmission, torque response and/or torque control. The torque coil 10 is flexible enough to be guided through blood vessels or body lumens and stiff

enough to be pushed also through complex anatomies and e.g. calcified lesions without buckling.

Figure 2 shows schematically and exemplarily an embodiment of the torque coil 10 according to one embodiment. The torque coil 10 includes a wound inner wire layer 11 and a wound outer wire layer 12. The outer wire layer 12 is wound over the inner wire layer 11. The inner wire layer 11 is then within the outer wire layer 12. A wire of the outer wire layer 12 is an optical fiber 13.

Figure 3 shows schematically and exemplarily an embodiment of the optical fiber 13. The optical fiber 13 includes a Bragg grating 14 and the Bragg grating 14 includes grating structures 15. The Bragg grating 14 is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures 15. The Bragg grating 14 is a type of distributed Bragg reflector in the optical fiber 13. It reflects particular wavelengths of light and transmits all others. The Bragg grating 14 is here arranged perpendicular to a longitudinal direction of the optical fiber 13.

The detection unit 20 shown in Fig. 1 is configured for detecting a change of the reflected wavelength range. The change of the reflected wavelength range is based on a change of a mutual distance of grating structures 15 of a Bragg grating 14 in the torque coil 10. The change of the mutual distance of the grating structures 15 is based on a change of a length of the torque coil 10 and/or an optical fiber 13 of the torque coil 10. The change of the length is based on a change of a mechanical condition or a temperature of the torque coil 10 and/or the optical fiber 13.

Consequently, the detection unit 20 may determine a change of a mechanical condition based on the change of the reflected wavelength range. The mechanical condition may be a pressure, a strain, a force, or the like. Further, the detection unit 20 may determine a change of temperature based on the change of the reflected wavelength range.

The torque coil 10 according to one embodiment therefore provides an integrated optical sensing that allows a sensing without e.g. electrical wires used for e.g. conventional mechanical and/or electrical sensor systems and without

additional space requirements of e.g. a conventional temperature sensor system. The controllability of the torque coil 10 within e.g. a blood vessel is not degraded by the integrated optical sensing in contrast to conventional sensor systems added to torque coils. As a result, the torque coil 10 according to one embodiment provides good flexibility, pushability and/or retrievability properties and is therefore easy to handle.

Figure 4 shows schematically and exemplarily another embodiment of a torque coil 10 according to one embodiment. Here, the torque coil 10 further includes an intermediate wire layer 16. The intermediate wire layer 16 is wound over the inner wire layer 11 and the outer wire layer 12 is wound over the intermediate wire layer 16. By means of the intermediate wire layer 16, a three layered coil instead of the two layered coil of Fig. 2 is formed.

The inner wire layer 11 is wound with a pitch in a first direction and the intermediate wire layer 16 is wound with a pitch in a second direction reverse to the first direction. The outer wire layer 12 is again wound with a pitch in the first direction. The inner wire layer 11 and the outer wire layer 12 are then wound with the same pitch.

The surface of the inner wire layer 11 is nearly closed, which means there are nearly no gaps between adjacent filars of the inner wire layer 11. For the intermediate wire layer 16 and the outer wire layer 12, groups of five filars form filar portions. The surfaces of the intermediate wire layer 16 and the outer wire layer 12 are open, which means there are gaps between the filars portions of the intermediate wire layer 16 and the outer wire layer 12, respectively.

Again, a wire of the outer wire layer 12 is an optical fiber 13. The optical fiber 13 includes a Bragg grating 14 and the Bragg grating 14 includes grating structures 15 (both not shown in Fig. 4). The Bragg grating 14 is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures 15.

Figure 5 shows a schematic overview of steps of a method for forming a torque coil 10 according to one embodiment. The method includes the following steps, not necessarily in this order:

- In a first step S1, winding an inner wire layer 11.
- In a second step S2, winding an outer wire layer 12 over the inner wire layer 11.

A wire of the outer wire layer 12 is an optical fiber 13 and the optical fiber 13 includes a Bragg grating 14. The Bragg grating 14 includes grating structures 15 and the Bragg grating 14 is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures 15.

It has to be noted that embodiments of one embodiment are described with reference to different subject matters. For example, some embodiments are described with reference to method type claims whereas other embodiments are described with reference to the device type claims. However, a person skilled in the art will gather from the above and the following description that, unless otherwise notified, in addition to any combination of features belonging to one type of subject matter also any combination between features relating to different subject matters is considered to be disclosed with this application. However, all features can be combined providing synergetic effects that are more than the simple summation of the features.

While the embodiments have been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. The invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing a claimed invention, from a study of the drawings, the disclosure, and the dependent claims.

In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. A single processor or other unit may fulfil the functions of several items re-cited in the claims. The mere fact that certain measures are re-cited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

WHAT IS CLAIMED IS:

1. A torque coil (10), comprising:
   - a wound inner wire layer (11), and
   - a wound outer wire layer (12),

   wherein the outer wire layer (12) is wound over the inner wire layer (11),
   wherein a wire of the outer wire layer (12) is an optical fiber (13),
   wherein the optical fiber (13) comprises a Bragg grating (14),
   wherein the Bragg grating (14) comprises grating structures (15), and
   wherein the Bragg grating (14) is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures (15).

2. Torque coil (10) according to claim 1, wherein the optical fiber (13) comprises at least an additional Bragg grating, and
   wherein the additional Bragg grating is configured for reflecting an additional predefined wavelength range based on a mutual distance of the grating structures (15) of the additional Bragg grating.

3. Torque coil (10) according to claim 1 or 2, wherein the Bragg grating (14) and/or the additional Bragg grating is arranged perpendicular to a longitudinal direction of the optical fiber (13).

4. Torque coil (10) according to claim 1 or 2, wherein the Bragg grating (14) and/or the additional Bragg grating is arranged with an angle between 20° and 70° relative to a longitudinal direction of the optical fiber (13).

5. Torque coil (10) according to one of the preceding claims, further comprising:
   an intermediate wire layer (16),

wherein the intermediate wire layer is wound over the inner wire layer (11) and the outer wire layer (12) is wound over the intermediate wire layer (16).

6. Torque coil (10) according to the preceding claim, wherein the inner wire layer (11) is wound with a pitch in a first direction and the intermediate wire layer (16) is wound with a pitch in a second direction reverse to the first direction.

7. Torque coil (10) according to one of the preceding claims, wherein the inner wire layer (11) and the outer wire layer (12) are wound with the same pitch.

8. A detection system (1), comprising:
- a torque coil (10) according to one of the preceding claims, and
- a detection unit (20),

wherein the detection unit (20) is configured for detecting a change of the reflected wavelength range.

9. Detection system (1) according to the preceding claim, wherein the detection unit (20) is further configured for determining a change of a mechanical condition based on the change of the reflected wavelength range.

10. Detection system (1) according to one of the preceding claims, wherein the detection unit (20) is further configured for determining a change of temperature based on the change of the reflected wavelength range.

11. Detection system (1) according to one of the preceding claims, wherein the detection unit (20) is further configured for determining a change in a spectrum based on the change of the reflected wavelength range.

12. A method for forming a torque coil (10), comprising the following steps:

– winding an inner wire layer (11), and

– winding an outer wire layer (12) over the inner wire layer (11),

wherein a wire of the outer wire layer (12) is an optical fiber (13),

wherein the optical fiber (13) comprises a Bragg grating (14),

wherein the Bragg grating (14) comprises grating structures (15), and

wherein the Bragg grating (14) is configured for reflecting a predefined wavelength range based on a mutual distance of the grating structures (15).

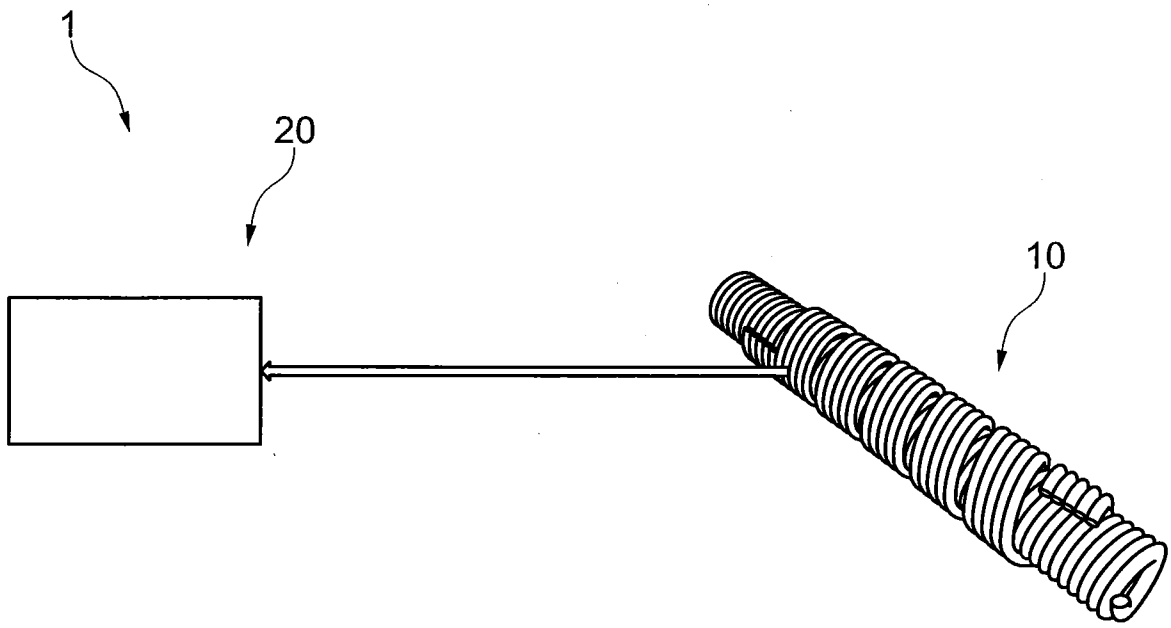


Fig. 1

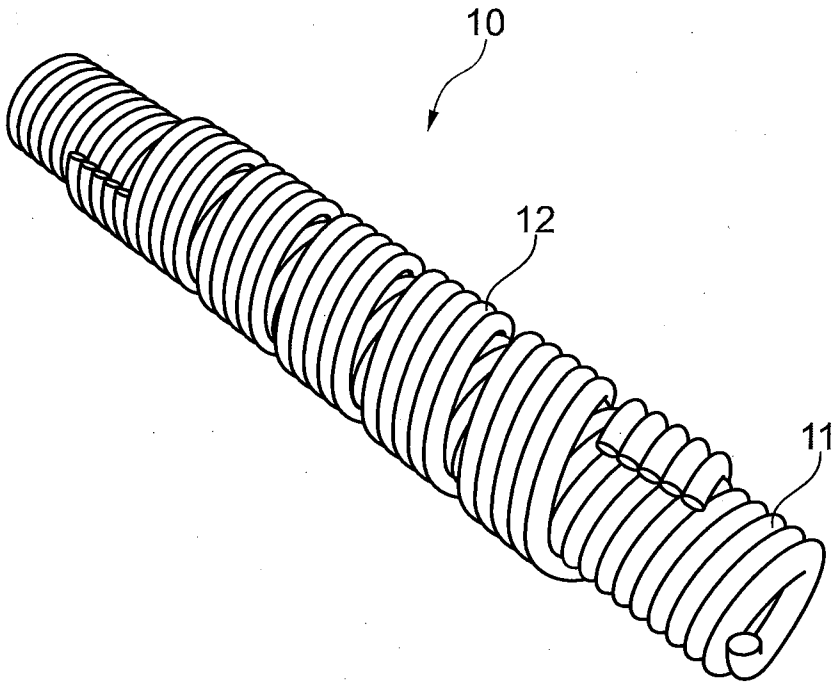


Fig. 2

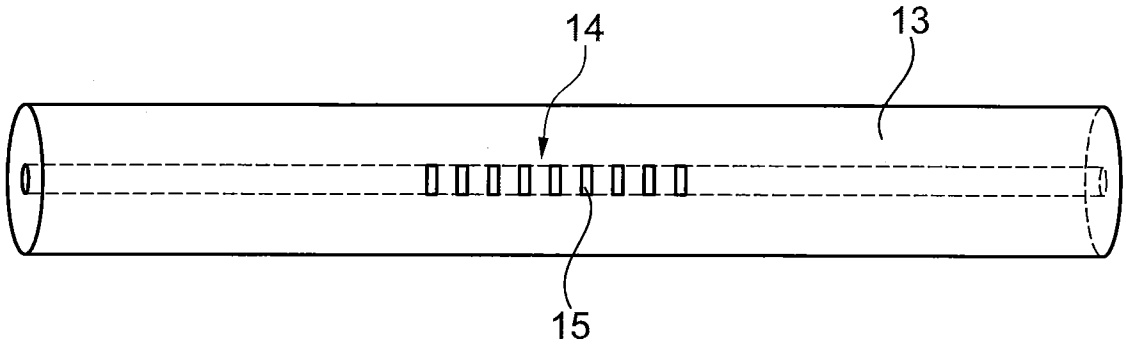


Fig. 3

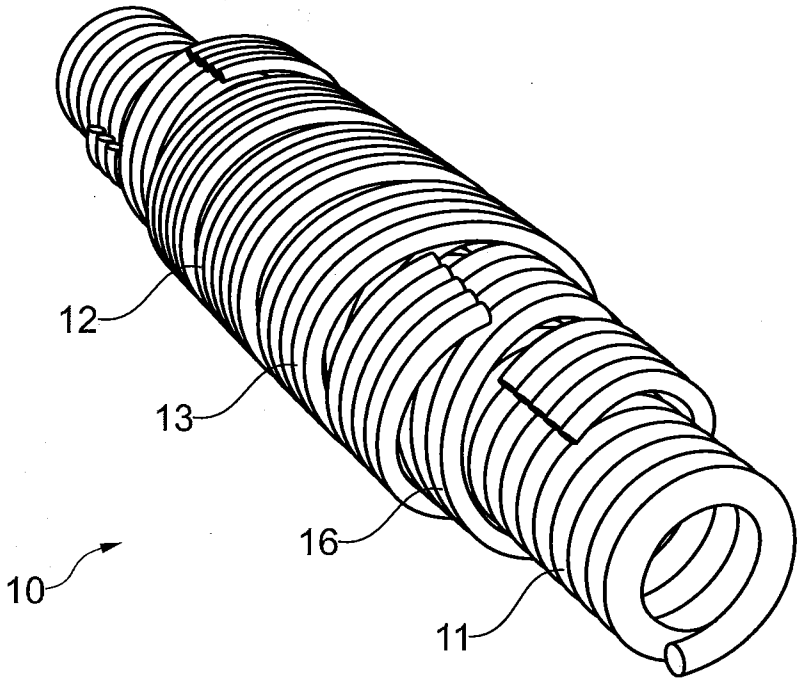


Fig. 4

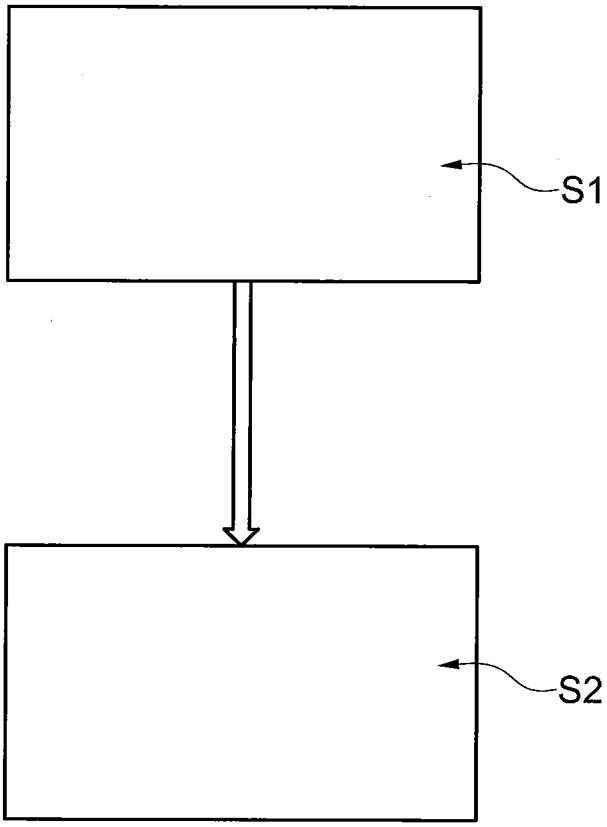


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/059759

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61M25/01 A61M25/09 F16C1/02 A61B5/00 A61B5/0215 A61B5/01
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)
A61M F16C 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, BIOSIS, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013/317372 A1 (EBERLE MICHAEL J [US] ET AL) 28 November 2013 (2013-11-28) paragraph [0007] - paragraph [0008] paragraph [0049] - paragraph [0055] paragraph [0061] paragraph [0167] - paragraph [0170] figures 1,14A-14C,15A-15C	1-12
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1 February 2017	08/02/2017

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