US 20220363902A9

(19) **United States**

(12) **Patent Application Publication**

SUDIN et al.

(10) **Pub. No.: US 2022/0363902 A9**

(48) **Pub. Date: Nov. 17, 2022**

CORRECTED PUBLICATION

(54) **ROTATIONALLY TORQUABLE ENDOVASCULAR DEVICE WITH ACTUATABLE WORKING END**

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(21) Appl. No.: **17/374,726**

(22) Filed: **Jul. 13, 2021**

Prior Publication Data

(15) Correction of US 2022/0002547 A1 Jan. 6, 2022
See (63) Related U.S. Application Data.

(65) US 2022/0002547 A1 Jan. 6, 2022

Related U.S. Application Data

(63) Continuation of application No. 16/388,056, filed on Apr. 18, 2019, now Pat. No. 11,090,464, which is a continuation-in-part of application No. PCT/IB2017/001663, filed on Sep. 28, 2017.

(60) Provisional application No. 62/401,387, filed on Sep. 29, 2016.

Publication Classification

(51) **Int. Cl.**

C08L 93/04	(2006.01)
C08L 77/02	(2006.01)
C08L 69/00	(2006.01)
C08L 101/00	(2006.01)
C08L 67/00	(2006.01)
C08L 77/00	(2006.01)

(52) **U.S. Cl.**

CPC ***C08L 93/04*** (2013.01); ***C08L 77/02*** (2013.01); ***C08L 69/00*** (2013.01); ***C08L 101/00*** (2013.01); ***C08L 67/00*** (2013.01); ***C08L 77/00*** (2013.01)

(57) **ABSTRACT**

In one exemplary embodiment, an endovascular device may include a hollow shaft having a proximal end and a distal end, and sized for insertion into a blood vessel. The endovascular device may also include a control line having a proximal end and a distal end, and extending through the hollow shaft. The endovascular device may also include an actuatable working element located proximate the distal end of the hollow shaft, and configured to receive an actuation force transmitted via the distal end of the control line. The endovascular device may further include an actuator configured to exert the actuation force on the proximal end of the control line, to thereby cause relative movement between the control line and the hollow shaft and to actuate the working element. The hollow shaft may also include a cable formed of a plurality of wound wires and including a proximal segment, at least one transition segment, and a distal segment. The proximal segment, at least one transition segment, and distal segment may include different numbers of wires.

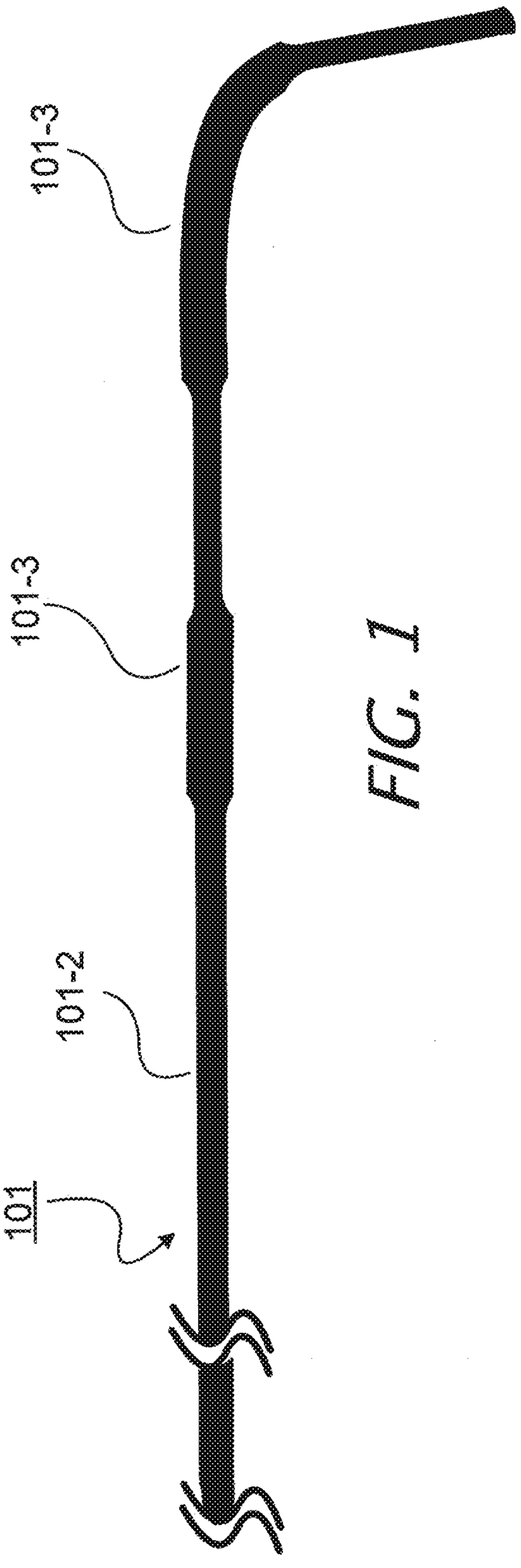

FIG. 1

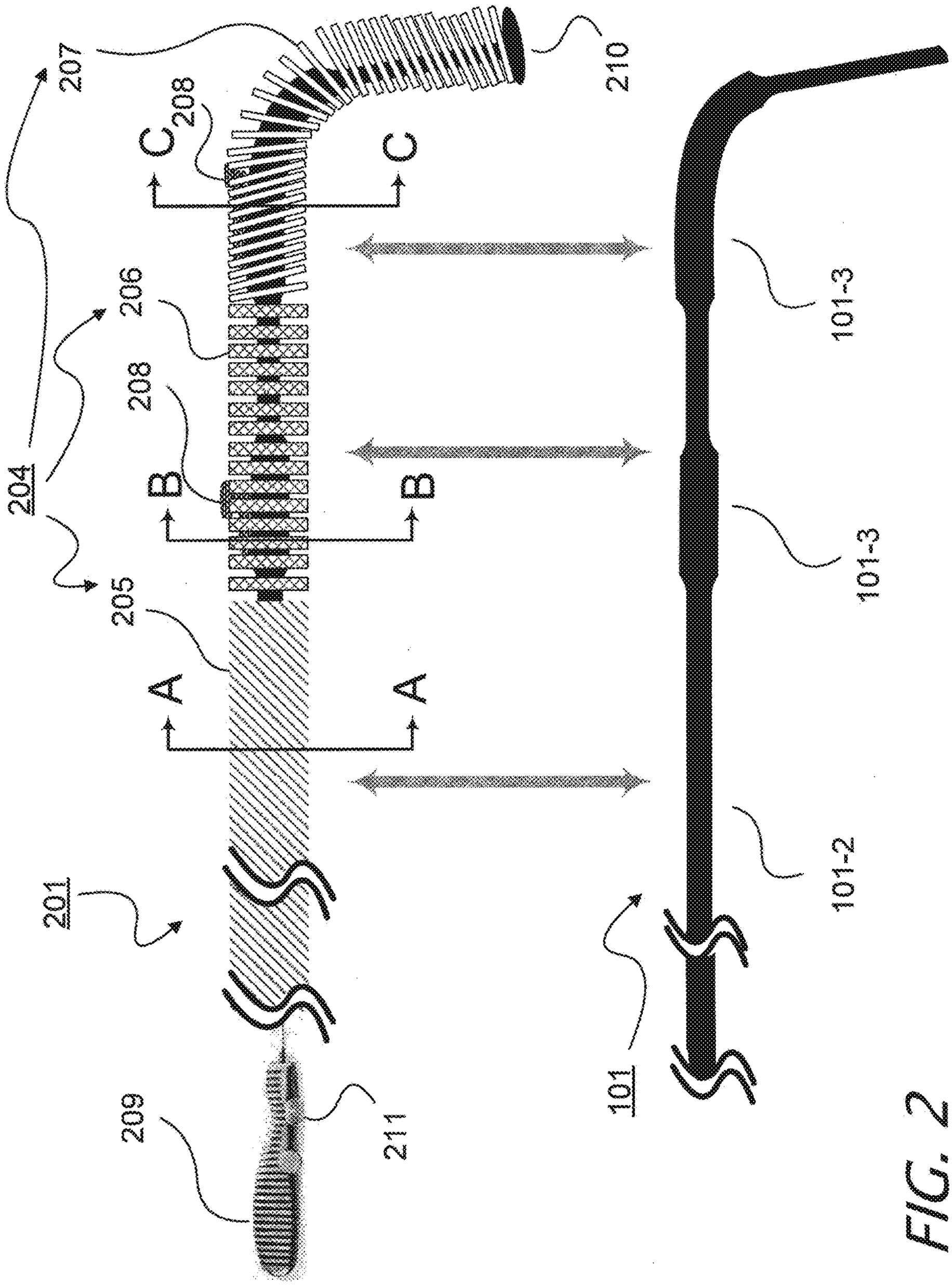
207
210
C
208
C
206
208
204
B
B
205
A
A
101-3
101-3
201
209
211
101
101-2

FIG. 2

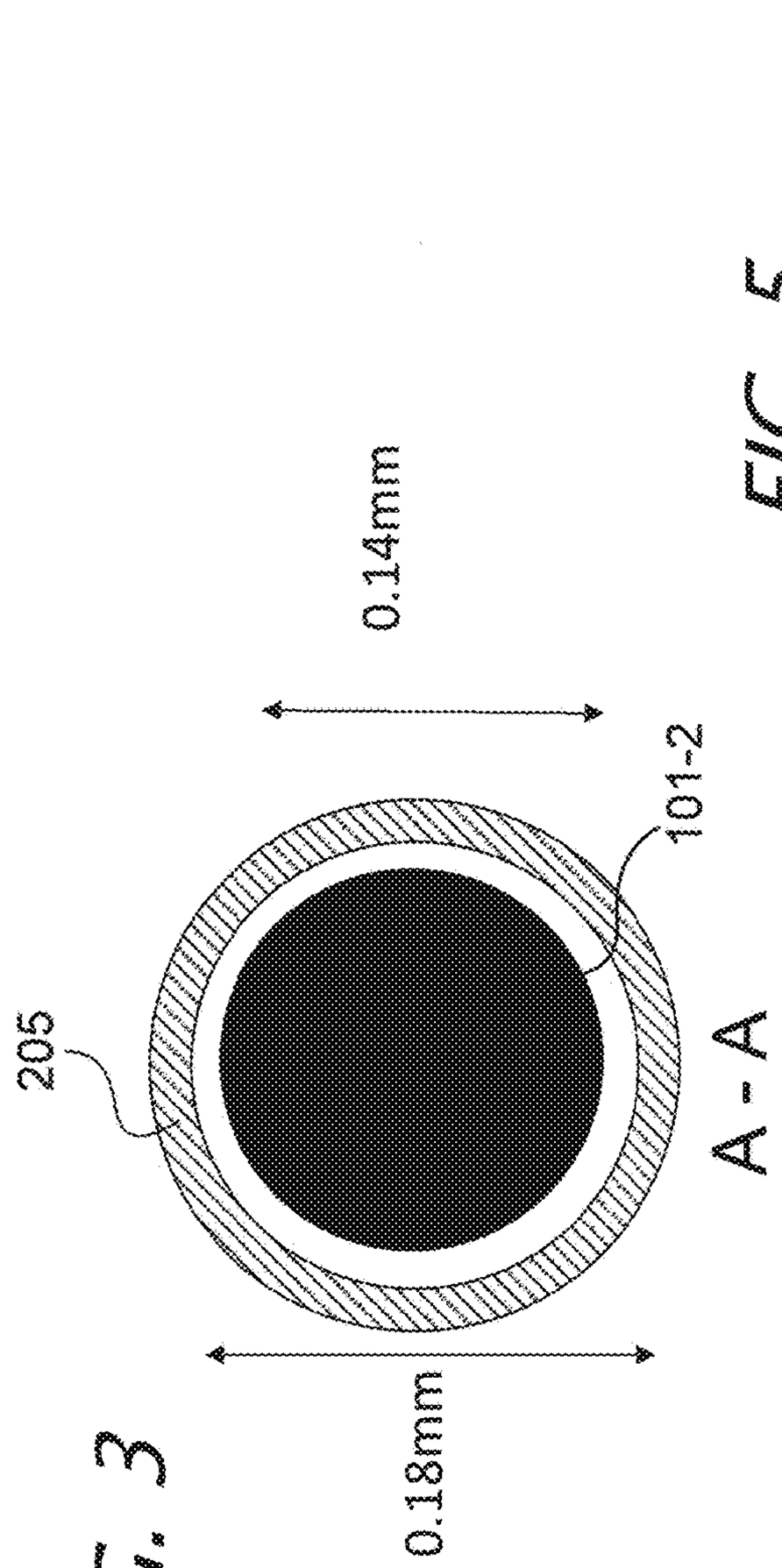

FIG. 3

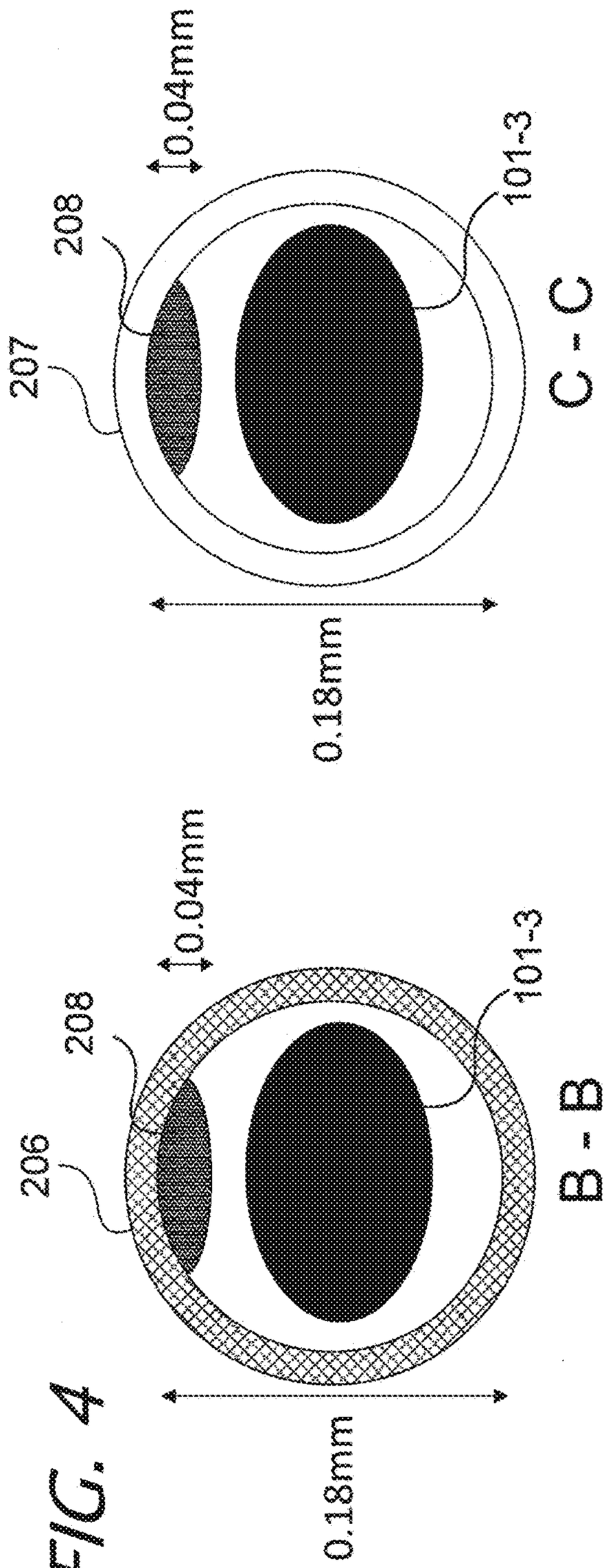

FIG. 5

FIG. 4

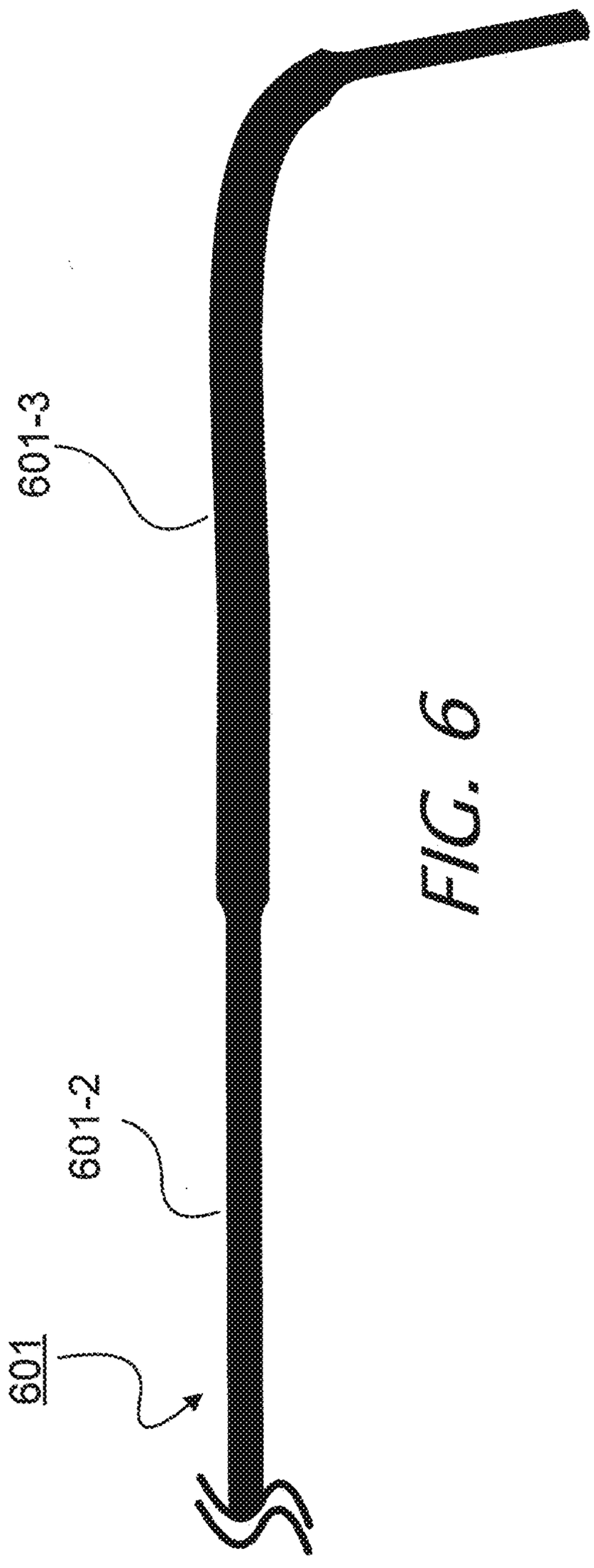

FIG. 6

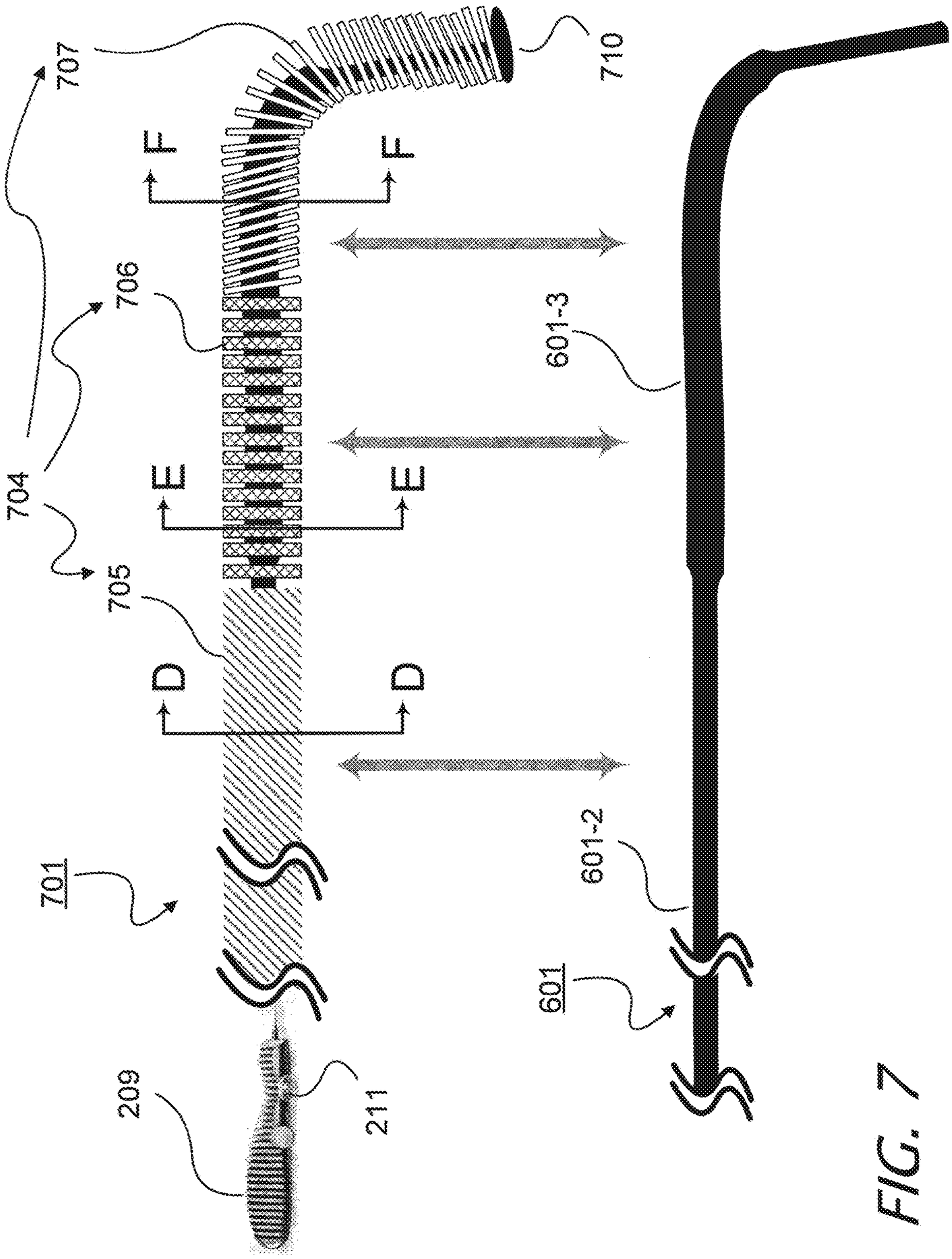

FIG. 7

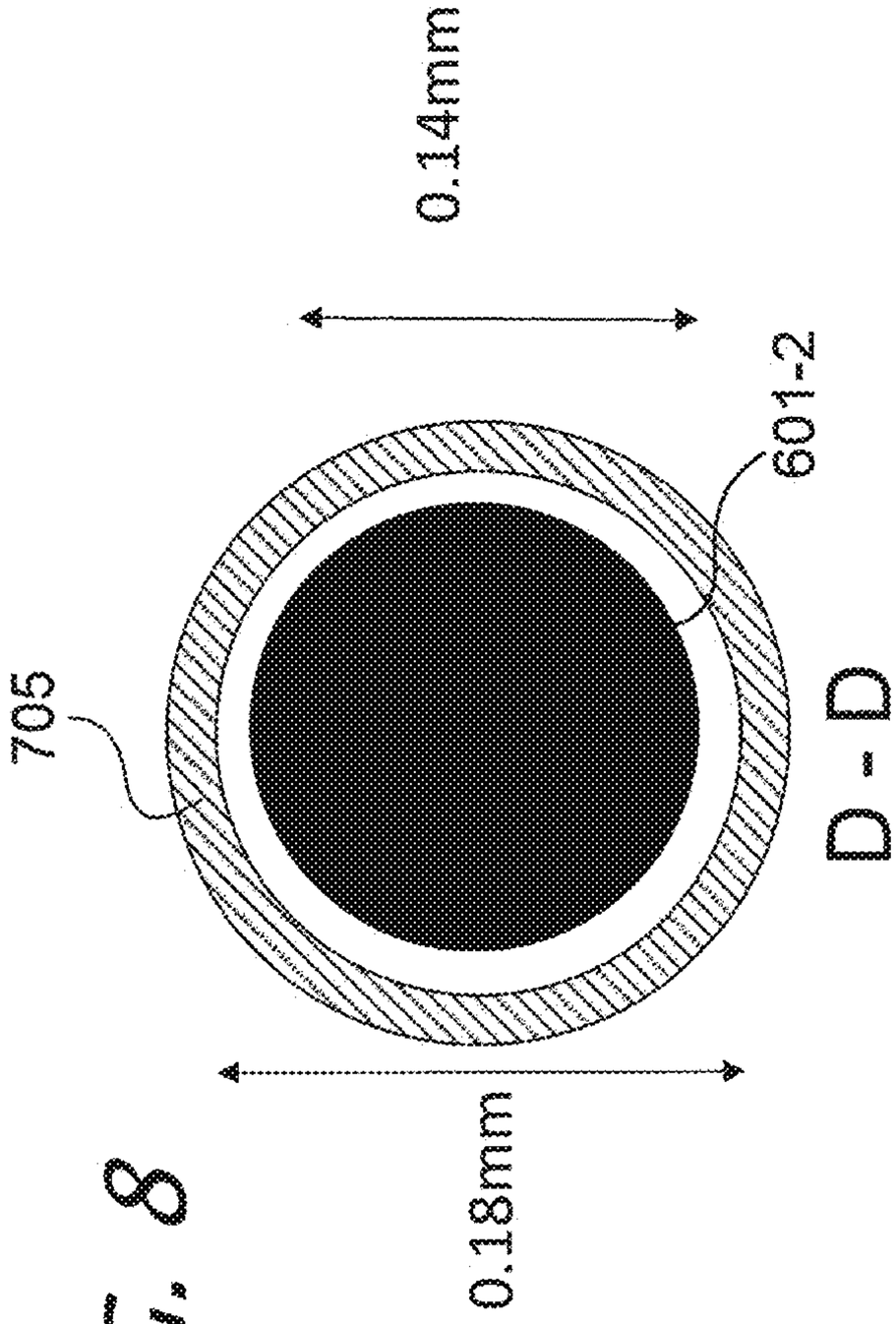

FIG. 8

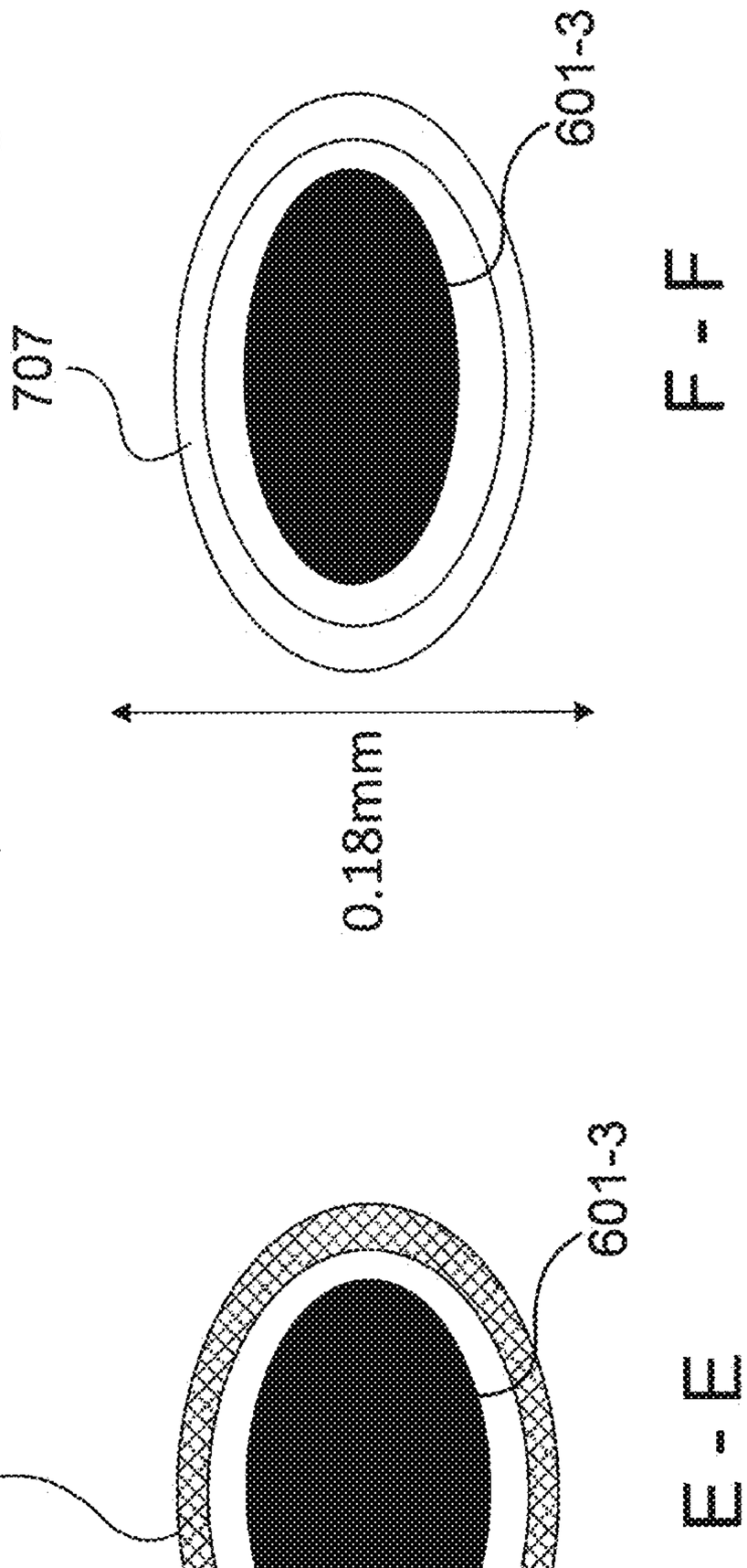

FIG. 10

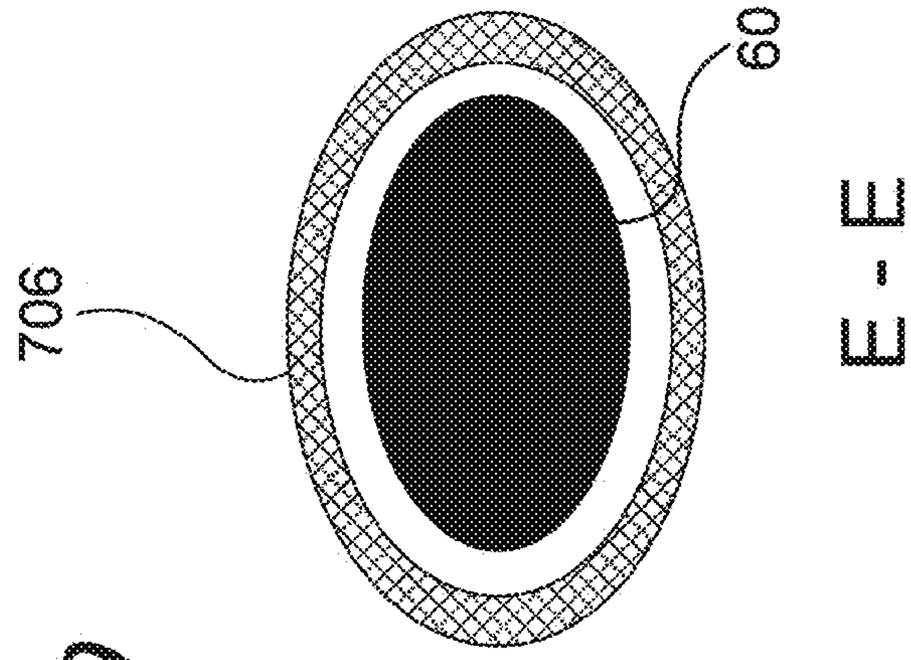

FIG. 9

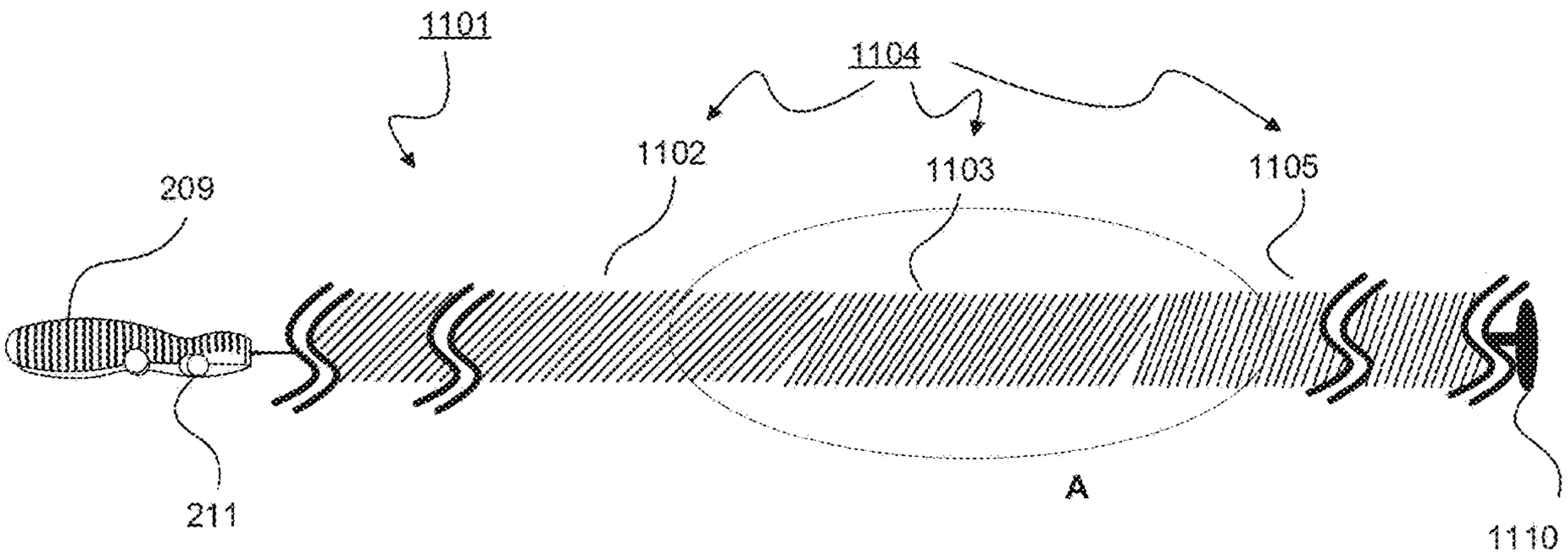

FIG. 11A

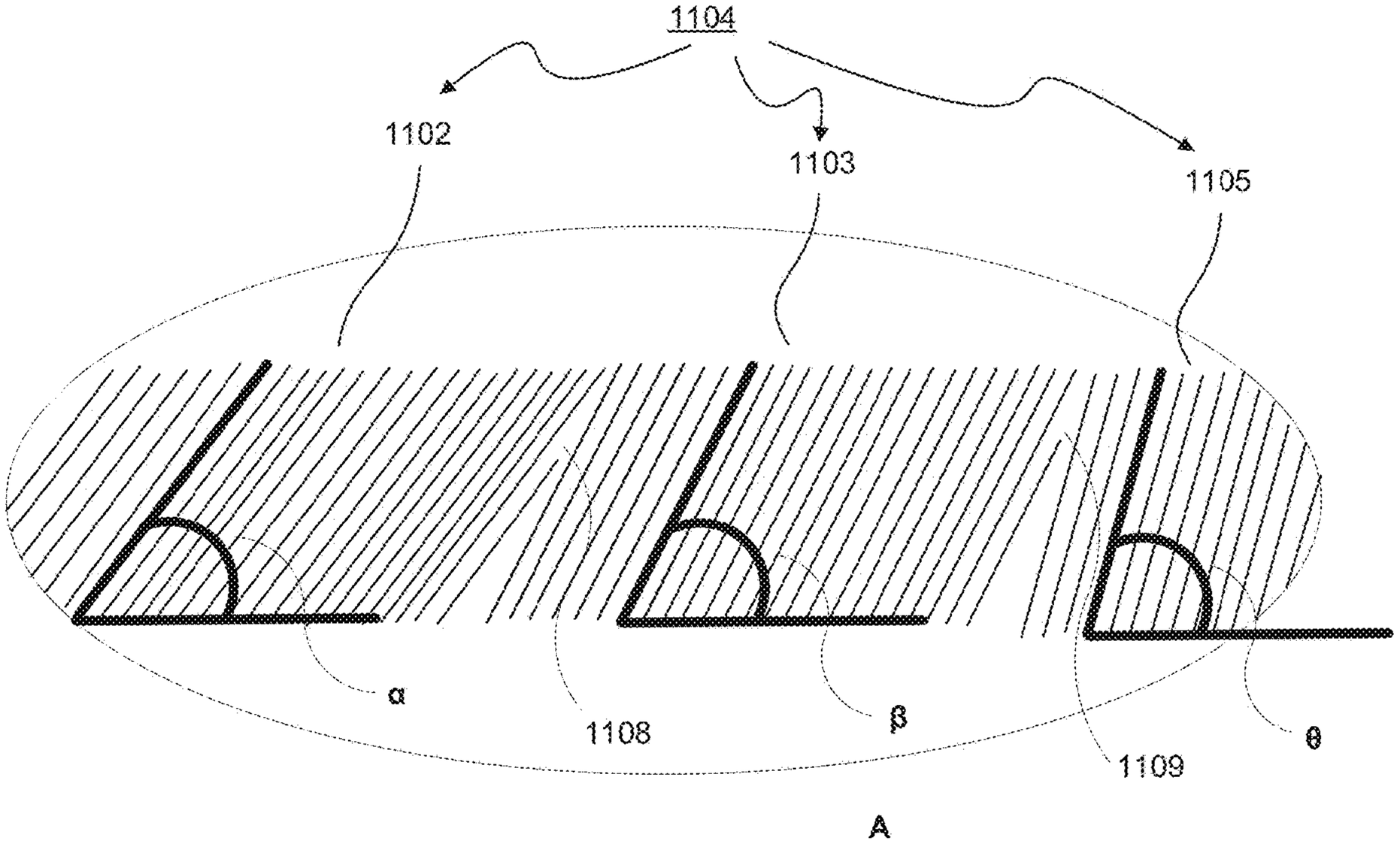

FIG. 11B

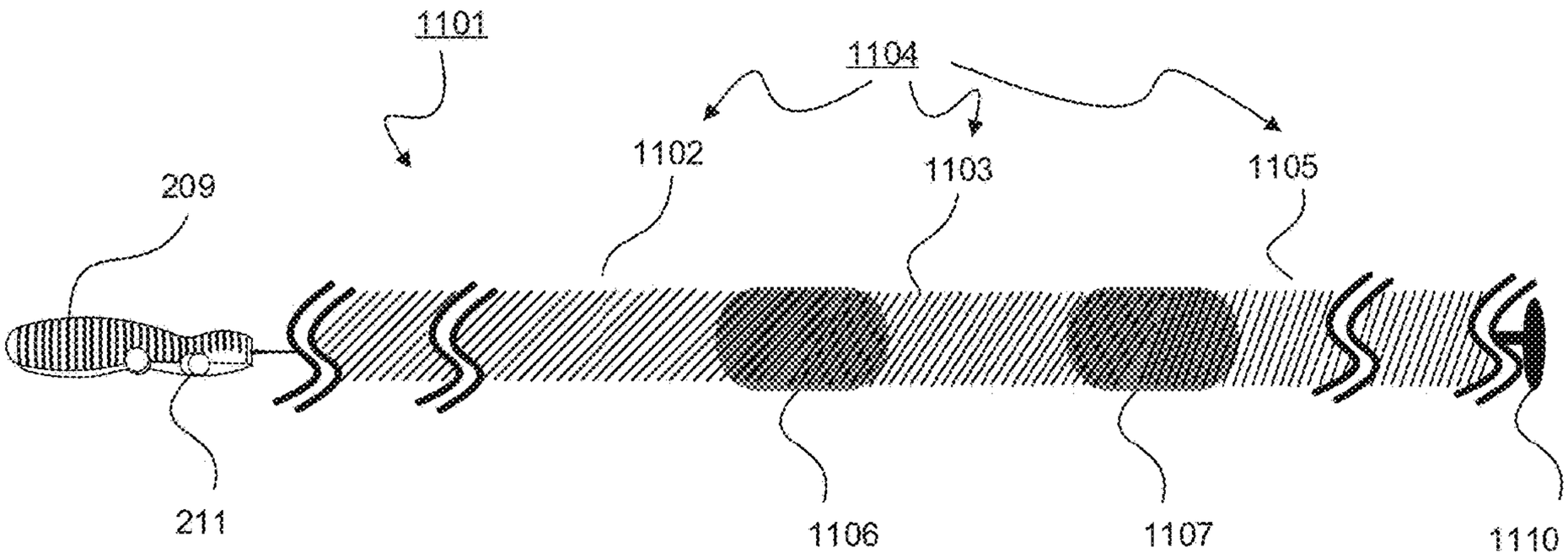

FIG. 11C

ROTATIONALLY TORQUABLE ENDOVASCULAR DEVICE WITH ACTUATABLE WORKING END

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. application Ser. No. 16/338,056, filed Apr. 18, 2019, which is a continuation-in-part of PCT Application No. PCT/IB2017/001663, filed Sep. 28, 2017, which claims the benefit of priority from U.S. Provisional Application No. 62/401,387 filed Sep. 29, 2016, both of which are herein incorporated by reference in their entireties.

TECHNICAL FIELD

[0002] This disclosure relates generally to endovascular devices. In particular, the disclosure relates generally to endovascular devices comprising a cable formed by a plurality of wound wires to transfer torque while maintaining flexibility and structural strength.

SUMMARY

[0003] Embodiments of the present disclosure may include an endovascular device including a hollow shaft having a proximal end and a distal end, a control line having a proximal end and a distal end, an actuatable working element located proximate the distal end of the hollow shaft, and an actuator. The hollow shaft may be sized for insertion into a blood vessel. The control line may extend through the hollow shaft. The actuatable working element may be configured to receive an actuation force transmitted via the distal end of the control line. The actuator may be configured to exert the actuation force on the proximal end of the control line, to thereby cause relative movement between the control line and the hollow shaft and to actuate the working element. The hollow shaft may also include a cable formed of a plurality of wound wires. The cable may include a proximal segment, at least one transition segment, and a distal segment. The proximal segment, the at least one transition segment, and the distal segment may include different numbers of wires.

[0004] In some embodiments, the proximal segment of the cable may include a first number of wires, the at least one transition segment may include a second number of wires, which may be less than the first number of wires, and the distal segment may include a third number of wires, which may be less than the second number of wires. The first number of wires may be wound at a first pitch angle, the second number of wires may be wound at a second pitch angle, and the third number of wires may be wound at a third pitch angle. The first, second, and third pitch angles may be determined based on at least one of a diameter of the wires, the number of wires, and a diameter of a winding mandrel. In some embodiments, the first pitch angle may be less than the second pitch angle, and the second pitch angle may be less than the third pitch angle.

[0005] In some embodiments, at least one of the plurality of wound wires may be configured to extend from the proximal segment to the distal segment of the cable. In other embodiments, the distal segment may have a flexibility greater than a flexibility of the proximal segment. In yet another embodiment, the cable may include at least three transition segments.

[0006] In some embodiments, a rotational force exerted on the proximal end of the hollow shaft may cause the rotational force to be applied to the working element. The ratio of the rotational force exerted on the proximal end of the hollow shaft to the rotational force applied to the working element may be approximately 1:1. In other words, the rotational force exerted on the proximal end of the hollow shaft may be approximately equal to the rotational force applied to the working element. In some embodiments, the cable may be configured to transfer rotational torque to the distal end of the working element when the hollow shaft is rotated.

[0007] Embodiments of the present disclosure may also include an endovascular device including a hollow shaft having a proximal end and a distal end, a control line having a proximal end and a distal end, an actuatable working element located proximate the distal end of the hollow shaft, and an actuator. The hollow shaft may be sized for insertion into a blood vessel. The control line may extend through the hollow shaft. The actuatable working element may be configured to receive an actuation force transmitted via the distal end of the control line. The actuator may be configured to exert the actuation force on the proximal end of the control line, cause relative movement between the control line and the hollow shaft, and actuate the working element. The hollow shaft may also include a cable formed of a plurality of wound wires. The cable may include a proximal segment formed of a first number of wires, at least one transition segment formed of a second number of wires less than the first number of wires, and a distal segment formed of a third number of wires less than the second number of wires.

[0008] In some embodiments, the first number of wires may be wound at a first pitch angle, the second number of wires may be wound at a second pitch angle, and the third number of wires may be wound at a third pitch angle. The first, second, and third pitch angles may be determined based on at least one of a diameter of the wires, the number of wires, and a diameter of a winding mandrel. In some embodiments, the first pitch angle may be less than the second pitch angle, and the second pitch angle may be less than the third pitch angle.

[0009] In some embodiments, at least one of the plurality of wound wires may be configured to extend from the proximal segment to the distal segment of the cable. In other embodiments, the distal segment may have a flexibility greater than a flexibility of the proximal segment. In yet another embodiment, the cable may include at least three transition segments. In some embodiments, the cable may be configured to transfer rotational torque to the distal end of the working element when the hollow shaft is rotated.

[0010] Embodiments of the present disclosure may also include a method of manufacturing an endovascular device. The method may include forming a hollow shaft sized for insertion into a blood vessel, disposing a control line having a proximal end and a distal end through the hollow shaft, connecting an actuatable working element at the distal end of the hollow shaft, and connecting an actuator at the proximal end of the control line. The hollow shaft may have a proximal end and a distal end. The actuatable working element may be configured to receive an actuation force transmitted via the distal end of the control line. The actuator may be configured to exert the actuation force on the proximal end of the control line, cause relative movement

between the control line and the hollow shaft, and actuate the working element. Forming the hollow shaft may also include winding a plurality of wires at a first pitch angle to form a proximal segment of a cable, cutting at least one of the wires forming the proximal segment, winding a first remainder of the wires at a second pitch angle to form a transition segment of the cable, cutting at least one of the first remainder of the wires forming the transition segment, and winding a second remainder of the wires at a third pitch angle to form a distal segment of the cable.

[0011] In some embodiments, a diameter of the winding mandrel may be changed after winding the plurality of wires at the first pitch angle and before winding the first remainder of the wires at the second pitch angle, to thereby compensate for a change in pitch angle. In other embodiments, the diameter of the winding mandrel may be changed after winding the first remainder of the wires at the second pitch angle and before winding the second remainder of the wires at the third pitch angle, to thereby compensate for a change in pitch angle.

[0012] Embodiments of the present disclosure may also include a method of manufacturing an endovascular device. The method may include forming a hollow shaft sized for insertion into a blood vessel, disposing a control line having a proximal end and a distal end through the hollow shaft, connecting an actuatable working element at the distal end of the hollow shaft, and connecting an actuator at the proximal end of the control line. The hollow shaft may have a proximal end and a distal end. The actuatable working element may be configured to receive an actuation force transmitted via the distal end of the control line. The actuator may be configured to exert the actuation force on the proximal end of the control line, cause relative movement between the control line and the hollow shaft, and actuate the working element. Forming the hollow shaft may also include winding a plurality of wires at a pitch angle to form a proximal segment of a cable, cutting at least one of the wires forming the proximal segment, decreasing a diameter of a winding mandrel, winding a first remainder of the wires at the pitch angle to form a transition segment of the cable, cutting at least one of the first remainder of the wires forming the transition segment, decreasing the diameter of the winding mandrel, and winding a second remainder of the wires at the pitch angle to form a distal segment of the cable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate disclosed embodiments and, together with the description, serve to explain the disclosed embodiments.

[0014] FIG. **1** is an illustration of a control wire for an exemplary endovascular device, consistent with at least one of the disclosed embodiments;

[0015] FIG. **2** is an illustration of an exemplary endovascular device with the control wire of FIG. **1**, consistent with at least one of the disclosed embodiments;

[0016] FIG. **3** is an illustration of an inner cross section of a section of the exemplary endovascular device of FIG. **2**, consistent with at least one of the disclosed embodiments;

[0017] FIG. **4** is an illustration of an inner cross section of a section of the exemplary endovascular device of FIG. **2**, consistent with at least one of the disclosed embodiments;

[0018] FIG. **5** is an illustration of an inner cross section of a section of the exemplary endovascular device of FIG. **2**, consistent with at least one of the disclosed embodiments;

[0019] FIG. **6** is an illustration of a control wire for another exemplary endovascular device, consistent with at least one of the disclosed embodiments;

[0020] FIG. **7** is an illustration of an exemplary endovascular device with the control wire of FIG. **6**, consistent with at least one of the disclosed embodiments;

[0021] FIG. **8** is an illustration of an inner cross section of a section of the exemplary endovascular device of FIG. **7**, consistent with at least one of the disclosed embodiments;

[0022] FIG. **9** is an illustration of an inner cross section of a section of the exemplary endovascular device of FIG. **7**, consistent with at least one of the disclosed embodiments; and

[0023] FIG. **10** is an illustration of an inner cross section of a section of the exemplary endovascular device of FIG. **7**, consistent with at least one of the disclosed embodiments.

[0024] FIG. **11**A is an illustration of an exemplary endovascular device, consistent with at least one of the disclosed embodiments.

[0025] FIG. **11**B is an illustration of a section of the exemplary endovascular device of FIG. **11**A, consistent with at least one of the disclosed embodiments.

[0026] FIG. **11**C is an illustration of the exemplary endovascular device of FIG. **11**A, consistent with at least one of the disclosed embodiments.

[0027] Annotations appearing in the figures are exemplary only, and are not restrictive of the invention as claimed.

DETAILED DESCRIPTION

[0028] Reference will now be made in detail to the present embodiments (exemplary embodiments) of the disclosure, examples of which are illustrated in the accompanying drawings.

[0029] FIG. **1** illustrates a control wire **101** of an exemplary endovascular device in accordance with the disclosure, which may be deformed or flattened in two zones **101-3**, and may be round in other areas along its axis **101-2**. FIG. **2** illustrates an exemplary endovascular device **201** using control wire **101** in accordance with the disclosure. (Solely to illustrate the position of zones **101-2** and **101-3** in endovascular device **201**, with the understanding that control wire **101** is part of endovascular device **201**, FIG. **2** also separately depicts control wire **101** of FIG. **1**, with zones **101-3** and **101-2** generally aligned to endovascular device **201**.) As shown in FIG. **2**, endovascular device **201** may also include an elongated shaft **204** which may include a tube **205**, a cable of wires **206**, and a single wire coil **207**. A distal tip **210** of the elongated shaft **204** may be attached to control wire **101**, for example. At a proximal end of the elongated shaft **204**, the control wire **101** may be connected to a slider **211** of a handle **209**, with the elongated shaft **204** connected to the handle **209** to facilitate the relative movement. (In FIG. **2**, handle **209** is not depicted to the same scale as that of elongated shaft **204**.) In accordance with at least some embodiments, two polymers **208** may be inserted between the elongated shaft **204** and the control wire **101** to prevent the radial movement between the control wire **101** and the elongated shaft **204**.

[0030] Consistent with the embodiment shown in FIGS. **9** and **10**, in at least some embodiments of an exemplary endovascular device of the disclosure, the cable of wires **206**

and the single wire coil **207** of the elongated shaft **204** may be elliptical. This elliptical shape resists relative rotation of the elongated shaft **204** and the control wire **101**, enabling torqueing of the device. Alternatively, other non-symmetrical shapes (e.g., cross-sections) may be employed, consistent with the invention to resist rotation and to permit torqueing.

[0031] At least some embodiments of an exemplary endovascular device of the disclosure may encompass a fixture enabling transmission of a radial force of the elongated shaft **204** to the control wire **101** with 1:1 ratio. This may be achieved, for example, by preventing axial rotation between the control wire **101** and the elongated shaft **204** without preventing the axial movement between the control wire **101** and the elongated shaft **204**. And such axial rotation prevention (without axial movement prevention) may be achieved, for example, by deforming at least a portion of the control wire **101** and making at least a portion of the inner cross section of the round elongated shaft **204** non-round respectively. For example, there may be an overlap between the two rectangular (or flattened) portions **101-3** even during axial movement of the control wire **101** compared to the elongated shaft **204**.

[0032] A control wire **101** with at least some flat or rectangular section or sections may be achieved by, for example, selectively pressing the control wire **101**, by adhesion of additional materials to form a non-round shape, or by other means.

[0033] Achieving a non-round inner cross section may be achieved, for example, by attaching rectangular shaped materials **208** to an inner wall of the elongated shaft **204**. As another example, a polymer **208** may be inserted through the wire cable to create a non-round cross section. The polymer **208** may be heated and inserted through holes in the wall of the elongated shaft **204** and shaped as needed by a rectangular mandrel.

[0034] As shown in FIG. **3**, which illustrates an inner cross section A-A of a section of exemplary endovascular device **201**, the control wire **101** may be made from 0.14 mm Nitinol wire. A distal tip of the wire **101** may be gradually grinded to an outer diameter of about 70 um. The elongated shaft **204** may be made from a 130 cm Nitinol tube with an inner diameter of 0.18 mm which may be bonded to a PTFE covered cable of ten 70 um Nitinol wires and the distal section may be a single 70 um wire which may be coiled.

[0035] As shown in FIG. **4**, which illustrates an inner cross section B-B of a section of exemplary endovascular device **201**, the control wire **101** may be pressed to create flat sections **101-3** of about 0.16 mm×0.12 mm of 30 mm of length. Using a rectangular mandrel, a polymer **208** may be inserted through the wire cable **206** to create a non-round cross section in areas that overlap the non-round sections of the control wire **101**. As a result, relative axial movement between the control wire **101** and the elongated shaft **204** may be maintained while the axial rotation between the control wire **101** and the elongated shaft **204** (which includes cable **206**) may be prevented.

[0036] FIG. **5** illustrates an inner cross section C-C of a section of exemplary endovascular device **201**, similar to cross section B-B of FIG. **4**. Again, as a result, relative axial movement between the control wire **101** and the elongated shaft **204** may be maintained while the axial rotation between the control wire **101** and the elongated shaft **204** (which includes single wire coil **207**) may be prevented.

[0037] In a further embodiment, FIG. **6** illustrates a control wire **601** of an exemplary endovascular device in accordance with the disclosure, which may be deformed or flattened in zone **601-3**, and may be round in other areas along its axis **601-2**. FIG. **7** illustrates an exemplary endovascular device **701** using control wire **601** in accordance with the disclosure. (Solely to illustrate the position of zones **601-2** and **601-3** in endovascular device **701**, with the understanding that control wire **601** is part of endovascular device **701**, FIG. **7** also separately depicts control wire **601** of FIG. **6**, with zones **601-3** and **601-2** generally aligned to endovascular device **701**.) As shown in FIG. **7**, endovascular device **701** may also include an elongated shaft **704** which may include a tube **705**, a cable of wires **706**, and a single wire coil **707**. A distal tip **710** of the elongated shaft **704** may be attached to control wire **601**, for example. At a proximal end of the elongated shaft **704**, the control wire **601** may be connected to a slider **211** of a handle **209**, with the elongated shaft **704** connected to the handle **209** to facilitate the relative movement. (In FIG. **7**, handle **209** is not depicted to the same scale as that of elongated shaft **704**.)

[0038] FIG. **8** illustrates an inner cross section D-D of a section of exemplary endovascular device **701**. The control wire **601** may be made from 0.14 mm Nitinol wire. A distal tip of the wire **601** may be gradually grinded to an outer diameter of about 70 um. The elongated shaft **704** may be made from a 130 cm Nitinol tube with an inner diameter of 0.18 mm which may be bonded to a PTFE covered cable of ten 70 um Nitinol wires and the distal section may be a single 70 um wire which may be coiled.

[0039] As shown in FIGS. **9** and **10**, which illustrates inner cross sections E-E and F-F of a section of exemplary endovascular device **701**, the control wire **601** may be pressed to create flat sections **101-3** of about 0.16 mm×0.12 mm of 30 mm of length. As mentioned above, in FIGS. **9** and **10**, the cable of wires **706** and the single wire coil **707** of the elongated shaft **704** may be elliptical. This elliptical shape resists relative rotation of the elongated shaft **704** and the control wire **601**, enabling torqueing of the device. Alternatively, other non-symmetrical shapes (e.g., cross-sections) may be employed, consistent with the invention to resist rotation and to permit torqueing.

[0040] In other embodiments, a single wire coil may be provided, extending from a multi-wire cable with a control wire that runs through the core of both. This enables the control wire to steer the more flexible coiled end of the coil, without causing the multi-wire cable to appreciably bend.

[0041] FIG. **11**A illustrates an exemplary endovascular device **1101**, according to the disclosure. As shown in FIG. **11**A, endovascular device **1101** may also include an elongated shaft **1104**, which may include a cable of wires, including a proximal segment **1102**, at least one transition segment **1103**, and a distal segment **1105**. A distal tip **1110** of the elongated shaft **1104** may be attached to control wire **101** (as shown in FIG. **1**), for example. At a proximal end of the elongated shaft **1104**, the control wire **101** may be connected to a slider **211** of a handle **209**, with the elongated shaft **1104** connected to the handle **209** to facilitate the relative movement. (In FIG. **11**A, handle **209** is not depicted to the same scale as that of elongated shaft **1104**.)

[0042] Hollow shaft **1104** may also include a tube (for example, tube **205** of FIG. **2** or tube **705** of FIG. **7**), and the cable of wires may be connected to a distal end of the tube (not shown). The cable may include a proximal segment

1102, at least one transition segment **1103**, and a distal segment **1105**. Proximal segment **1102** may be configured to transfer torque. In some embodiments, for example, a torque device, such as a torquer, may be threaded over the proximal end of the elongated shaft **1104** and tightened over the proximal end of the elongated shaft **1104**. A rotational force exerted on the proximal end of the elongated shaft **1104**, using the torquer, may cause a rotational force to be applied to a working element located proximate the distal end of the elongated shaft **1104**. The ratio of the rotational force exerted on the proximal end of the elongated shaft **1104** to the rotational force applied to the working element may be approximately 1:1. The position of the torquer over the elongated shaft **1104** may be adjusted.

[0043] In some embodiments, proximal segment **1102** may be more rigid, compared to at least one transition segment **1103** and distal segment **1105**, such that proximal segment **1102** may be configured to transfer torque. Proximal segment **1102** may be formed of a first number of wires, and the first number of wires required to form proximal segment **1102** may be based on certain constraints. For example, certain constraints may include an outer diameter of the cable, an inner diameter of the cable, or an optimal cable angle for torque transfer. In some embodiments, proximal segment **1102** may be formed of about 5-20 wires. For example, proximal segment **1102** may be formed of about 9 wires. In another example, proximal segment **1102** may be formed of about 10 wires.

[0044] The cable may further include at least one transition segment **1103** adjacent to the proximal segment **1102**. Transition segment **1103** may be configured to provide a gradual transition between the proximal segment **1102** and a distal segment **1105**. In some embodiments, the cable may include about 1-10 transition segments **1103**. For example, the cable may include about 2 transition segments **1103**. The number of transition segments **1103** may vary based on various parameters, including rigidity of proximal segment **1102**, flexibility of distal segment **1105**, length of the elongated shaft **1104**, a length of the cable, or number of wires used to form the cable. Transition segment **1103** may be formed of about 2-19 wires. For example, transition segment **1103** may be formed of about 3-6 wires. If the cable includes more than one transition segment **1103**, the number of wires used to form each transition segment **1103** may vary. For example, the number of wires used to form each transition segment may decrease as transition segment **1103** moves closer to distal segment **1105**, to thereby provide gradual increase in flexibility from proximal segment **1102** to distal segment **1105**.

[0045] Distal segment **1105** may be configured to be atraumatic, and thus, may be configured to be very flexible. Accordingly, distal segment **1105** may be more flexible than proximal segment **1102** and at least one transition segment **1103**. In order to maintain flexibility, distal segment **1105** may be formed of about 1-5 wires. For example, distal segment **1105** may be formed of about 1-2 wires, and thus, may enable small coil winding, which may determine the flexibility of distal segment **1105**.

[0046] While proximal segment **1102**, transition segment **1103**, and distal segment **1105** appear to have a constant cable diameter in FIG. **11**A, the segments may not necessarily have a constant diameter. For example, the diameter of transition segment **1103** may be smaller than the diameter of proximal segment **1102**, and the diameter of distal segment **1105** may be smaller than the diameter of the transition segment **1103**. By way of example, the diameter of hollow shaft **1104** may gradually decrease from proximal segment **1102** to distal segment **1105**. Accordingly, coil winding may decrease from proximal segment **1102** to distal segment **1105**, to thereby achieve rigidity at proximal segment **1102**, relative to distal segment **1105**, and flexibility at distal segment **1105**, relative to proximal segment **1102**. Rigidity may gradually decrease from proximal segment **1102** to distal segment **1105**.

[0047] FIG. **11**B illustrates section A of exemplary endovascular device **1101** of FIG. **11**A, in accordance with the disclosure. In addition to decreasing the number of wires, the pitch angle at which the wires are wound may vary from proximal segment **1102** to distal segment **1105**, to thereby transfer maximum torque while maintaining tip flexibility and structural strength of endovascular device **1101**. As seen in FIG. **11**B, proximal segment **1102** may be formed of a first number of wires wound at a first pitch angle α. In addition, at least one transition segment **1103** may be formed of a second number of wires (less than the first number of wires) wound at a second pitch angle β. Finally, distal segment **1105** may be formed of a third number of wires (less than the second number of wires) wound at a third pitch angle θ. As illustrated in FIG. **11**B, the pitch angle may refer to the angle, relative to the bottom planar surface of the hollow shaft **1104**, at which the wires are wound. The pitch angle, at which the wires are wound to form the cable, may increase gradually from proximal segment **1102** to distal segment **1105**. For example, pitch angle α may be smaller than pitch angle β, and pitch angle β may be smaller than pitch angle θ. Increasing the pitch angle θ at distal segment **1105** may make distal segment **1105** more bendable. Although FIG. **11**B only illustrates one transition segment **1103** formed of wires wound at pitch angle β, hollow shaft **1104** may include two or more transition segment **1103** at varying pitch angles. For example, hollow shaft **1104** may include a first transition segment and a second transition segment, and the first transition segment may be formed of wires wound at a smaller pitch angle than the wires forming the second transition segment. In some embodiments, hollow shaft **1104** may include at least three transition segments **1103**.

[0048] In some embodiments, the pitch angle may be determined by various parameters, including, for example, a diameter of a winding mandrel, a diameter of the wire, and a number of wires required to form each segment. By way of example, assuming that the diameter of the wire and the initial cable diameter are known, then the diameter of the winding mandrel and the number of wires required may be calculated to obtain the optimal pitch angle. As such, the diameter of the winding mandrel may be increased or decreased to compensate for any changes in the pitch angle.

[0049] In order to provide a gradual transition in flexibility by decreasing the number of wires used from proximal segment **1102** and ultimately to distal segment **1105**, the wires may need to be cut. By way of example, at a distal end **1108** of proximal segment **1102**, one or more wires used to form proximal segment **1102** may be cut or removed during the winding process. Then, the remaining wires used to form proximal segment **1102** may be used to continue winding and forming transition segment **1103**. Likewise, at a distal end **1109** of transition segment **1103**, one or more wires used to form transition segment **1103** may be cut or removed during the winding process. Then, the remaining wires used

to form proximal segment **1102** and transition segment **1103** may be used to continue winding and forming distal segment **1105**. If hollow shaft **1104** includes two or more transition segments **1103**, the process may be repeated by removing more wires and continuing to wind the remaining wires to form another transition segment **1103**. As such, at least one common wire may be continuously wound to form proximal segment **1102**, at least one transition segment **1103**, and distal segment **1105**. Therefore, instead of forming separate segments and connecting the segments together, the entire cable with proximal segment **1102**, at least one transition segment **1103**, and distal segment **1105** can be made with the same wire. By providing a continuous, gradual cable without any connection points along the cable, this obviates the need to incorporate rigid connections to connect separate segments together, thereby improving the flexibility of the cable.

[0050] Once wires are cut during the winding process, exposed edges of the cut wires may be dangerous, particularly when endovascular device **1102** needs to be inserted inside the blood vessel. Therefore, as seen in FIG. **11**C, once the winding process is finished, the cable may be post-processed by cutting any excess wires and covering the exposed edges of the cut wires with a material **1106**. By way of example, material **1106** used to cover exposed edges of the cut wires may include any adhesives, epoxy glues, heat shrink, polyether ether ketone (PEEK), or any other bonding material.

[0051] In some embodiments, after wires are cut or removed during the winding process, the pitch angle at which the wires are wound may also change as a result, and thereby reduce the optimal torque transmission of the cable. Accordingly, a diameter of the winding mandrel may need to be adjusted in order to compensate for the wire removal. By way of example, at the distal end **1108** of proximal segment **1102** or at the distal end **1109** of transition segment **1103**, one or more wires may be cut or removed. Therefore, at the distal end **1108** of proximal segment **1102** or at the distal end **1109** of transition segment **1103**, the diameter of the winding mandrel may be decreased in order to compensate for the reduction in the number of wires used to form each segment. By decreasing the diameter of the winding mandrel, the pitch angle, at which the wires are wound to form each segment, may remain optimal without any overlapping of wires. For example, by decreasing the diameter of the winding mandrel, the pitch angle may remain constant without any overlapping of the wires. The diameter of the winding mandrel may be determined based on the number of wires used, the diameter of the wires, and the required pitch angle at each segment.

[0052] Moreover, while illustrative embodiments have been described herein, the scope includes any and all embodiments having equivalent elements, modifications, omissions, combinations (e.g., of aspects across various embodiments), adaptations or alterations based on the present disclosure. The elements in the claims are to be interpreted broadly based on the language employed in the claims and not limited to examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive. Further, the steps of the disclosed methods can be modified in any manner, including by reordering steps or inserting or deleting steps. It is intended, therefore, that the specification and examples be considered as example only, with a true scope and spirit being indicated by the following claims and their full scope of equivalents.

1. An endovascular device, including:

a hollow shaft having a proximal end and a distal end, the hollow shaft being sized for insertion into a blood vessel;

a control line having a proximal end and a distal end, and extending through the hollow shaft;

an actuatable working element located proximate the distal end of the hollow shaft, and configured to receive an actuation force transmitted via the distal end of the control line; and

an actuator configured to exert the actuation force on the proximal end of the control line, to thereby cause relative movement between the control line and the hollow shaft and to actuate the working element, wherein:

the hollow shaft includes a cable formed of a plurality of wound wires;

the cable includes a proximal segment, at least one transition segment, and a distal segment; and

the proximal segment, the at least one transition segment, and the distal segment include different numbers of wires.

2. The endovascular device of claim **1**, wherein:

the proximal segment includes a first number of wires;

the at least one transition segment includes a second number of wires, the second number of wires being less than the first number of wires; and

the distal segment includes a third number of wires, the third number of wires being less than the second number of wires.

3. The endovascular device of claim **1**, wherein:

the first number of wires are wound at a first pitch angle;

the second number of wires are wound at a second pitch angle; and

the third number of wires are wound at a third pitch angle.

4. The endovascular device of claim **3**, wherein the first, second, and third pitch angles are determined based on at least one of a diameter of the wires, the number of wires, and a diameter of a winding mandrel.

5. The endovascular device of claim **3**, wherein:

the first pitch angle is less than the second pitch angle; and

the second pitch angle is less than the third pitch angle.

6. The endovascular device of claim **1**, wherein at least one of the plurality of wound wires is configured to extend from the proximal segment to the distal segment of the cable.

7. The endovascular device of claim **1**, wherein the distal segment has a flexibility greater than a flexibility of the proximal segment.

8. The endovascular device of claim **1**, wherein the cable includes at least three transition segments.

9. The endovascular device of claim **1**, wherein a rotational force exerted on the proximal end of the hollow shaft causes a rotational force to be applied to the working element, the ratio of the rotational force exerted on the proximal end of the hollow shaft to the rotational force applied to the working element being approximately 1:1.

10. The endovascular device of claim **1**, wherein the cable is configured to transfer the rotational torque to the distal end of the working element when the proximal end of the hollow shaft is rotated.

11. An endovascular device, including:
a hollow shaft having a proximal end and a distal end, the hollow shaft being sized for insertion into a blood vessel;
a control line having a proximal end and a distal end, and extending through the hollow shaft;
an actuatable working element located proximate the distal end of the hollow shaft, and configured to receive an actuation force transmitted via the distal end of the control line; and
an actuator configured to exert the actuation force on the proximal end of the control line, cause relative movement between the control line and the hollow shaft, and actuate the working element, wherein:
the hollow shaft includes a cable formed of a plurality of wound wires;
the cable includes a proximal segment formed of a first number of wires, at least one transition segment formed of a second number of wires less than the first number of wires, and a distal segment formed of a third number of wires less than the second number of wires.

12. The endovascular device of claim **11**, wherein:
the first number of wires are wound at a first pitch angle;
the second number of wires are wound at a second pitch angle; and
the third number of wires are wound at a third pitch angle.

13. The endovascular device of claim **12**, wherein the first, second, and third pitch angles are determined based on at least one of a diameter of the wires, the number of wires, and a diameter of a winding mandrel.

14. The endovascular device of claim **12**, wherein:
the first pitch angle is less than the second pitch angle; and
the second pitch angle is less than the third pitch angle.

15. The endovascular device of claim **11**, wherein at least one of the plurality of wound wires is configured to extend from the proximal segment to the distal segment of the cable.

16. The endovascular device of claim **11**, wherein the distal segment has a flexibility greater than a flexibility of the proximal segment.

17. The endovascular device of claim **11**, wherein the cable includes at least three transition segments.

18. The endovascular device of claim **11**, wherein the cable is configured to transfer rotational torque to the distal end of the working element when the proximal end of the hollow shaft is rotated.

19. A method of manufacturing an endovascular device, the method including:
forming a hollow shaft sized for insertion into a blood vessel, the hollow shaft having a proximal end and a distal end;
disposing a control line having a proximal end and a distal end through the hollow shaft;
connecting an actuatable working element at the distal end of the hollow shaft, wherein the actuatable working element is configured to receive an actuation force transmitted via the distal end of the control line; and
connecting an actuator at the proximal end of the control line, wherein the actuator is configured to exert the actuation force on the proximal end of the control line, cause relative movement between the control line and the hollow shaft, and actuate the working element, wherein forming the hollow shaft includes:
winding a plurality of wires at a first pitch angle to form a proximal segment of a cable;
cutting at least one of the wires forming the proximal segment;
winding a first remainder of the wires at a second pitch angle to form a transition segment of the cable;
cutting at least one of the first remainder of the wires forming the transition segment; and
winding a second remainder of the wires at a third pitch angle to form a distal segment of the cable.

20. The method of claim **19**, further including changing a diameter of the winding mandrel after winding the plurality of wires at the first pitch angle and before winding the first remainder of the wires at the second pitch angle, to thereby compensate for a change in pitch angle.

21-22. (canceled)

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