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(54) **Sensor mounted flexible guidewire**

Flexibler Führungsdraht mit Sensor

Fil guide flexible incluant un capteur

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Description

FIELD OF THE DISCLOSED TECHNIQUE

[0001] The disclosed technique relates to guidewires, in general, and to methods and systems for including electronic components in guidewires and for making guidewires more flexible, in particular.

BACKGROUND OF THE DISCLOSED TECHNIQUE

[0002] Guidewires are employed in noninvasive operations, to enable the physician to navigate to a desired location within the lumen of the body of the patient, and then insert the catheter to the desired location, with the aid of the guidewire. Such guidewires are known in the art. One type of guidewire includes a sensor at the tip thereof, which is connected to an electronic unit, with a pair of wires which pass through a lumen within the guidewire. The guidewire includes a coil in front of the sensor, to enable maneuverability. Another type of guidewire includes a sensor at the tip thereof, which is connected to the electronic unit, with a pair of wires, which pass through the lumen within the guidewire. This guidewire is devoid of a flexible element to provide maneuverability.

[0003] US Patent No. Re. 35,648 issued to Tenerz et al., and entitled "Sensor Guide Construction and Use Thereof", is directed to a guidewire which includes a thin outer tube, an arched tip, a radiopaque coil, a solid metal wire, a sensor element, and a signal transmitting cable. The radiopaque coil is welded to the arched tip. The solid metal wire is formed like a thin conical tip, and it is located within the arched tip and the radiopaque coil. The solid metal wire successively tapers toward the arched tip. At the point where the solid metal wire joins the radiopaque coil, the thin outer tube commences. The signal transmitting cable extends from the sensor element to an electronic unit, through an air channel within the thin outer tube.

[0004] US Patent No. 4,873,986 issued to Wallace, and entitled "Disposable Apparatus for Monitoring Intrauterine Pressure and Fetal Heart Rate", is directed to an apparatus to monitor the fetal condition during labor and childbirth. The apparatus includes a cable, a pressure transducer, a plug, and a pair of wires. The pressure transducer is located within the leading edge of the cable. The plug is located at a proximal end of the cable. The signals from the pressure transducer are conveyed to the plug, by way of the pair of wires, which pass through a vent channel within the cable.

[0005] US Patent No. 6,428,489 issued to Jacobsen et al and entitled "Guidwire System", is directed to a catheter guidewire which includes an elongate solid body. Around this elongated solid body, a catheter guided toward a target location in the vasculature system of a body. The elongate body includes a proximal end and a distal end, with the distal end being curved. Cuts are formed by either saw-cutting, laser cutting or etching at spaced-apart locations along the length of the body thereby increasing the lateral flexibility of the guidewire. Integral beams are also formed within the body to maintain its torsional strength. The relative location and size of cuts and beams may be selectively adjusted thereby determining the direction and degree of flexure, and the change in torsional stiffness relative to flexibility.

[0006] US 2004/0167436 A1 discloses a guidewire having a core wire. The core wire includes a distal section and a proximal section. The core wire further includes a distal cap connected to the distal end of the core wire and a coil around the core wire along the length thereof. The distal portion can be continuously tapered or can have a tapered section, or, alternatively, a series of tapered sections of differing diameters.

[0007] US 2004/0167442 A1 discloses a guide wire having a proximal guidewire section and a distal guidewire section. The distal guidewire section includes several constant diameter regions interconnected by tapering regions. These regions are disposed such that the distal guidewire section includes a geometry that decreases in cross sectional area toward the distal end thereof. A tip is provided to the distal section and a coil spring at its outer diameter.

[0008] US 2003/028128 describes a guidewire, which includes an elongated flexible member with a proximal end and a distal end and a central lumen. The diameter of the elongated flexible member reduces along the length thereof toward the distal tip thereof. The lumen is filled with a core. An insulating layer is provided between the core and the inner wall of the lumen. The core is made of an electrically conductive material and has an essentially constant diameter over its entire length. An electrical sensor is attached to the distal end of the elongated flexible member and is electrically connected to the core. Further, a coil is provided at least partially along the length of the guidewire.

SUMMARY OF THE PRESENT DISCLOSED TECHNIQUE

[0009] It is an object of the disclosed technique to provide a novel flexible guidewire and a method for forming such a guidewire.

[0010] This object is solved by a flexible guidewire comprising the features of claim 1 and a method comprising the features of claim 8. Preferred embodiments are defined by the dependent claims.

[0011] In accordance with the disclosed technique, there is thus provided a flexible guidewire including a hollow tube, a plug and a tubular spring. The hollow tube has a proximal section and a distal section. The distal section has a distal tip. The outer diameter of the distal section gradually decreases toward the distal tip. The outer diameter of the distal tip is larger than the smallest outer diameter of the distal section. The spring is placed around the distal section of the hollow tube for maintaining the outer diameter of the hollow tube over the length thereof and for supporting compressive loads. The plug is coupled with the distal tip of the hollow tube, for creating a non-traumatic tip.

[0012] In accordance with another aspect of the disclosed technique, there is thus provided a method for forming a flexible guidewire. The method comprises the procedures of reducing the outer diameter of the distal section of a hollow tube and placing a tubular spring over the distal section of the hollow tube. The method further comprises the procedures of enlarging the distal end of the distal tip of the hollow tube, thereby creating a sensor housing, and inserting a plug onto the sensor housing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The disclosed technique will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

Figure 1A is a schematic illustration of a guidewire in a cross-sectional view, constructed and operative in accordance with an embodiment of the disclosed technique;

Figure 1B is a schematic illustration showing the flexibility of a guidewire, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 2 is a schematic illustration of another guidewire, in a cross-sectional view, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 3A is a perspective illustration of a guidewire having a tip which exhibits substantially increased flexibility, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 3B is an orthographic illustration, in top view, of the guidewire of Figure 3A, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 3C is an orthographic illustration, in front view, of the guidewire of Figure 3A, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 4 is a schematic illustration showing the procedures executed in forming the guidewire of Figure 3A, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 5A is a perspective illustration of another guidewire having a substantially flexible tip, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 5B is an orthographic illustration, in top view, of the guidewire of Figure 5A, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 5C is an orthographic illustration, in front view, of the guidewire of Figure 5A, also showing cross-sections of the guidewire, constructed and operative in accordance with another embodiment of the disclosed technique;

Figure 6 is a schematic illustration showing the procedures executed in forming the guidewire of Figure 5A, constructed and operative in accordance with a further embodiment of the disclosed technique;

Figure 7, is a schematic illustration of a cross sectional view of a guidewire not showing all features of the invention;

Figures 8A is a schematic perspective exploded illustrations of a guidewire not showing all features of the invention;

Figures 8B is a schematic perspective illustration of a guidewire not showing all features of the invention:

Figures 8C is a schematic perspective illustration of a guidewire not showing all features of the invention;

Figure 8D is a schematic illustration of a cross sectional view of a guidewire not showing all features of the invention;

Figure 9A is a schematic perspective exploded illustration of a guidewire not showing all features of the invention; and

Figure 9B is schematic perspective illustration of a guidewire not showing all features of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0014] The disclosed technique overcomes the disadvantages of the prior art by providing a novel guidewire design and forming technique. The novel design enables electronic components, such as sensors and electrical wires, to be placed within the guidewire, in particular in the tip of the guidewire. Such electronic components allow for scalar and vector values to be measured at the guidewire's tip. The design also increases the flexibility of the guidewire, in particular at its distal end. The novel forming technique enables a guidewire to be formed having a substantially increased level of flexibility over prior art guidewires. Throughout the description, the guidewire of the disclosed technique is described in reference to medical guidewires. It is noted that the terms "position" and "location" are used interchangeably throughout the description and in general refer to the three dimension location of an object in a predefined coordinate system.

[0015] Reference is now made to Figure 1A, which is a schematic illustration of a guidewire, in a cross-sectional view, generally referenced 100, constructed and operative in accordance with an embodiment of the disclosed technique. Figure 1A substantially shows the inside of guidewire 100. Guidewire 100 includes a hollow tube 105, a plug 110, a sensor 112, a twisted pair of wires 114 and a tubular spring 118. Guidewire 100 can be coupled with an interconnect 116. In general, guidewire 100 includes two sections, a distal section 102 and a proximal section 104. Distal section 102 refers to the distal end of guidewire 100, the end of guidewire 100 which is distant from interconnect 116. Proximal section 104 refers to the proximal end of guidewire 100, the end of guidewire 100 which is nearest to interconnect 116. In Figure 1A, distal section 102 and proximal section 104 are separated by a set of lines 103. Hollow tube 105 includes a walled section 106 and a hollow section 108. Hollow section 108 can also be referred to as a cavity or a lumen. Twisted pair of wires 114, referred to herein as twisted pair 114, are coupled with sensor 112 and with interconnect 116. Plug 110 is coupled with the distal tip of guidewire 100. As explained in further detail below, tubular spring 118 is placed around a particular section of distal section 102 of guidewire 100. Sensor 112 and twisted pair of wires 114 are located inside hollow tube 105 in hollow section 108.

[0016] Sensor 112 is a sensor capable of measuring scalar values such as pressure and temperature as well as vector values such as position and orientation of a magnetic field. For example, sensor 112 is a coil sensor capable of measuring the strength and orientation of a magnetic field. In general, micro-coil sensor can have a thickness on the order of a few hundred micrometers, such as 0,25 mm. Twisted pair 114 includes wires capable of transferring electrical signals from sensor 112 to interconnect 116. The wires of twisted pair 114 can have a thickness on the order of tens of micrometers, for example, between 0,01mm-0,025mm. Plug 110 can be made of metal or of a polymer bonded into guidewire 100. Plug 110 may further be made of bonding material shaped into a hemispherical shape. Plug 110 is coupled to the distal tip of guidewire 100 by gluing, bonding, welding or soldering. Plug 110 can also just be glue. Tubular spring 118 is a tube exhibiting lateral flexibility (i.e., perpendicular to the central axis of the tube). Tubular spring 118 is, for example, a metal (e.g., Stainless Steel, Platinum, Iridium, Nitinol) coil spring a flexible polymer tube or a braided or coiled plastic tube. Tubular spring 118 maintains the outer diameter of guidewire 100 over the length thereof (i.e., typically tubular spring 118 maintains diameter 132). Furthermore, tubular spring supports compressive loads and resists buckling of the section 122 without substantially increasing torsional and bending stiffness. Tubular spring 118 can also be made of a radiopaque material, which prevents radiation from passing there through. Interconnect 116 enables guidewire 100, and in particular twisted pair of wires 114, to be coupled with other devices, such as a computer, a power source, a device measuring magnetic field strength and orientation and the like. Guidewire 100 may be further covered by a thin elastic polymer layer (not shown) over sections 120 and 122. This polymer layer is typically a heat shrink tube of a few microns thickness, which provides a slick, smooth and lubricious surface.

[0017] As mentioned above, guidewire 100 can be used to measure various scalar and vector values and in particular scalar and vector values as detected and determined at the distal tip of guidewire 100. When sensor 112 is a micro-coil sensor, and located in the distal tip of guidewire 100, guidewire 100 can be used to determine the strength and orientation of a magnetic field at the distal tip of guidewire 100, which in turn can be used to determine the position and orientation of the distal tip of guidewire 100. For example, if guidewire 100 is used in a medical application, where guidewire 100 is inserted inside a living object, such as a human or an animal, then guidewire 100 can determine the position and orientation of its distal tip based on the measurements of sensor 112. In general, in such an application a magnetic field is generated in the vicinity of the living object and sensor 112 is capable of measuring the magnetic field strength and orientation. These measurements are provided as electrical signals from sensor 112 to twisted pair 114 which in turn provide the electrical signals to interconnect 116. Interconnect 116 can be coupled with a computer capable of determining the position and orientation of the micro-coil sensor based on the electrical signals received. Since sensor 112 is located in the distal tip of guidewire 100, the position and orientation of sensor 112 is substantially the position and orientation of the distal tip of guidewire 100.

[0018] In position sensing applications involving magnetic fields, magnetic interference, such as induced electrical currents, can cause errors and biases in the electrical signals provided from twisted pair 114 to interconnect 116. In order to reduce the amount of magnetic interference, the wires located inside hollow section 108 are generally twisted, which reduces the amount of induced electrical current in the wires due to the presence of a magnetic field. Furthermore, tubular spring 118 may be made of a radiopaque material such that it can be seen on an X-ray. If guidewire 100 is used in a medical application where it is inserted inside a living object, and tubular spring 118 is made of a radiopaque material, then, tubular spring 118 will appear on an X-ray of the living object and therefore, distal section 102 of the guidewire will also appear on the X-ray image. This information can be used along with the measurements of sensor 112 to enhance the determination of the position and orientation of the distal tip of guidewire 100.

[0019] As described in more detail in Figure 1B, distal section 102 of guidewire 100 is flexible which provides increased maneuverability to guidewire 100. Increased maneuverability enables a user of guidewire 100 to more easily maneuver the guidewire when it is inserted into a living object. The flexibility of the distal end of guidewire 100 is achieved by changing the outer diameter of walled section 106 of hollow tube 105 as further described. In general, to increase the flexibility of hollow tube 105, it is required to reduce the outer diameter thereof, while maintaining the ability of hollow tube 105 to withstand compressive loads, buckling and kinking. Hollow tube 105 is generally made of a metal, such as Stainless Steel or Nitinol. In the embodiment shown in Figure 1A, hollow tube 105 is made from a single piece of metal. The fact that hollow tube 105 is made of metal provides twisted pair 114 with shielding from electromagnetic interferences. Thus, twisted pair 114 may be an unshielded twisted pair, thereby reducing the thickness of twisted pair 114 to the order of tens of micrometers. Hollow tube 105 can be defined by the diameter of hollow section 108, known as the inner diameter, as well by the diameter of walled section 106, known as the outer diameter. In Figure 1A, both the inner and outer diameters of hollow tube 105 are measured from a centerline 150. The inner diameter, as shown by an arrow 134, is substantially on the order of hundreds of micrometers, such as 0,1mm. In cardiological applications, the inner, diameter shown by an arrow 134, is substantially on the order of tens of micrometers. As can be seen in Figure 1A, the inner diameter of hollow tube 105 does not change along the length of guidewire 100. The outer diameter, as can be seen in Figure 1A, changes along the length of guidewire 100, as shown by an arrow 132, an arrow 136 and an arrow 138. Hollow tube 105 can also be described in terms of the thickness of walled section 106. For example, as the outer diameter of hollow tube 105 reduces, the thickness of walled section 106 also reduces, as shown by an arrow 140, an arrow 142 and an arrow 144. The outer diameter shown by arrow 132 represents the original diameter of hollow tube 105, which is substantially on the order of hundreds of micrometers, such as 0,35mm. In general, the outer diameter of distal section 102 of guidewire 100 is reduced, in a step-like, gradual manner, using various techniques such as grinding and drawing.

[0020] As can be seen in Figure 1A, a first section 130 represents the shape of hollow tube 105 over a majority of the length of guidewire 100. Recall that lines 103 represent a break between the distal and proximal sections of guidewire 100 wherein the dimensions of the guidewire do not change and remain fixed. Guidewire 100 can measure, for example up to 200 centimeters. Section 130 can measure, for example, up to 160 centimeters. Adjacent to first section 130 is a first transition section 128, where the outer diameter of walled section 106 is gradually tapered until a first predetermined reduced outer diameter, such as the outer diameter defined by arrow 136. Adjacent to first transition section 128 is a second section 126, where the dimensions of the guidewire do not change and remain fixed. Adjacent to second section 126 is a second transition section 124, where the outer diameter of walled section 106 is gradually tapered until a second predetermined reduced outer diameter, such as the outer diameter defined by arrow 138. Adjacent to second transition section 124 is a third section, which is subdivided into a floppy section 122 and a sensor housing section 120. This third section is characterized in that the thickness of walled section 106 does not change and remains fixed as can be seen from arrow 144 and an arrow 146, both of which are the same size. In general, the length of the distal section, over which the diameter of the guidewire is reduced (i.e., sections 120, 122, 124, 126 and 128) is between 20-40 centimeters.

[0021] In general, the thickness of walled section 106 in the third section is substantially on the order of tens of micrometers, such as 0,025mm, meaning that the outer diameter in floppy section 122, as shown by an arrow 138, is substantially on the order of hundreds of micrometers, such as 125μm. At an outer diameter of hundreds of micrometers, floppy section 122 and sensor housing section 120 of guidewire 100 have increased flexibility and maneuverability. In general, floppy section 122 can typically measure between 40mm to 300mm. As floppy section 122 is flexible and not rigid, tubular spring 118 is placed around this section to strengthen the distal tip of guidewire 100 while at the same time not reducing its flexibility. Sensor housing section 120, which initially had an inner diameter similar to the inner diameter of floppy section 122, as shown by arrow 134, is enlarged to an inner diameter as shown by an arrow 148 such that sensor 112 can be inserted into sensor housing section 120. When sensor 112 is a micro-coil sensor, the thickness of sensor 112 may be on the order of hundreds of micrometers, such as 0,25mm, meaning that the inner diameter of the distal tip of guidewire 100, in this example, is substantially doubled, from approximately 0,1mm to 0,2mm. The outer diameter of sensor housing section 120 can be increased by drawing the distal tip of guidewire 100 over a mandrel. In general, sensor housing section can typically measure between 1mm and 5mm. It is noted that the dimensions of the general configuration, as shown in Figure 1A, can be changed and varied so as to provide increased flexibility, pushability, torque response and tactile feel. For example, more transitions sections or fewer transition sections could have been present in guidewire 100. The number of transition sections, as well as their respective length can be determined and altered by one skilled in the art according to the needs of a particular application, user or both. Alternatively, the outer diameter of guidewire 100 may decrease continuously, either linearly or according to a determined function (e.g., the outer diameter may decrease exponentially).

[0022] Reference is now made to Figure 1B, which is a schematic illustration showing the flexibility of a guidewire, generally referenced 170, constructed and operative in accordance with another embodiment of the disclosed technique. Guidewire 170 is substantially similar to guidewire 100 (Figure 1A). Guidewire 170 is constructed from a hollow tube 172. As in Figure 1A, the distal and proximal sections of guidewire 170 are separated by a set of lines 173. As in Figure 1A, hollow tube 172 is characterized by an outer diameter and an inner diameter, whereby the outer diameter of the hollow tube is reduced at the distal end of the guidewire. Guidewire 170 includes a first section 174, which represents the shape of hollow tube 172 over a majority of the length of guidewire 170. In first section 174, the dimensions of the guidewire do not change and remain fixed. Adjacent to first section 174 is a first transition section 176, where the outer diameter of hollow tube 172 is gradually tapered until a first predetermined reduced outer diameter. Adjacent to first transition section 176 is a second section 178, where the dimensions of the guidewire do not change and remain fixed. Adjacent to second section 178 is a second transition section 180, where the outer diameter of hollow tube 172 is gradually tapered until a second predetermined reduced outer diameter. Adjacent to second transition section 172 is a third section, which is subdivided into a floppy section 182A and a sensor housing section 184A. This third section is characterized in that the thickness of the walled section of hollow tube 172 (not shown) does not change and remains fixed.

[0023] In Figure 1B, a tubular spring 186A is placed around floppy section 182A in order to strengthen the third section while also maintaining the flexibility of this section. Two additional positions of the floppy section and the sensor housing section of guidewire 170 are shown using broken lines, demonstrating the flexible nature of the third section. In a first additional position, shown by a floppy section 182B, a sensor housing section 184B and a tubular spring 186B, the distal end of guidewire 170 is displaced by an amount shown as an arrow 188A. In a second additional position, shown by a floppy section 182C, a sensor housing section 184C and a tubular spring 186C, the distal end of guidewire 170 is displaced by an amount shown as an arrow 188B. Due to the reduced outer diameter of the floppy section and the sensor housing section of guidewire 170, the two additional positions shown in Figure 1B are possible. Also, because the tubular spring applies a restoring force when the distal end of guidewire 170 is in either of the two additional positions shown in Figure 1B, the distal end of guidewire 170 maintains a certain amount of rigidness as the tubular spring is always trying to maintain the floppy section in the position of floppy section 182A.

[0024] Reference is now made to Figure 2, which is a schematic illustration of another guidewire, in a cross-sectional view, generally referenced 220, constructed and operative in accordance with a further embodiment of the disclosed technique. Guidewire 220 is substantially similar to guidewire 100 (Figure 1A) and includes a distal section 226, a proximal section 228 and a set of lines 230 separating the two. Unlike the embodiment of the guidewire shown in Figure 1A, guidewire 220 is constructed from two hollow tubes of different inner and outer diameters, a thicker hollow tube 224 and a thinner hollow tube 222. Thicker hollow tube 224 and thinner hollow tube 222 can both be hypotubes. In general, thinner hollow tube 222 is shorter in length than thicker hollow tube 224. For example, thinner hollow tube 222 may typically measure between 5 and 30 centimeters, whereas thicker hollow tube 224 may typically measure between 160 and 170 centimeters. As in Figure 1A, guidewire 220 includes a tubular spring 238 and a plug 252, which is placed over the distal end of guidewire 220 in the direction of an arrow 254. Guidewire 220 has a lumen 236, where a sensor (not shown) can be placed, and a hollow section 232, where a twisted pair of wires (not shown) can be placed, which are coupled with the sensor. Guidewire 220 can also be coupled with an interconnect (not shown). Similar to guidewire 100 (Figure 1A), guidewire 220 may be also be covered by a thin elastic polymer layer (not shown) over sections 240 and 242.

[0025] As in Figure 1A, guidewire 220 has an initial outer diameter which is tapered in distal section 226 to enable the distal section of guidewire 220 to have increased flexibility. As shown in Figure 2, guidewire 220 includes a first section 250, which represents the shape of thicker hollow tube 224 over a majority of the length of guidewire 220. In first section 250, the dimensions of the guidewire do not change and remain fixed. Adjacent to first section 250 is a first transition section 248, where the outer diameter of thicker hollow tube 224 is gradually tapered until a first predetermined reduced outer diameter. Adjacent to first transition section 248 and partially overlapping is a second section 246, where the dimensions of the guidewire do not change and remain fixed. The second section represents the initial shape of thinner hollow tube 222. Adjacent to second section 246 is a second transition section 244, where the outer diameter of thinner hollow tube 222 is gradually tapered until a second predetermined reduced outer diameter. Adjacent to second transition section 244 is a third section, which is subdivided into a floppy section 242 and a sensor housing section 240. This third section is characterized in that the thickness of the walled section of thinner hollow tube 222 does not change and remains fixed as shown by arrows 260 and 262.

[0026] In general, the outer and inner diameters of both thicker hollow tube 224 and thinner hollow tube 222 are on the order of hundreds of micrometers. For example, the inner and outer diameters of thicker hollow tube 224 may be 0,18mm and 0,35mm, respectively, whereas the inner and outer diameters of thinner hollow tube 222 may be 0,1mm and 0,18mm, respectively. The inner diameter of thinner hollow tube 222 is shown as an arrow 259. In general, the outer diameter of the thinner hollow tube is selected such that it is substantially similar to the inner diameter of the thicker hollow tube. In the embodiment shown in Figure 2, thicker hollow tube 224 is coupled with thinner hollow tube 222 by either welding, bonding or gluing. As shown in Figure 2, the area which is coupled between the two hollow tubes is where first transition section 248 and second section 246 overlap.

[0027] In this embodiment, the initial thickness of the walled section of each hollow tube, as shown by an arrow 256 and an arrow 258, is reduced and tapered by reducing the outer diameter of the walled section of each hollow tube. As mentioned above, the outer diameter can be reduced by grinding or drawing. In one embodiment, the outer diameters of thicker hollow tube 224 and thinner hollow tube 222 are both reduced after they have been coupled together. In another embodiment, the outer diameters of thicker hollow tube 224 and thinner hollow tube 222 are both reduced before they are coupled together. In a further embodiment, the outer diameters of thicker hollow tube 224 and thinner hollow tube 222 are both reduced before they are coupled together and after they are coupled together. It is noted that in this embodiment, sensor housing section 240 can be formed (i.e., the distal end of guidewire 220 can be enlarged) before tubular spring 238 is placed on floppy section 242. This can be achieved by first enlarging the distal end of guidewire 220 before thicker hollow tube 224 and thinner hollow tube 222 are coupled together. Once the distal end has been enlarged, tubular spring 238 can be placed over floppy section 242 and then thicker hollow tube 224 and thinner hollow tube 222 can be coupled together, thereby trapping tubular spring 238 between the larger outer diameters of sensor housing section 240 and first section 250. In another embodiment, the two hollow tubes can first be coupled together, then tubular spring 238 can be placed over floppy section 242 and finally, sensor housing section 240 can be enlarged to fit the sensor. As mentioned above in conjunction with Figure 1A, the dimensions of the general configuration, as shown in Figure 2, can be changed and varied so as to provide increased flexibility, pushability, torque response and tactile feel. For example, more transition sections could have been present in guidewire 220. The number of transition sections, as well as their respective length can be determined and altered by one skilled in the art according to the needs of a particular application, user or both.

[0028] Reference is now made to Figure 3A, which is a perspective illustration of a guidewire having a tip which exhibits substantially increased flexibility, generally referenced 280, constructed and operative in accordance with another embodiment of the disclosed technique. In general, the flexibilities of the hollow tubes illustrated in Figures 1A and 2 are determined by the thickness of the walled section of each guidewire near the distal end, as shown by arrows 144 (Figure 1A) and 146 (Figure 1A) for guidewire 100 (Figure 1A), and as shown by arrows 260 (Figure 2) and 262 (Figure 2) for guidewire 220 (Figure 2). The flexibility is also determined by the inner diameter of each guidewire, as shown by arrow 134 (Figure 1A) for guidewire 100 and by arrow 259 for guidewire 220. By reducing the thickness of the walled sections of these guidewires near the distal end and by reducing the inner diameter, the flexibility of these guidewires can be increased. This flexibility is limited by two factors, the first being the minimal size of the inner diameter of each guidewire such that a twisted pair of wires can be threaded through. The second is the minimal thickness of the walled section of each guidewire such that the general form of the guidewire is maintained and that the walled section of each guidewire does not break or tear during use. In Figure 3A, the distal end of guidewire 280 is formed, according to the disclosed technique, in a manner such that it exhibits increased flexibility over the flexibility of guidewires 100 and 220. Thus the distal tip of guidewire 280 exhibits substantial maneuverability.

[0029] Guidewire 280 is substantially similar to guidewire 100. Guidewire 280 has a distal section 284 and a proximal section 286. Guidewire 280 is constructed from a hollow tube 282. Guidewire 280 can be coupled with an interconnect (not shown). Also, guidewire 280 has a sensor (not shown) and a twisted pair of wires (not shown) threaded through the lumen (not shown) of hollow tube 282. The outer diameter of guidewire 280 is tapered in distal section 284 and the distal end of guidewire 280 is enlarged to enable the sensor to be placed therein. As in guidewire 100, the inner diameter of hollow tube 282 remains constant along the length of the guidewire. Guidewire 280 has a first section 288, where the outer diameter of the guidewire remains fixed and constant along a majority of the length of the guidewire. Adjacent to first section 288 is a floppy section 290, where the outer diameter of guidewire 280 is reduced to a predetermined reduced outer diameter and then kept constant at the predetermined reduced outer diameter. A tubular spring (not shown) can be placed around floppy section 290. Adjacent to floppy section 290 is a sensor housing section 292 where the sensor is placed. As can be seen in Figure 3A, sensor housing section 292 is enlarged to enable the sensor to fit in. Similar to guidewire 100 (Figure 1A), guidewire 280 may be also be covered by a thin elastic polymer layer (not shown) over sections 290 and 292.

[0030] In guidewire 280, a part of the walled section of hollow tube 282, in floppy section 290, is completely removed, thereby exposing the lumen of hollow tube 282. This is illustrated in Figure 3A as an opening 296 and an opening 298. Openings 296 and 298 are located at opposite sides of hollow tube 282, thereby increasing the flexibility of guidewire 280 in a horizontal plane, as shown by an arrow 299. An area 297 represents the walled section of hollow tube 282 which is visible once a part of the walled section in floppy section 290 has been removed. The walled section removed in floppy section 290 can be removed by either grinding or cutting by laser. Besides removing a part of the walled section in floppy section 290, hollow tube 282 is split in two in a vertical plane, as shown by an arrow 295, from the beginning of sensor housing section 292 to substantially the end of floppy section 290. This splitting generates two distal ends (i.e., two prongs) in distal section 284, a distal end 300A and a distal end 300B. This is more clearly illustrated in Figure 3B. It is noted that other embodiments of the construction of distal section 284 are possible. For example, instead of removing the upper and lower sides of the walled section of floppy section 290, the lateral sides of the walled section of floppy section 290 can be removed. In this embodiment, the sensor housing section and the floppy section would be split into two in a horizontal plane.

[0031] Once distal section 284 has been constructed as shown in Figure 3A, the sensor is placed inside an opening 294, and the twisted wire pair, coupled with the sensor, are threaded through the lumen of hollow tube 282. Openings 296 and 298 may be filled with a glue to prevent the twisted pair of wires from moving and being exposed. However, when the glue affects the flexibility of distal section 284, glue may be applied only at selected locations along distal section 284 to prevent the twisted pair of wires from moving. Also distal ends 300A and 300B can be glued to the sensor to keep the sensor in place. A plug (not shown) can be placed over opening 294 to seal the sensor in. Similar to guidewire 100 (Figure 1A), guidewire 320 may be also be covered by a thin elastic polymer layer (not shown) over sections 290 and 292.

[0032] Reference is now made to Figure 3B, which is an orthographic illustration, in top view, of the guidewire of Figure 3A, generally referenced 320, constructed and operative in accordance with a further embodiment of the disclosed technique. As can be seen in Figure 3B, guidewire 320 is constructed from hollow tube 322, which is substantially similar to hollow tube 282 (Figure 3A). Guidewire 320 has a proximal section 324 and a distal section 326 as well as a first section 332, a floppy section 330 and a sensor housing section 328. First section 332, floppy section 330 and sensor housing section 328 are respectively substantially similar to first section 288 (Figure 3A), floppy section 290 (Figure 3A) and sensor housing section 292 (Figure 3A). As can be seen from the top view of Figure 3B, sensor housing section 328 and floppy section 330 are split into two distal ends, a distal end 336A and a distal end 336B. A hollow 334 is where a sensor (not shown) is placed, in between distal end 336A and 336B.

[0033] Reference is now made to Figure 3C, which is an orthographic illustration, in front view, of the guidewire of Figure 3A, also showing cross-sections of the guidewire, generally referenced 350, constructed and operative in accordance with another embodiment of the disclosed technique. As can be seen in Figure 3C, guidewire 350 is substantially similar to guidewire 280. Guidewire 350 has a proximal section 354 and a distal section 356 as well as a first section 366, a first transition section 364, a floppy section 362, a second transition section 360 and a sensor housing section 358. First section 366, floppy section 362 and sensor housing section 358 are respectively substantially similar to first section 288 (Figure 3A), floppy section 290 (Figure 3A) and sensor housing section 292 (Figure 3A). A first transition section and a second transition section are shown in both Figures 3A and 3B but are not specifically numbered.

[0034] In Figure 3C, dash-dot lines 368_1, 368_2, 368_3, 368_4 and 368_5 represent cut-away cross-sections of guidewire 350. In first section 366, a cross-section 370 shows that the hollow tube forming guidewire 350 has an initial outer diameter and is completely closed. In first transition section 364, the cross-sections 372A and 372B show that the outer diameter has been reduced and that the hollow tube of the guidewire is not completely closed and is split into two sections. As can be seen, the outer diameter of cross-sections 372A and 372B is smaller than the outer diameter of cross-section 370. It should be noted that in first transition section 364, a minority amount of the walled section of the hollow tube has been completely removed, as this represents the beginning of the area of guidewire 350 where the walled section of the hollow tube is removed. In floppy section 362, the cross-sections 374A and 374B show that the outer diameter has been further reduced from that of cross-sections 372A and 372B, and that the majority of the walled section of the hollow tube of the guidewire has been completely removed. In second transition section 360, the cross-sections 376A and 376B show that the outer diameter now remains constant, as the outer diameter of these cross-sections is substantially similar to the outer diameter as shown in cross-sections 374A and 374B. These cross-sections also show that only a minority of the walled section of the hollow tube of the guidewire has been completely removed, as this represents the end of the area of guidewire 350 where the walled section of the hollow tube is removed. In sensor housing section 358, the cross-sections 378A and 378B show that the outer diameter is still constant, as the outer diameter of these cross-sections is substantially similar to the outer diameter as shown in cross-sections 374A, 374B, 376A and 376B. Also, these cross-sections show that the hollow tube is cut in a vertical plane and split into two sections which are not coupled (i.e., two prongs).

[0035] Reference is now made to Figure 4, which is a schematic illustration showing the procedures executed in forming the guidewire of Figure 3A, generally referenced 400, constructed and operative in accordance with a further embodiment of the disclosed technique. In a first procedure 402, a hollow tube 410 having a fixed inner and outer diameter is selected. In a second procedure 404, the outer diameter of a distal section 414 of a hollow tube 412 is reduced in a step-like, gradual manner. The outer diameter of a proximal section 416 of hollow tube 412 remains constant. As mentioned above, the outer diameter can be reduced by grinding or by drawing. In procedure 404, a sub-section 415 of distal section 414 may be further grounded, or cut by a laser, to completely remove a part of the walled section of hollow tube 412 in sub-section 415, as shown as openings 296 and 298 (both in Figure 3A) in Figure 3A. Also, in procedure 404, distal section 414 is cut all the way through in a vertical plane, thereby generating two distal ends (not shown).

[0036] In a third procedure 406, once the outer diameter of a distal section 420 has been reduced and distal section 420 of a hollow tube 418 has been split into two, a tubular spring 422A such as a coil spring is placed over distal section 420 in the direction of an arrow 424. The tubular spring is placed over distal section 420 until it is in the location of a tubular spring 422B. In a fourth procedure 408, the distal end of a hollow tube 426 is enlarged, for example, by of drawing or pulling hollow tube 426 over a mandrel, or stamping the tip over a mandrel between two die sections thereby generating a sensor housing section 428. Section 428 may further be reinforced by a small section of thin tube placed there over there by holding the split section. A tubular spring 434 is essentially trapped in a floppy section 430, as the diameters of a first section 432 and sensor housing section

428 are larger than the diameter of tubular spring 434. The diameter of sensor housing section 428, as shown by an arrow 435, which represents the full diameter of sensor housing section 428 and not the inner or outer diameter of that section, is large enough that a tubular spring (not shown) can be inserted. In a fifth procedure 409, once the general configuration of the guidewire has been prepared, a sensor 436, coupled with a twisted pair of wires 438, referred herein as twisted pair 438, is threaded into the guidewire, in the direction of an arrow 446, through a sensor housing section 442. It is noted that twisted pair 438 may be long, as represented by set of lines 440. Once sensor 436 and twisted pair 438 are threaded through the guidewire, a plug 444 is inserted over the opening of sensor housing section 442 in the direction of an arrow 448. As mentioned above, a sensor 436 may be glued or bonded to the inner sides of sensor housing section 442. Also, the floppy section (not shown) of the guidewire may be covered with a glue to cover any section of twisted pair of wires 438 which are exposed. Twisted pair 438 can then be coupled with an interconnect, thereby generating a finished, functional guidewire, substantially similar in configuration to guidewire 280 (Figure 3A) and in functionality to guidewire 100 (Figure 1A). Additionally, an elastic polymer layer may be applied to the distal end of the guidewire. This elastic polymer layer is typically a heat shrink tube having a thickness in the order of a few microns, which provides a slick, smooth, lubricious surface.

[0037] Reference is now made to Figure 5A, which is a perspective illustration of another guidewire having a substantially flexible tip, generally referenced 470, constructed and operative in accordance with another embodiment of the disclosed technique. In Figure 5A, the distal end of guidewire 470 is formed, according to the disclosed technique, in a manner such that it exhibits increased flexibility over the flexibility of guidewires 100 (Figure 1A) and 220 (Figure 2). Thus, the distal tip of guidewire 470 exhibits substantial flexibility, similar to the flexibility of guidewire 280 (Figure 3A). Guidewire 470 is substantially similar to guidewire 100. Guidewire 470 has a distal section 474 and a proximal section 476. Guidewire 470 is constructed from a hollow tube 472. Guidewire 470 can be coupled with an interconnect (not shown). Also, guidewire 470 has a sensor (not shown) and a twisted pair of wires (not shown) threaded through the lumen (not shown) of hollow tube 472. The outer diameter of guidewire 470 is tapered in distal section 474 and the distal end of guidewire 470 is enlarged to enable the sensor to be placed therein. As in guidewire 100, the inner diameter of hollow tube 472 remains constant along the length of the guidewire. Guidewire 470 has a first section 478, where the outer diameter of the guidewire remains fixed and constant along a majority of the length of the guidewire. Adjacent to first section 478 is a floppy section 480, where the outer diameter of guidewire 470 is reduced to a predetermined reduced outer diameter and then kept constant at the predetermined reduced outer diameter. A tubular spring (not shown) is placed around floppy section 480. Adjacent to floppy section 480 is a sensor housing section 482 where the sensor is placed. As can be seen in Figure 5A, sensor housing section 482 is enlarged to enable the sensor to fit in. Similar to guidewire 100 (Figure 1A), guidewire 470 may be also be covered by a thin elastic polymer layer (not shown) over sections 480 and 482.

[0038] In guidewire 470, a part of the walled section of hollow tube 472, in floppy section 480, is completely removed, thereby exposing the lumen of hollow tube 472. This is illustrated in Figure 5A as an opening 486. As opposed to the configuration of guidewire 280 (Figure 3A), guidewire 470 has an opening on only one side of hollow tube 472. Opening 486 is located on the upper side of hollow tube 472, thereby giving guidewire 470 an increase in flexibility in a vertical plane, as shown by an arrow 483. An area 487 represents the walled section of hollow tube 472 which is visible once a part of the walled section in floppy section 480 has been removed. The walled section removed in floppy section 480 can be removed by either grinding or cutting by laser. Unlike the configuration in Figure 3A, floppy section 480 and sensor housing section 482 are not split into two separate ends. It is noted that other embodiments of the construction of distal section 474 are possible. For example, instead of removing the upper side of the walled section of floppy section 480, the lateral side or the lower side of the walled section of floppy section 480 can be removed. Once distal section 474 has been constructed as shown in Figure 5A, the sensor is placed inside an opening 484, and the twisted pair of wires coupled with the sensor are threaded through the lumen of hollow tube 472. Opening 486 can be filled with a glue to prevent the twisted pair of wires from being exposed. A plug (not shown) can be placed over opening 484 to seal in the sensor.

[0039] Reference is now made to Figure 5B, which is an orthographic illustration, in top view, of the guidewire of Figure 5A, generally referenced 500, constructed and operative in accordance with a further embodiment of the disclosed technique. As can be seen in Figure 5B, guidewire 500 is constructed from hollow tube 502, which is substantially similar to hollow tube 472 (Figure 5A). Guidewire 500 has a proximal section 504 and a distal section 506 as well as a first section 512, a floppy section 510 and a sensor housing section 508. First section 512, floppy section 510 and sensor housing section 508 are respectively substantially similar to first section 478 (Figure 5A), floppy section 480 (Figure 5A) and sensor housing section 482 (Figure 5A). As can be seen from the top view of Figure 5B, a part of the walled section of floppy section 510 is completely removed. Unlike the guidewire shown in Figure 3B, sensor housing section 508 is not split into two distal ends. Similar to guidewire 100 (Figure 1A), guidewire 470 may be also be covered by a thin elastic polymer layer (not shown) over sections 508 and 510.

[0040] Reference is now made to Figure 5C, which is an orthographic illustration, in front view, of the guidewire of Figure 5A, also showing cross-sections of the guidewire, generally referenced 530, constructed and operative in accordance with another embodiment of the disclosed technique. As can be seen in Figure 5C, guidewire 530 is substantially similar to guidewire 470. Guidewire 530 has a proximal section 534 and a distal section 532 as well as a first section 546, a first transition section 544, a floppy section 542, a second transition section 540 and a sensor housing section 538. First section 546, floppy section 542 and sensor housing section 538 are respectively substantially similar to first section 478 (Figure 5A), floppy section 480 (Figure 5A) and sensor housing section 482 (Figure 5A). A first transition section and a second transition section are shown in both Figures 5A and 5B but are not specifically numbered.

[0041] In Figure 5C, dash-dot lines 548_1, 548_2, 548_3, 548_4 and 548_5 represent cut-away cross-sections of guidewire 530. In first section 546, a cross-section 550 shows that the hollow tube forming guidewire 530 has an initial outer diameter and is completely closed. In first transition section 544, the cross-section 552 shows that the outer diameter has been reduced and that the hollow tube of the guidewire is not completely closed. As can be seen, the outer diameter of cross-section 552 is smaller than the outer diameter of cross-section 550. It should be noted that in first transition section 544, a minority amount of the walled section of the hollow tube has been completely removed, as this represents the beginning of the area of guidewire 530 where the walled section of the hollow tube is removed. In floppy section 542, the cross-section 554 shows that the outer diameter has been further reduced from that of cross-section 552, and that the majority of the walled section of the hollow tube of the guidewire has been completely removed thereby creating a single prong. In second transition section 540, the cross-section 556 shows that the outer diameter now remains constant, as the outer diameter of this cross-section is substantially similar to the outer diameter as shown in cross-section 554. This cross-section also show that only a minority of the walled section of the hollow tube of the guidewire has been completely removed, as this represents the end of the area of guidewire 530 where the walled section of the hollow tube is removed. In sensor housing section 538, the cross-section 558 shows that the outer diameter is still constant, as the outer diameter of this cross-section is substantially similar to the outer diameter as shown in cross-sections 556 and 554. Also, this cross-section shows that the hollow tube is completed, as in cross-section 550.

[0042] Reference is now made to Figure 6, which is a schematic illustration showing the procedures executed in forming the guidewire of Figure 5A, generally referenced 580, constructed and operative in accordance with a further embodiment of the disclosed technique. In a first procedure 582, a hollow tube 594 having a fixed inner and outer diameter is selected. In a second procedure 584, the outer diameter of a distal section 598 of a hollow tube 596 is reduced in a step-like, gradual manner. The outer diameter of a proximal section 600 of hollow tube 596 remains constant. As mentioned above, the outer diameter can be reduced by grinding or by drawing. In a third procedure 586, a sub-section 606 of the distal section may be further grounded, or cut by a laser, to completely remove a part of the walled section of a hollow tube 602 in sub-section 606, as shown as opening 486 (Figure 5A) in Figure 5A. The area of the distal section cut out to generate sub-section 606 is shown as a dotted line in procedure 586. As can be seen, the diameter of sub-section 606 is smaller than the diameter of another sub-section 604.

[0043] In a fourth procedure 588, once the outer diameter of a distal section 612 has been reduced, a tubular spring 614A is placed over distal section 612 in the direction of an arrow 616. The tubular spring is placed over distal section 612 until it is in the location of a tubular spring 614B. In a fifth procedure 590, the distal end of a hollow tube 618 is enlarged, thereby generating a sensor housing section 620. A tubular spring 626 is essentially trapped in a floppy section 622, as the diameters of a first section 624 and sensor housing section 620 are larger than the diameter of tubular spring 626. The diameter of sensor housing section 620, as shown by an arrow 628, which represents the full diameter of sensor housing section 620 and not the inner or outer diameter of that section, is large enough that a tubular spring (not shown) can be inserted. In a sixth procedure 592, once the general configuration of the guidewire has been prepared, a sensor 630, coupled with a twisted pair of wires 632, referred to herein as twisted pair 632, are threaded into the guidewire, in the direction of an arrow 640, through a sensor housing section 636. It is noted that twisted pair 632 may be long, as represented by set of lines 634. Once sensor 630 and twisted pair 632 are threaded through the guidewire, a plug 638 is inserted over the opening of sensor housing section 636 in the direction of an arrow 642. As mentioned above, the floppy section (not shown) of the guidewire may be covered with a glue to cover any section of twisted pair of wires 632 which are exposed. Twisted pair of wires 632 can then be coupled with an interconnect, thereby generating a finished, functional guidewire, substantially similar in configuration to guidewire 470 (Figure 5A) and in functionality to guidewire 100 (Figure 1A). Additionally, an elastic polymer layer may be applied to the distal end of the guidewire. This elastic polymer layer is typically a heat shrink tube having a thickness in the order of a few microns, which provides a slick, smooth, lubricious surface.

[0044] Reference is now made to Figure 7, which is a schematic illustration of a cross sectional view of a guidewire generally referenced 660, which does not show all features of the invention. Guidewire 660 includes a grooved corewire 662, a plug 664, a sensor 666, a twisted pair of wires 668, referred to herein as twisted pair 668, a tubular proximal end 670 and a tubular spring 672. Grooved corewire 662 is made of metal (e.g., Stainless Steel, Nitinol) Sensor 666 is sensor capable of measuring scalar values such as pressure and temperature as well as vector values such as position and orientation of a magnetic field. For example, sensor 66 is a coil sensor capable of measuring the strength and orientation of a magnetic field. Guidewire 660 can be coupled with an interconnect 674. Twisted pair 668 are coupled with sensor 666 and with interconnect 674. Plug 664 is coupled with the distal tip section 688 of guidewire 660. Tubular spring 670 is placed around distal sections 688 and 690 of guidewire 660. Grooved corewire 662 is coupled with tubular proximal end 670 (e.g., by bonding or welding).

[0045] In Figure 7, dash-dot lines 676_1, 676_2, 676_3, 676_4 and 676_5 represent lateral cross-sections of guidewire 660. Along section 694, the diameter of grooved corewire 694 remains substantially constant and is in the order of hundreds of micrometers. In first cross-section 678, the diameter of grooved corewire 662 has an initial outer diameter and is inserted into tubular proximal end 670. Twisted pair 668 are placed within a groove along grooved corewire 662. It is noted that although twisted pair 668 is an unshielded twisted pair, tubular spring 672 may provide electrical shielding for twisted pair 668. In second cross-section 680 the diameter of grooved corewire 662 has an initial outer diameter and twisted pair 668 are placed within a groove along grooved corewire 662. However, grooved corewire 662 is no longer within tubular proximal end 670.

[0046] Along section 692 of guidewire 660, the diameter of grooved corewire 662 is gradually reduced. Furthermore, the shape of the lateral cross-section of grooved corewire 662 gradually changes. In third cross-section 682 the shape of the lateral cross-section of grooved corewire 662 is that of a semi-circle. Furthermore, in third cross-section 682, the diameter of grooved corewire 662 is smaller than in first and second cross-sections 678 and 680. Along section 690, the diameter of grooved corewire 660 is substantially constant, however, this diameter is smaller than the diameter shown in cross-section 682. In forth cross-section 684 the shape of lateral cross-section of grooved corewire 662 is that of circular segment. Fifth cross-section 686 is a cross section of the distal tip of guidewire 670 (i.e. section 688). Along section 188 the residual volume between sensor 666 and tubular spring 672 is filled with a polymer bond 665, thus securing the sensor in place. In Figure 7, the distal end of guidewire 670 is formed, according to the disclosed technique, in a manner such that it exhibits increased flexibility over the flexibility of guidewires 100 and 220. Thus the distal tip of of guidewire 670 exhibits substantial maneuverability.

[0047] Reference is now made to Figures 8A , 8B and 8C, which are schematic perspective illustration of a guidewire not showing all features of the invention and generally referenced 750. Figure 8A is a schematic perspective exploded illustration of the guidewire 750. Guidewire 750 includes a corewire 752, a sensor 754, a sensor core 756 and a coupler 758. Sensor 754 is coupled with a sensor core 756. The length of sensor core 756 is larger than the length of sensor 754. Thus, when sensor 754 is coupled with sensor core 756, sensor 754 covers only a portion of sensor core 756 such that sensor core 756 extends from one side of sensor 754. The lengths of sensor 754 and sensor core 756 are on the order of a few millimeters. In Figures 8A, 8B and 8C, sensor 754 is a coil sensor capable of measuring the strength and orientation of a magnetic field. In general, coil sensor can have a thickness on the order of a few hundred micrometers (e.g., 0,25 mm). Corewire 752 and sensor core 756 exhibit substantially the same diameter (e.g., on the order of hundreds of micrometers). Coupler 758 is a hollow tube with a part of the wall thereof removed along the length of coupler 758. The inner diameter of coupler 758 is substantially similar to the diameters of corewire 752 and sensor core 756.

[0048] Figure 8B is a schematic perspective illustration of the guidewire 750 at an intermediate stage of assembly. In Figure 8B, corewire 752 is inserted into one side of coupler 754. The portion sensor core 756 that is not covered by sensor 754 is inserted into the other side of coupler 754. Figure 8C a schematic perspective illustration of the guidewire 750 at a final stage of assembly. In Figure 8C, a twisted pair of wires 758 are coupled with sensor 754 by a coupling material 760. Twisted par 758 may be coupled, at the proximal end of the guidewire with an interconnect (not shown) which enables twisted pair 758, and thus sensor 754, to be coupled with other devices, such as a computer, a power source, a device measuring magnetic field strength and orientation and the like. Guidewire 750 may be further covered with a thin elastic polymer layer (not shown) over a portion of the length thereof. This polymer layer is typically a heat shrink tube of a few microns thickness, which provides a slick, smooth and lubricious surface.

[0049] A tubular spring (not shown) may placed around a portion the distal section of guidewire 750. This tubular spring is a tube exhibiting lateral flexibility (i.e., perpendicular to the central axis of the tube) made of a metal (e.g., Stainless Steel, Platinum, Iridium, Nitinol), a flexible polymer tube or a braided or coiled plastic tube. The tubular spring maintains the outer diameter of guidewire 750 over the length thereof and supports compressive loads and resists buckling of the guidewire without substantially increasing torsional and bending stiffness.

[0050] Reference is now made to Figure 8D which is a schematic illustration of a cross sectional view of a guidewire, generally referenced 780 and not showing all features of the invention. Guidewire 780 includes a core wire 786, a sensor 782, a sensor core 784, a coupler 788, a twisted pair of wires 790 and an interconnect 792. Sensor 782 is coupled with sensor core 784. The length of sensor core 784, delineated by a bracket 794, is larger than the length of sensor 782, delineated by a bracket 796. Thus, when sensor 782 is coupled with sensor core 784, sensor 754 covers only a portion of sensor core 756. The portion of sensor core 784 that is not covered sensor

782, delineated by a bracket 798, extends from one side of sensor 782. Corewire 786 and sensor core 784 exhibit substantially the same diameter (e.g., on the order of hundreds of micrometers). Coupler 788 is a hollow tube with a part of the wall thereof removed along the length of coupler 788. The inner diameter of coupler 788 is substantially similar to the diameters of corewire 786 and sensor core 784.

[0051] Corewire 786 is inserted into one side of coupler 788. The portion sensor core 756 delineated by bracket 798 (i.e., the portion of sensor core 784 that is not covered by sensor 782) is inserted into the other side of coupler 788. Twisted pair of wires 790 are coupled with sensor 782 and with an interconnect 780 which enables twisted pair 790, and thus sensor 782 to be coupled with other devices. As described above (i.e., in conjunction with Figure 8A, 8B and 8C regarding guidewire 750), guidewire 780 may be further covered with a thin elastic polymer layer (not shown). Furthermore, a tubular spring (not shown) may placed around a portion the distal section of guidewire 780.

[0052] Reference is now made to Figures 9A and 9B, which are schematic perspective illustration of a guidewire, generally reference 800 and not showing all features of the invention. Figure 9A is a schematic perspective exploded illustration of the guidewire 800. Guidewire 800 includes a first corewire 806, a second corewire 808, a sensor 802, a sensor core 804 a first coupler 810 and a second coupler 812. Sensor 808 is coupled with a sensor core 804. The length of sensor core 804 is larger than the length of sensor 802. Thus, when sensor 802 is coupled with sensor core 804, sensor 802 covers only a portion of sensor core 756 such that sensor core 804 extends from both sides of sensor 802. The lengths of sensor 802 and sensor core 802 are on the order of a few millimeters. In Figures 9A and 9B sensor 802 is a coil sensor. However, sensor 802 may be any other type of sensor capable of measuring scalar of vector values.

[0053] First and second corewires 806 and 808 and sensor core 804 exhibit substantially the same diameter (e.g., on the order of hundreds of micrometers). First coupler 810 is a hollow tube with a part of the wall thereof removed along the length of first coupler 810. Second coupler 812 is a whole hollow tube. The inner diameters of first coupler 810 and second coupler 812 are substantially similar to the diameters of first and second corewires 806 and 808 and the diameter of sensor core 804.

[0054] Figure 9B is a schematic perspective illustration of the guidewire 800 at a final stage of assembly. In Figure 9B, a twisted pair of wires 814 are coupled with sensor 802 by a coupling material 816. First corewire 806 is inserted into one side of first coupler 810. One side of sensor core 804 is inserted into the other side of first coupler 810. The other side of sensor core 804 is inserted into one side of second coupler 812. Second corewire 808 is inserted into the other side of coupler 812. Thus, sensor 802 is positioned anywhere along the length of guidewire 800.

[0055] Twisted pair 814 may be coupled, at the proximal end of the guidewire with an interconnect (not shown) which enables twisted pair 814, and thus sensor 802, to be coupled with other devices. Similarly to as describe above, guidewire 800 may also be covered with a thin elastic polymer layer (not shown) over a portion of the length thereof. Furthermore, a tubular spring (not shown) may be placed around a portion the distal section of guidewire 800.

[0056] It will be appreciated by persons skilled in the art that the disclosed technique is not limited to what has been particularly shown and described hereinabove. Rather the scope of the disclosed technique is defined only by the claims, which follow.

Claims

1. A flexible guidewire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) comprising:

a tube (105; 172; 222, 224; 282; 322; 410,412,418,426; 472; 502 ; 594,596,602,618), having a proximal section (104; 228; 286; 326; 416/476; 504; 534; 600) and a distal section (102; 226; 284; 324; 414/420; 474; 506; 532; 612), said distal section having a distal tip, the outer diameter of said distal section (102; 226; 284; 324; 414/420; 474; 506; 532; 612) gradually decreasing toward said distal tip, the outer diameter of said distal tip being larger than the smallest outer diameter of said distal section (102; 226; 284; 324; 414/420; 474; 506; 532; 612),

a plug (110; 252; 444; 638) coupled with said distal tip of said tube (105; 172; 222, 224; 282; 322; 410, 412,418, 426; 472; 502 ; 594, 596, 602, 618) for creating a non-traumatic tip; and

a tubular (118; 186A; 238; 422A; 434,436; 614A, 626, 630) spring, being placed around the distal section of said tube (105; 172; 222, 224; 282; 322; 410, 412, 418, 426; 472; 502 ; 594, 596, 602, 618) for maintaining the outer diameter of said tube (105; 172; 222, 224; 282; 322; 410, 412, 418, 426; 472; 502 ; 594, 596, 602, 618) over the length thereof and for supporting compressive loads;

characterized in that the tube (105; 172; 222, 224; 282; 322; 410, 412,418, 426; 472; 502 ; 594, 596, 602, 618); and

the flexible guide wire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) further comprises a position and orientation sensor (112) being placed within said distal tip of said hollow tube, said sensor (112) being operable for detecting electromagnetic fields; and a twisted pair of wires (114;438;632), coupled with said sensor, and being located inside said hollow tube.

2. The flexible guidewire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) according to claim 1, wherein a part of the wall of said hollow tube (105; 172; 222, 224; 282; 322; 410,412,418,426; 472; 502 ; 594,596,602,618) being completely removed from opposite sides of a at least a portion of the length said distal section (102; 226; 284; 324; 414/420; 474; 506;532;612), thereby splitting said distal section (102; 226; 284; 324; 414/420; 474; 506;532;612) and said distal tip, creating two prongs.

3. The flexible guide wire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) according to claim 2, wherein said sensor (112) is a coil sensor.

4. The flexible guidewire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) according to claim 3, wherein said hollow tube (105; 172; 222, 224; 282; 322; 410,412,418,426; 472; 502 ; 594,596,602,618) is made of metal and wherein said hollow tube (105; 172; 222, 224; 282; 322; 410,412,418,426; 472; 502 ; 594,596,602,618) provides said twisted pair of wires (114; 438; 632) shielding from electromagnetic interferences.

5. The flexible guidewire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) according to claim 1 or 3, wherein the majority of the wall of said hollow tube (105; 172; 222, 224; 282; 322; 410,412,418,426; 472; 502 ; 594,596,602,618) is removed from at least a portion of the length said distal section thereby creating a prong, said wall of said hollow tube (105; 172; 222, 224; 282; 322; 410,412,418,426; 472; 502 ; 594,596,602,618) being complete at said distal tip.

6. The flexible guidewire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) according to claim 1, wherein said guidewire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) is covered with an elastic polymer over said distal tip and a portion of said distal end.

7. The flexible guidewire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) according to claim 1 further including an interconnect (116), for coupling said flexible guidewire (100; 170; 220; 280; 320; 350; 400; 470; 500; 530;580) with another device.

8. A method for forming a flexible guidewire comprising the procedures of:

   reducing the outer diameter of the distal section of a hollow tube;
   placing a tubular spring over said distal section of said hollow tube;
   enlarging the distal end of the distal tip of said hollow tube, thereby creating a sensor housing;
   threading a twisted pair of wires through said hollow tube;
   inserting a position and orientation sensor into said sensor housing, said sensor being coupled with said twisted pair, said sensor being operable for detecting magnetic fields; and
   inserting a plug onto said sensor housing.

9. The method of claim 8, wherein said sensor is a coil sensor.

10. The method according to claim 8, wherein said procedure of reducing the outer diameter of the distal section of said hollow tub is performed by one of:

   grinding;
   drawing; and
   cutting said hollow tube with a laser.

11. The method according to claim 8, wherein said procedure of enlarging is performed by one of:

   drawing said hollow tube over a mandrel;
   pulling said hollow tube over a mandrel; and
   stamping said hollow tube over a mandrel.

12. The method according to claim 8 further including the procedure of applying an elastic polymer layer onto said distal end of said guidewire.

13. The method according to claim 8, where said procedure of reducing is performed to completely remove opposite sides of a at least a portion of the length said distal section, thereby splitting said distal section and said distal tip, creating two prongs.

14. The method according to claim 8, wherein said procedure of reducing is performed to completely remove the majority of the wall of said hollow tube from at least a portion of the length said distal section thereby creating a prong, said wall of said hollow tube being complete at said distal tip.

Patentansprüche

1. Flexibler Führungsdraht (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580), enthaltend:

   ein Rohr (105; 172; 222; 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618), das einen proximalen Abschnitt (104; 228; 286; 326; 416; 476; 504; 534; 600) und einen distalen Abschnitt (102; 226; 284; 324; 414/420; 474; 506; 532; 612) hat, wobei der distale Abschnitt eine distale Spitze hat, der Außendurchmesser des distalen Abschnitts (102; 226; 284; 324;

414/420; 474; 506; 532; 612) graduell in Richtung der distalen Spitze abnimmt, wobei der Außendurchmesser der distalen Spitze größer als der kleinste Außendurchmesser des distalen Abschnitts (102; 226; 284; 324; 414/420; 474; 506; 532; 612) ist;
einen Stöpsel (110; 252; 444; 638), der mit der distalen Spitze des Rohrs (105; 172; 222, 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618) gekoppelt ist zum Erzeugen einer atraumatischen Spitze;
eine röhrenförmige Feder (118; 186A; 238; 422A; 434; 436; 614A; 626; 630), die um den distalen Abschnitt des Rohrs (105; 172; 222, 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618) zum Aufrechterhalten des Außendurchmesser des Rohrs (105; 172; 222; 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618) über dessen Länge und zum Abstützen von kompressiven Lasten platziert ist; **dadurch gekennzeichnet, dass** das Rohr (105; 172; 222, 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618) hohl ist; und der flexible Führungsdraht (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580) weiter einen Positions- und Ausrichtungssensor (112) enthält, der innerhalb der distalen Spitze des hohlen Rohrs platziert ist, wobei der Sensor (112) zum Erfassen von elektromagnetischen Feldern betreibbar ist; und
ein verwundenes Paar von Drähten (114; 438; 632), die mit dem Sensor gekoppelt sind und im Inneren des hohlen Rohrs angeordnet sind.

2. Flexibler Führungsdraht (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580) nach Anspruch 1, wobei ein Teil der Wand des hohlen Rohrs (105; 172; 222, 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618) vollständig von gegenüberliegenden Seiten von zumindest einem Teil der Länge des distalen Abschnitts (102; 226; 284; 324; 414/420; 474; 506; 532; 612) entfernt ist, wodurch der distale Abschnitt (102; 226; 284; 324; 414/420; 474; 506; 532; 612) und die distale Spitze gesplittet werden und zwei Zinken erzeugt werden.

3. Flexibler Führungsdraht (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580) nach Anspruch 2, wobei der Sensor (112) ein Spulensensor ist.

4. Flexibler Führungsdraht (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580) nach Anspruch 3, wobei das hohle Rohr (105; 172; 222, 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618) aus Metall gebildet ist und wobei das hohle Rohr (105; 172; 222, 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618) das verwundene Paar von Drähten (114; 438; 632) vorsieht, die vor elektromagnetischen Interferenzen abschirmen.

5. Flexibler Führungsdraht (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580) nach Anspruch 1 oder 3, wobei der Hauptteil der Wand des hohlen Rohrs (105; 172; 222, 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618) von zumindest einem Teil der Länge des distalen Abschnitts entfernt ist, wodurch ein Zinken erzeugt wird, wobei die Wand des hohlen Rohrs (105; 172; 222, 224; 282; 322; 410; 412; 418; 426; 472; 502; 594; 596; 602; 618) an der distalen Spitze vollständig ist.

6. Flexibler Führungsdraht (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580) nach Anspruch 1, wobei der flexible Führungsdraht (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580) mit einem elastischen Polymer über die distale Spitze und einen Teil des distalen Endes bedeckt ist.

7. Flexibler Führungsdraht (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580) nach Anspruch 1, weiter enthaltend ein Verbindungsstück (116) zum Koppeln des flexiblen Führungsdrahts (100; 170; 220; 280; 320; 350; 400; 470; 500; 530; 580) mit einem anderen Gerät.

8. Verfahren zum Ausbilden eines flexiblen Führungsdrahts, enthaltend die Schritte:

Verringern des Außendurchmessers des distalen Abschnitts eines hohlen Rohrs;
Platzieren einer röhrenförmigen Feder über den distalen Abschnitt des hohlen Rohrs;
Vergrößern des distalen Endes der distalen Spitze des hohlen Rohrs, wodurch ein Sensorgehäuse erzeugt wird;
Aufschrauben eines verwundenen Paars von Drähten durch das hohle Rohr;
Einführen eines Positions- und Ausrichtungssensors in das Sensorgehäuse, wobei der Sensor mit dem verwundenen Paar gekoppelt ist, wobei der Sensor betreibbar ist zum Erfassen von magnetischen Feldern; und
Einführen eines Stöpsels auf das Sensorgehäuse.

9. Verfahren nach Anspruch 8, wobei der Sensor ein Spulensensor ist.

10. Verfahren nach Anspruch 8, wobei der Vorgang des Verringerns des Außendurchmessers des distalen Abschnitts des hohlen Rohrs ausgeführt wird durch eines aus:

Schleifen;
Ziehen; und
Schneiden des hohlen Rohrs mit einem Laser.

11. Verfahren nach Anspruch 8, wobei der Vorgang des Vergrößerns ausgeführt wird durch eines aus:

Ziehen des hohlen Rohrs über einen Ziehkern;
Ausziehen des hohlen Rohrs über einen Ziehkern; und
Prägen des hohlen Rohrs über einen Kern.

12. Verfahren nach Anspruch 8, weiter enthaltend den Vorgang des Aufbringens einer elastischen Polymerschicht auf das distale Ende des Führungsdrahtes.

13. Verfahren nach Anspruch 8, wobei der Vorgang des Verringerns durchgeführt wird zum vollständigen Entfernen von gegenüberliegenden Seiten von zumindest einem Teil der Länge des distalen Abschnitts, wodurch der distale Abschnitt und die distale Spitze gesplittet werden und zwei Zinken erzeugt werden.

14. Verfahren nach Anspruch 8, wobei der Vorgang des Verringerns durchgeführt wird zum vollständigen Entfernen des Hauptteils der Wand des hohlen Rohrs von zumindest einem Teil der Länge des distalen Abschnitts, wodurch ein Zinken erzeugt wird, wobei die Wand des hohlen Rohrs an der distalen Spitze vollständig ist.

Revendications

1. Fil métallique de guidage flexible (100 ; 170 ; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) comprenant :

un tube (105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) ayant une section proximale (104 ; 228 ; 286 ; 326 ; 416 ; 476 ; 504 ; 534 ; 600) et une section distale (102 ; 226 ; 284 ; 324 ; 414/420 ; 474 ; 506 ; 532 ; 612), ladite section distale ayant une pointe distale, le diamètre externe de ladite section distale (102 ; 226 ; 284 ; 324 ; 414/420 ; 474 ; 506 ; 532 ; 612) diminuant graduellement vers ladite pointe distale, le diamètre externe de ladite pointe distale étant plus grand que le diamètre externe le plus petit de ladite section distale (102 ; 226 ; 284 ; 324 ; 414/420 ; 474 ; 506 ; 532 ; 612) ;
un obturateur (110 ; 252 ; 444 ; 638) couplé à ladite pointe distale dudit tube creux (105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) pour créer une pointe non traumatique ; et
un ressort tubulaire (118 ; 186A ; 238 ; 422A ; 434, 436 ; 614A, 626, 630) qui est placé autour de la section distale dudit tube creux (105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) pour maintenir le diamètre externe dudit tube creux (105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) sur sa longueur et pour supporter des charges de compression ;
caractérisé en ce que le tube (105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) est creux ; et
le fil métallique de guidage flexible (100 ; 170 ; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) comprend par ailleurs un capteur de position et d'orientation (112) qui est placé à l'intérieur de ladite pointe distale dudit tube creux, ledit capteur (112) étant à même de détecter des champs électromagnétiques ; et
une paire torsadée de fils métalliques, couplée audit capteur, et se trouvant à l'intérieur dudit tube creux.

2. Fil métallique de guidage flexible (100 ; 170 ; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) selon la revendication 1, dans lequel une partie de la paroi dudit tube creux (105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) est complètement retirée des côtés opposés d'au moins une partie de la longueur de ladite section distale (102 ; 226 ; 284 ; 324 ; 414/420 ; 474 ; 506 ; 532 ; 612), scindant ladite section distale (102 ; 226 ; 284 ; 324 ; 414/420 ; 474 ; 506 ; 532 ; 612) et ladite pointe distale, créant deux fourches.

3. Fil métallique de guidage flexible (100 ; 170 ; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) selon la revendication 2, dans lequel ledit capteur (112) est un capteur à boudin.

4. Fil métallique de guidage flexible (100 ; 170 ; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) selon la revendication 3, dans lequel ledit tube creux (105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) est constitué d'un métal et dans lequel ledit tube creux (105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) fournit ladite paire torsadée de fils métalliques (114 ; 438 ; 632) protégeant d'interférences électromagnétiques.

5. Fil métallique de guidage flexible (100 ; 170 ; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) selon la revendication 1 ou 3, dans lequel la majeure partie de la paroi dudit tube creux 105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) est retirée d'au moins une partie de la longueur de ladite section distale, créant de la sorte une fourches, ladite paroi dudit tube creux (105 ; 172 ; 222, 224 ; 282 ; 322 ; 410, 412, 418, 426 ; 472 ; 502 ; 594, 596, 602, 618) étant complète au niveau de ladite pointe distale.

6. Fil métallique de guidage flexible (100 ; 170 ; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) selon la revendication 1, dans lequel ledit fil métallique de guidage (100 ; 170.; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) est revêtu d'un polymère élastique sur ladite pointe distale et une partie de ladite extrémité distale.

7. Fil métallique de guidage flexible (100 ; 170 ; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) selon la revendication 1, comprenant en outre une interconnexion (116) pour coupler ledit fil métallique de guidage flexible (100 ; 170 ; 220 ; 280 ; 320 ; 350 ; 400 ; 470 ; 500 ; 530 ; 580) avec un autre dispositif.

8. Procédé de formation d'un fil métallique de guidage flexible comprenant les étapes consistant à :

réduire le diamètre externe de la section distale d'un tube creux ;
placer un ressort tubulaire par-dessus ladite section distale dudit tube creux ;
agrandir l'extrémité distale de la pointe distale dudit tube creux, créant de la sorte un logement de capteur ;
enfiler une paire torsadée de fils métalliques à travers ledit tube creux ;
insérer un capteur de position et d'orientation dans ledit logement de capteur, ledit capteur étant couplé à ladite paire torsadée, ledit capteur étant à même de détecter des champs magnétiques ; et
insérer un obturateur sur ledit logement de capteur.

9. Procédé selon la revendication 8, dans lequel ledit capteur est un capteur de bobine.

10. Procédé selon la revendication 8, dans lequel ladite étape de réduction du diamètre externe de la section distale dudit tube creux est effectuée par l'une des opérations suivantes :

meulage ;
étirage ; et
découpe dudit tube creux avec un laser.

11. Procédé selon la revendication 8, dans lequel ladite étape d'agrandissement est effectuée par l'une des étapes suivantes :

étirage dudit tube creux sur un mandrin ;
traction dudit tube creux sur un mandrin ; et
estampage dudit tube creux sur un mandrin.

12. Procédé selon la revendication 8, comprenant par ailleurs l'étape d'application d'une couche de polymère élastique sur ladite extrémité distale dudit fil métallique de guidage.

13. Procédé selon la revendication 8, dans lequel ladite étape de réduction est effectuée pour éliminer complètement les côtés opposés d'au moins une partie de la longueur de ladite section distale, en scindant de la sorte ladite section distale et ladite pointe distale, créant deux fourchons.

14. Procédé selon la revendication 8, dans lequel ladite étape de réduction est effectuée pour éliminer complètement la majeure partie de la paroi dudit tube creux d'au moins une partie de la longueur de ladite section distale, créant de la sorte un fourchon, ladite paroi dudit tube creux étant complète au niveau de ladite pointe distale.

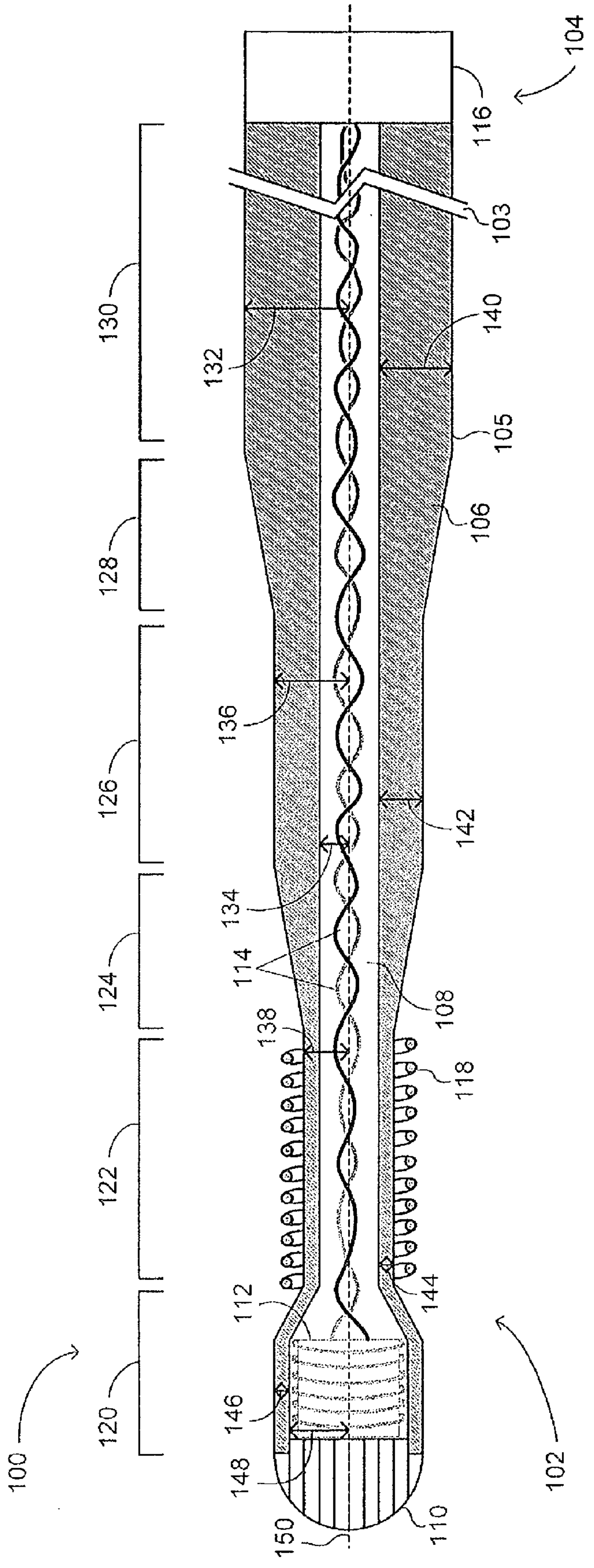
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FIG. 1A

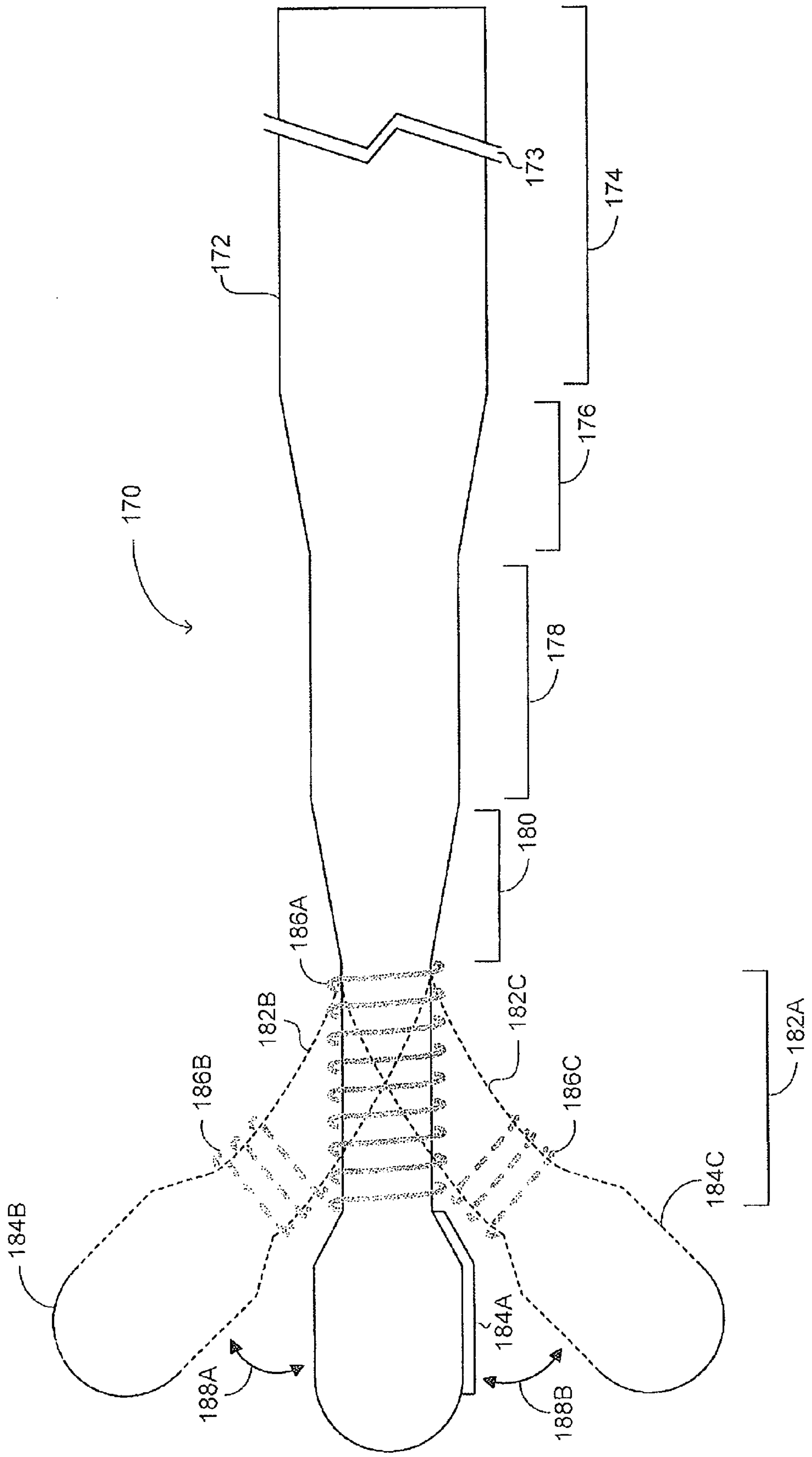
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FIG. 1B

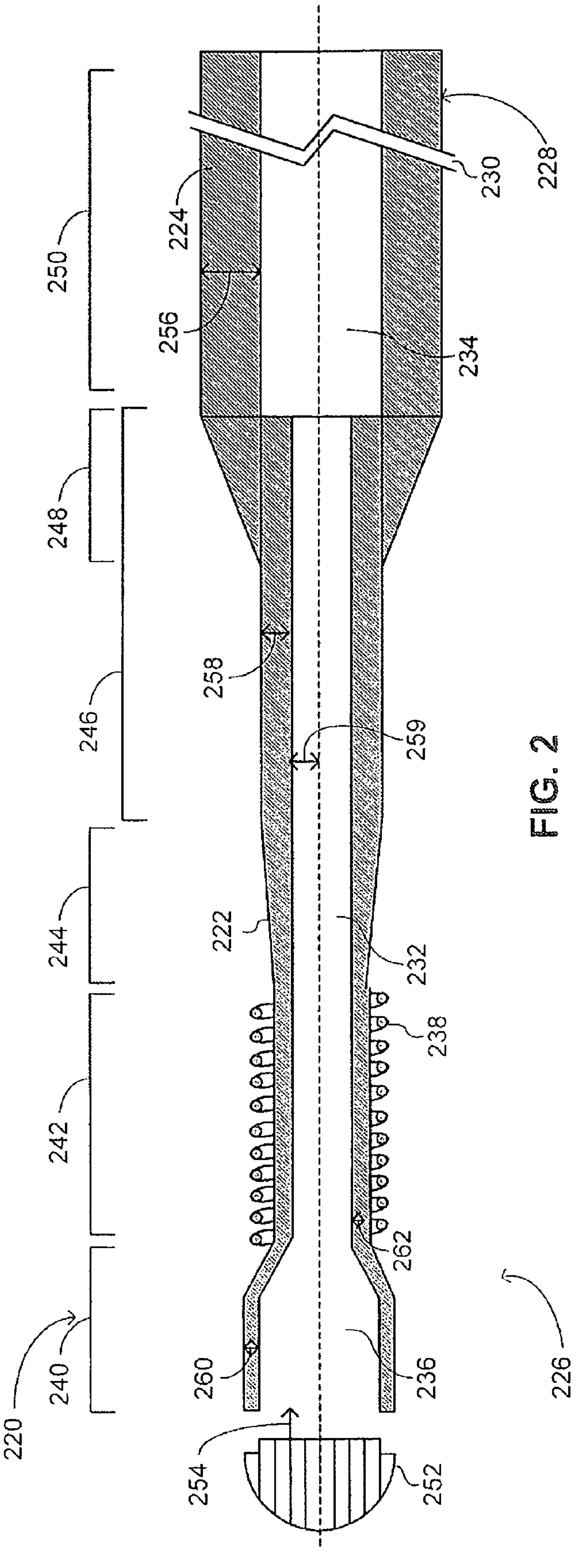
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FIG. 2

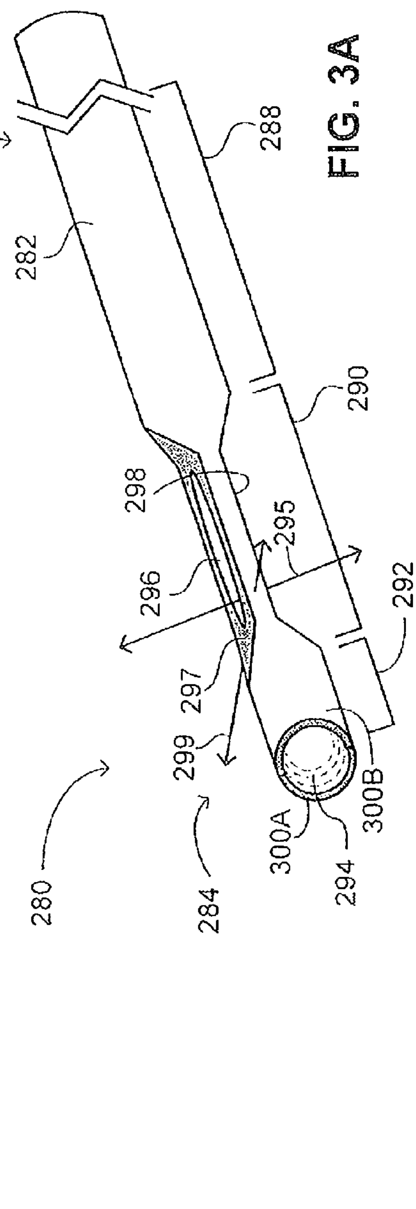
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FIG. 3A

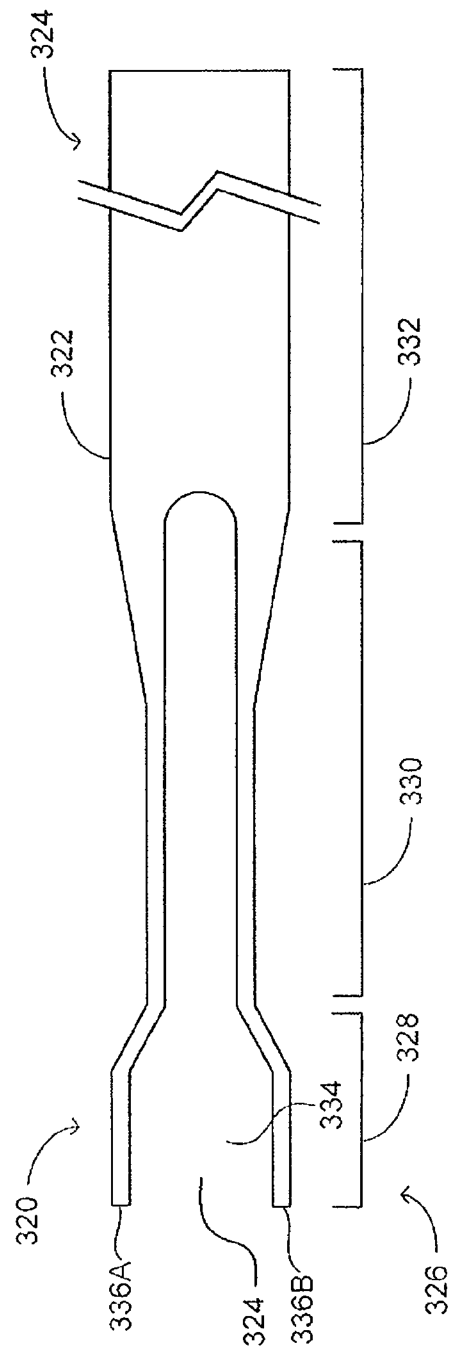

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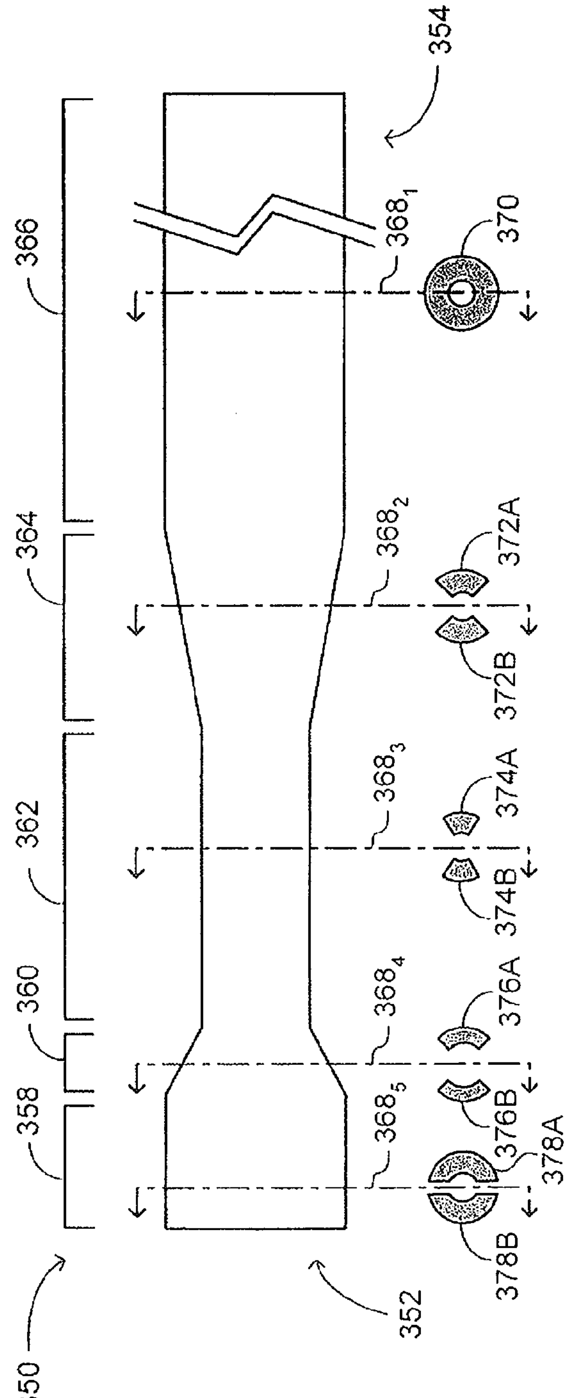
FIG. 3B



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368_5
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FIG. 3C

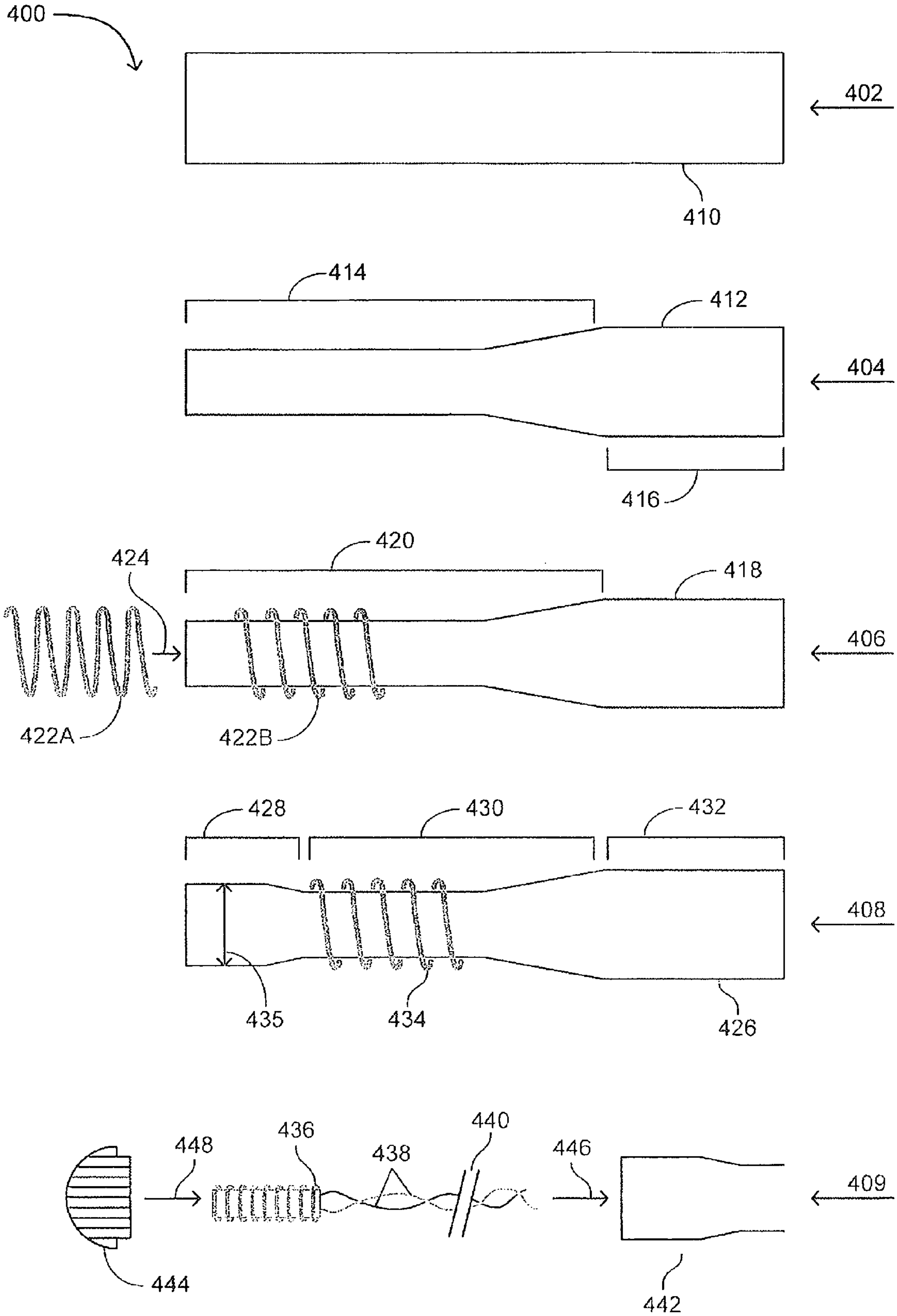
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FIG. 4

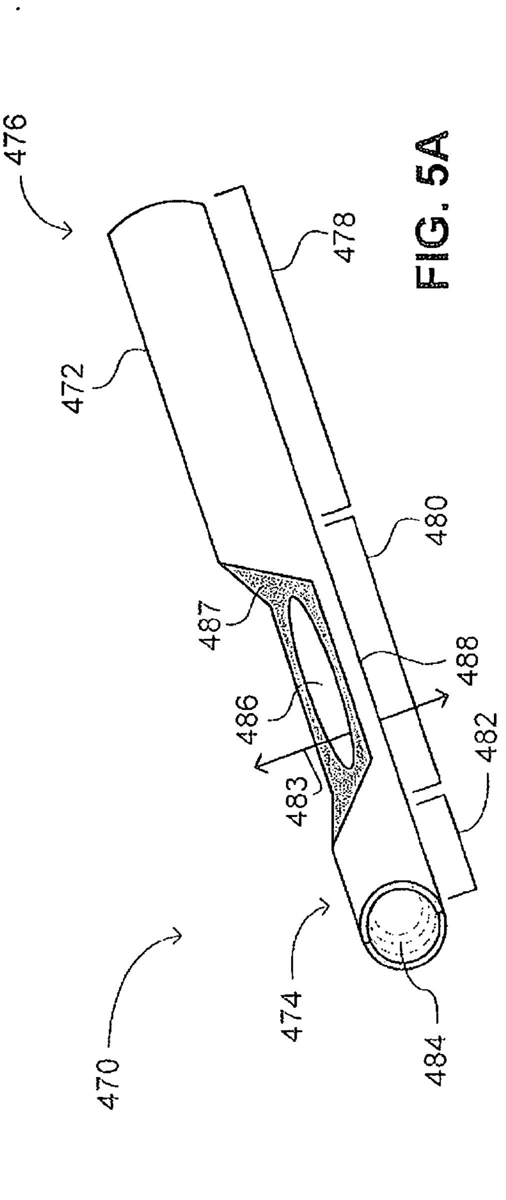
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FIG. 5A

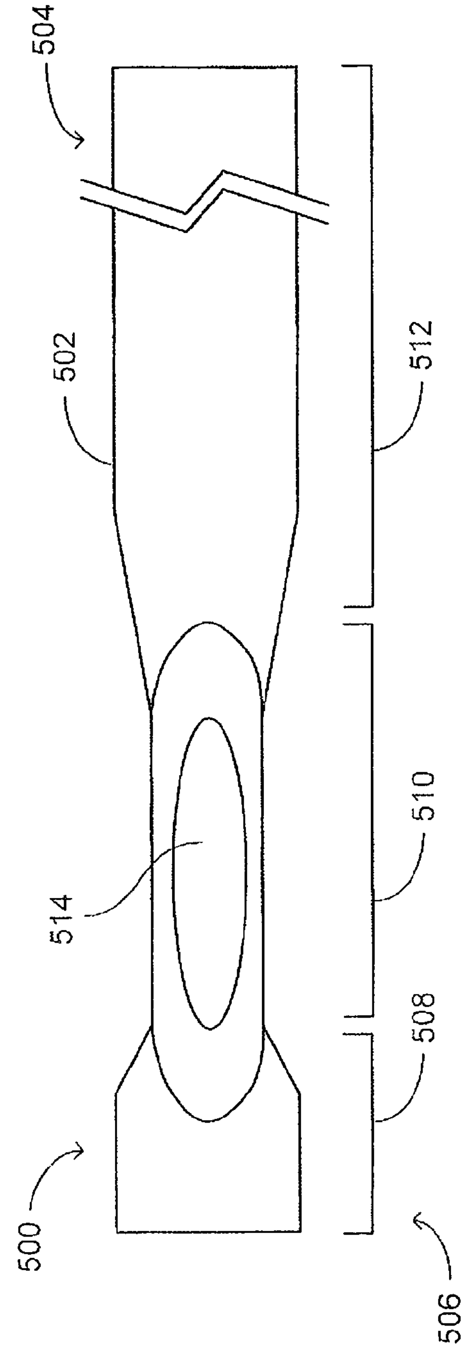
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FIG. 5B

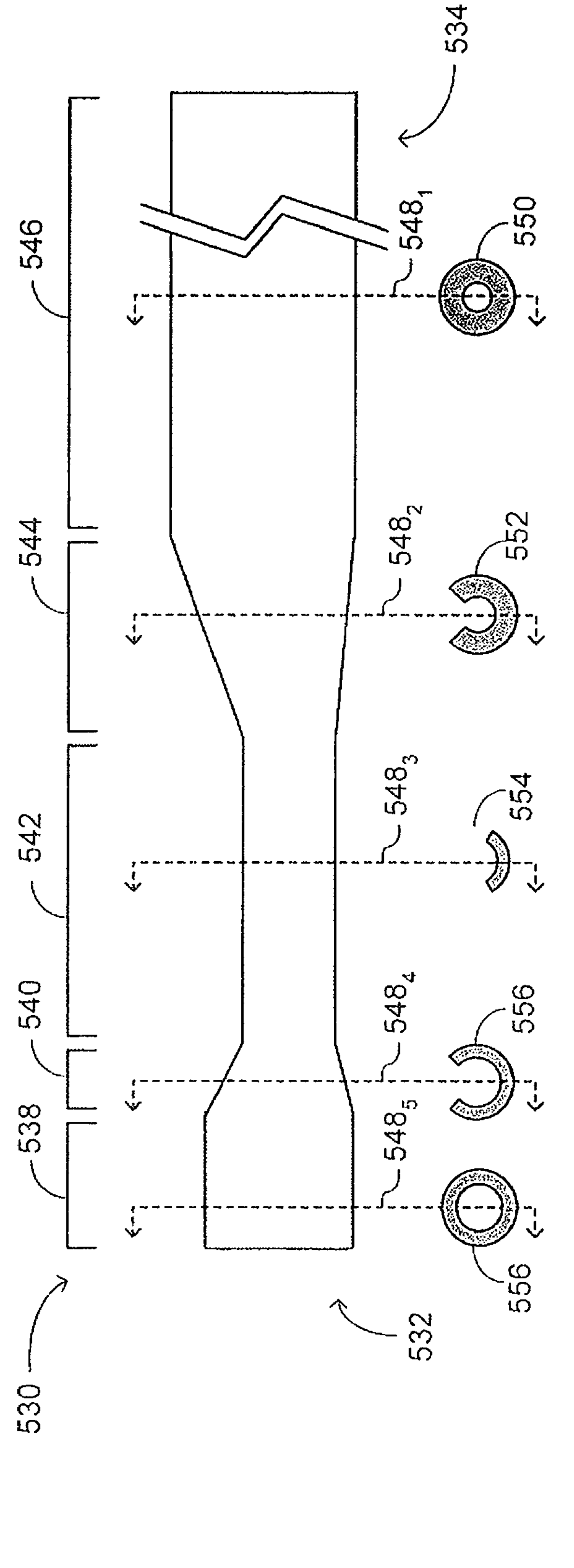
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FIG. 5C

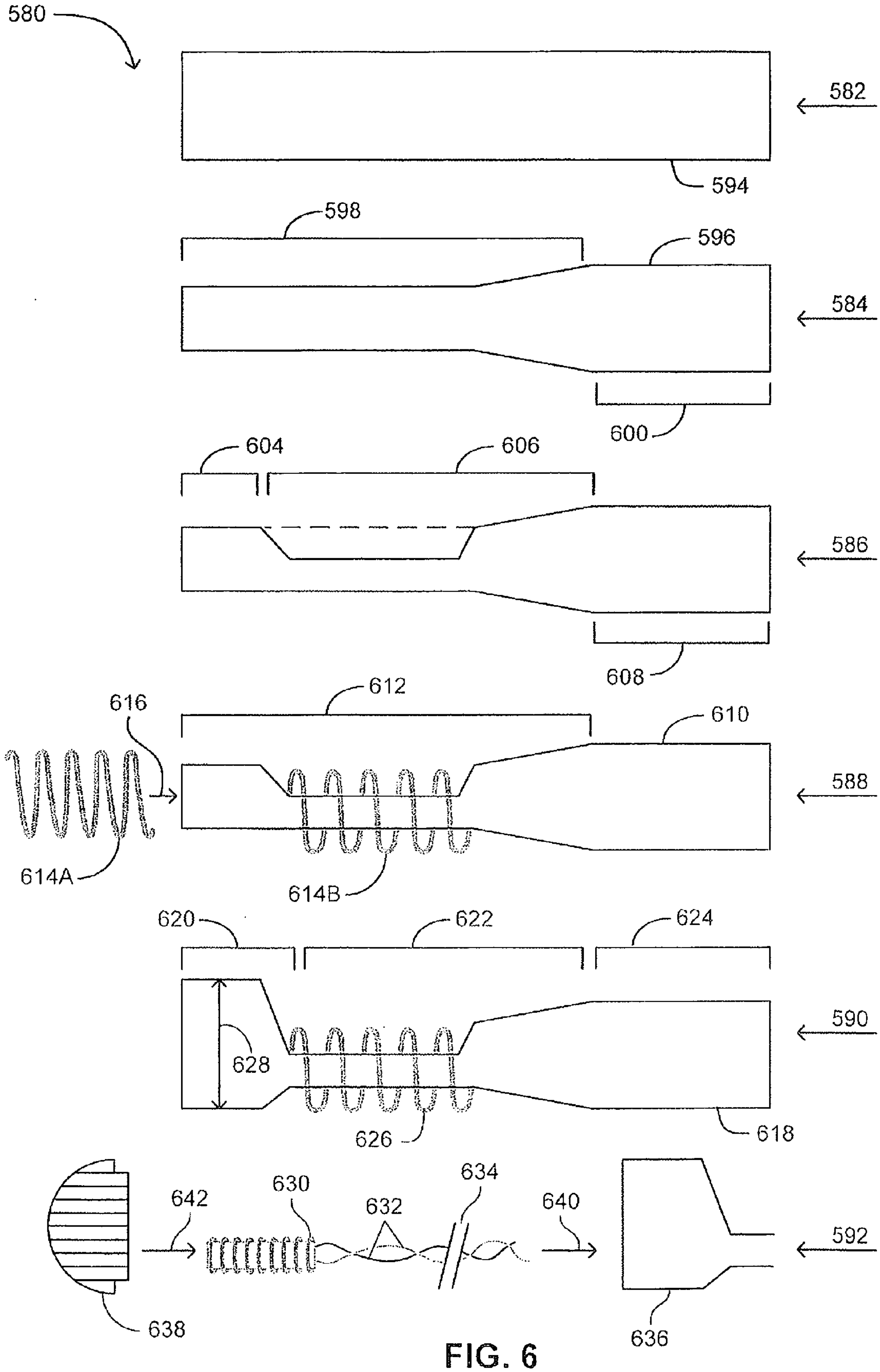
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FIG. 6

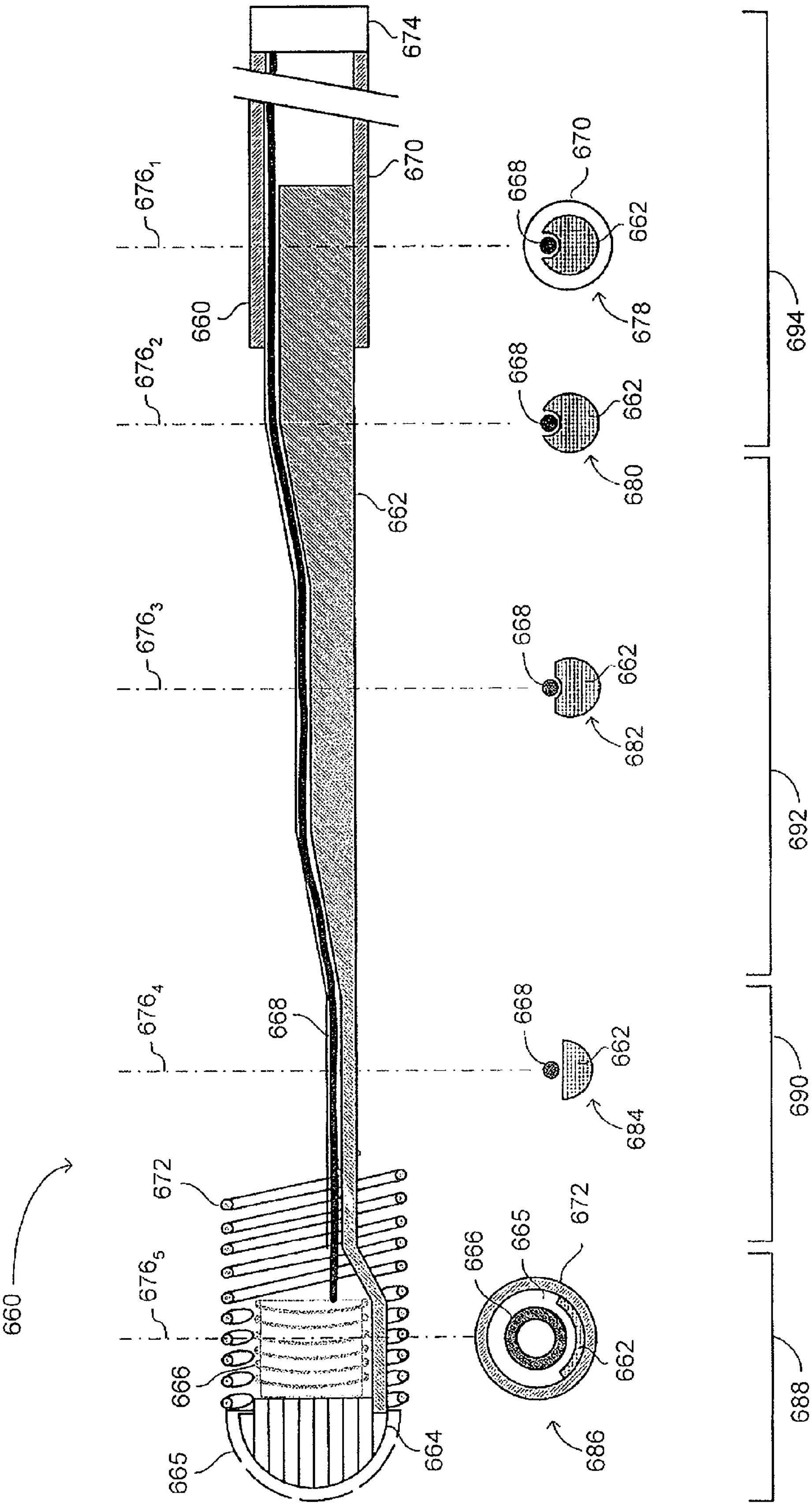
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FIG. 7

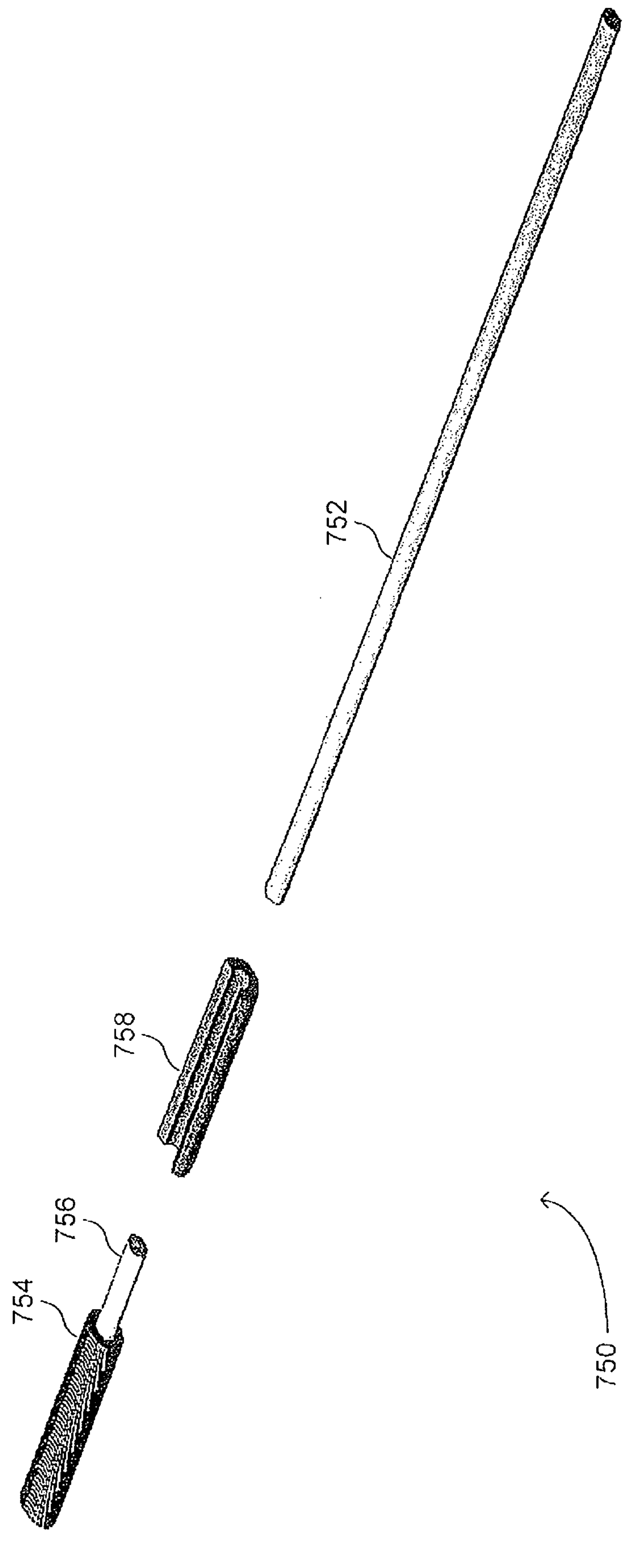

FIG. 8A

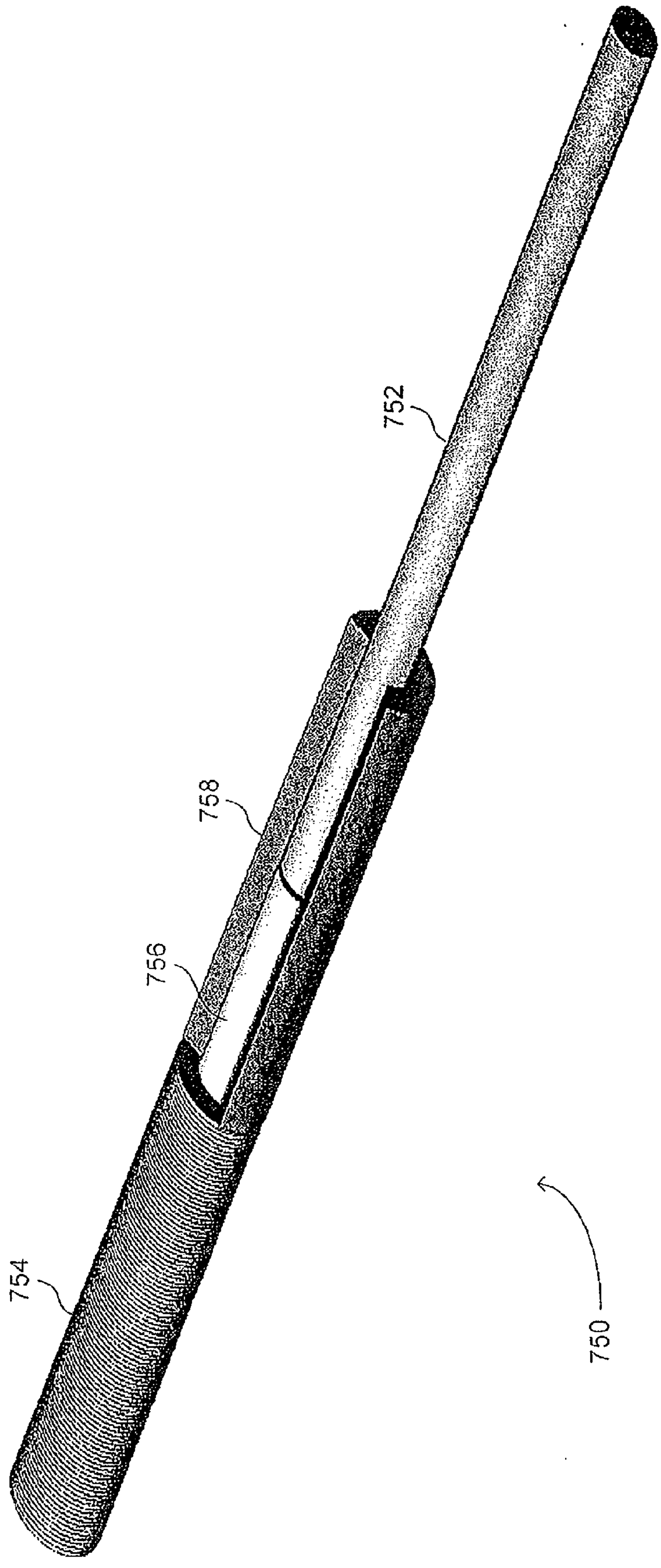

FIG. 8B

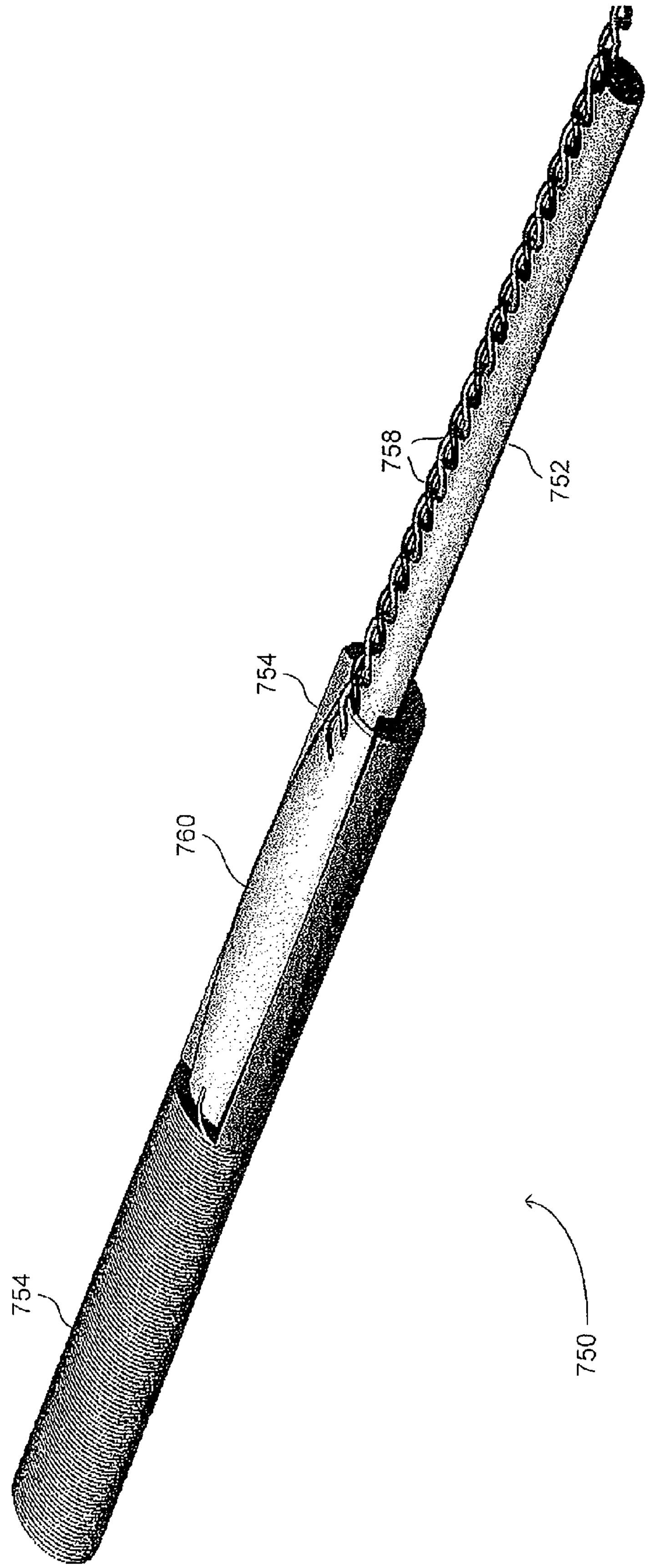

FIG. 8C

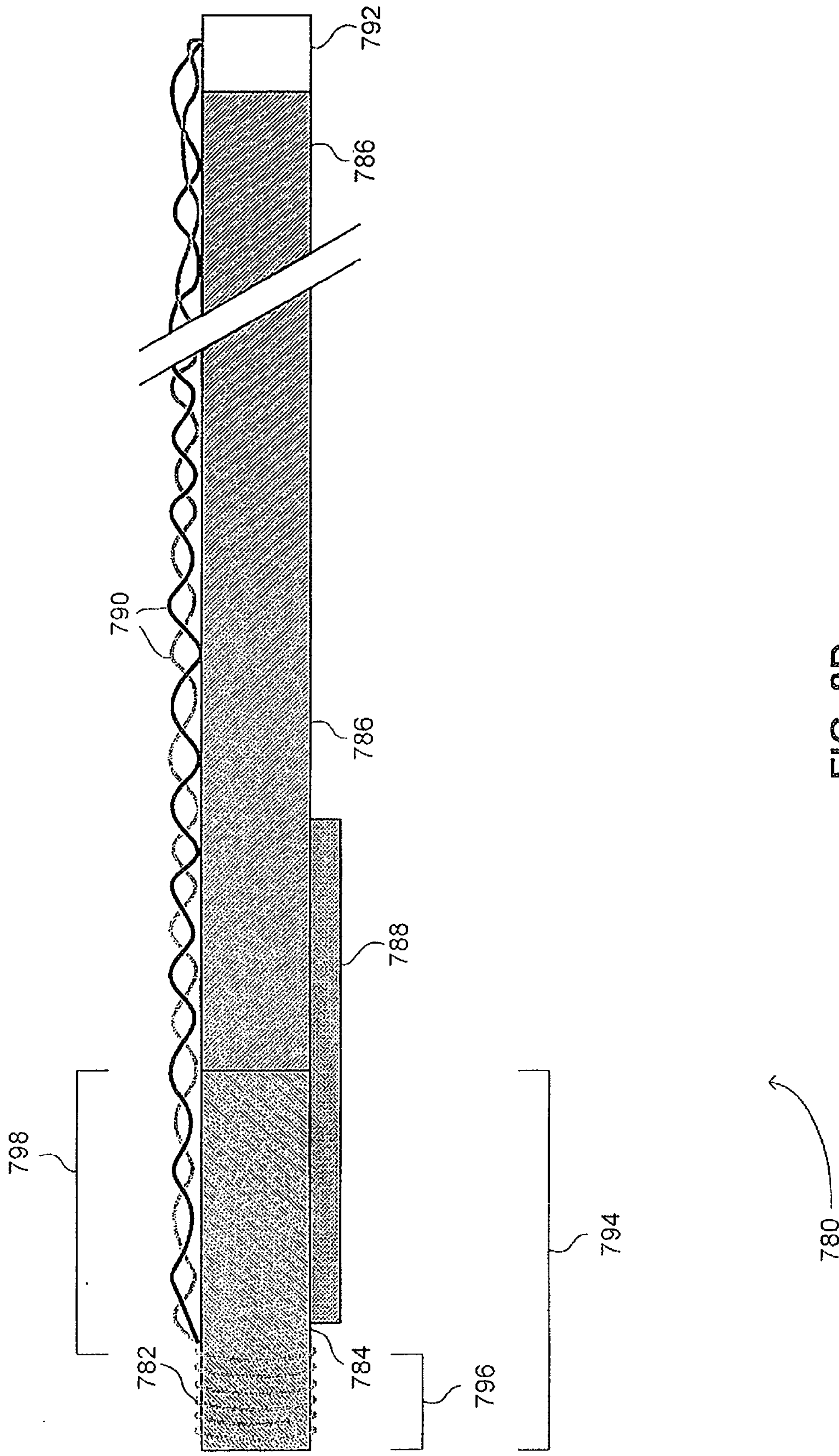

FIG. 8D

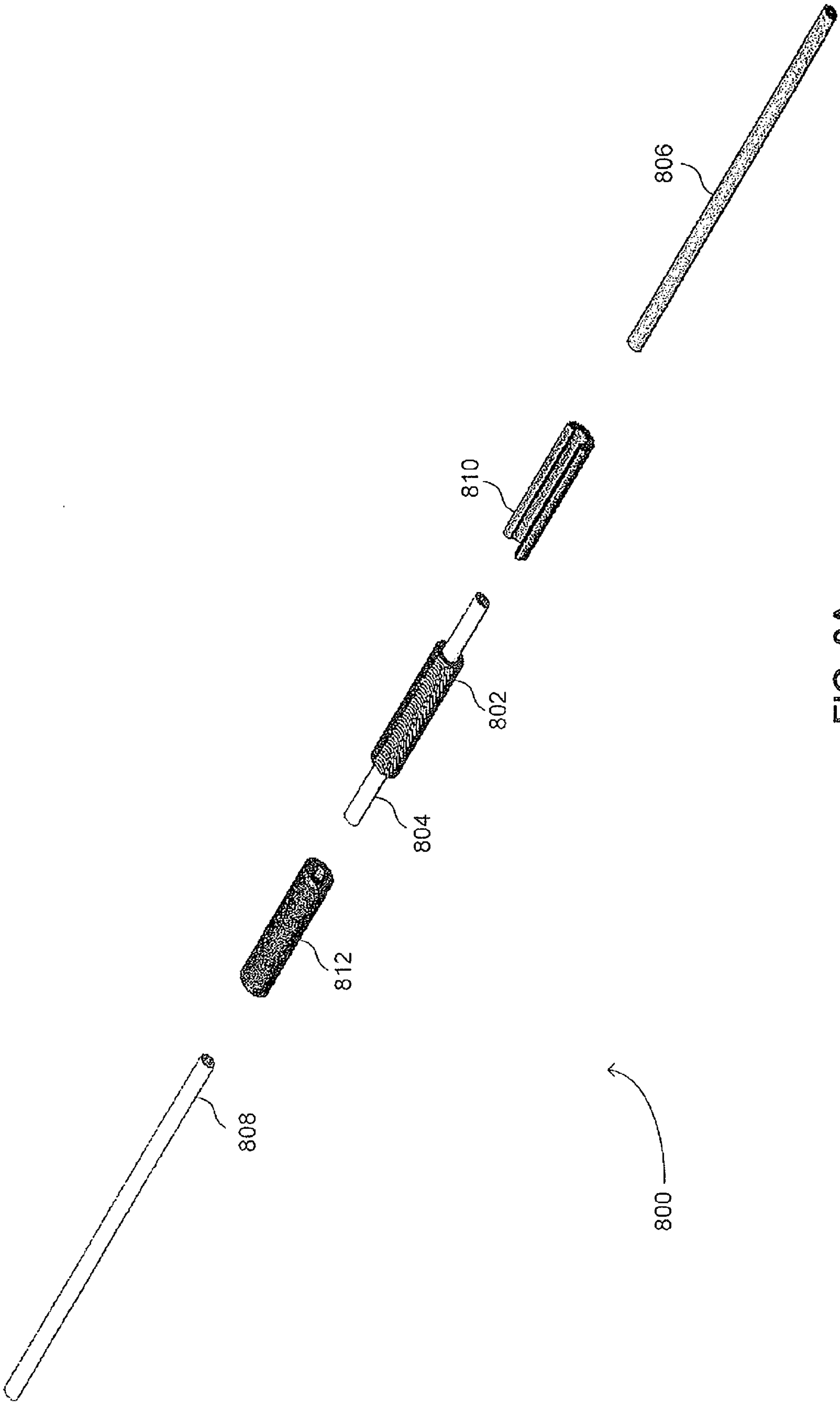

FIG. 9A

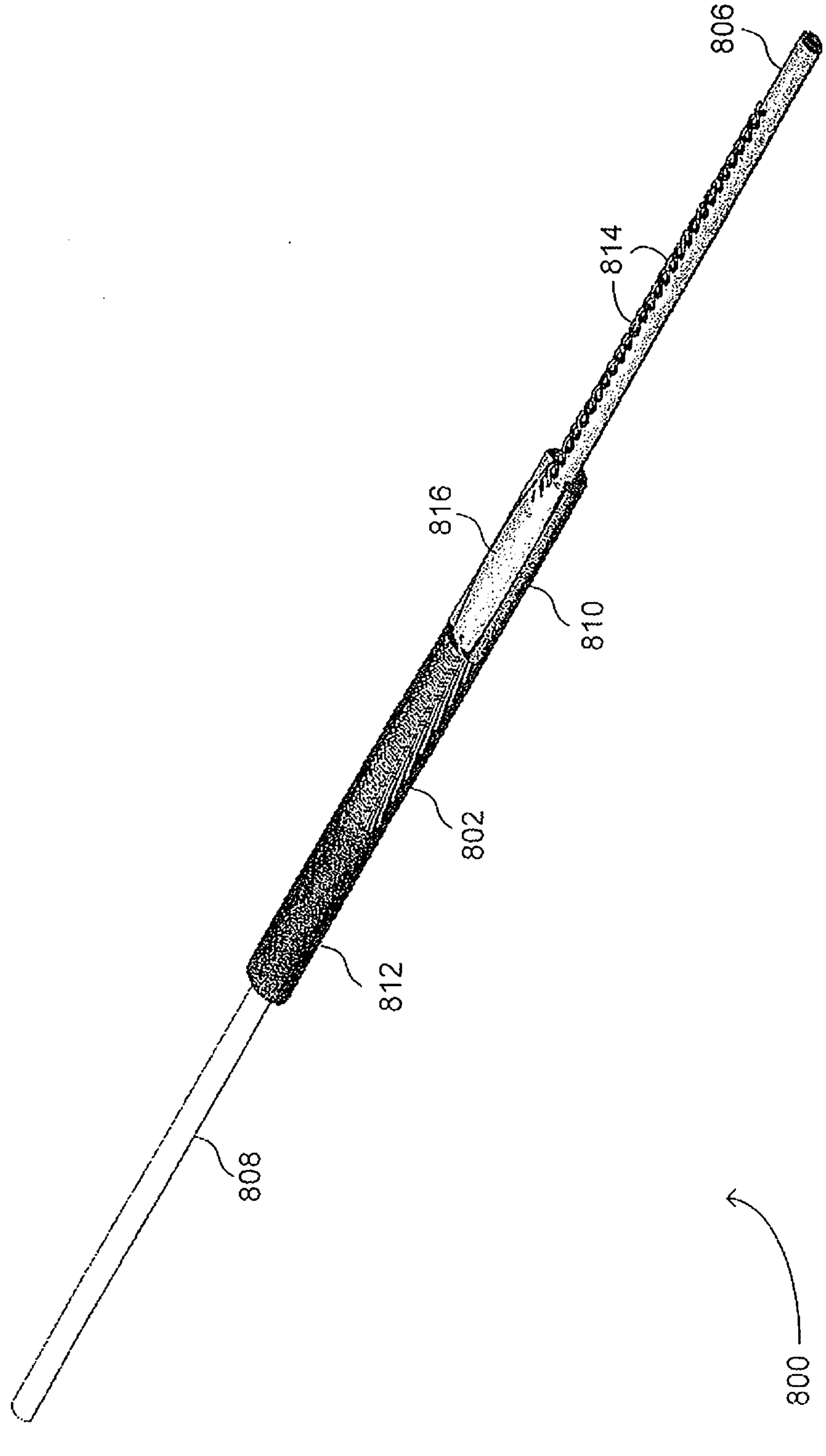

FIG. 9B

REFERENCES CITED IN THE DESCRIPTION

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