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(54) **IMPLANTABLE LEAD WITH IMPROVED CONDUCTOR LUMENS**

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(76) Inventors: **Xavier E. Pardo**, Minneapolis, MN (US); **Shahn S. Sage**, Andover, MN (US); **Scott B. Kokones**, Minneapolis, MN (US); **Jeffrey S. Gagnon**, Champlin, MN (US)

(57) **ABSTRACT**

Correspondence Address:
MEDTRONIC, INC.
710 MEDTRONIC PARKWAY NE
MS-LC340
MINNEAPOLIS, MN 55432-5604 (US)

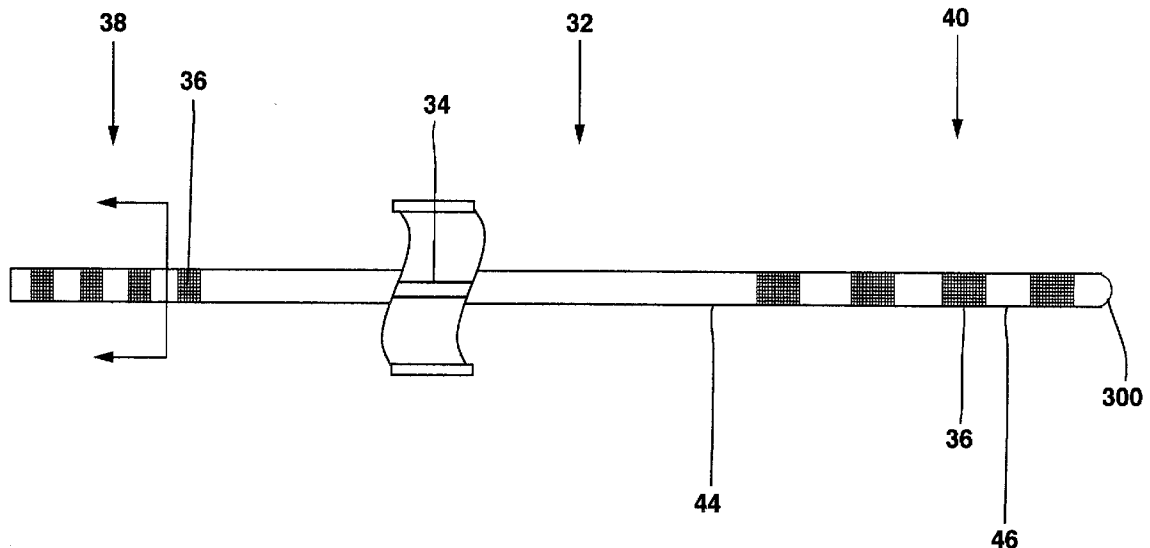
An implantable lead body for a medical device with improved conductor lumens separates and insulates conductors while permitting access to the conductors through the implantable lead outer surface. The implantable lead comprises a lead body, a stylet lumen, at least one conductor lumen, and at least one axial slit in the lead body. The lead body has a proximal end, a distal end, an internal portion, and an external portion. The stylet lumen is formed in the internal portion. The conductor lumen is formed in the internal portion and positioned near an outer surface of the internal portion such that there is only a web between the conductor lumen and the outer surface of the internal portion. The axial slit is formed in the lead body distal end between the conductor lumen and the outer surface of the internal portion.

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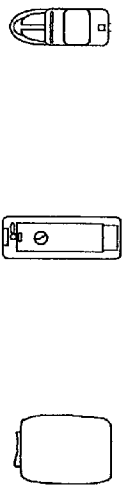
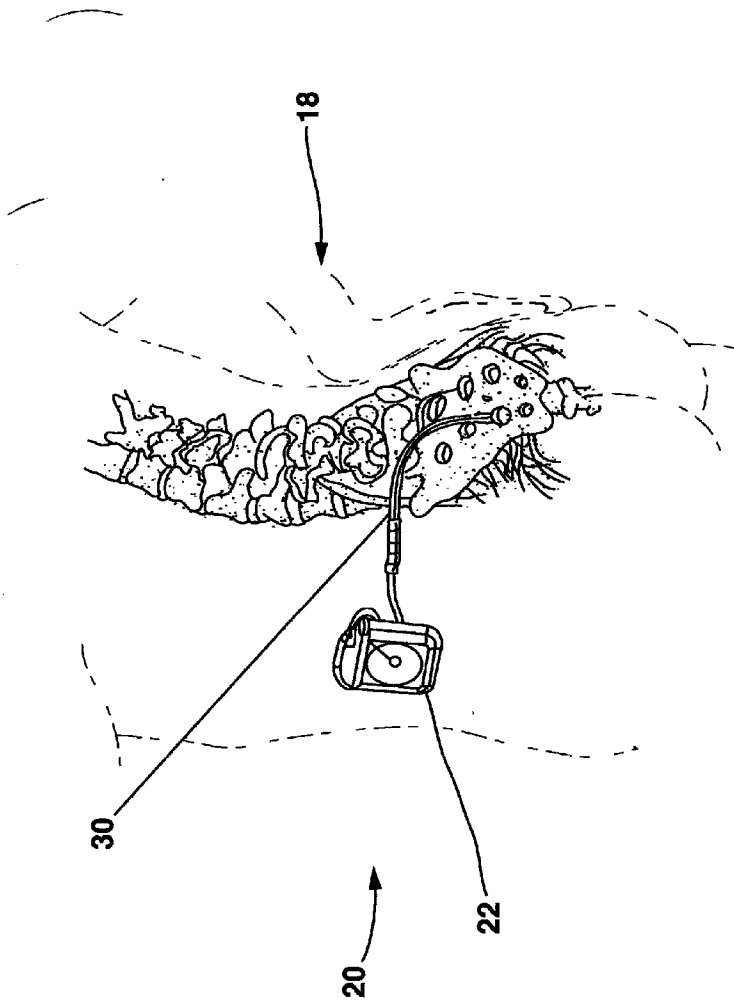


FIG. 1

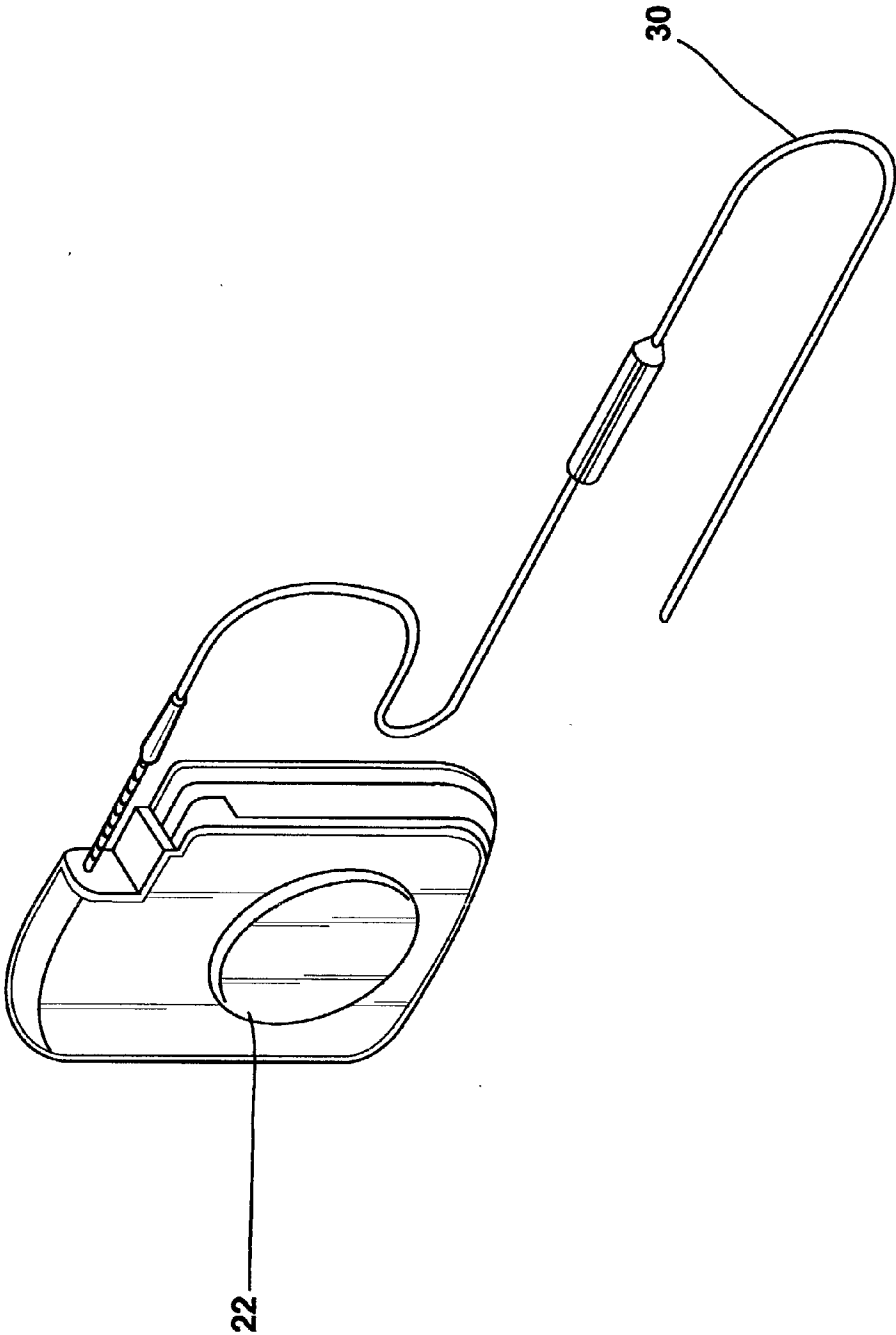


FIG. 2

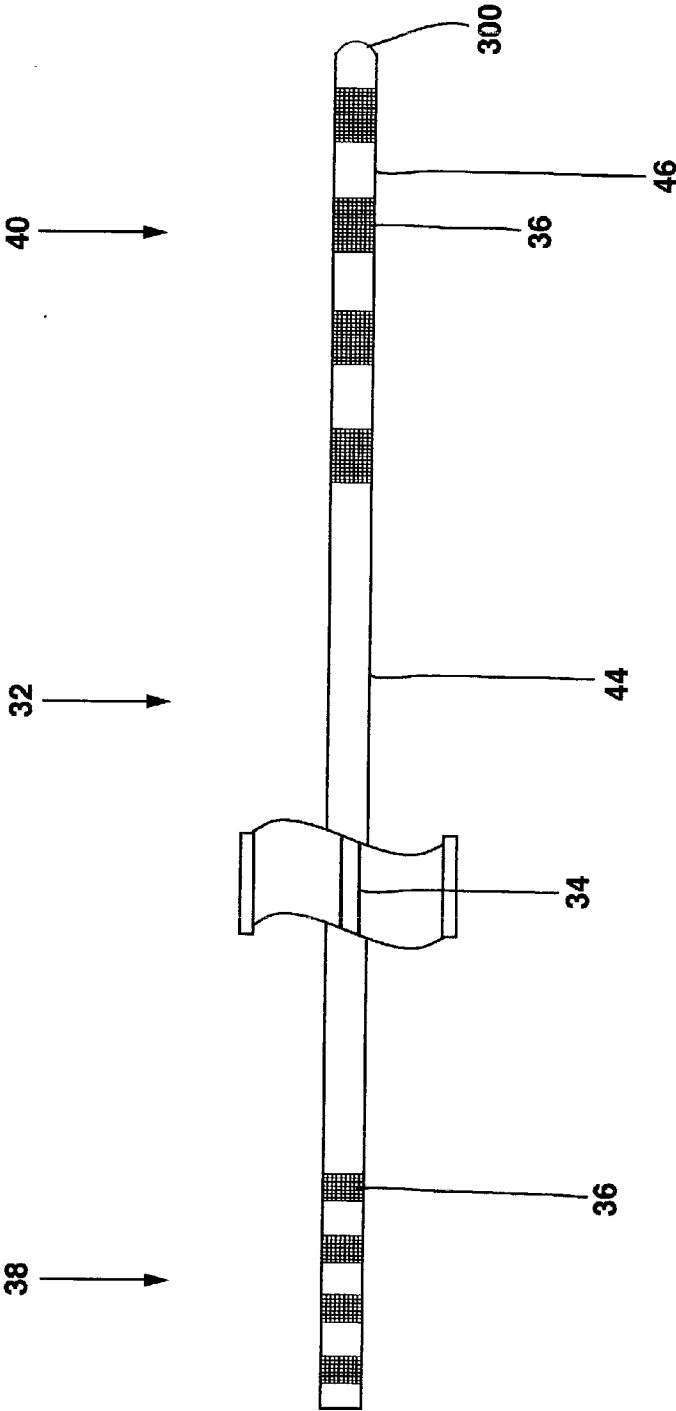
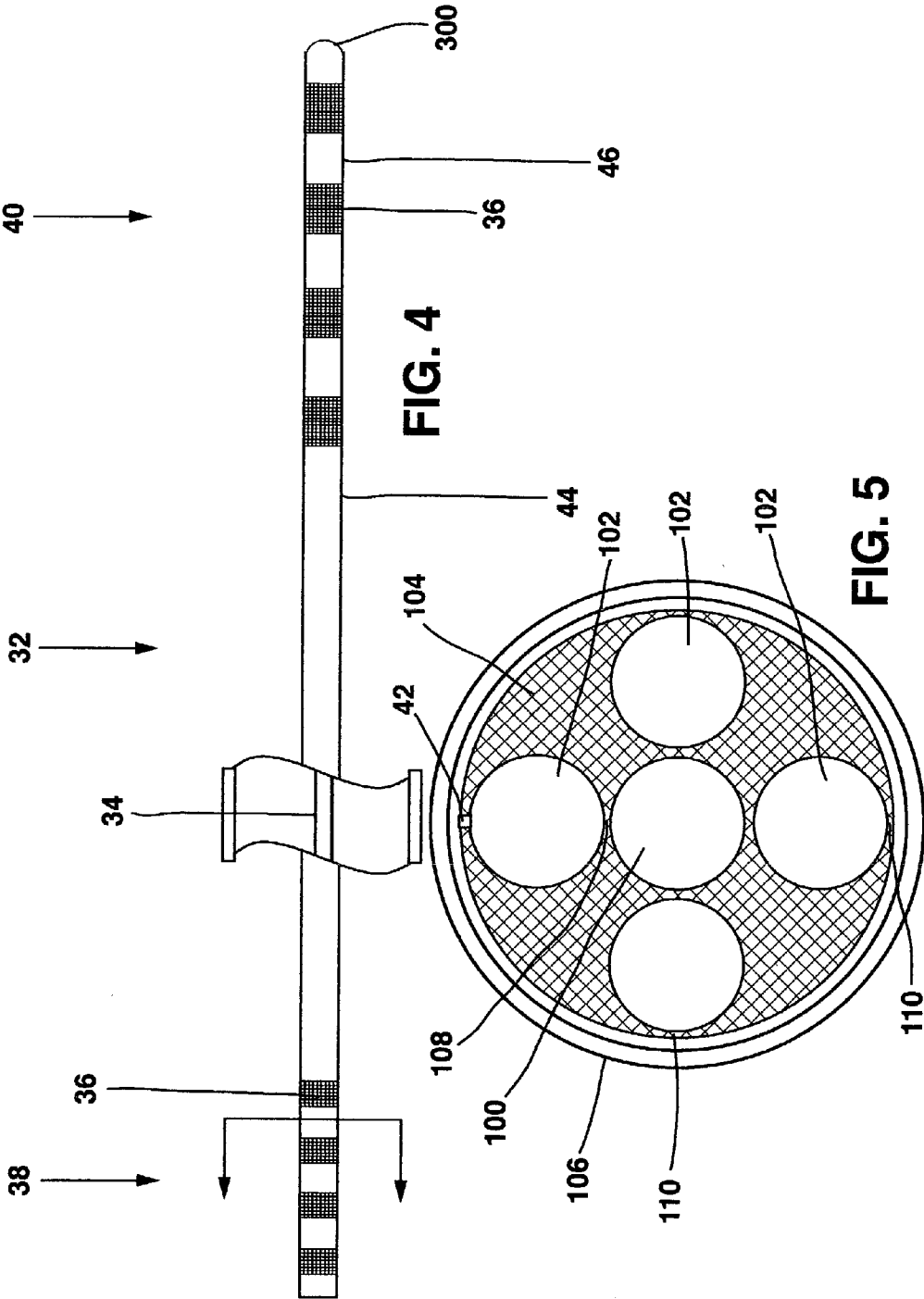


FIG. 3



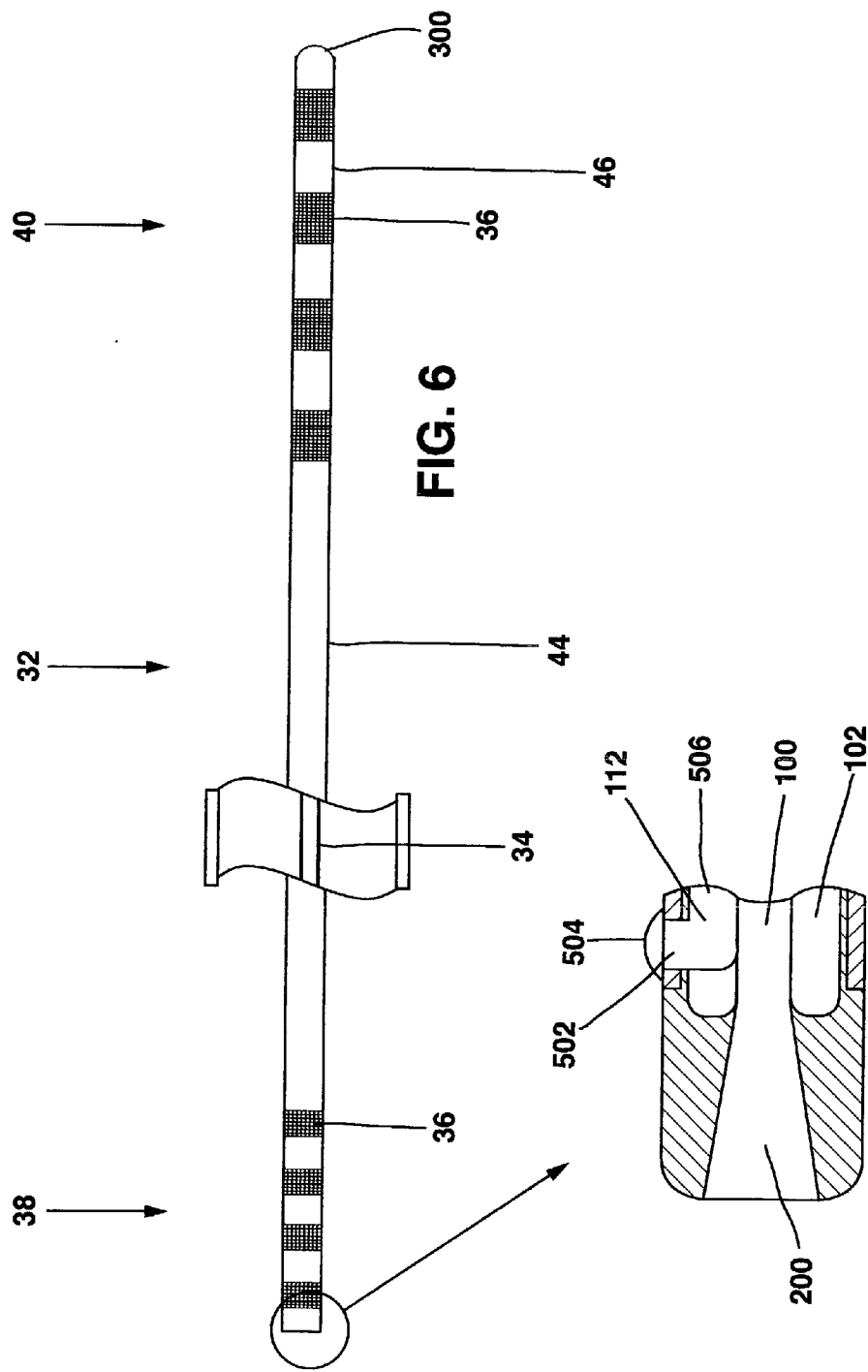


FIG. 6

FIG. 7

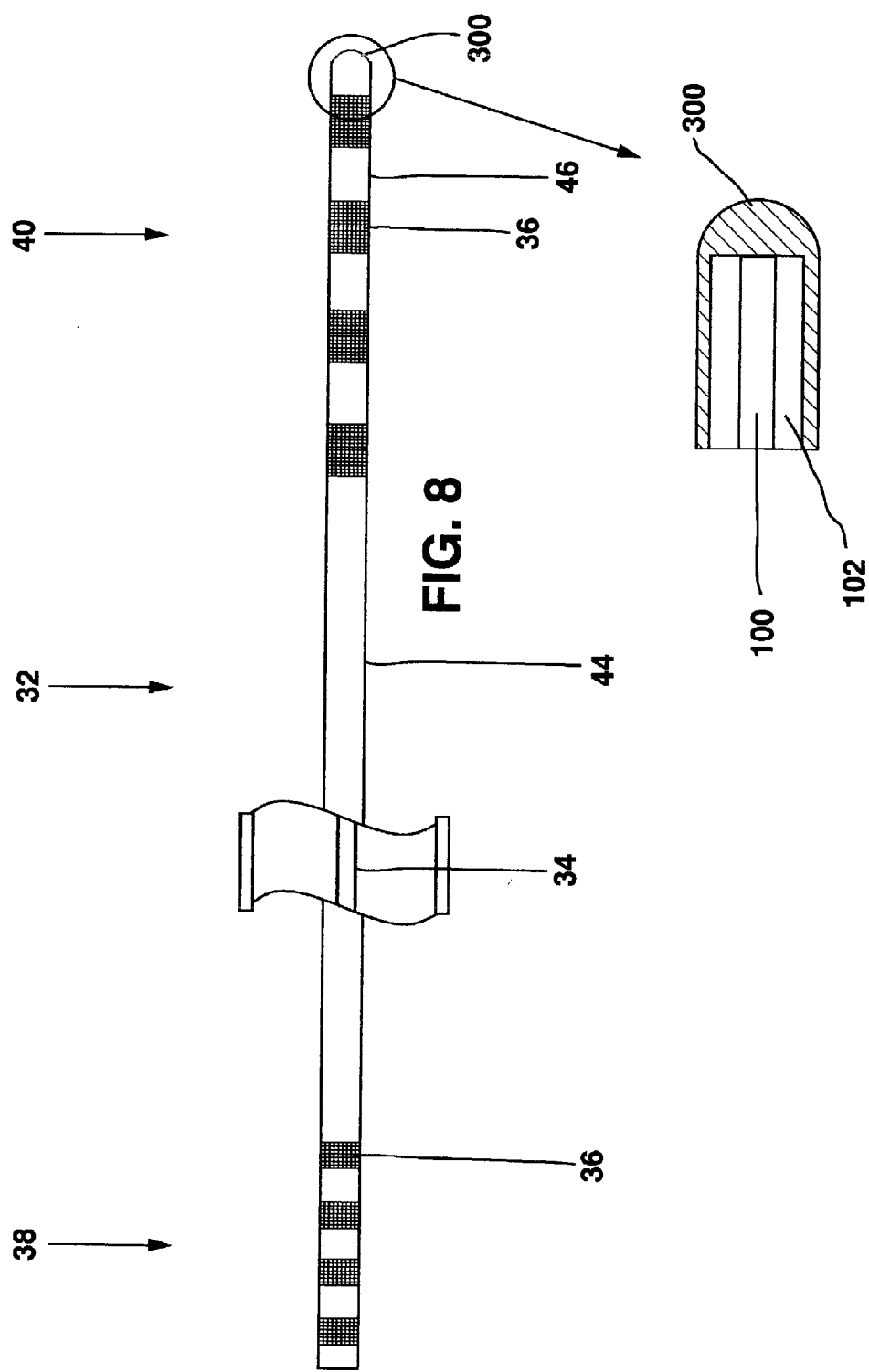
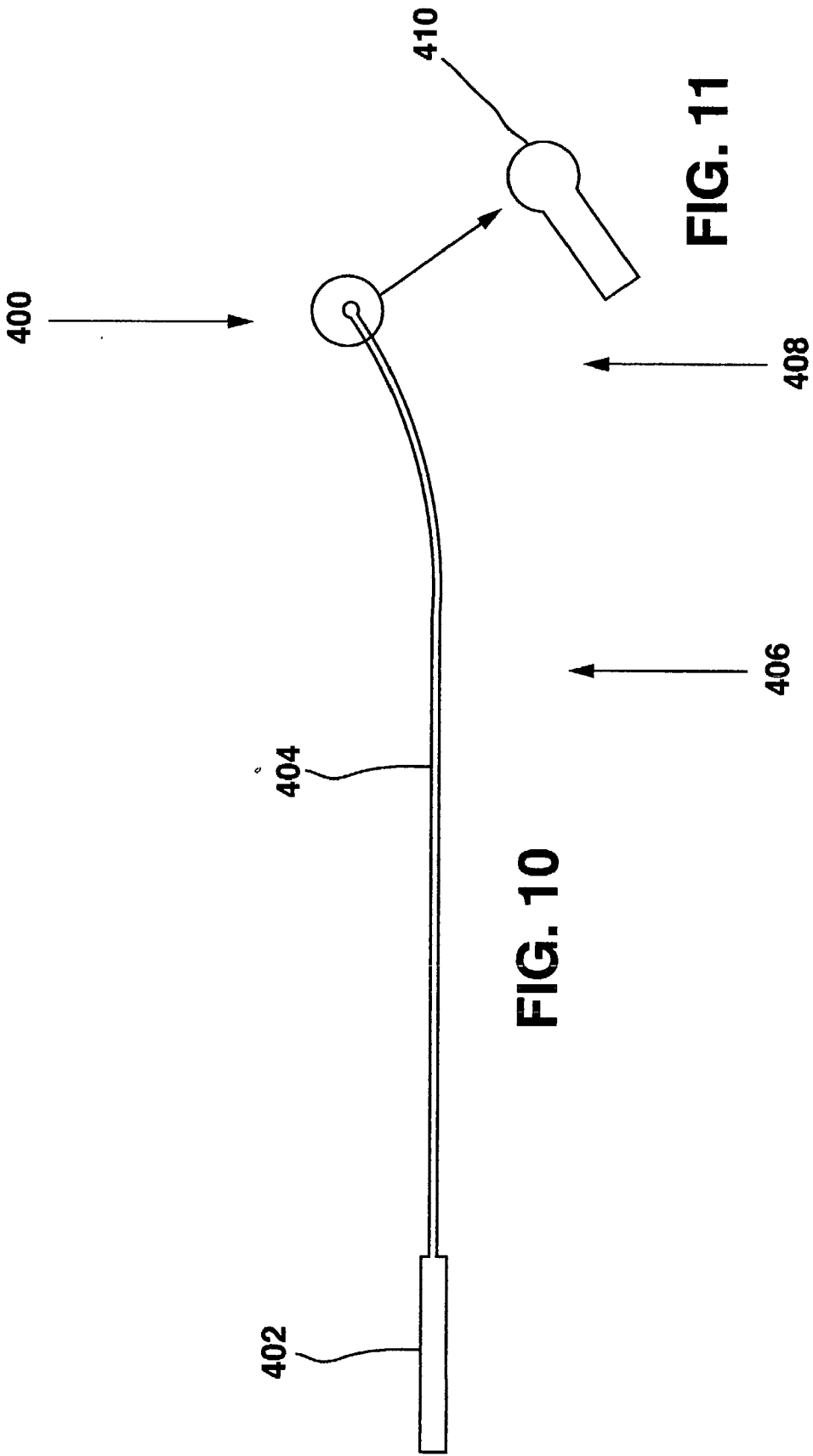


FIG. 9



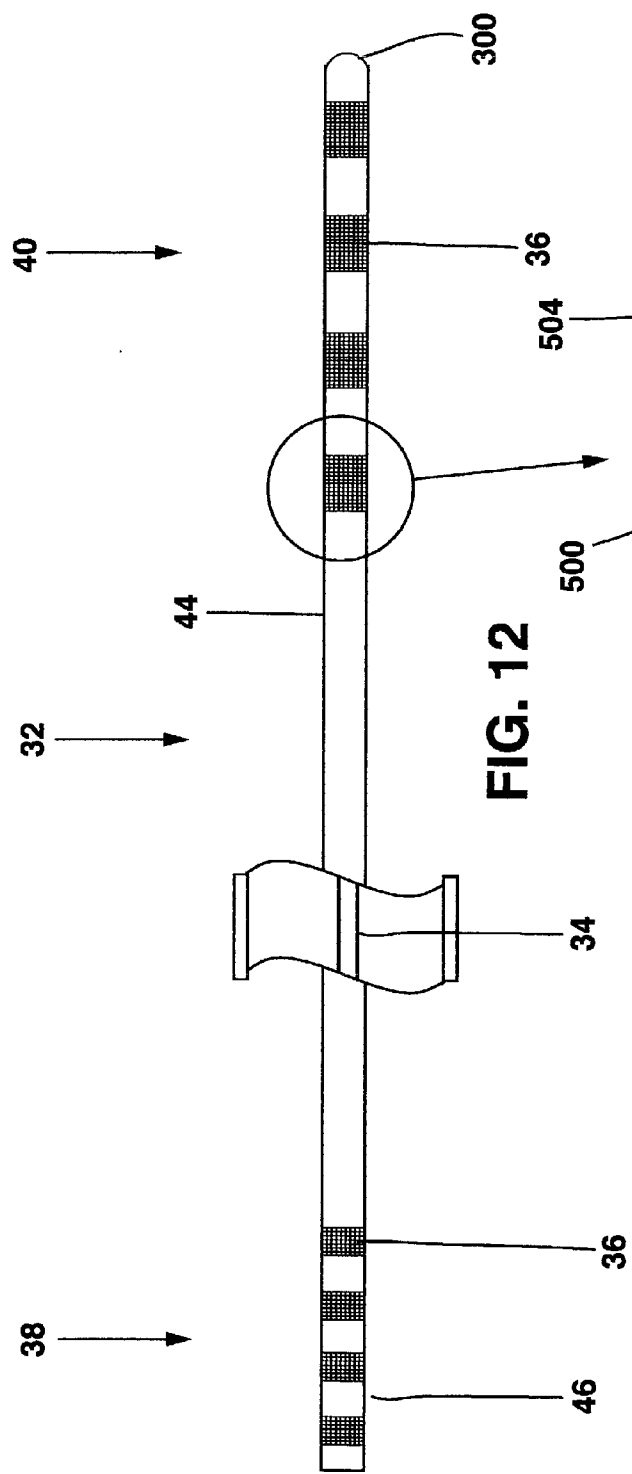


FIG. 12

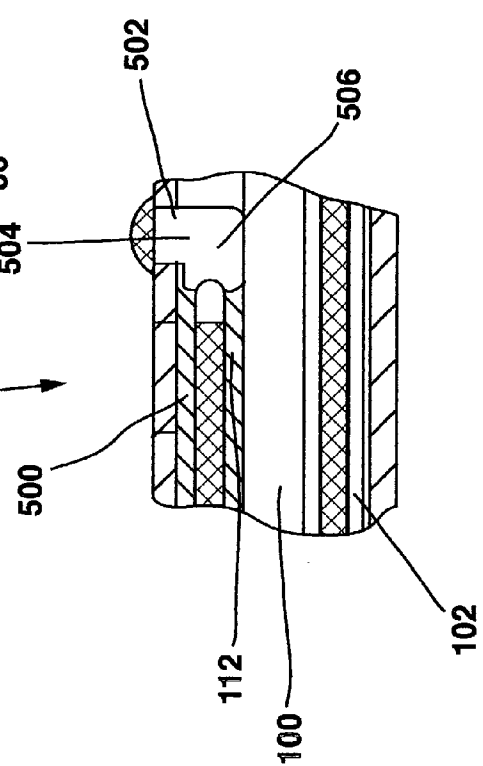


FIG. 13

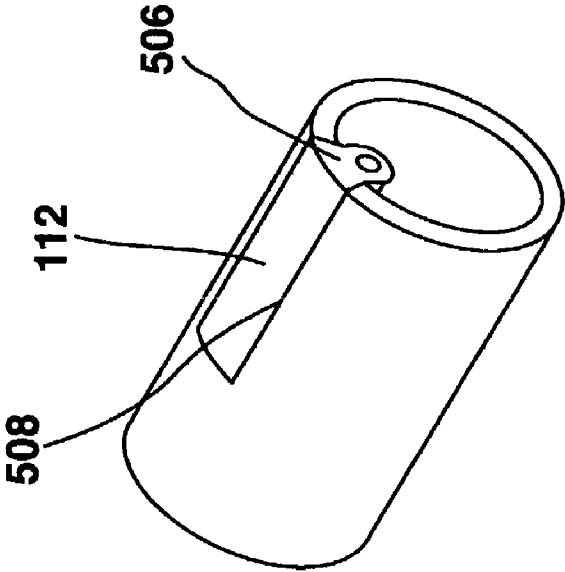


FIG. 14

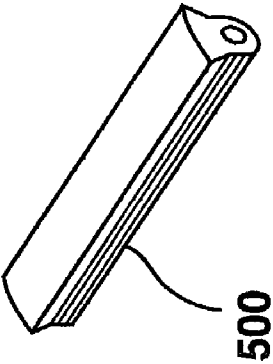


FIG. 15

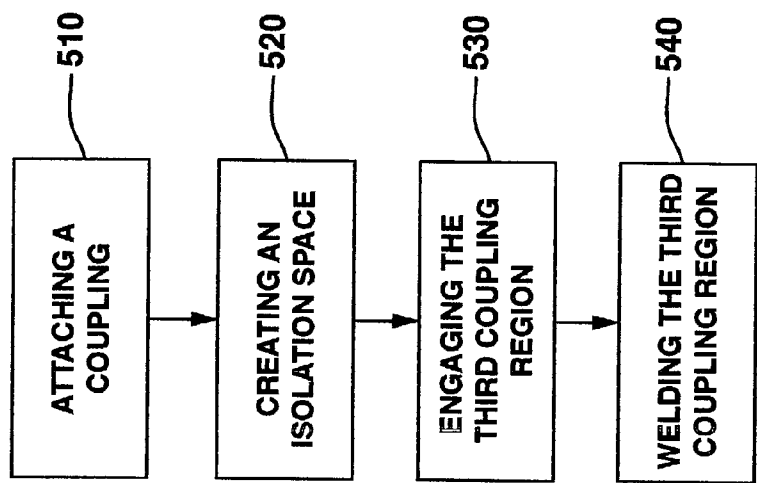


FIG. 16

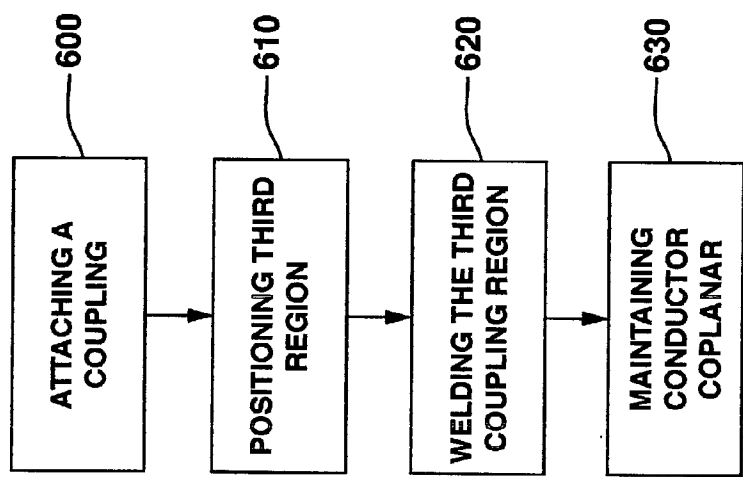


FIG. 17

IMPLANTABLE LEAD WITH IMPROVED CONDUCTOR LUMENS

CROSS REFERENCES

[0001] This application is related to the following co-pending applications entitled “Implantable Lead With Improved Stylet Lumen” by Pardo et al. (attorney docket no. P10707.00); “Implantable Lead With Improved Distal Tip” by Stolz et al. (attorney docket no. P10708.00); “Improved Stylet For An Implantable Lead” by Pardo et al. (attorney docket no. P10709.00); “Implantable Lead With Isolated Contact Coupling” by Pardo et al. (attorney docket no. P10109.00); and, “Implantable Lead With Coplanar Contact Coupling” by Cole et al. (attorney docket no. P10748.00), which are not admitted as prior art with respect to this application by its mention in this cross reference section.

BACKGROUND OF THE INVENTION

[0002] This disclosure relates to medical devices and more particularly to an implantable lead.

[0003] The medical device industry produces a wide variety of electronic and mechanical devices for treating patient medical conditions such as pacemakers, defibrillators, neuro-stimulators and therapeutic substance delivery pumps. Medical devices can be configured to be surgically implanted or connected externally to the patient receiving treatment. Clinicians use medical devices alone or in combination with therapeutic substance therapies and surgery to treat patient medical conditions. For some medical conditions, medical devices provide the best and sometimes the only therapy to restore an individual to a more healthful condition and a fuller life. One type of medical device is an implantable neurological stimulation system that can be used to treat conditions such as pain, movement disorders, pelvic floor disorders, gastroparesis, and a wide variety of other medical conditions. The neurostimulation system typically includes a neurostimulator, a stimulation lead, and an extension such as shown in Medtronic, Inc. brochure “Implantable Neurostimulation System” (1998). More specifically, the neurostimulator system can be an Irel II® Model 7424 or an Irel 3® Model 7425 available from Medtronic, Inc. in Minneapolis, Minn. that can be used to treat conditions such as pain, movement disorders and pelvic floor disorders. The neurostimulator is typically connected to a stimulation lead that has one or more electrodes to deliver electrical stimulation to a specific location in the patient’s body.

[0004] Implantable lead having multiple conductors typically require that each conductor be electrically insulated from the other conductors and each conductor can be assessed at an appropriate location in the implantable lead for forming a connection with a contact. Some implantable leads use electrically insulating conductor coating to electrically isolate the conductors, but electrically insulating conductor coatings can have dielectric limitations. Other implantable leads have used separate lumens for each conductor and the stylet to electrically isolate the conductors. However, implantable lead with separate conductor lumens can be difficult to manufacture particularly with regard to accessing the conductor through an appropriate location in the implantable lead outer surface for forming a connection with a contact. An example of a lead with multiple lumens

is shown in U.S. Pat. No. 6,181,971 “Joining Conductor Cables And Electrodes On A Multi-Lumen Lead Body” by Doan (Jan. 30, 2001). An example of a lead is shown in U.S. Pat. No. 6,216,045 “Implantable Lead And Method Of Manufacture” by Black et al. (Apr. 10, 2001).

[0005] For the foregoing reasons, there is a need for an implantable lead with improved conductor lumens to separate and insulate conductors while also permitting access to conductors through the implantable lead outer surface.

BRIEF SUMMARY OF THE INVENTION

[0006] An implantable lead body with improved conductor lumens separates and insulates conductors while permitting access to the conductors through the implantable lead outer surface. The implantable lead body comprises a lead body, a stylet lumen, at least one conductor lumen, and at least one axial slit in the lead body. The lead body has a proximal end, a distal end, an internal portion, and an external portion. The stylet lumen is formed in the internal portion. The conductor lumen is formed in the internal portion and positioned near an outer surface of the internal portion such that there is only a web between the conductor lumen and the outer surface of the internal portion. The axial slit is formed in the lead body distal end between the conductor lumen and the outer surface of the internal portion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 shows a general environmental view for a neurostimulation system embodiment;

[0008] FIG. 2 shows a neurostimulation system embodiment;

[0009] FIG. 3 shows an implantable lead embodiment;

[0010] FIG. 4 shows an implantable lead with cross-section indication embodiment;

[0011] FIG. 5 shows a cross section of the implantable lead embodiment shown in FIG. 4;

[0012] FIG. 6 shows an implantable lead with proximal end enlargement indication embodiment;

[0013] FIG. 7 shows an enlarged cross section of the proximal end shown in FIG. 6;

[0014] FIG. 8 shows an implantable lead with distal end enlargement indication embodiment;

[0015] FIG. 9 shows an enlarged cross section of the distal end shown in FIG. 8 embodiment;

[0016] FIG. 10 shows a stylet with distal end enlargement indication embodiment;

[0017] FIG. 11 shows the enlarged distal end shown in FIG. 10 embodiment;

[0018] FIG. 12 shows an implantable lead with enlargement indication of a contact embodiment;

[0019] FIG. 13 shows a cross section of the enlarged contact embodiment;

[0020] FIG. 14 shows an isometric view of a contact and coupling embodiment;

[0021] FIG. 15 shows an isometric view of the coupling embodiment shown in FIG. 14;

[0022] FIG. 16 shows a flow chart of a method for creating an isolation space in an implantable lead contact connection embodiment; and,

[0023] FIG. 17 shows a flow chart of a method for creating a coplanar connection in an implantable lead between a conductor and a contact embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] FIG. 1 shows a general environmental view of an implantable neurostimulation system embodiment and FIG. 2 shows a neurostimulation system embodiment. Neurostimulation systems are used to treat conditions such as pain, movement disorders, pelvic floor disorders, gastroparesis, and a wide variety of other medical conditions. The neurostimulation system 20 includes a neurostimulator 22 such as an Irel II® Model 7424 or an Irel 3® Model 7425 available from Medtronic, Inc. in Minneapolis, Minn., a stimulation lead extension 24, and a stimulation lead 30. The neurostimulator 22 is typically implanted subcutaneously in the patient's body 18 at a location selected by the clinician. The stimulation lead 30 is typically fixed in place near the location selected by the clinician using a device such as the adjustable anchor. The implantable lead 30 can be configured as a neurological stimulation lead, a neurological sensing lead, and a combination of both as a neurological stimulation and sensing lead, a cardiac lead, and the like.

[0025] FIG. 3 shows an implantable lead embodiment. An implantable lead comprises a lead body 32, at least one conductor 34, at least two contacts 36. The lead body has a proximal end 38, a distal end 40, and an exterior surface 44. The lead body 32 can be composed of a wide variety of electrically isolative materials and configurations. Materials may include, but are not limited to, silicone rubber, polyurethane, fluoropolymers and the like. Configurations could include monolumen and multilumen lead bodies. The exterior surface 44 is composed of one or more biocompatible materials.

[0026] The conductor 34 is contained in the lead body and generally extends from the lead proximal end 38 to the distal end 40. The conductors 34 can be manufactured from a wide range of materials that are electrically conductive such as MP35N, platinum and the like. In some embodiments, the conductor 34 can comprise a plurality of wires that can be configured as braided strand wire (BSW). BSW is available in many configurations including seven wire BSW. When low impedance is desired, the core of each wire can be manufactured from a low impedance metal such as silver and the jacket can be manufactured from a material with good mechanical strength properties such as MP35N. One embodiment of conductor 34 uses seven wire BSW with a silver core and an MP35N jacket typically with a resistance of less than about 0.098 ohms/cm (3 ohms/foot) and a tensile strength greater than 5N. The conductor 34 can be electrically insulated with a fluoropolymer such as ethylenetetrafluoroethylene with a coating thickness of approximately 0.0002 cm (0.0008 inch).

[0027] The contacts 36 includes at least one contact 36 carried on the lead distal end 40 that is electrically connected

to the conductor 34 and at least one contact 36 carried on the proximal end 38 that is electrically connected to the conductor 34. The proximal contacts are typically manufactured from a material with good mechanical strength and biocompatible properties such as MP35N and the like to withstand interaction with mating devices such as an implantable neurological extension. The distal contacts are typically manufactured from materials with good electrical and biocompatibility properties such as platinum and iridium alloys that can be configured in a mixture such as 90% platinum and 10% iridium. In some embodiments, spacers 46 are inserted between contacts 36 so the proximal end 38 and distal end 40 are substantially iso-diametric.

[0028] FIG. 4 shows an implantable lead embodiment, and FIG. 5 shows a cross section of the implantable lead in FIG. 4. An implantable lead with improved conductor lumens comprises a lead body 32, a stylet lumen 100, at least one conductor lumen 102, and at least one axial slit 42. The lead body has an internal portion 104 and an external portion 106. The stylet lumen 100 and the conductor lumen 102 are formed in the internal portion 104. The internal portion 104 is a continuous material that has a proximal end 38, distal end 40 and an outer surface that is encapsulated by the external portion 104. This structure can be extruded and its configuration can be substantially the same at any longitudinal cross section. The internal portion 104 has an outside diameter smaller than the inside diameter of the external portion 106. In some embodiments, the internal portion 104 outside diameter is approximately 0.102 cm (0.04 inch) smaller than the external portion 104 inside diameter. The internal portion 104 is fitted inside of the external portion 106. The external portion 106 exterior surface 44 typically has an outer diameter selected for the therapeutic application such as in the range from about 0.05 cm (0.02 inch) to about 0.20 cm (0.08 inch) with one embodiment having an outer diameter of about 0.127 cm (0.05 inch). The stylet lumen 100 is formed in the internal portion 104 typically in the center and sized to provide clearance between the stylet lumen 100 and the coaxially inserted stylet wire 404 in the range from about 0.00025 cm (0.0001 inch) to about 0.025 cm (0.01 inch), and in some embodiments that clearance is about 0.0038 cm (0.0015 inches).

[0029] The conductor lumen 102 is formed in the internal portion 104 and positioned near an outer surface of the internal portion 104 such that there is only a web 110 between the conductor lumen 102 and the outer surface of the internal portion 104. Some embodiments have a plurality of conductor lumens 102 such as in the range from about two to sixteen conductor lumens 102. The implantable lead embodiment shown has four conductor assembly lumens that are substantially equidistant from each other and to the centrally localized stylet lumen. The conductor lumens 102 and stylet lumen 100 geometry provides axial stability, and the centrally located stylet lumen 100 improves navigation. Each conductor lumen 102 can be configured to resemble a polygon that is not necessarily symmetrical, and each conductor lumen 102 has a diameter typically greater than about 0.0254 cm (0.01 inch). In some embodiments, the conductor lumens 102 electrically insulate each conductor 34 and physically separate each conductor 34 to facilitate identification of the conductor 34 that is appropriate for its single corresponding contact 36. The film 108 thickness between the conductor lumens 102 and the stylet lumen 100 is no less than about 0.00254 cm (0.001 inch). This film 108 is flexible

enough to allow the entering stylet to slide through the lead body without penetrating through into a conductor lumen 102 or out of the lead body.

[0030] The web 110 allows an axial slit 42 to be created in the internal portion 104 distal end for a path to exist between the conductor lumen 102 and the internal portion 104 outer surface. The web 110 is no greater than 0.005 cm (0.002 inch) thick. The web 110 provides the means for a conductor lumen 102 formed inside the lead body to be positioned near the exterior surface 44 of the lead body. The axial slit 42 is formed in the internal portion 104 distal end between the conductor lumen 102 and the outer surface of the internal portion 104. The axial slit 42 provides a temporary opening for a coupling 112 (FIG. 9) to exit the conductor lumen 102 and attach to a contact 36. The axial slit 42, when stretched ajar, opens to a width of at least about 0.01 cm (0.0039 inch) to allow the coupling 112 to exit the conductor lumen 102. Once the coupling 112 is connected to the contact 36, the axial slit 42 preferably seals back.

[0031] FIG. 6 shows an implantable lead with proximal end 38 enlargement indication embodiment, and FIG. 7 shows an enlarged cross section of the proximal end 38 shown in FIG. 6. An implantable lead with improved stylet lumen comprises a lead body, at least two conductors 34, contacts 36, and a proximal flare 200. The lead body has a proximal end 38, a distal end 40, a stylet lumen 100, and at least two conductor lumens 102. The conductors 34 are contained in the conductor lumens 102 extending from the lead proximal end 38 to the distal end 40. The contacts 36 are carried on the distal end 40 and electrically connected to the conductors 34. Typically, conductors 34 are also carried on the proximal end 38 and electrically connected to the conductors 34.

[0032] The proximal flare 200 is formed on the lead body proximal end 38 and it has tapering walls that narrow toward a stylet opening to guide insertion of a stylet (FIG. 10) into the stylet lumen 100, and the proximal flare 200 seals the conductor lumens 102 proximal end to isolate the conductor lumens 102. The proximal flare 200 is manufactured for a non-rigid material typically similar to the lead body material. The tapering walls have a slope typically in the range from about 0.25 cm/cm to about 0.50 cm/cm. The axial length of the flare 200 is no greater than about 0.064 cm (0.025 inches). The wall thickness of the flare 200 ranges from 0.01 cm (0.004 inch), at the most proximal end, to 0.05 cm (0.019 inch), at the distal end of the flare 200. The proximal flare 200 is flexible to reduce stylet deformation during insertion or withdrawal of the stylet. During stylet insertion into the stylet lumen 100, navigation, and withdrawal, the tapered walls absorb energy and stretch to accommodate movement of the stylet to reduce stylet deformation. Also during stylet insertion into the stylet lumen 100, the proximal flare 200 substantially prevents the stylet from entering the conductor lumens 102. The flare 200 provides a progressive tactile feedback to indicate to the clinician the amount of stylet pressure being applying to the lead proximal end 38 which reduces lead/stylet damage or deformation during implant.

[0033] The proximal flare 200 seals the conductor lumens 102 proximal end to isolate the conductor lumens 102. The forming of the flare 200 places material in the conductor lumens 102 that typically extends no farther than the begin-

ning of the conductors 34 located within the conductor lumens 102. Sealing the conductor lumens 102 minimize electrical conductance between the conductors 34, fluid migration into the lumens or other attached neurological devices, and unwanted stylet introduction into the conductor lumens 102. The proximal flare 200 is manufactured from a non-rigid material that can be the same material as the lead body. The flare 200 can be formed by inserting the proximal end 38 of the lead body into a mold that has a conical shape. This conical shape is inserted axially into the center stylet lumen 100. Heat is transferred from the conical mold to the polyurethane internal portion 104 that seals the outer lumens and creates the flare 200.

[0034] FIG. 8 shows an implantable lead with distal end 40 enlargement indication embodiment, and FIG. 9 shows an enlarged cross section of the distal end 40 shown in FIG. 8. An implantable lead with an improved distal tip 300 comprises a lead body, at least two conductors 34, contacts 36, a stylet lumen 100, conductor lumens 102, and a distal tip 300. The lead body has a proximal end 38, a distal end 40, a stylet lumen 100, and at least two conductor lumens 102. The at least two conductors 34 contained in the conductor lumens 102 extending from the lead proximal end 38 to the distal end 40. The at least two contacts 36 carried on the proximal end 38 are electrically connected to the conductors 34. The at least two contacts 36 carried on the lead distal end 40 are also electrically connected to the conductors 34.

[0035] The formed distal tip 300 seals the conductor lumens 102 free from adhesive or solvents. The conductor lumens 102 closed off by the formed distal tip 300 improve electrical isolation between the conductors 34. The formed distal tip 300 penetrates the lumens 100, 102 of the lead body. The material filling reaches no further into the lumens than making contact to the enclosed conductors 34.

[0036] The distal tip 300 can be formed from the lead body by inserting into a mold; this mold has the shape of the desired distal tip 300. The distal tip 300 has a diameter approximately equal to the lead final diameter of approximately 0.127 cm (0.05 inch). The heat conducted from the mold to the lead distal tip 300, melts the surrounding material into the conductor lumen 102 and into the stylet lumen 100, completely sealing them from the outside. Sufficient material is left between the lumens 100, 102 to the outside of the lead such that substantial force would be needed to perforate, if at all, through the finally formed distal tip 300. The formed distal tip 300 is of the same material of the lead body and significantly minimizes the possibility of separation from the lead body.

[0037] The distal tip 300 is substantially symmetrical since there is no need to align a separate distal tip 300. The distal tip 300 is symmetrically formed such that it is coaxial with the lead body. Symmetry is desirable for minimized protuberances from the exterior lead surface 44, thus reducing the potential of lead body ruptures. The symmetrical formation of the distal tip 300 also reduces physical and material discontinuities in the distal tip 300 to improve the navigational sensitivity of the lead 30 during implant potentially reducing operating room time.

[0038] The distal tip 300 is a more robust stylet stop which reduces the opportunity for stylet penetration of the lead body distal end 40. The material penetrates the most distal

end of the stylet lumen 100 by about 0.15 cm (0.059 inch) into the stylet lumen 100 of the lead beginning from the most distal end of the hemi-spherical distal tip 300. The force transfer required for perforation of the lead distal end 40 is significantly increased, therefore, reducing any potential of tissue damage due to an exiting stylet and reducing the potential of creating an opening in the lead which may disable electrical properties of the device.

[0039] FIG. 10 shows a stylet with stylet distal end 400 enlargement indication embodiment, and FIG. 11 shows the enlarged distal end shown in FIG. 10. An implantable lead with an improved stylet comprises a lead body, a stylet lumen 100, at least one conductor 34, contacts 36, and a stylet. The lead body has a proximal end 38, a distal end 40, an exterior surface 44, and a stylet lumen 100 contained inside the lead body. The conductor 34 is contained in the lead body and generally extends from the lead proximal end 38 to the distal end 40. The conductor 34 is electrically insulated by the lead body. There is at least one contact 36 carried on the lead proximal end 38 that is electrically connected to the conductor 34, and there is at least one contact 36 carried on the lead distal end 40 that is electrically connected to the conductor 34.

[0040] The stylet is composed of a stylet handle 402 that attaches to the proximal end 38 of the lead and a stylet wire 404. The stylet wire 404 is configured for insertion into the stylet lumen 100 with a straight portion 406, a curved portion 408, and a ball tip 410 on the stylet distal end 400. The straight portion of the lead has a diameter of about 0.0254 cm (0.01 inch) and has a parylene insulation of about 1.0 micron. The electrical insulation also serves as a coating that has a lower coefficient of friction than the stainless steel of the stylet wire 404.

[0041] The curved portion of the stylet wire 404 has an angle, between the tangent of the curved portion and the straight portion that increases as the curve approaches the stylet distal end 400. The curved portion begins at about less than 3.75 cm (1.48 inches) from the stylet distal end 400 of the stylet wire 404. The most distal angle of the curved portion has an angle greater than about 15 degrees from the straight portion.

[0042] The tangent of the curve with respect to the straight portion of stylet increases linearly as the curve approaches the stylet distal end 400. Once fully inserted into the lead, the stylet/lead results in a distal end angle that allows the physician to manipulate the device into the desired location over the epidural space. The continuous and incremental curve of the lead distal tip 300 aids the physician to guide the lead past anatomical obstructions, that would otherwise, hinder the ease of introduction of the lead to its designated location for stimulation.

[0043] The ball tip 410 is spherical and has a diameter that is greater than the stylet diameter and is no greater than the stylet lumen 100 inner diameter. The ball tip 410 is configured to ease insertion of the stylet wire 404 through the stylet lumen 100 to the stylet distal end 400. The ball tip 410 functions by stretching the lumen where the stylet wire 404 is inserted to ease insertion of the remaining portion of the stylet wire 404. In addition, the ball tip 410 reduces abrasion to the stylet lumen 100 to reduce the risk of the stylet wire 404 protruding into the adjacent conductor lumens 102 or out of the exterior surface 44 of the lead body.

[0044] FIG. 12 shows an implantable lead with contact 36 enlargement indication, and FIG. 13 shows a cross section of an enlarged contact 36 embodiment. The coupling 112 has a conductor coupling 500 and a contact coupling 502. The conductor coupling 500 and the contact coupling 502 are manufactured from a material with good mechanical and electrical properties such as MP35N and the like. The conductor coupling 500 is placed over the conductor 34 and attached to the conductor 34 mechanically. The contact coupling 502 exits the lead body and has a weld 504 to connect the contact coupling 502 to the contact 36. The weld 504, such as a laser weld, can be performed substantially on the contact 36 exterior surface 44 for ease of manufacturing. The weld 504 is performed such that the weld 504 pool is typically contained within the contact 36 perimeter. In addition, the weld 504 height is controlled to be less than about 0.0127 cm (0.005 inch), so interaction with other devices is facilitated. Each contact 36 has a contact slot 508 opening that in some embodiment is in the range from about 0.0127 cm (0.005 inch) to about 0.0381 cm (0.015 inch) in width and at least about 0.0508 cm (0.020 inch) in length. In other embodiments, the contact slot 508 can extend the entire length of the contact 36.

[0045] An isolation space 506 is created between the conductor 34 and the contact 36 to prevent directly welding the conductor 34 to the contact 36. The isolation space 506 separates the conductor 34 from the weld 504 to substantially prevent the conductor 34 from contacting the weld 504. The isolation space 506 is necessary since silver is not wanted in the weld 504 pool because silver potentially weakens the strength and integrity of a weld 504. In addition, it is desirable to avoid having silver contact the outside surface of the lead to avoid any direct contact with tissue. Although silver contact with tissue is not considered harmful, the separation serves as an additional precaution. The isolation space 506 is greater than about 0.05 cm (0.02 inch). The isolation space 506 serves as a means for isolation created between the conductor 34 and the contact 36 to prevent directly welding the conductor 34 to the contact 36. In some embodiments, the isolation space can include a fill material such as epoxy.

[0046] FIG. 14 shows an isometric view of a contact 36 and coupling 112 embodiment, and FIG. 15 shows an isometric view of the coupling 112 embodiment shown in FIG. 14. In this embodiment, the isolation space 506 is provided by the specific geometry of the contact coupling 502 and more specifically the non-welded material between the conductor 34 and the weld 504 to the contact 36. The non-welded material is sized appropriately for the dimensions of the lead such as greater than about 0.005 cm (0.002 inches). In this embodiment, the interface between the outer surface of the contact 36 and the other surface of the coupling 500 can be continuously welded along selected sides of the interface or intermittently welded along the interface.

[0047] FIG. 16 shows a flow chart of a method for creating an isolation space 506 in an implantable lead contact connection embodiment. The method for creating an isolation space 506 comprises the following elements. A coupling 112 is attached 510 to a conductor 34 so that the conductor 34 extends into a first coupling region 500 of the coupling 112. The coupling 112 has a second coupling region 506 that is adjacent to the first coupling region 500

and a third coupling region **502** adjacent to the second coupling region **506**. An isolation space **506** is created **520** and formed by the second coupling region **506**. The isolation space **506** is void of the conductor **34**. The third coupling region **502** is engaged **530** into a contact slot **508** formed in a contact **36**. The third coupling region **502** is welded **540** to the contact **36** creating a contact weld **504**.

[0048] In the coupling **112** embodiment shown in FIG. 13, the method for creating an isolation space **506** in an implantable lead contact connection is performed as follows. A coupling **112** is attached to a conductor **34** distal end so that a first coupling region **500**, a second coupling region **506**, and a third coupling region **502** are formed. The first coupling region **500** is mechanically attached to the conductor **34** in a crimping process that substantially reduces the diameter of the first coupling region **500** such that it engages the conductor **34** firmly. During mechanical attachment, the crimping force is adjusted to obtain an adequate pull strength while avoiding undesired damage/deformation to the wire **404**. The conductor **34** distal end extends into the first coupling region **500** of the coupling **112**. The second coupling region **506** is distal to the first coupling region **500**, and the third coupling region **502** is distal to the second coupling region **506**. The first region can be about 0.10 cm (0.04 inch) long, the second region can be about 0.05 cm (0.02 inch) and the third region can be about 0.076 cm (0.03 inch) long. An isolation space **506** is created and formed by the second coupling region **506**, with the isolation space **506** void of the conductor **34**. The isolation space **506** is void of the conductor **34** so that the weld **504** encompasses the third region and the contact **36**.

[0049] The assembly consisting of the conductor **34** and the attached couplings **112** on either end can be fed through a lead body. The placement of the assembly is such that the proximal coupling is on the proximal end **38** of the lead body and the distal coupling is on the distal end of the lead body. The contact **36** with a contact slot **508** is placed on the lead body distal end. The contact slot **508** width is slightly less than the diameter of the third coupling region **502**. The length of the contact slot **508** is greater than the diameter of the coupling **112** to allow for placement anywhere along its length. The contact slot **508** assists in holding the coupling **112** in place prior to welding the third region to the contact **36**.

[0050] An axial slit **42** is created in the lead body distal end. The axial slit **42** is long enough such that it allows for an opening of at least the diameter of the third coupling region **502**. The coupling **112** attached to the conductor **34** is exited through the axial slit **42** in the lead body distal end. The axial slit **42** permits the coupling **112** to pass through to mate to the contact **36** with the minimum amount of movement of the conductor **34** assembly within the lead body. Also, the axial slit **42** allows for a minimum sized path to exist between the conductor lumen **102** and the contact **36**. In the creation of the axial slit **42**, material is not removed, only a cut is made such that it allows the passage of the coupling **112** from the conductor lumen **102** to the contact slot **508** area. The cut is created with a sharp razor and extends for about 0.076 cm (0.030 inch). It is made approximately under the location where the contact **36** will be placed over and mate with the coupling **112**.

[0051] The third coupling region **502** is bent in the range from about 85 degrees to about 120 degrees in relation to the

longitudinal axis of the conductor **34**. The bend can be made with a tool the size of a wrench that creates a bend beginning at the same location of the coupling **112**, roughly 0.076 cm (0.03 inch) distally. The third coupling region **502** distal end is formed into a contact coupling **502** that is complimentary to a contact slot **508**. The diameter of the third coupling region **502** is deformed such that it closes the conductor **34** void opening of the third coupling region **502**. Also, the formed final geometry of the third region of the coupling **502** has an interference fit with the contact slot **508**.

[0052] The contact coupling **502** is engaged into the contact slot **508**. The entire perimeter and cross section of the third region **502** is placed within the open area of the contact slot **508**. At this point the third coupling region **502** is held by the contact slot **508** and is ready for a more secure attachment. The contact coupling **502** is welded to the contact slot **508**. The weld **504** can be created with a laser welder that heats up the slot **508** region of the contact **36** and the third region of the coupling to the point where they become an alloy. The weld **504** bump created is no greater than about 0.013 cm (0.005 inch) over the surface of the contact **36**. Also, the weld **504** bridges over each end of the slot **508** to provide mechanical integrity. The inner void of the third coupling region **502** distal end is sealed by the weld **504**. The weld **504** surface area extends over the third region **502** of the coupling and the proximate perimeter of the contact slot **508**. The weld **504** material creates a closed section in the third region **502** opening creating a closed section of the coupling distal end (third coupling region **502**).

[0053] FIG. 12 shows an implantable lead with contact enlargement indication, and FIG. 13 shows a cross section of an enlarged contact embodiment. An implantable lead with coplanar contact connection comprises a lead body having a proximal end **38** and a distal end **40**, at least one conductor **34**, at least one contact **36** carried on the proximal end **38**, at least one contact **36** carried on the distal end **40**, and at least one coupling **112**. The lead body **32** has an exterior surface **44**. The conductor **34** is contained in the lead body **32** and extends generally from the lead proximal end **38** to the distal end **40**. The conductor **34** is electrically insulated. There is at least one contact **36** carried on the proximal end **38** that is electrically connected to the conductor **34**, and at least one contact **36** carried on the distal end **40** that is electrically connected to the conductor **34**. The coupling **112** has a conductor coupling **500** and a contact coupling **502**. The conductor coupling **500** is placed over the conductor **34** and attached to the conductor **34**. The contact coupling **502** exits the lead body and is welded to connect the contact coupling **502** to the contact **36** carried on the distal end **40**. The contact coupling **502** is further configured to exit the conductor lumen **102** and mate with the contact **36** while retaining the conductor **34** coplanar to the contact **36**. The coplanar relationship between the conductor **34** and the contact **36** is such that the longitudinal axis of the conductor **34** is maintained substantially parallel to the longitudinal axis of the contact **36**.

[0054] In some embodiments such as shown in FIG. 13, the contact coupling **502** can be bent to exit the conductor lumen **102** and mate with the contact **36** while maintaining the conductor **34** coplanar to the contact **36**. The contact coupling **502** bend serves as a means for orienting the contact coupling **502** to exit the conductor lumen **102** and

mate with the contact **36**. The contact coupling **502** can be bent in the range from about 85 degrees to about 120 degrees in relation to the conductor **34**. In other embodiments such as shown in **FIGS. 14 and 15**, the geometry of the contact coupling **502** is such that the contact coupling **502** does not require mechanical deformation of the second region **506** or third region **502**.

[0055] The conductors **34** are contained within the lumens throughout the lead body, such that it does not exit the lead at any point. The conductor **34** is parallel to the lead body in its entire length. This allows the conductor **34** to not directly contact the outside surface of the lead or the surrounding tissue. Conductor **34** stresses are significantly reduced by not allowing the conductor **34** to have a bending moment. Lead reliability is improved as a result from this coplanar conductor **34** to contact **36** attachment.

[0056] **FIG. 17** shows a flow chart of a method for creating a coplanar connection in an implantable lead between a conductor **34** and a contact **36** embodiment. The method for creating a coplanar connection in an implantable lead between a conductor **34** and a contact **36** comprises the following elements. A coupling **112** is attached **600** to a conductor **34** distal end, so the conductor **34** distal end extends into a first coupling region **500** of the coupling. The coupling **112** has a second coupling region **506** adjacent to the first coupling region **500**. The coupling second region **506** is positioned **610** in a conductor lumen **102** adjacent **620** to a contact **36**. The second region **506** is welded **62** to the contact **36** creating a contact weld **504**. The conductor **34** distal end is maintained in a coplanar relation **630** to the contact **36**.

[0057] Thus, embodiments of the implantable lead with improved conductor lumens **102** are disclosed to improve separation of conductors **34** while facilitating connections through the conductor **34** lumens. One skilled in the art will appreciate that the present invention can be practiced with embodiments other than those disclosed. The disclosed embodiments are presented for purposes of illustration and not limitation, and the present invention is limited only by the claims that follow.

What is claimed is:

1. An implantable lead body with improved conductor lumens, comprising:

a lead body having a proximal end, a distal end, an internal portion, and an external portion;

a stylet lumen formed in the internal portion;

at least one conductor lumen formed in the internal portion and positioned near an outer surface of the internal portion such that there is only a web between the conductor lumen and the outer surface of the internal portion; and,

at least one axial slit in the web of the lead body distal end between the conductor lumen and the outer surface of the internal portion.

2. The implantable lead body as in claim 1, further comprising

at least one conductor contained in the internal portion extending from the lead proximal end to the distal end, the conductor being electrically insulated;

at least one contact carried on the proximal end and electrically connected to the conductor;

at least one contact carried on the lead distal end and electrically connected to the conductor; and,

at least one coupling having a conductor coupling and a contact coupling, the conductor coupling being placed over the conductor and attached to the conductor and the contact coupling exiting the axial slit and having a weld to connected the contact coupling to the contact.

3. The implantable lead body as in claim 1, wherein the web is no greater than about 0.005 centimeters thick.

4. An implantable lead body, comprising:

a lead body having a proximal end, a distal end, an internal portion, and an external portion;

a stylet lumen formed in the internal portion;

means for conductor lumen formed in the internal portion and positioned near the exterior portion such that there is only a web between the conductor lumen and an outer surface of the internal portion; and,

means for axial slit in the web of the lead body distal end between the means for conductor lumen and the exterior surface.

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