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Description

FIELD OF THE INVENTION

[0001] The invention relates to a medical microelectrode, to a bundle of microelectrodes, and to an array of microelectrodes and/or microelectrode bundles. The microelectrode, microelectrode bundle and array of microelectrodes or microelectrode bundles of the invention are intended for insertion into soft tissue such as the brain, the spinal cord, endocrine organs, muscles, and connective tissue. The medical microelectrode, the bundle of microelectrodes, and the array of microelectrodes and/or microelectrode bundles are designed to resist displacement in the tissue.

BACKGROUND OF THE INVENTION

[0002] Microelectrodes that can be implanted for a long time into the central nervous system (CNS) have a wide field of application. In principle, all brain nuclei can be recorded from or stimulated by such electrodes and their functions monitored. Of particular importance is the use of a multichannel design in brain nuclei stimulation. In such a design, groups of electrodes or even individual electrodes can be addressed separately. This allows the user to select those electrodes whose stimulation produces a therapeutic effect that is improved in comparison with unselective stimulation. Stimulation of the brain or spinal cord can be of particular value in situations when brain nuclei are degenerated or injured. In certain situations it would also be useful to be able to combine controlled electrical stimulation and localized gene transfer. A multichannel design may also allow the user to effectively measure the effects on multiple neurons and other cells following systemic or local drug administration or gene transfer. Of particular interest is an ability to simultaneously measure the effects of multiple drug candidates on neuronal function. Monitoring brain activity through implanted electrodes can also be useful if used to control drug delivery either locally or systemically or other therapeutic methods such as electrical stimulation of brain nuclei. Multichannel electrodes may also be used to lesion specific and circumscribed sites in tissue after abnormal impulse activity has been detected by recordings from the electrodes.

[0003] To record and stimulate brain structures various forms of implantable electrodes have been developed (US 6,253,110 B1, US 5,957,958, US 4,573,481, US 7,146,221 B2, US 5,741,319, US 4,920,979, US 5,215,008, US 5,031,621, US 6,993,392 B2, US 6,032,062, US 4,852,573, US 3,995,560, US 7,041,492, US 6,421,566 B1, US 4,379,462, US 5,417,719, US 3,822,708, US 5,501,703, US 7,099,718 B1, US 3,724,467; US 2007/0197892 A1).

[0004] For the function of an electrode implant it is important to have a fixed spatial relationship between the recording/stimulation sites on the implant and the measured entities. The body and thus the tissue exhibit considerable movements during daily life. Movements are caused by for example respiration, the heart beat, intestinal movement, skeletal movements such as rotating the head in relation to the body. Movements may also be caused by external forces on the body. Relative movements between tissue and electrodes can cause changes in the recorded biological signals such as electrical or chemical signals such as transmitter substances. For example, an action potential corresponds to a voltage change in the order of 100mV over the neuronal membrane. This potential change fades quickly with distance from the cell. Consequently, movements of the electrode relative to a measured cell can result in a considerable variation in the amplitude of the measured action potential. Likewise, when the electrodes are used for electrical stimulation, a shift in location of the electrode relative to the tissue may result in a shift of the neurons stimulated. It is thus very important that the sites on the medical electrode from where recordings or stimulations are made in the tissue can follow the movements of the tissue in which it is embedded as faithfully as possible. Besides impairing the recorded signal or efficacy of stimulation, movements between implants and tissue may cause injuries to the tissue that in turn can trigger a tissue reaction and loss of function of the implant. Mechanical stability between electrode and tissue is particularly important for intracellular recordings because movements of electrode relative to the cell can easily damage the membrane and cause leakage of extracellular fluid into the cell and vice versa. Today there is no known electrode implants designed or suitable for intracellular recordings simultaneously in many neurons over long time spans such as days, weeks or months in freely moving animals or humans.

[0005] Ultra thin electrodes that are flexible and thereby overcome some of the problems related to movements between tissue and electrode are known in the art (WO 2007/040442). By embedding such electrodes in a dissolvable hard matrix it is possible to implant them in soft tissue, without any additional support such as a syringe. Such ultrathin electrodes should be made of a material that is not degraded by the tissue or easily oxidized causing high electrical resistance and thereby decreased signal to noise ratio. Examples of suitable conductors are noble metals such as gold and platinum. Commonly an alloy of platinum and iridium is used as a material for implants used for stimulation.

[0006] To achieve a physically stable contact with cells in the nervous system it is also important that the electrode is anchored in the tissue close to the measured or stimulated tissue. Electrodes with electrically conducting barbs and electrode sheets equipped with holes through which the tissue may grow and thereby attach firmly to the electrode are known in the art (WO 2007/040442; WO 2008/091197; WO 2009/075625). However, implants may cause chronic inflammation and even infections and may have to be removed. In the situation when the electrode is withdrawn from the tissue anchoring devices known by the art such as barbs or in particular holes in the electrode body allowing tissue ingrowth may cause extensive damage to the tissue. It is thus desirable to solve the problem of how to anchor a medical electrode in soft tissue such that the medical electrode is physically stabilized in the tissue and yet can be withdrawn from the tissue with reduced tissue damage.

OBJECTS OF THE INVENTION

[0007] It is an object of the invention to provide a microelectrode that is stabilized against displacement within the tissue into which it has been implanted.

[0008] It is another object of the invention to provide a microelectrode bundle comprising such electrode(s).

[0009] It is a further object of the invention to provide a microelectrode array and a microelectrode bundle array comprising such electrode(s).

[0010] Further objects of the invention will become apparent from the following summary of the invention, a number of preferred embodiments thereof illustrated in a drawing, and the appended claims.

SUMMARY OF THE INVENTION

[0011] The present invention is based on the insight that, to optimally resist displacement within soft tissue to which has been implanted, a microelectrode should approximate the specific weight of the tissue. By such approximation, the electrode is "floating" in the tissue, and may be termed floating microelectrode. The floating property of the electrode makes it follow the displacement of the surrounding tissue when the tissue is accelerated or decelerated. The stabilization according to the invention thus is one against displacement within a tissue, in contrast to stabilization against withdrawal from tissue by mechanical anchoring means, such as barbs, spikes, and the like. It is, of course, feasible to provide the electrode of the invention additionally with such means against withdrawal from tissue. Stabilization according to the invention is particularly useful for electrodes implanted into delicate non-fibrous soft tissue, such as tissues of the brain, the spinal canal, and bone marrow.

[0012] The microelectrode of the invention is intended for recording electrical signals arising in the tissue, in particular nervous tissue, but may also be used for electrical stimulation of tissue.

[0013] Thus, according to the present invention is disclosed a medical microelectrode resistant to displacement in soft tissue by inertia according to claim 1.

[0014] According to the present invention is also disclosed an electrode bundle comprising two or more electrodes of the invention according to claim 14.

[0015] According to the present invention is furthermore disclosed an electrode array comprising two or more electrodes and/or electrode bundles of the invention according to claims 16 or 17. The invention will now be described in more detail by reference to a number of preferred embodiments illustrated in a drawing. Figs. 1-4b of the drawing are not to scale but only intended to clearly illustrate principal features of the invention.

SHORT DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1
: shows an embodiment of the electrode of the invention in an axial (B-B) section;

Fig. 2
: shows a variation of the embodiment of Fig.1, in the same view;

Fig.3
: shows the electrode of Fig. 2 embedded in dissolvable matrix body;

Figs. 4a - 4b
: show examples of electrode leads of the invention in radial section.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0017] An embodiment 801 of the medical microelectrode of the invention illustrated in Fig. 1 comprises a solid electrode lead 802 of titanium having a front end 803 and a rear end 804, the front end 803 being provided with a pointed tip 811. Except for at its tip 811 the lead 802 is enclosed by a buoyant layer 814 of polymer foam with closed pores, which abuts the lead 802 and firmly adheres to it. The buoyant layer 814 has substantially the form of a sleeve on the lead 802. At the rear end of the lead 802 an electrode signal amplifier 813 is disposed, which is sealed by a thin layer 815 of lacquer. The amplifier 813 is in electrical communication with an electrode control unit (not shown) by an insulated ultrathin metal wire 809.

[0018] A variation 901 of the embodiment of the medical microelectrode of the invention is illustrated in Fig. 2. The buoyant layer comprises two sections 914, 914' spaced apart, the first section 914 disposed near the front end 903 and the second section 914' disposed near the rear end 904 of the electrode lead 902 of tungsten. The surface of the lead 902 extending between the sections 914, 914' is insulated by a lacquer 915. Thus, only the rotationally asymmetric tip 911 is not insulated. At its rear end the electrode 901 has an ultra-thin electrically insulated wire 909 soldered to it, which provides for electrical communication with an electrode control unit (not shown) disposed at a distance from the electrode 901 intra- or extracorporeally.

[0019] Fig. 3 shows the electrode of Fig. 2 incorporated into a body of a carbohydrate matrix 920 by which the tiny electrode 901 can be inserted into soft tissue without jeopardizing its physical integrity. Upon insertion the matrix body 920 is dissolved by aqueous body fluid so as to establish physical contact of the electrode with the tissue. The matrix body 920 is rotationally symmetric and so arranged around the electrode 901 to make its axis of rotation coincide with that of the electrode 901. At its front end the matrix body 920 has a pointed tip 921.

Dimensioning of electrodes of the invention

[0020] Radial dimensioning of electrodes of the invention so as to have their density approach 1.0 g/cm^3 is illustrated below in a number of examples. The outer diameter of the electrodes is set to 100 µm. Radial dimensions of thicker or thinner electrodes are obtained by multiplying the thickness of the electrode layers by the desired size factor. In the Examples the axial length of the electrode tip is assumed to be negligible in relation to the total length of the electrode lead.

EXAMPLE 1

[0021] Gold wire lead covered with polyurethane foam with closed pores, Fig. 4a. d_{Au} = 19.3 g/cm^3; D_{PUF} = 0.24 g/cm^3. Diameter of gold wire: 40 µm. Density (calculated): 1.00 g/cm^3.

EXAMPLE 2

[0022] Tubiform titanium lead covered with polyurethane foam with closed pores, Fig. 4b. d_{Ti} = 4.5; D_{PUF} = 0.20 g/cm^3. Outer diameter of titanium lead: 70 µm; inner (lumen) diameter: 53 µm. Density (calculated): 1.04 g/cm^3.

EXAMPLE 3

[0023] Porous nickel lead manufactured by the electroforming method ofUS 7,393,446 B2 using polystyrene beads about 60 µm in diameter. Outer diameter of the lead: 500 µm. A lead with a density of about 1.1 was produced as one of a series of leads produced by varying the duration of electroforming. Upon formation of the cellular metal structure with open pores the polystyrene matrix is removed by soaking with acetone. The cylindrical porous nickel lead is thoroughly rinsed with acetone, dried, and then electroplated with gold to a plating thickness of about 10 µ so as to retain the pores open. The lead is thoroughly rinsed with water, then with acetone, and dried. One end of the lead is cautiously heated with an acetylene burner so as to shrink it to form a blunt tip. To the other end of the lead is attached by soldering a thin insulated copper wire. Except for the shrunken tip portion, the electrode lead is dipped into a solution of polyurethane (Tecoflex® solution grade SG-85A, The Lubrizol Corporation, Cleveland, OH) in THF (20 % ,w/w)) to close the pores and to insulate the main portion of the electrode lead. Other dip-coating materials, such as Thoralon®, for use in the invention comprise polyetherurethane urea containing soft segments made of polytetramethylene oxide and hard segments made of 4.4'-diphenylmethane diisocyanate and ethylene diamine (BPS-215, Thoratec Corporation, Pleasanton, CA).

Manufacture of electrodes of the invention

[0024] Tubiform electrodes of the invention can be manufactured from corresponding metal microtubes. Microtubes of noble metals can be obtained by, for instance, electrolytically coating a less noble metal like aluminum or iron with the noble metal like silver, gold, platinum, etc. but also copper, followed by dissolving the less noble metal by an non-oxidizing strong acid like hydrochloric acid. The

front ends of the microtubes can be closed by heating a short portion of the raw tube to slightly below its melting point, then draw its ends in opposite directions at this temperature followed by raising the temperature to the melting point so that a finely drawn out portion collapses. The tube is then drawn apart and two pointed, sharply or rounded, depending on the material and working conditions, microtubes are obtained, which can be cut to a desired length. Alternatively a microtube can be closed at its one end by welding, optionally after flattening the end portion prior to welding. The rear end of microtube closed at its front end can be sealed by, for instance, a slightly conical polyethylene or polypropylene plug which is forced into the open end for a desired distance. Filling the lumen of a microtube with polymer foam is accomplished by injecting a prepolymer solution or suspension in a highly volatile solvent such as propane or butane, followed by gentle heating of the filled microtube. Particulate solid fillers can be poured into the lumen and compressed there by a piston of suitable diameter, if necessary.

[0025] Electrically conducting polymers suitable for use in the invention include polyethylenedioxythiophene, polyaniline, polyacetylene, and polypyrrole.

[0026] Wire electrodes can be covered with polymer foam by, for instance, arranging them in a closed compartment comprising a receptacle filled with a prepolymer solution or suspension of the aforementioned, dipping them into the solution or suspension, withdrawing them from the solution or suspension, closing the receptacle, admitting air, in particular humid air, to the compartment, storing the so covered electrodes in a humid atmosphere until the polymer is fully cured. The thickness of the layer of polymer with closed pores on the wire can be controlled by controlling the viscosity of the prepolymer solution or suspension and/or the temperature of the solution or suspension in the receptacle and/or the kind of solvent.

[0027] Ultra-thin insulation layers can be obtained by applying electrically insulating lacquers to desired portion of the electrode. Alternatively or additionally, insulation coatings of parylene-C can be used, for instance.

[0028] Electrodes of the invention comprising porous metal structures can be manufactured, for instance, by methods described in US 7,393,446 B2.

[0029] Electrodes of the invention can be bundled or stacked in substantially the same manner as described in WO 2007/040442 A1. Electrodes of the invention can also be incorporated into arrays like those described in WO 2008/091197 A1. Suitable procedures for incorporating electrodes of the invention and electrode bundles and arrays of electrode bundles of the invention into rigid matrix bodies dissolvable in body fluid are disclosed in WO 2009/075625 A1.

Methods of embedding microelectrodes of the invention in a dissolvable matrix

[0030] A method for embedding the microelectrode of the invention comprises providing a fixation means, fixing the electrode and, optionally, additional elements to be imbedded, such as optical fibres, contractile elements, etc., in the fixation means in a desired configuration, applying a sheath covering the thus fixed electrode and accessories except for at the proximal coupling section thereof, applying a solution or suspension of a first matrix material on the electrode in a manner so as to cover the portions of the electrode intended to be embedded, allowing the solvent/dispersant of the matrix solution or suspension, respectively, to evaporate or harden, removing the sheath, and releasing the electrode from the fixation means. For embedment of the electrode in two matrix materials so as to form corresponding matrix compartments, each enclosing a portion of the electrode, an appropriate portion of the electrode fixed by a fixation means as described above is coated with a solution or suspension of the first matrix material, the solvent/dispersant of which is subsequently evaporated, followed by coating the portion of the electrode remaining to be coated with a solution or suspension of the second matrix material, subsequently evaporating the solvent/dispersant of the second matrix material, and releasing the electrode from the fixation means. In the method the electrode is preferably disposed in a sheath of smooth material of low wettability such as a polyfluorinated hydrocarbon polymer or silicon rubber, and fixed therein. To facilitate solvent evaporation the sheath material is advanta-

geously porous, in particular micro-porous. After application and drying of the matrix material(s), the electrode is withdrawn from the sheath. If desired, a drug or a combination of drugs can be incorporated in the matrix.

[0031] An alternative method of embedding an electrode of the invention into two matrix materials forming distinct matrix compartments, comprises embedding the entire electrode in a first matrix material, dissolving a portion of the first matrix material, preferably a distal portion extending from the distal end, covering the now non-embedded distal portion of the electrode with a second matrix material by, for instance, taking recourse to a sheath applied on the non-embedded distal portion, filling the sheath with a solution or suspension of the second matrix material, evaporating the solvent so as to dry/harden the second matrix material, and removing the sheath.

[0032] The electrode of the invention can be coated by using a single coating technique or combination of coating techniques, such as by dip coating, spray coating, melting processes including extrusion, compression molding and injection molding or a combination of different techniques.

[0033] In a representative example of a stepwise procedure, the electrode is first dipcoated with a suitable resorbable polymer or blend of polymers, in particular collagen, gelatin, polyvinyl alcohol and starch, dissolved in a proper solvent. Other polymers can also be used. The thickness of the polymer layer is controlled in manner known to a person skilled in the art. The coating is then subjected to a drying step. The dip coating and drying steps can be done once or can be repeated, depending on required thickness of the final coating. In the next step the polymer is loaded with the drug. The electrode is submerged into a solution containing the drug. The solvent used should be one in which the polymer swells and in which the drug dissolves. After an appropriate contact time, such as from less than a second to 5 min or more, the electrode is removed from the solution and the matrix dried by evaporation of the solvent, possibly under reduced pressure.

[0034] In a one-pot procedure the electrode is submerged into a solution of the polymer and the drug of choice in an optimal concentration for a desired coat

thickness and, optionally, a desired drug loading. The electrode is then removed from the solution and the solvent evaporated, possibly under reduced pressure.

[0035] Alternatively the coating is generated by spray coating, in which a polymer solution optionally containing a drug or a combination of drugs in a suitable solvent is sprayed on the electrode body. The thickness of the coating can be controlled by the number of spraying and drying (evaporation) cycles and the amount of polymer and drug in the solution.

[0036] Also comprised by the invention are hydrogel coats of partially hydrolyzed water-soluble polymers such as polyvinyl alcohol, polyacrylic acid and derivatives of polyacrylic acid, e.g., poly (N-isopropylacrylamide). An increase in temperature makes these hydrogels contract, thereby expelling a drug or a combination of drugs incorporated in the coating. Alternatively, the temperature-sensitive hydrogel is an interpenetrating hydrogel network of poly(acrylamide) and poly(acrylic acid), and the increase in temperature causes the hydrogel to swell, thereby allowing the drug to diffuse out of the gel.

[0037] Also comprised by the invention is the use of a polymer or a polymer blends for electrically triggered release, such as polyvinyl alcohol/chitosan.

[0038] Electrode bundles and arrays of electrodes and electrode bundles of the invention can be embedded in a matrix in substantially the same manner as described above for single electrodes.

Uses

[0039] The present disclosure also relates to the use of the matrix-embedded electrode, the matrix-embedded electrode bundle or the array of matrix-embedded electrode bundles for long-lasting nerve stimulation, multi-channel recordings of electrical neuronal activity and levels of transmitter substance through measurements of redox reactions and lesions of the tissue for scientific, medical and animal care purposes.

[0040] According to a preferred aspect the microelectrode, the microelectrode bundle, and the array of microelectrodes or microelectrode bundles of the invention is used in a patient or animal for: recording signals from neurons remaining after brain and/or spinal damage; stimulating neurons to compensate for lost functions; providing pain relief by stimulation of analgesic brain stem centres; providing relief or decrease of tremor and other motor symptoms in Parkinson's disease; relief or decrease of choreatic and other involuntary movements by stimulation within the basal ganglia or associated nuclei; boosting memory by stimulation of cholinergic and/or monoaminergic nuclei in case of Alzheimer's disease or other degenerative disease; control of mood, aggression, anxiety, phobia, affect, sexual overactivity, impotence, eating disturbances by stimulation of limbic centres or other brain areas; providing rehabilitation after stroke or damage of the brain and/or spinal cord by stimulation of remaining connections in the cortex cerebri or descending motor pathways; providing re-establishment of control of spinal functions such as bladder and bowel emptying after spinal cord injury by stimulating relevant parts of the spinal cord; providing control of spasticity by stimulation of inhibitory supraspinal descending centres or appropriate cerebellar areas; providing re-establishment of somatosensory, auditory, visual, olfactory senses by stimulation of relevant nuclei in the spinal cord and the brain.

[0041] According to another preferred aspect the microelectrode, the microelectrode bundle, and the array of microelectrodes or microelectrode bundles of the invention is used in a patient or animal for combined monitoring and stimulation, in particular for: monitoring of epileptic attacks by electrodes implanted into the epileptic focus coupled to a system for delivering antiepileptic drugs or electrical pulses; compensating for a lost connection in the motor system by recording central motor commands, followed by stimulating executive parts of the motor system distal to a lesions; recordings of blood glucose levels to control the hormone release.

[0042] According to a further preferred aspect the microelectrode, the microelectrode bundle, and the array of microelectrodes or microelectrode bundles of the invention is used in a patient or animal for locally lesioning tissue, in particular tumour or abnormally active or epileptogenic nervous tissue by passing current of

sufficient magnitude through said electrode, electrode bundle or array of electrode bundles.

[0043] In biomedical research, use of the microelectrode, the microelectrode bundle, and the array of microelectrodes or microelectrode bundles of the invention can be used for studying normal and pathological functions of the brain and spinal cord, in particular over a long time.

[0044] In a patient having a neuroprosthetic device, the microelectrode, the microelectrode bundle, and the array of microelectrodes or microelectrode bundles of the invention can be used to form an interface between a nerve and said device.

[0045] In a patient or an animal, the microelectrode, the microelectrode bundle, and the array of microelectrodes or microelectrode bundles of the invention can be used for controlling the function of an endocrine or exocrine organ, such as in controlling hormone secretion.

[0046] In a patient or animal, the microelectrode, the microelectrode bundle, and the array of microelectrodes or microelectrode bundles of the invention can be used for controlling the function of one or more skeletal muscles or a heart muscle.

PATENTKRAV

1. Medicinsk mikroelektrode til implantation i blødt væv hos en person eller et dyr, og som er resistent overfor forskydning i vævet som følge af inerti, hvor elektroden har en forende, en bagende og en massefylde ved 20^0 C på fra 0,80 g/cm^3 til 1,15g/cm^3, især fra 0,90 g/cm^3 til 1,07 g/cm^3, i særdeleshed fra 0,95 g/cm^3 til 1,03 g/cm^3, omfattende
en elektrisk ledende trådledning indeholdende eller bestående af et metal og/eller en elektrisk ledende polymer, hvor ledningen har en overflade og et opdriftselement med en massefylde på mindre end 1,0 g/cm^3 fastgjort til overfladen;
hvor overfladen er elektrisk isoleret;
hvor opdriftselementet omfatter en polymer indeholdende lukkede porer.

2. Elektrode ifølge krav 1, hvori massefylden af polymeren ved 20^0 C er mindre end 0,8 g/cm^3, fortrinsvis mindre end 0,6 g/cm^3.

3. Elektrode ifølge krav 1, hvori polymeren er bøjelig, især elastisk bøjelig.

4. Elektrode ifølge krav 1 helt eller delvis indlejret i en matrix, der kan opløses eller nedbrydes i en legemsvæske.

5. Elektrode ifølge krav 1 omfattende et elektronisk forstærkerorgan og/eller et mikroprocessororgan, med det forbehold, at kombinationen af elektrode og elektronisk forstærker-/mikroprocessororgan har en massefylde ved 20^0 C på fra 0,80 g/cm^3 til 1,15 g/cm^3, især fra 0,90 g/cm^3 til 1,07 g/cm^3, i særdeleshed fra 0,95 g/cm^3 til 1,03 g/cm^3.

6. Elektrode ifølge krav 5, hvori massefylden af kombinationen af elektrode og elektronisk forstærker-/mikroprocessororgan er 0,99 ± 0,02 g/cm^3.

7. Elektrode ifølge krav 5, hvori det elektroniske forstærker-/mikroprocessororgan er anbragt ved eller nær bagenden.

8. Elektrode ifølge krav 1 fastgjort ved eller nær sin bagende til en ultratynd isoleret tråd til elektrisk kommunikation med et elektronisk forstærker-/mikroprocessororgan anbragt i afstand derfra.

9. Elektrode ifølge krav 8, hvori den ultratynde isolerede tråd er integreret med elektrodetråden.

10. Elektrode ifølge krav 5, hvori det elektroniske forstærker-/mikroprocessororgan kan anbringes i blødt væv hos personen eller dyret.

11. Elektrode ifølge krav 5, hvori det elektroniske forstærker-/mikroprocessororgan omfatter en kilde med elektrisk energi.

12. Elektrode ifølge krav 5, hvori det elektroniske forstærker-/mikroprocessororgan omfatter et organ til udsendelse og/eller modtagelse af stråling til/fra en kontrolenhed anbragt eksternt i forhold til patienten eller dyret.

13. Elektrode ifølge krav 1 omfattende forankringsorganer anbragt ved eller nær dens forende.

14. Elektrodebundt indeholdende to eller flere elektroder ifølge ethvert af kravene 1-13.

15. Elektrodebundt ifølge krav 14 delvis eller helt indesluttet i et materiale, der kan opløses eller nedbrydes i en legemsvæske.

16. Elektrodegruppe indeholdende to eller flere elektroder ifølge ethvert af kravene 1-13.

17. Elektrodegruppe indeholdende to eller flere elektrodebundter ifølge krav 14 eller 15.

18. Elektrodegruppe ifølge krav 16 delvis eller helt indesluttet i et materiale, der kan opløses eller nedbrydes i en legemsvæske.

19. Elektrode ifølge ethvert af kravene 1-13, elektrodebundt ifølge ethvert af kravene 14-15 eller elektrodegruppe ifølge ethvert af kravene 16-18 indeholdende et forseglet porøst materiale.

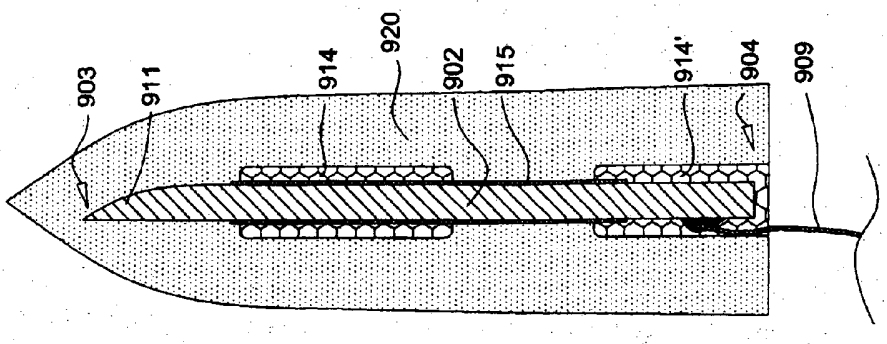

Fig. 3

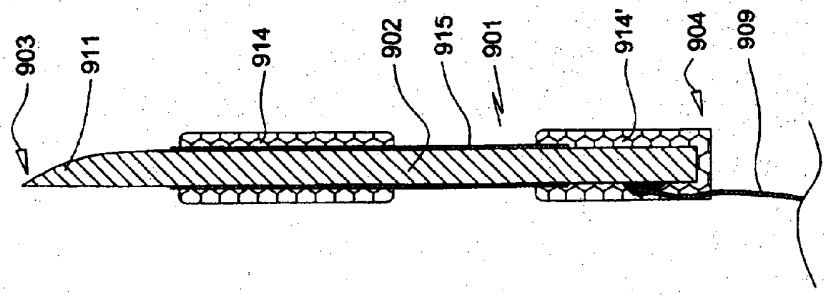

Fig. 2

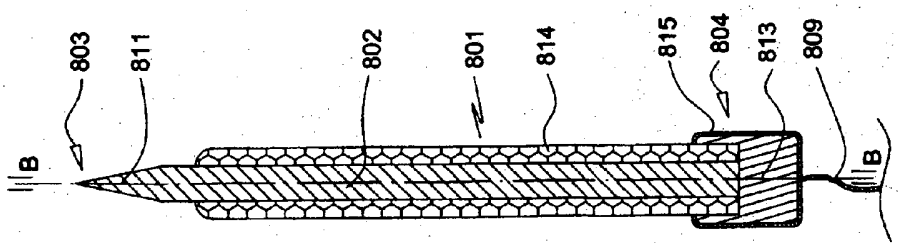

Fig. 1

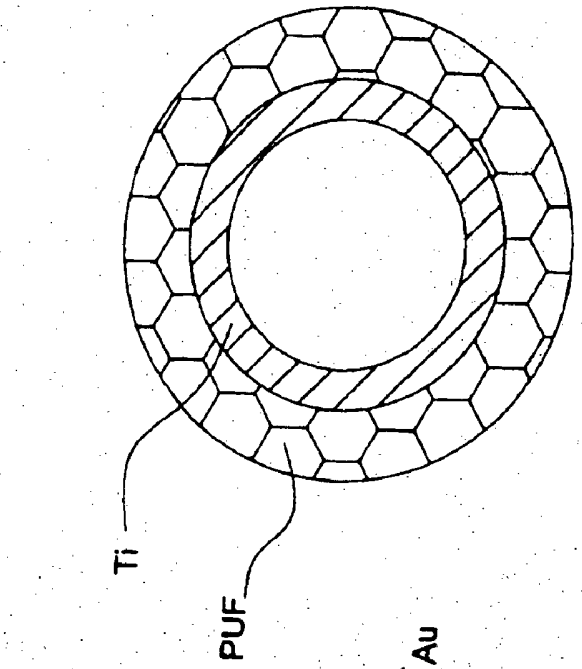

Fig. 4b

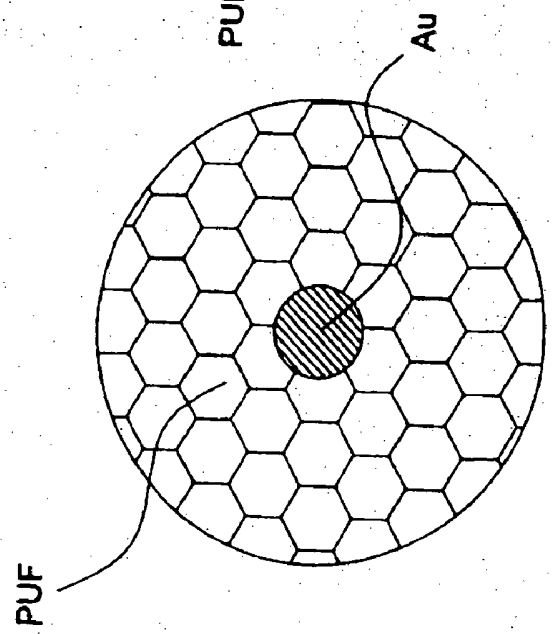

Fig. 4a