(54) **Electrical conductivity probes and methods of making the same**

Stromleitfähigkeitssonden und Herstellungsverfahren dafür

Sondes à conductivité électrique et leur procédé de fabrication

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Description

BACKGROUND

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1. Technical Field

[0001]   The present disclosure relates to electrosurgical instruments, systems and methods of making the same. More particularly, the present disclosure relates to conductivity probes for sensing directional attributes of tissue and methods of making the same.

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2. *Discussion of Related Art*

[0002]   It has been observed that biological tissue has different thermal and/or electrical conductivities in different directions.

15   [0003]   Thermal conductivity of biological tissues is dependent on the particular type of biological tissue and on the composition of the biological tissue. Different biological tissues exhibit different and/or unique thermal conductivity based on factors such as tissue density, vascularization, age, direction and distance to major blood vessels, etc. Additionally, different biological tissues may exhibit a different and/or unique thermal conductivity in different directions.

[0004]   Electrical conductivity is not only determined by tissue type and composition, but also by other externally applied

20   physical and chemical influences during thermal treatment, such as, for example, temperature inducement and saline pretreatment.

[0005]   Knowing the thermal and/or electrical conductivity of tissue may be used by a surgeon in a number of applications, including, but not limited to, predicting the effect of thermal treatment on given tissue, identifying the location and size of internal structures, and enhancing the resolution of traditional imaging devices.

25   [0006]   In proceedings of IMECE2005, 2005 ASME International Mechanical Engineering Congress and Exposition, November 5-11, 2005, Orlando, Florida, USA, a two-electrode micro probe was fabricated using standard photolithography IC fabrication techniques. The design layout included two electrodes, sensor area, bonding pad, and different thin film layers. The starting material for the probe fabrication is a 300 μm thick biocompatible polyimide substrate. The polyimide substrate is coated with a seed layer of 30 nm thick titanium (Ti) layer deposited by evaporation. This is

30   followed by deposition of 300 nm gold (Au) film which forms the basis for the electrodes. The metal layer is then patterned by etching into two electrodes. These two parallel electrodes are 2000 μm long, 150 μm wide and are separated by a gap of 300 μm. Then, an insulating dielectric layer of BCB (BisbenzoCycloButene) is spun on the top and patterned to define the exposed electrode area for the measurement and bonding pads for soldering.

35   ### SUMMARY

[0007]   Accordingly, a need exists for thermal and electrical conductivity probes for sensing the directional attributes of tissue and methods of making the same.

[0008]   According to the present invention, there is provided a method according to Claim *1.*

40   [0009]   The adhesive layer and conductive layer may be deposited using evaporation techniques. The pattern may define first and second electrodes. The adhesive layer may be selected from the group consisting of titanium (Ti), titanium tungsten (TiW) and platinum (Pt), and may measure about 30 nm thick. The conductive layer selected from the group consisting of gold (AU), iridium (Ir) and platinum-iridium (Pt-Ir), and may measure about 330 nm thick. The insulative layer may be spun onto the conductive layer and pattern. The widths of the electrodes may be approximately 150 μm.

45   The lengths of the electrodes may be between approximately 200 μm to approximately 6000 μm. The electrodes may be spaced approximately 300 μm from one another.

DETAILED DESCRIPTION OF THE DRAWINGS

50   [0010]   Embodiments of the present disclosure are disclosed herein with reference to the drawings, wherein:

FIG. 1 is a schematic perspective view of a sensing system;

FIG. 2 is a schematic illustration of a micro thermal probe of the sensing system of FIG. 1;

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FIG. 2A is an enlarged view of the indicated area of detail of FIG. 2;

FIGS. 3-9 are schematic illustrations of exemplary steps in the fabrication of the micro thermal probe of FIG. 2;

FIG. 10 is a schematic illustration of an electrical microprobe of the sensing system of FIG. 1;

FIG. 10A is an enlarged view of the indicated area of detail of FIG. 10;

FIGS. 11-16 are schematic illustrations of exemplary steps in the fabrication of the electrical microprobe of FIG. 10 according to an embodiment of the present invention;

FIG. 17 is a schematic illustration of an electrosurgical system including the sensing system of FIG. 1, shown in operative association with a target tissue;

FIG. 18 is a perspective view of a distal end of an electrical microprobe of the present disclosure

FIG. 19 is a transverse, cross-sectional view of an electrical microprobe as taken through 19-19 of FIG. 1;

FIG. 20 is a transverse, cross-sectional view of another electrical microprobe as taken through 19-19 of FIG. 1;

FIG. 21 is a schematic illustration of a distal end of an electrical microprobe according to yet another embodiment of the present disclosure;

FIG. 22 is a schematic illustration of a distal end of an integrated electrical and thermal microprobe according to still another embodiment of the present disclosure;

FIG. 23 is a schematic illustration of a distal end of an electrical ablation device according to an embodiment of the present disclosure;

FIG. 24 is a schematic illustration of a distal end of an electrosurgical device according to another embodiment of the present disclosure; and

FIG. 25 is a schematic illustration of a distal end of an electrosurgical device according to still another embodiment of the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENT

[0011] The devices, systems and methods of the present disclosure provide for the sensing of directional attributes of tissue in order to help in predicting and/or planning thermal therapy procedures. In the drawings and in the description which follows, the term "proximal", as is traditional, will refer to the end of the system, or component thereof, which is closest to the operator, and the term "distal" will refer to the end of the system, or component thereof, which is more remote from the operator.
[0012] As used herein, the term "Thermal treatment" is understood to include and is not limited to radio-frequency (RF) treatment, laser treatment, microwave treatment and cryoablation treatment.

1. Sensing System

[0013] With reference to FIG. 1, in accordance with an embodiment of the present disclosure, a sensing system for sensing directional attributes of tissue is generally designated as 100. System 100 includes a thermal conductivity probe 200, power supply "PS" connected to or connectable to probe 200, a multimeter "M" connected to or connectable to probe 200, and a computer "C" connected to or connectable to multimeter "M". System 100 may further include an electrical conductivity probe 300 connected to an impedance analyzer "IA", or other suitable devices. Impedance analyzer "IA" may be formed integral with multimeter "M", or may instead include a separate unit. Power supply "PS" may include any power source capable of providing constant power. For example, power supply "PS" may include a DC power source.
[0014] As seen in FIG. 1, thermal conductivity probe 200 includes a first pair of bonding pads 202 electrically connected to or electrically connectable to power supply "PS", and a second pair of bonding pads 204 electrically connected to or electrically connectable to multimeter "M". Electrical conductivity probe 300 may include a pair of bonding pads 304 electrically connected to or electrically connectable to impedance analyzer "1A".

2. Thermal Conductivity Probe

[0015] A micro thin-film thermal conductivity probe has been developed to measure thermal conductivity of biological

tissues based on the principle of traditional hot-wire method. An embodiment of the design of the microprobe of the present disclosure includes a resistive line heating element on a substrate and a Resistance Temperature Detector (RTD) based temperature sensor.

[0016]   With continued reference to FIG. 1 and with reference to FIGS. 2 and 2A, a more detailed discussion of thermal conductivity probe 200 is provided. Probe 200 may be in the form of a needle, probe antenna or the like or any other suitable configuration. In one embodiment, probe 200 may include an elongate body 210, in the form of a catheter, defining a sharpened or pointed distal tip 212.

[0017]   Probe 200 further includes a microprobe sensor 220 suitably secured to catheter 210. Microprobe sensor 220 may be disposed at least partially within catheter 210, on an outer surface of catheter 210, imbedded in the outer surface of catheter 210 and/or according to any other suitable method.

[0018]   As seen in FIGS. 2 and 2A, microprobe sensor 220 includes a line heating element 222 having a pair of resistive inner thin-film heating elements 222a, 222b, a detector element 224 having a pair of outer "resistance temperature detector" (RTD) elements 224a, 224b, and a substrate 226 for supporting heating elements 222a, 222b and RTD elements 224a, 224b.

[0019]   In one embodiment, line heating element 222 has a width of approximately $100\mu m$ and a length of approximately $5000\mu m$. Meanwhile, detector element 224 may have a width of approximately $100\mu m$ and a length of approximately $1500\mu m$. The dimensions disclosed herein are representative, it is envisioned and within the scope of the present disclosure for the dimensions to have any suitable value, such as, for example, having lengths that are approximately 3.0 times greater than the lengths specified or having lengths that are approximately 0.2 times less than the lengths specified. It is contemplated that the lengths selected, for example, may be chosen for optimal use in a specific target tissue, e.g., liver, lung, kidney, muscle, etc.

[0020]   As best seen in FIG. 2A, heating elements 222a, 222b of line heating element 222 are substantially parallel to one another and are spaced a distance "Y1" from one another. Distance "Y1" may be approximately $100\mu m$. Each heating element 222a, 222b is spaced apart from a respective RTD element 224a, 224b by a distance "Y2". Distance "Y2" may be approximately $50\mu m$.

[0021]   Turning now to FIGS. 3-9, a representative method of manufacturing microprobe sensor 220 is shown and described. The steps involved in the manufacture of microprobe sensor 220 include, as seen in FIG. 3, providing a substrate 226, e.g., glass, polyimide (kapton) or other polymeric substrate that is inert. In an embodiment, substrate 226 may have a thickness approximately equal to 1.0mm. Next, as seen in FIG. 4, a first layer 228 is deposited on substrate 226 using evaporation techniques or other suitable deposition techniques. First layer 228 may be fabricated from titanium (Ti) titanium tungsten (TiW), platinum (Pt) or other like materials, and may have a thickness of approximately 50nm. Next, as seen in FIG. 5, a second layer 230 is deposited on first layer 228 using evaporation techniques or other suitable deposition techniques. Second layer 230 may be fabricated from gold (Au), iridium (Ir), platinum-iridium alloy (Pt-Ir) or other like materials, and may have a thickness of approximately 500nm. The dimensions of microprobe sensor 220 provided herein are merely representative, and may be made larger or smaller depending on the application. For example, microprobe sensor 220 may be reduced in size when configured for use with infants. In one exemplary embodiment, microprobe sensor 220 may include a substrate 226 having a thickness approximately equal to $300\mu m$ to $1000\mu m$, and in a further embodiment approximately equal to $500\mu m$,

[0022]   As seen in FIG. 6, suitable photolithography techniques or other suitable etching or removal techniques are used to generate a desired first pattern 232 in first and second layers 228, 230 by using a precision photomask (not shown). Next, as seen in FIG. 7, second layer 230 is etched, using photolithography techniques or other suitable etching or removal techniques, to create a second pattern 234 therein. In this manner, the heating elements and the RTD elements are defined.

[0023]   As seen in FIG. 8, an insulating layer 236 is deposited, i.e., spun onto, overtop first and second layers 228, 230 and first and second patterns 232, 234. Insulating layer 236 may comprise a dielectric layer of benzocyclobutane (BCB), silica (SiO2), parylene, polyimide, SU8, or other like materials. Insulating layer 236 functions to protect first and second layers 228, 230 from corrosive element in tissue, such as, for example, saline. As seen in FIG. 9, areas 238 are exposed in insulating layer 236 to define bonding pads 202, 204 and expose bonding pads 202, 204 for soldering or the like. Sensor 220 may further be coated with a hydrophilic or hydrophobic layer (not shown) for increasing the biocompatibility of sensor 220.

[0024]   Wires (not shown) may be welded, soldered, ball bonded, epoxied, etc. to each bonding pad 202, 204 and microprobe sensor 220 may then be placed within elongate body 210 (see FIG. 1). A waterproof epoxy may be used to hold microprobe sensor 220 in place within elongate body 210 and to protect microprobe sensor 220.

3. Method of Using, Thermal Conductivity Probe

[0025]   With reference to FIGS. 1-2A, a representative method of using thermal conductivity probe 200, is provided. As seen in FIG. 1, with the first pair of bonding pads 202 electrically connected to power source "PS", and with the

second pair of bonding pads 204 electrically connected to multimeter "M", thermal conductivity probe 200 may be used to determine the thermal conductivity of target tissue. The transient time response of heating elements 222a, 222b is dependent on a thermal conductivity of the medium surrounding microprobe sensor 220 and the substrate underlying microprobe sensor 220.

[0026] According to a method of the present disclosure, a 5V output, generated by power source "PS", is used to provide a constant current through heating elements 222a, 222b. A resistance change of the RTD elements 224a, 224b, due to the transient temperature elevation, is measured by multimeter "M", an impedance analyzer or the like. Computer "C" is used to monitor, record and acquire the data and/or readings generated by microprobe sensor 220.

[0027] The transient time response of the RTD elements 224a, 224b depends on the thermal conductivity of the surrounding medium and the substrate. A theoretical analysis of the transient conduction, for a configuration where the heater source is sandwiched between two materials (the substrate and the surrounding medium), shows that the composite thermal conductivity calculated from the temperature versus the logarithm of time response is simply an average of the thermal conductivity of the two materials.

[0028] The equation for the calculation is:

$$k = \frac{k_{tissue} + k_{substrate}}{2} = \frac{q''}{2\pi}\left(\frac{dT}{d\ln t}\right)^{-1}$$

k - is the calculated thermal conductivity;

k_{tissue} - is the thermal conductivity of the tested tissue;

$k_{substrate}$ - is the thermal conductivity of the sensor substrate;

q'' - is the heat flux produced by heating element;

T - is the temperature; and

t - is the time.

[0029] In use, catheter 210 is inserted into the target tissue "T" and microprobe sensor 220 is activated to determine the thermal conductivity of said target tissue. Thermal conductivity probe 200 is adapted to measure thermal conductance K_{eff} as represented by the following equation, as commonly known in the field:

$$K_{eff} = K\left\{1 + \frac{n\left[(\rho c)_b \pi r_b^2 \overline{V} \cos\gamma\right]^2}{\sigma_\Delta K^2}\right\} + q_{met}$$

where:

k_{eff} - is the "effective" tissue conductance which is measured. K_{eff} is the combination of conduction (due to intrinsic thermal conductivity) and convection (due to perfusion);
k_{tissue} - is tissue conductance in the absence of perfusion;
n - is the number of blood vessels;
p - in $(pc)_b$ is the density of blood;
c - in $(pc)_b$ is the specific heat of blood;
r_b - is vessel radius;
V - is the blood flow velocity vector within the vessel;
γ - is the relative angle between blood vessel direction and tissue temperature gradient;
σ_Δ - is a shape factor term; and
q_{met} - is metabolic heat generation.
-S. Weinbaum and L.M. Jiji, "A new simplified equation for the effect of blood flow on local average tissue temperature," ASME J. Biomech. Eng. 107: 131-139, 1985.

4. Electrical Conductivity Probe

[0030] With reference to FIG. 1 and with reference to FIGS. 10 and 10A, a more detailed discussion of electrical conductivity probe 300 is provided. Probe 300 may be in the form of a needle, probe antenna or the like or any suitable configuration. For example, probe 300 may include an elongate body 310, in the form of a catheter, defining a sharpened or pointed distal tip 312.

[0031] Probe 300 further includes a sensor 320 suitably secured to catheter 310. Sensor 320 may be disposed at least partially within catheter 310, on an outer surface of catheter 310, imbedded in the outer surface of catheter 310 and/or according to any other suitable.

[0032] As seen in FIGS. 10 and 10A. sensor 320 includes a pair of electrodes 322a, 322b defining a sensor area "SA", a pair of electrical leads 323a, 323b respectively connecting electrodes 322a, 322b to bonding pads 304, and a substrate 326 for supporting electrodes 322a, 322b, leads 323a, 323b and bonding pads 304.

[0033] In one embodiment, each electrode 322a, 322b has a width of approximately $150\mu m$ and a length of approximately $2,000\mu m$. While the dimensions disclosed herein are representative or exemplar, it is envisioned and within the scope of the present disclosure for the dimensions to have any suitable value, such as, for example, having lengths that are approximately 3.0 times greater than the lengths specified or having lengths that are approximately 0.2 times less than the lengths specified. It is contemplated that the lengths selected, for example, may be chosen for optimal use in a specific target tissue, e.g., liver, lung, kidney, muscle, etc. As best seen in FIGS. 10 and 10A, electrodes 322a, 322b are substantially parallel to one another and are spaced a distance "Y3" from one another. Distance "Y3" may be approximately $300\mu m$.

[0034] Turning now to FIGS. 11-16, an exemplary method of manufacturing sensor 320 is shown and described. The steps involved in the manufacture of sensor 320 include, as seen in FIG. 11, providing a substrate 326, e.g., a polyimide or other suitable substrate that is inert. In an embodiment, substrate 326 may have a thickness between approximately $300\mu m$ and $1,000\mu m$, and in a further embodiment may be approximately $500\mu m$. Next, as seen in FIG. 12, an adhesive layer 328 is deposited on substrate 326 using suitable deposition by evaporation techniques or other suitable deposition and/or evaporation techniques. Adhesive layer 328 may be fabricated from titanium (Ti) titanium tungsten (TiW), platinum (Pt) or other like materials, and may have a thickness of approximately 30nm. Next, as seen in FIG. 13, a conductive layer 330 is deposited on adhesive layer 228 using suitable deposition by evaporation techniques or other suitable deposition and/or evaporation techniques. Conductive layer 330 may be fabricated from gold (Au), iridium (Ir), platinum-indium alloy (Pt-Ir) or other like materials, and may have a thickness of approximately 300nm. The dimensions of microprobe sensor 320 provided herein are merely representative, and may be made larger or smaller depending on the application.

[0035] As seen in FIG. 14, suitable photolithography and/or etching techniques are used to generate a desired pattern 332 defining first and second electrodes 322a, 322b. Next, as seen in FIG. 15, an insulating layer 336 is deposited, e.g., spun onto, overtop conductive layer 330 and pattern 332. Insulating layer 336 may comprise a dielectric layer of benzocyclobutane (BCB), silica (SiO_2), parylene C or other like materials. Insulating layer 336 functions to protect conductive layer 330 from corrosive element in tissue, such as, for example, saline. As seen in FIG. 16, areas 338 are patterned into insulating layer 336 to define first and second electrodes 322a, 322b and bonding pads 304 and to expose bonding pads 304 for soldering or the like.

[0036] Wires (not shown) may be welded, soldered, ball bonded, epoxied, etc. to each bonding pad 304 and sensor 320 may then be paced within elongate body 310 (see FIG. 1). A waterproof epoxy may be used to hold sensor 320 in place within elongate body 310 and to protect sensor 320. Sensor 320 may further be coated with a hydrophilic or hydrophobic layer (not shown) for increasing the biocompatibility of sensor 320.

5. Method of Using Electrical Conductivity Probe

[0037] With reference to FIGS. 1, 10 and 10A, a representative method of using electrical conductivity probe 300, is provided. As seen in FIG. 1, with the pair of bonding pads 304 electrically connected to multimeter "M" or impedance analyzer, electrical conductivity probe 300 may be used to determine the electrical conductivity of target tissue prior to an electrosurgical procedure.

[0038] According to a method of the present disclosure, a 500kHz output frequency, generated by multimeter "M", is used to provide electrosurgical energy to electrodes 322a, 322b. A return pad or electrode (not shown) is employed to complete a circuit with electrodes 322a, 322b, via tissue "T". The computer "C" is used to monitor, record and acquire the data and/or readings generated by sensor 320.

[0039] Before use, the impedance values by the micro electrical probe are calibrated in different salinity levels against the standard four-electrode probe which provides a direct measure of the electrical conductivity. A calibration curve is generated that relate the impedance value given by the micro electrical probe to the electrical conductivity measured by the standard four-electrode probe at different salinity levels. The electrical conductivity can be calculated by comparing

the impedance value with the calibration curve. In use, catheter 310 is inserted into the target tissue "T" and sensor 320 is activated to determine the electrical conductivity of said target tissue "T".

[0040] While each of the above embodiments illustrates a single sensor 220, 320 associated with each respective device 200, 300, in accordance with the present disclosure, devices 200, 300 may employ or include at least two or multiple sensors 220, 320 disposed around a circumference thereof. As seen in FIG. 19, each of devices 200, 300 may include a pair of sensors 220a, 320a disposed on opposed sides thereof, or as seen in FIG. 20, each of devices 200, 300 may include a sensors 220b, 320b disposed at 90° angles relative to one another.

[0041] As seen in FIG. 21, sensors 220, 320 may be disposed at different axial locations along a length of respective catheter 210, 310. As seen in FIG. 22, sensors 220, 320 may be provided on a single electrosurgical device 400. In this manner, electrosurgical device 400 will be capable of measuring and/or capturing both the values of thermal conductivity and electrical conductivity of target tissue "T".

[0042] According to an alternate embodiment of the present disclosure, as seen in FIG. 22, sensors 220, 320 may be incorporated into or otherwise associated with a thermal treatment device 500, in the form of an ablation needle, probe, antenna or the like. Thermal treatment device 500 defines an electrically exposed distal tip 502 configured and adapted to deliver therapeutic energy to target tissue, according to any suitable known method in the art. Distal tip 502 extends from an insulated shaft 504 or the like.

[0043] As seen in FIG. 23, sensors 220, 320 may be provided along and/or incorporated into distal tip 502 and/or provided along and/or incorporated into shaft 504. The particular arrangement, location and orientation of sensors 220, 320 relative to one another and relative to distal tip 502 and 504 may be selected or chosen as needed and/or desired.

[0044] As seen in FIG. 24, sensors 220, 320 may be provided along and/or incorporated into an outer tube 602 of a thermal treatment device 600. In this manner, outer tube 602 of thermal treatment device 600 may be retracted relative to shaft 604, or in the alternative, shaft 604 may be extended relative to outer tube 602, to expose an operational end 606 of thermal treatment device 600. In an alternate embodiment, as seen in FIG. 25, sensors 220, 320 may be provided along and/or incorporated into a shaft 702 of a thermal treatment device 700. In this manner, shaft 702 of thermal treatment device 700 may be extended relative to an operational outer tube 704, thereby exposing sensors 220, 320. In a further embodiment, operational outer tube 704 may be replaced with an energy delivery needle or the like for delivering therapeutic energy to surrounding tissue and thermal treatment device 700 may be extended relative to energy delivery needle 704.

[0045] While several embodiments of the disclosure have been shown in the drawings, it is not intended that the disclosure be limited thereto, as it is intended that the disclosure be as broad in scope as the art will allow and that the specification be read likewise. Therefore, the above description should not be construed as limiting, but merely as exemplifications of preferred embodiments.

Claims

1. A method of making an electrical conductivity probe (300), comprising the step of disposing at least two sensors around a circular circumference of an elongate body (310), wherein the at least two sensors are each made by a method comprising the steps of:

   providing a substrate (326);
   depositing an adhesive layer (328) on the substrate;
   depositing a conductive layer (330) on the adhesive layer;
   generating a pattern (332) on the adhesive layer and the conductive layer;
   depositing an insulating layer (336) over the conductive layer and the pattern; and
   exposing areas (338) of the insulating layer to define substantially parallel first and second electrodes(322a, 322b) and bonding pads (304).

2. The method of claim 1, further comprising the step of depositing the adhesive layer and conductive layer using evaporation techniques.

3. The method of claim 1, further comprising the step of defining first and second electrodes in the pattern.

4. The method of claim 1, wherein the adhesive layer is selected from the group consisting of titanium (Ti), titanium tungsten (TiW) and platinum (Pt).

5. The method of claim 1, further comprising the step of providing an adhesive layer measuring approximately 30 nm thick.

6. The method of claim 1, wherein the conductive layer is selected from the group consisting of gold (AU), iridium (Ir) and platinum-iridium (Pt--Ir).

7. The method of claim 1, further comprising the step of providing the conductive layer measuring approximately 330 nm thick.

8. The method of claim 1, further comprising the step of spinning the insulative layer onto the conductive layer and pattern.

9. The method of claim 1, wherein the widths of the electrodes are approximately 150 μm.

10. The method claim 1, wherein the lengths of the electrodes are between approximately 400 μm to approximately 6000 μm.

11. The method of claim 1, wherein the electrodes are spaced approximately 300 μm from one another.

Patentansprüche

1. Verfahren zum Herstellen einer elektrischen Leitfähigkeitssonde (300), umfassend den Schritt des Anordnens von mindestens zwei Sensoren rund um einen kreisförmigen Umfang eines langgestreckten Körpers (310), wobei die mindestens zwei Sensoren jeweils durch ein Verfahren hergestellt werden, das die Schritte umfasst:

   - Bereitstellen eines Substrats (326);
   - Auftragen einer Klebstoffschicht (328) auf dem Substrat;
   - Auftragen einer leitfähigen Schicht (330) auf der Klebstoffschicht;
   - Erzeugen einer Struktur (332) auf der Klebstoffschicht und der leitfähigen Schicht;
   - Auftragen einer isolierenden Schicht (336) über der leitfähigen Schicht und der Struktur; und
   - Freilegen von Bereichen (338) der isolierenden Schicht, um im Wesentlichen parallele erste und zweite Elektroden (322a, 322b) und Bondinseln (304) zu definieren.

2. Verfahren nach Anspruch 1, ferner umfassend den Schritt des Aufbringens der Klebstoffschicht und der leitfähigen Schicht unter Verwendung von Verdampfungstechniken.

3. Verfahren nach Anspruch 1, ferner umfassend den Schritt des Definierens erster und zweiter Elektroden in der Struktur.

4. Verfahren nach Anspruch 1, wobei die Klebstoffschicht aus der Gruppe ausgewählt ist, die aus Titan (Ti), Titan-Wolfram (TiW) und Platin (Pt) besteht.

5. Verfahren nach Anspruch 1, ferner umfassend den Schritt des Bereitstellens einer Klebstoffschicht, die eine Dicke von annähernd 30 nm aufweist.

6. Verfahren nach Anspruch 1, wobei die leitfähige Schicht aus der Gruppe ausgewählt ist, die aus Gold (Au), Iridium (Ir) und Platin-Iridium (Pt--Ir) besteht.

7. Verfahren nach Anspruch 1, ferner umfassend den Schritt des Bereitstellens einer leitfähigen Schicht, die eine Dicke von annähernd 330 nm aufweist.

8. Verfahren nach Anspruch 1, ferner umfassend den Schritt des Aufschleuderns der isolierenden Schicht auf die leitfähige Schicht und die Struktur.

9. Verfahren nach Anspruch 1, wobei die Breiten der Elektroden annähernd 150 μm betragen.

10. Verfahren nach Anspruch 1, wobei die Längen der Elektroden zwischen annähernd 400 μm bis annähernd 6.000 μm betragen.

11. Verfahren nach Anspruch 1, wobei die Elektroden annähernd 300 μm voneinander beabstandet sind.

Revendications

1. Procédé de fabrication d'une sonde à conductivité électrique (300), comprenant l'étape consistant à disposer au moins deux capteurs autour d'une circonférence circulaire d'un corps allongé (310), dans lequel les au moins deux capteurs sont chacun fabriqués par un procédé comprenant les étapes de :

    fourniture d'un substrat (326) ;
    dépôt d'une couche adhésive (328) sur le substrat ;
    dépôt d'une couche conductrice (330) sur la couche adhésive ;
    production d'un motif (332) sur la couche adhésive et la couche conductrice ;
    dépôt d'une couche isolante (336) sur la couche conductrice et le motif ; et
    exposition de zones (338) de la couche isolante pour définir des première et seconde électrodes sensiblement parallèles (322a, 322b) et des plages de liaison (304).

2. Procédé selon la revendication 1, comprenant en outre l'étape consistant à déposer la couche adhésive et la couche conductrice en utilisant des techniques d'évaporation.

3. Procédé selon la revendication 1, comprenant en outre l'étape consistant à définir des première et seconde électrodes dans le motif.

4. Procédé selon la revendication 1, dans lequel la couche adhésive est sélectionnée à partir du groupe constitué par du titane (Ti), du titane-tungstène (TiW) et du platine (Pt).

5. Procédé selon la revendication 1, comprenant en outre l'étape consistant à fournir une couche adhésive mesurant approximativement 30 nm d'épaisseur.

6. Procédé selon la revendication 1, dans lequel la couche conductrice est sélectionnée à partir du groupe constitué par de l'or (Au), de l'iridium (Ir) et du platine-iridium (Pt-Ir).

7. Procédé selon la revendication 1, comprenant en outre l'étape consistant à fournir la couche conductrice mesurant approximativement 330 nm d'épaisseur.

8. Procédé selon la revendication 1, comprenant en outre l'étape consistant à appliquer par centrifugation la couche isolante sur la couche conductrice et le motif.

9. Procédé selon la revendication 1, dans lequel les largeurs des électrodes font approximativement 150 μm.

10. Procédé selon la revendication 1, dans lequel les longueurs des électrodes font entre approximativement 400 μm à approximativement 6 000 μm.

11. Procédé selon la revendication 1, dans lequel les électrodes sont espacées approximativement de 300 μm l'une de l'autre.

Fig. 1

Fig. 2

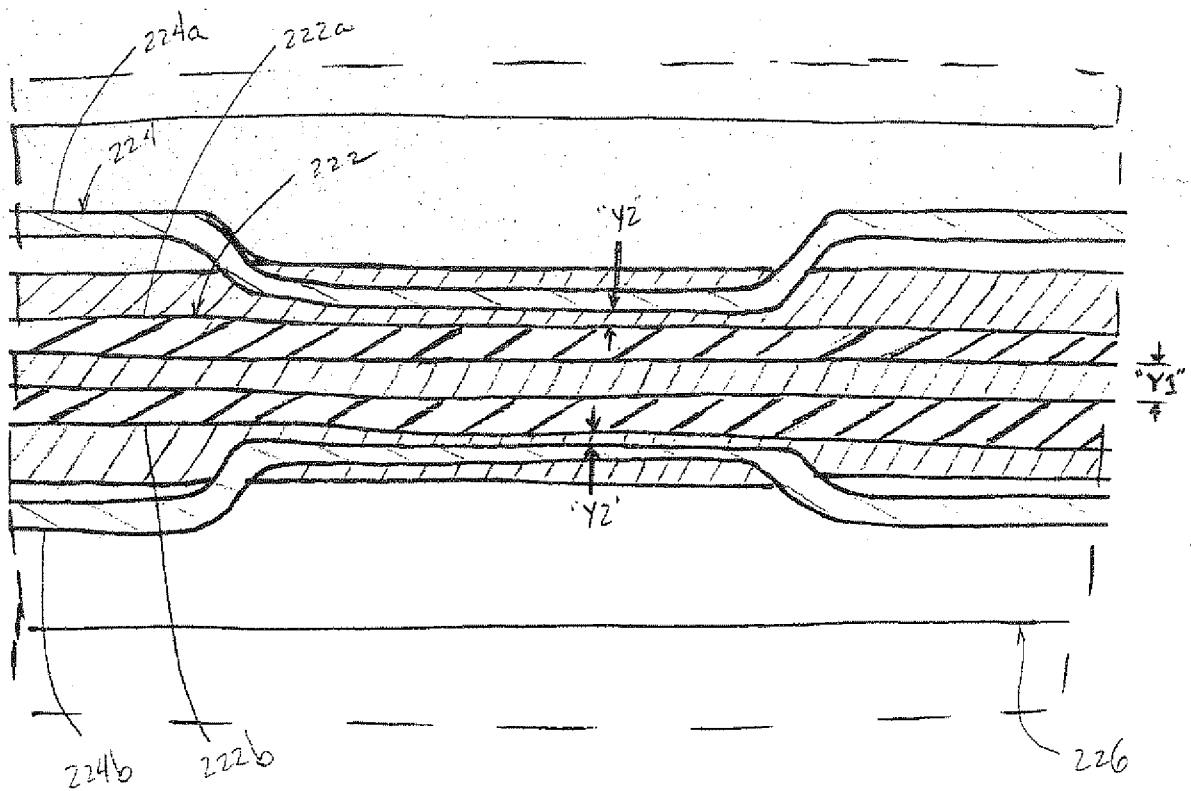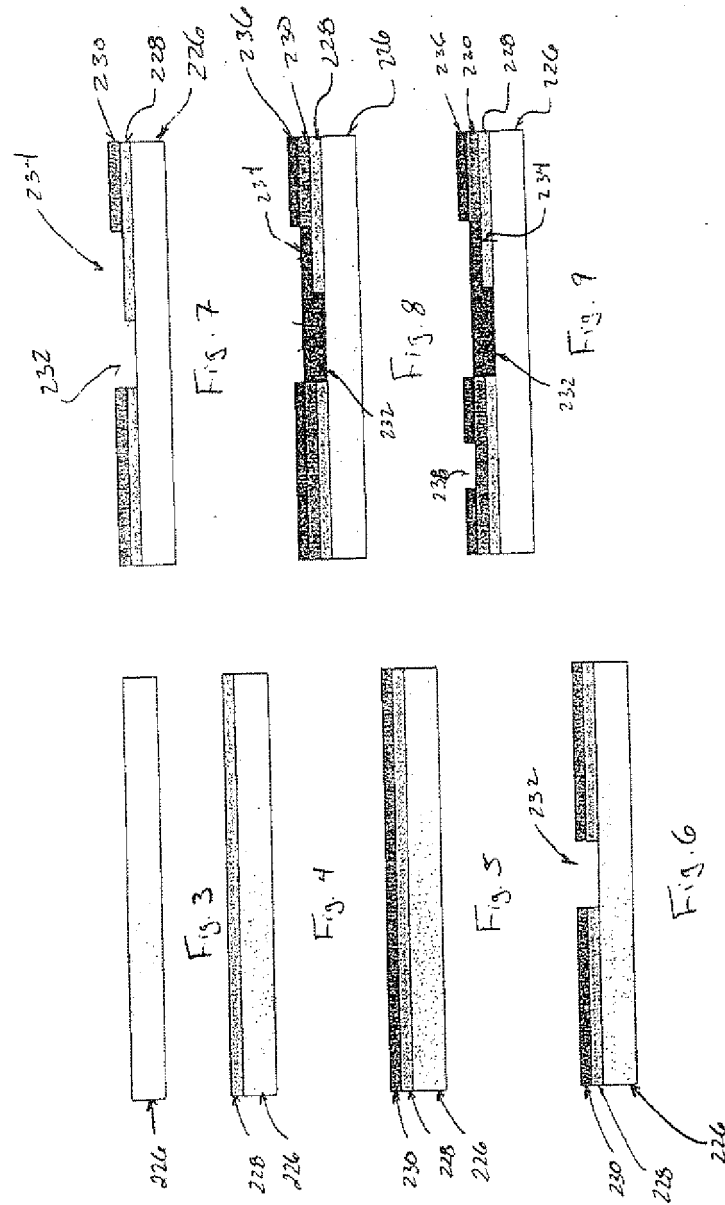Fig. 2A

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

320

322a

"SA"

326

304

304

322b

10A

Fig. 10

322a

322b

Fig. 10A

326

Fig. 11

328
326

Fig. 12

330
328
326
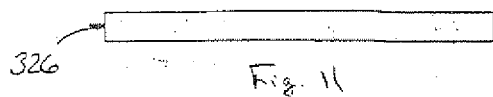
Fig. 13

332

330
328
326

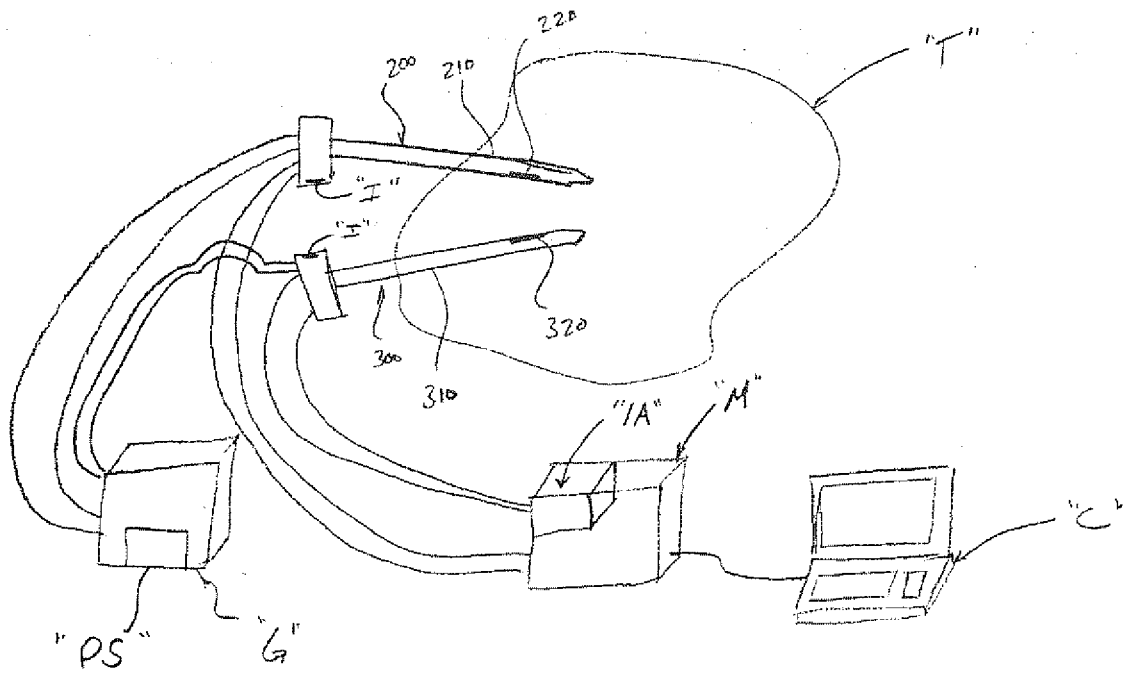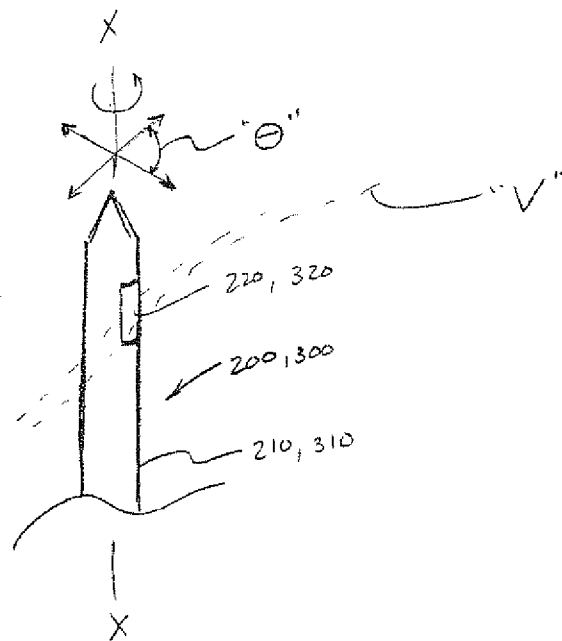Fig. 14

332

338B
330
328
326
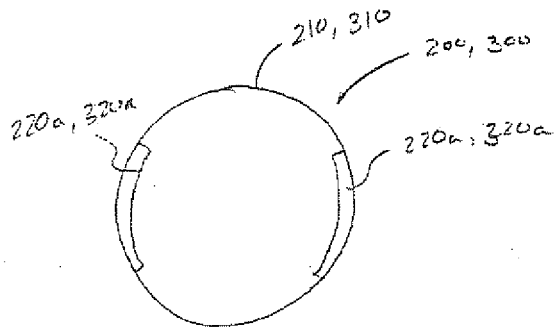
Fig. 15

338   338   336
330
328
326

Fig. 16
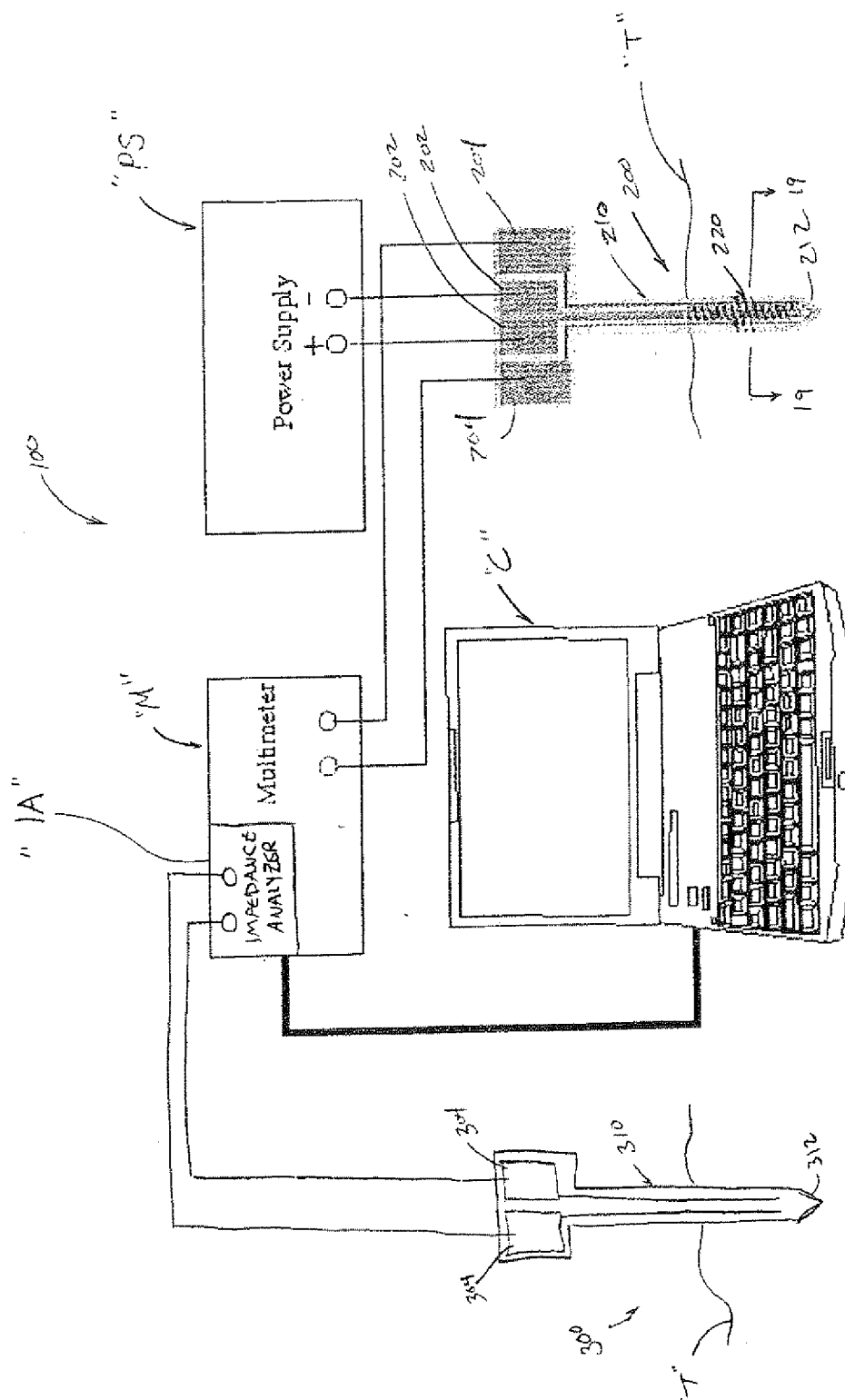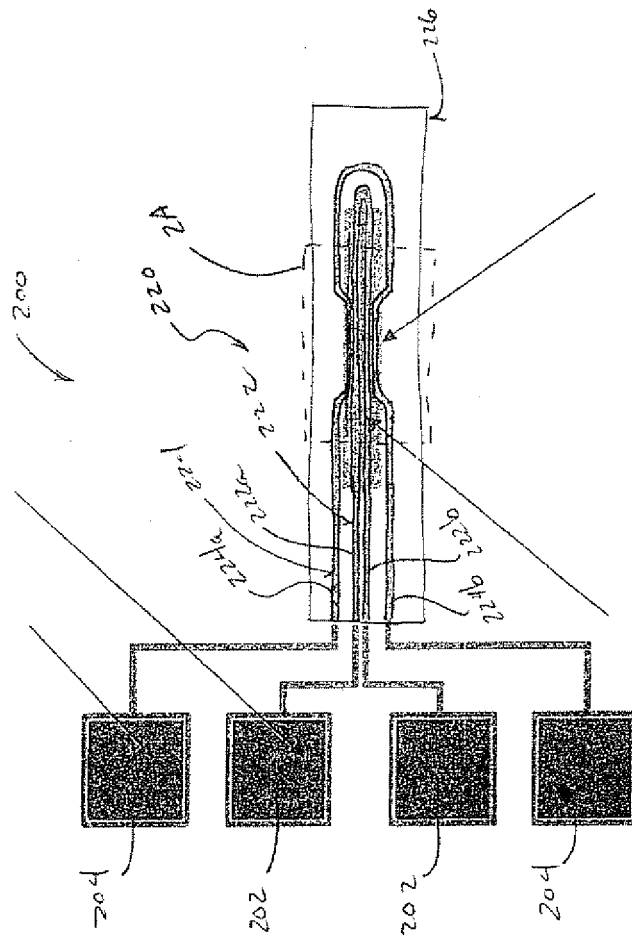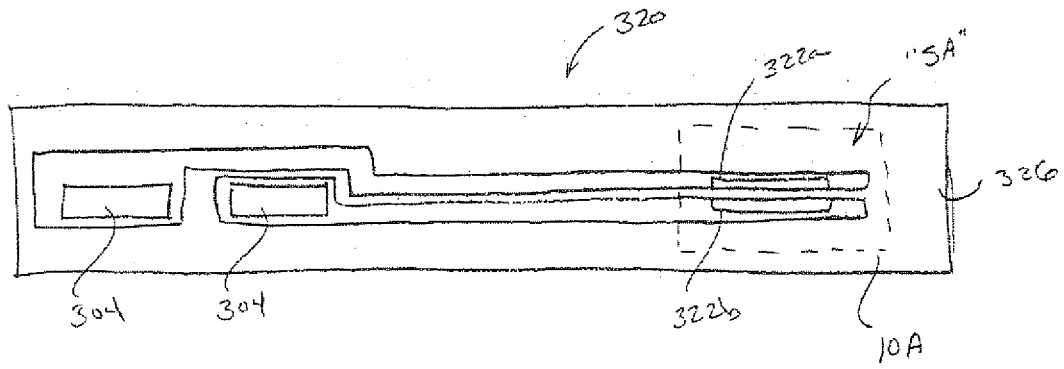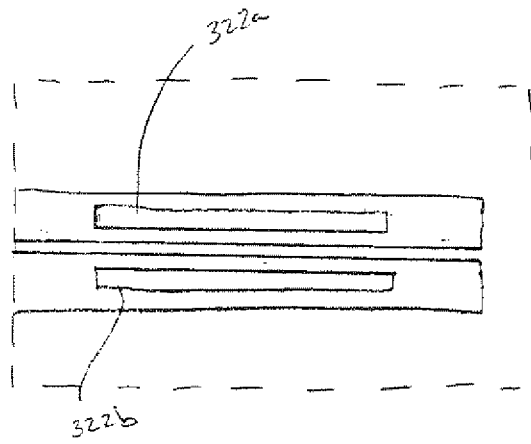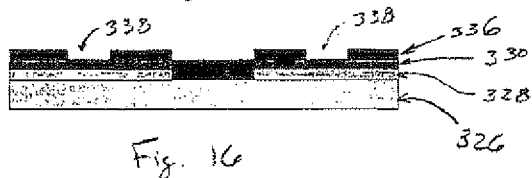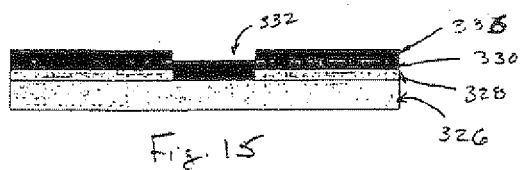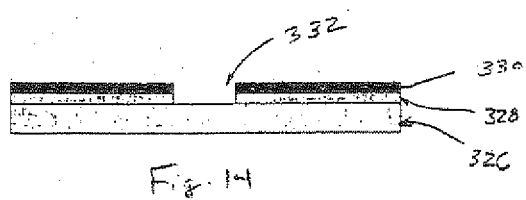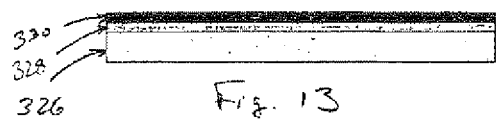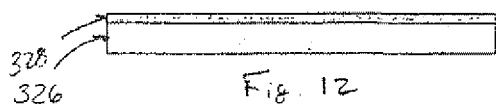
Fig. 17

Fig. 18

Fig. 19
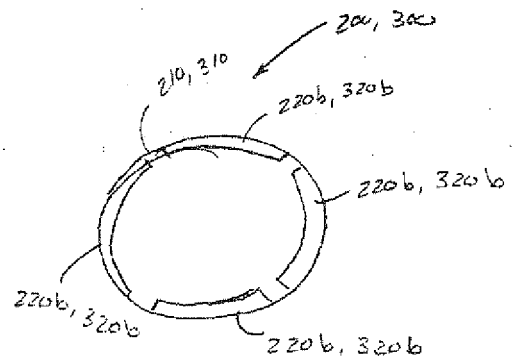
Fig. 20
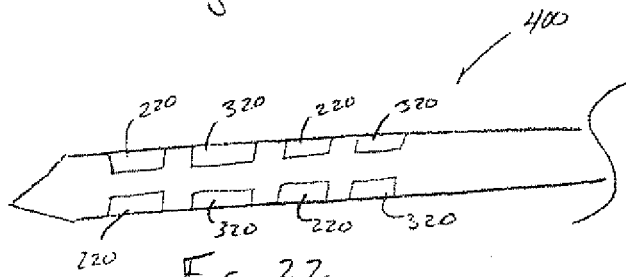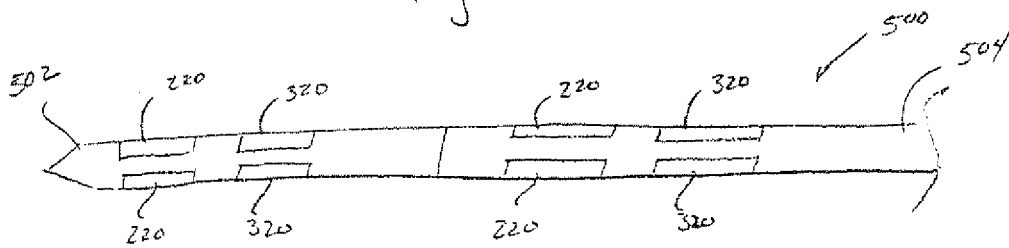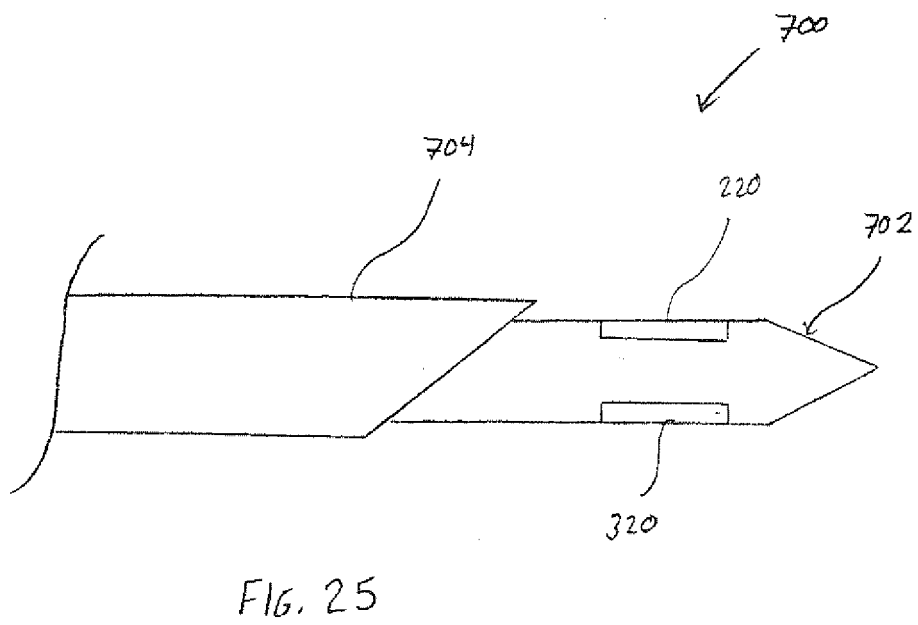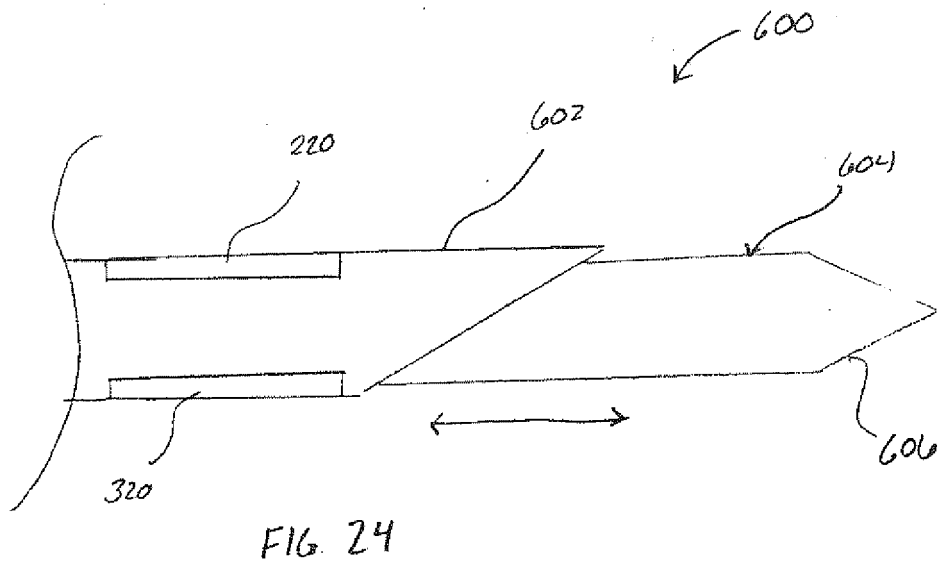

Fig. 21

Fig. 22

Fig. 23

FIG. 24

FIG. 25
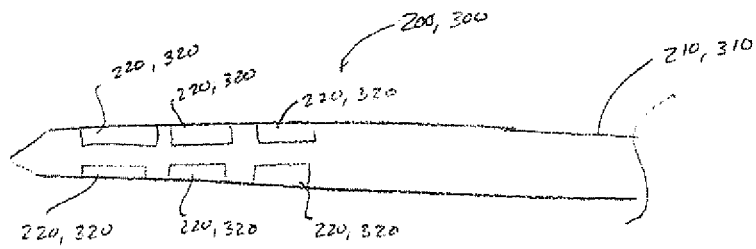
REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **S. WEINBAUM ; L.M. JIJI.** A new simplified equation for the effect of blood flow on local average tissue temperature. *ASME J. Biomech. Eng.,* 1985, vol. 107, 131-139 **[0029]**

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外部链接	[Espacenet](#)

摘要(译)

提供了一种用于计划，执行和/或评估靶组织的治疗处理的有效性的系统。该系统包括导热探针和导电探针中的至少一个，所述导热探针包括微探针传感器，所述微探针传感器被配置并适于在至少一个方向上测量靶组织中的导热率，所述导电探针包括微探针传感器，所述微探针传感器被配置并适于测量导电率。靶组织至少在一个方向上。该系统还包括可操作地连接到导热探针和导电探针中的至少一个的万用表，该万用表被配置并适于将能量输送到导热探针和导电探针中的至少一个以及计算机可操作地连接到万用表。

$$k = \frac{k_{tissue} + k_{substrate}}{2} = \frac{q''}{2\pi}\left(\frac{dT}{d\ln t}\right)^{-1}$$