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(54) Thermal and electrical conductivity probes and methods of making the same

(57) According to the present disclosure, a system for sensing attributes of tissue in at least one direction is provided. The system includes a thermal conductivity probe having a sensor configured to measure thermal conductivity in the target tissue in at least one direction, and an electrical conductivity probe having a sensor configured to measure electrical conductivity in the target tissue in at least one direction, a power supply operatively coupled to the thermal conductivity probe and being configured to supply power to the thermal conductivity probe, an impedance analyzer operatively coupled to the electrical conductivity probe, and a computer operatively coupled to at least one of the power supply, the multimeter and the impedance analyzer.

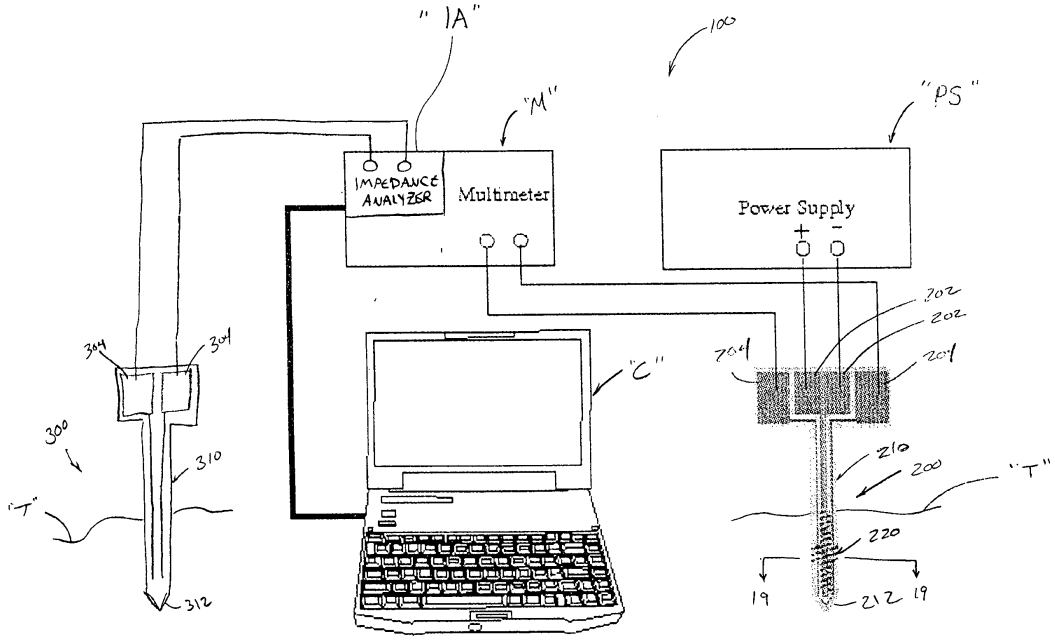

Fig. 1

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Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims the benefit of and priority to U.S. Provisional Application Serial No. 60/881,238, filed on January 19, 2007, the entire content of which is incorporated herein by reference.

BACKGROUND

1. *Technical Field*

[0002] 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.

2. *Discussion of Related Art*

[0003] It has been observed that biological tissue has different thermal and/or electrical conductivities in different directions.

[0004] 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.

[0005] Electrical conductivity is not only determined by tissue type and composition, but also by other externally applied physical and chemical influences during thermal treatment, such as, for example, temperature inducement and saline pretreatment.

[0006] 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.

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] A system for sensing attributes of tissue in at least one direction is provided. The system includes a thermal conductivity probe including a sensor configured to measure thermal conductivity in the target tissue in at least one direction, , a power supply operatively connected to the thermal conductivity probe and being configured to supply power to the thermal conductivity probe, a multimeter operatively connected the thermal conductivity probe; an electrical conductivity probe including a sensor configured to measure electrical conductivity in the target tissue in at least one direction, an impedance analyzer to measure the tissue impedance (or equivalently electrical conductivity) and a computer operatively connected to at least one of the multimeter and impedance analyzer. In the system, the thermal conductivity probe and the electrical conductivity probe may be integrated into a single probe.

[0009] Also provided is a thermal conductivity probe for sensing directional attributes of tissue. The probe includes a body and a sensor operably connected to the body. The sensor includes a line heater having one or more resistive heating elements, a detector having one or more detector elements, and a substrate for supporting the line heater and the detector and to provide thermal conductivity contrast. The body of the probe may define a catheter configured for insertion into tissue. The pair of outer detector elements may form resistance temperature detector elements (RTD). The pair of inner heating elements may be substantially parallel. The probe may further include an array of sensors.

[0010] A method of making a thermal conductivity probe is also provided. The method includes providing an inert substrate, depositing a first layer on the substrate, depositing a second layer on the first layer, generating a first pattern in the first and second layers, generating a second pattern in the second layer, and depositing an insulative layer over the first and second layers. The first and second layers may be deposited using evaporation techniques. The first layer may be selected from the group consisting of titanium (Ti), titanium tungsten (TiW) and platinum (Pt). The second layer may be selected from the group consisting of gold (AU), iridium (Ir) and platinum-iridium (Pt-1r). The first layer may measure about 50 nm thick. The second layer may measure about 500 nm thick. The first and second patterns may be generated using an etching technique.

[0011] In addition, an electrical conductivity probe for measuring attributes of tissue is provided. The probe includes a body and a sensor for sensing electrical conductivity. The sensor includes a pair of electrodes, a pair of bonding pads

coupled to the pair of electrodes by a pair of electrical leads, and a substrate for supporting the electrodes, boding pads and leads. The pair of electrodes may be parallel. The body of the probe may define a catheter configured for insertion into tissue.

[0012] The sensor may include insulating material at least partially overlying the pair of electrodes, and an exposed region formed in the insulation and associated with each electrode.

[0013] A method of making an electrical conductivity probe is also provided. The method includes providing a substrate, depositing an adhesive layer on the substrate, depositing a conductive layer on the adhesive layer, generating a pattern on the adhesive layer and the conductive layer, and depositing an insulating layer over the conductive layer and the pattern. 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.

DETAILED DESCRIPTION OF THE DRAWINGS

[0014] Embodiments of the present disclosure are disclosed herein with reference to the drawings, wherein:

[0015] FIG. 1 is a schematic perspective view of a sensing system according to an embodiment of the present disclosure;

[0016] FIG. 2 is a schematic illustration of an embodiment of a micro thermal probe of the sensing system of FIG. 1;

[0017] FIG. 2A is an enlarged view of the indicated area of detail of FIG. 2;

[0018] FIGS. 3-9 are schematic illustrations of exemplary steps in the fabrication of the micro thermal probe of FIG. 2;

[0019] FIG. 10 is a schematic illustration of an embodiment of another electrical microprobe of the sensing system of FIG. 1;

[0020] FIG. 10A is an enlarged view of the indicated area of detail of FIG. 10;

[0021] FIGS. 11-16 are schematic illustrations of exemplary steps in the fabrication of the electrical microprobe of FIG. 10;

[0022] 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;

[0023] FIG. 18 is a perspective view of a distal end of an electrical microprobe of the present disclosure;

[0024] FIG. 19 is a transverse, cross-sectional view of an electrical microprobe as taken through 19-19 of FIG. 1;

[0025] FIG. 20 is a transverse, cross-sectional view of another electrical microprobe as taken through 19-19 of FIG. 1;

[0026] FIG. 21 is a schematic illustration of a distal end of an electrical microprobe according to yet another embodiment of the present disclosure;

[0027] 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;

[0028] FIG. 23 is a schematic illustration of a distal end of an electrical ablation device according to an embodiment of the present disclosure;

[0029] FIG. 24 is a schematic illustration of a distal end of an electrosurgical device according to another embodiment of the present disclosure; and

[0030] 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 EMBODIMENTS

[0031] 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.

[0032] 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

[0033] 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.

[0034] 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 "IA".

2. Thermal Conductivity Probe

[0035] 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.

[0036] 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.

[0037] 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.

[0038] 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.

[0039] In one embodiment, line heating element 222 has a width of approximately 100μm and a length of approximately 5000μm. Meanwhile, detector element 224 may have a width of approximately 100μm and a length of approximately 1500μm. 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.

[0040] 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 100μm. Each heating element 222a, 222b is spaced apart from a respective RTD element 224a, 224b by a distance "Y2". Distance "Y2" may be approximately 50μm.

[0041] 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 300μm to 1000μm, and in a further embodiment approximately equal to 500μm.

[0042] 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.

[0043] 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 (SiO_2), 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.

[0044] 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

[0045] 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.

[0046] 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.

[0047] 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.

[0048] 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.

[0049] 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;

y - 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

[0050] 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.

[0051] 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.

[0052] 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.

[0053] In one embodiment, each electrode 322a, 322b has a width of approximately 150μm and a length of approximately 2,000μm. 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 300μm.

[0054] 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 300μm and 1,000μm, and in a further embodiment may be approximately 500μm. 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-iridium 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.

[0055] 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.

[0056] 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

[0057] 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.

[0058] 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.

[0059] 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".

[0060] 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.

[0061] 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".

[0062] 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.

[0063] 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.

[0064] 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.

[0065] 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. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

Claims

1. A system for sensing attributes of tissue, the system comprising:

a thermal conductivity probe including a sensor configured to measure a thermal conductivity in the target tissue in at least one direction;
an electrical conductivity probe including a sensor configured to measure an electrical conductivity in the target tissue in at least one direction;
a power supply operatively coupled to the thermal conductivity probe and configured to supply power to the thermal conductivity probe;
a multimeter operatively coupled to at least one of the thermal conductivity probe and the electrical conductivity probe, the multimeter configured to deliver energy to at least one of the thermal conductivity probe and the electrical conductivity probe; and
a computer operatively coupled to at least one of the power supply, the multimeter and an impedance analyzer.

2. The system of claim 1, wherein the thermal conductivity probe and the electrical conductivity probe are integrated into a single probe.

3. The system of claim 1, wherein the impedance analyzer is operably coupled to the electrical conductivity probe.

4. A thermal conductivity probe for sensing directional attributes of tissue, the probe comprising:

a body; and
a sensor operably coupled to the body, wherein the sensor includes:

a line heater having at least one resistive heating element;
a detector having at least one detector element; and
a substrate for supporting the line heater and the detector, wherein the substrate provides a thermal conductivity contrast.

5. The probe of claim 4, wherein the body defines a catheter configured for insertion into tissue.

6. The probe of claim 4, wherein the pair of outer detector elements are resistance temperature detector elements (RTD).

7. The probe of claim 4, wherein the pair of inner heating elements are substantially parallel.

8. The probe of claim 4, further including an array of sensors.

9. A method of making a thermal conductivity probe, the method comprising the steps of:

providing an inert substrate;
depositing a first layer on the substrate;
depositing a second layer on the first layer;
generating a first pattern in the first and second layers;
generating a second pattern in the second layer;

depositing an insulative layer over the first and second layers; and
exposing at least a portion of the insulating layer.

10. The method of claim 9, further comprising the step of depositing the first and second layers using evaporation techniques.

11. The method of claim 9, wherein the first layer is selected from the group consisting of titanium (Ti), titanium tungsten (TiW) and platinum (Pt).

12. The method of claim 9, wherein the second layer is selected from the group consisting of gold (AU), iridium (Ir) and platinum-iridium (Pt-Ir).

13. The method of claim 9, further comprising the step of providing a first layer measuring approximately 50 nm thick.

14. The method of claim 9, further comprising the step of providing a second layer measuring approximately 500 nm thick.

15. The method of claim 9, further comprising the step of generating the first and second patterns using an etching technique.

16. An electrical conductivity probe for measuring attributes of tissue, the probe comprising:

a body; and
a sensor for sensing electrical conductivity, wherein the sensor includes;

a pair of electrodes;
a pair of bonding pads coupled to the pair of electrodes by a pair of electrical leads; and
a substrate for supporting the electrodes, bonding pads and leads.

17. The probe of claim 16, wherein the pair of electrodes are parallel.

18. The probe of claim 16, wherein the body defines a catheter configured for insertion into tissue.

19. The probe of claim 16, wherein the sensor includes insulating material at least partially overlying the pair of electrodes, and an exposed region formed in the insulation and associated with each electrode.

20. A method of making an electrical conductivity probe, the method comprising the steps of:

providing a substrate;
depositing an adhesive layer on the substrate;
depositing a conductive layer on the adhesive layer;
generating a pattern on the adhesive layer and the conductive layer;
depositing an insulating layer over the conductive layer and the pattern; and
exposing at least a portion of the insulating layer.

21. The method of claim 20, further comprising the step of depositing the adhesive layer and conductive layer using evaporation techniques.

22. The method of claim 20, further comprising the step of defining first and second electrodes in the pattern.

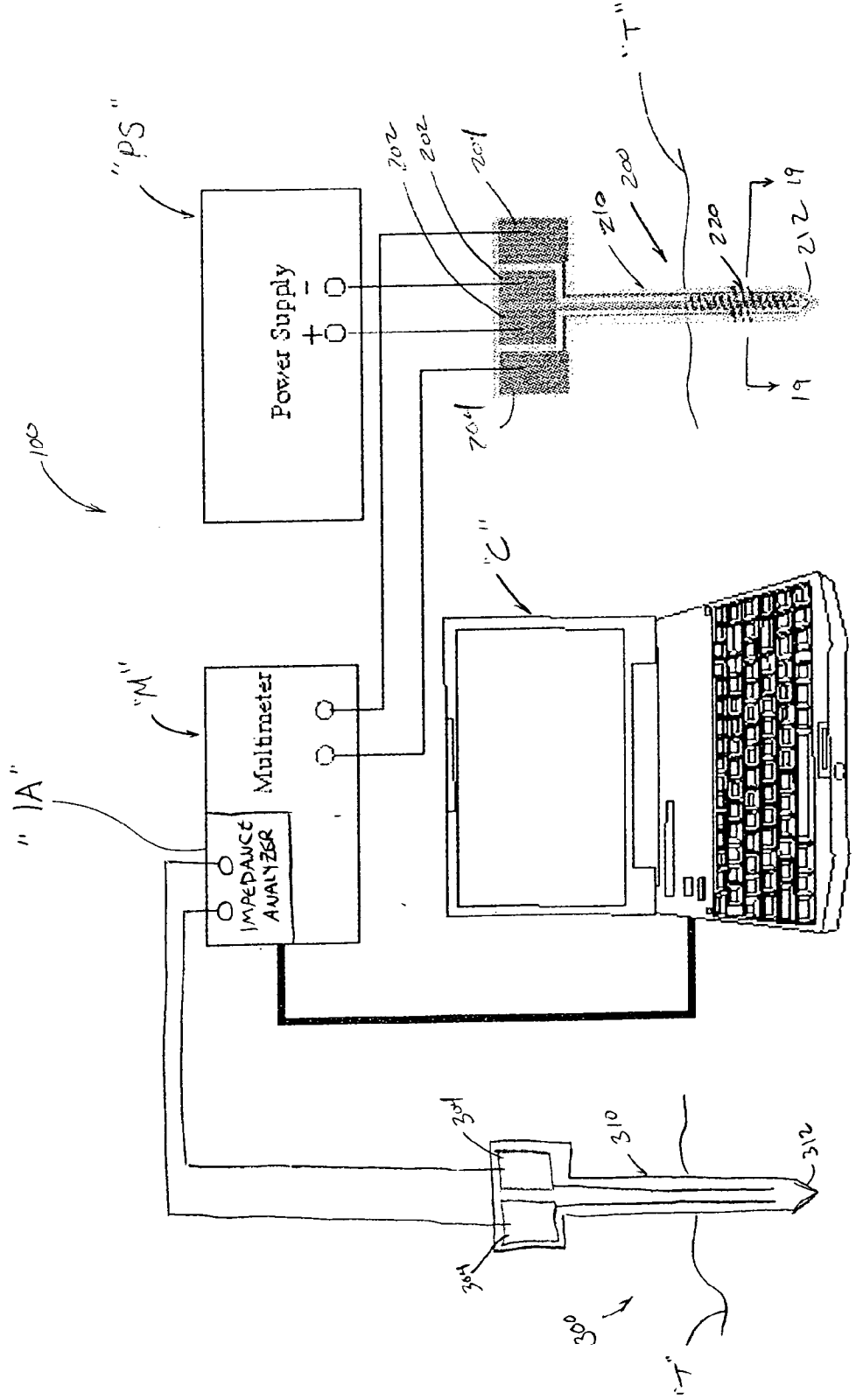
23. The method of claim 20, wherein the adhesive layer is selected from the group consisting of titanium (Ti), titanium tungsten (TiW) and platinum (Pt).

24. The method of claim 20, further comprising the step of providing an adhesive layer measuring approximately 30 nm thick.

25. The method of claim 20, wherein the conductive layer selected from the group consisting of gold (AU), iridium (Ir) and platinum-iridium (Pt-1r).

26. The method of claim 20, further comprising the step of providing a conductive layer measuring approximately 330 nm thick.

27. The method of claim 20, further comprising the step of spinning the insulative layer onto the conductive layer and pattern.


"PS"
Power Supply
-
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100
"C"
"M"
Multimeter
"IA"
IMPEDANCE ANALYZER
304
310
312
306
300
"T"

Fig. 1

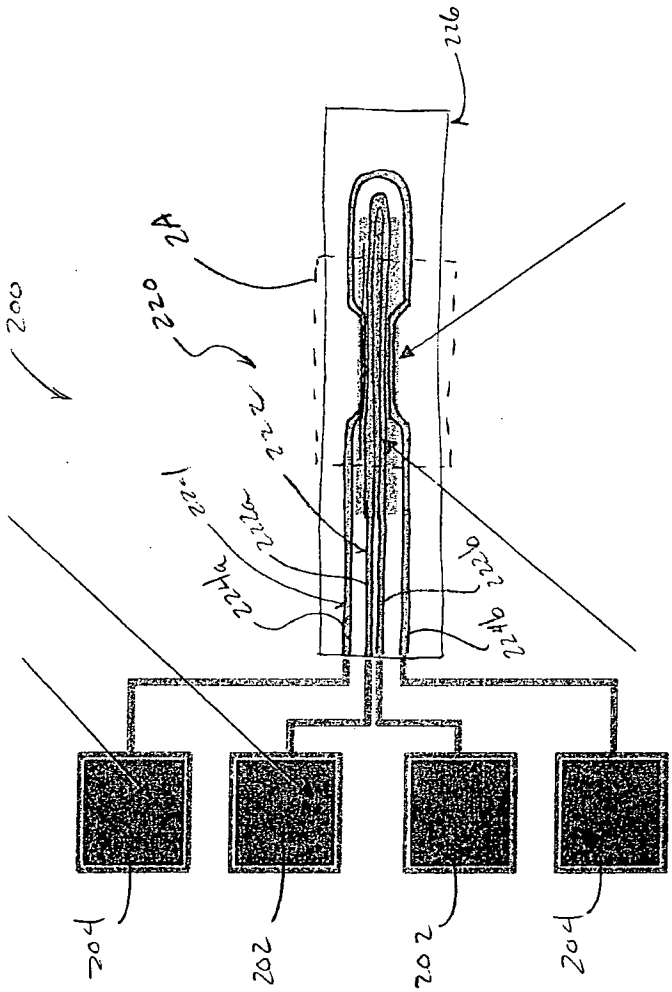


Fig. 2

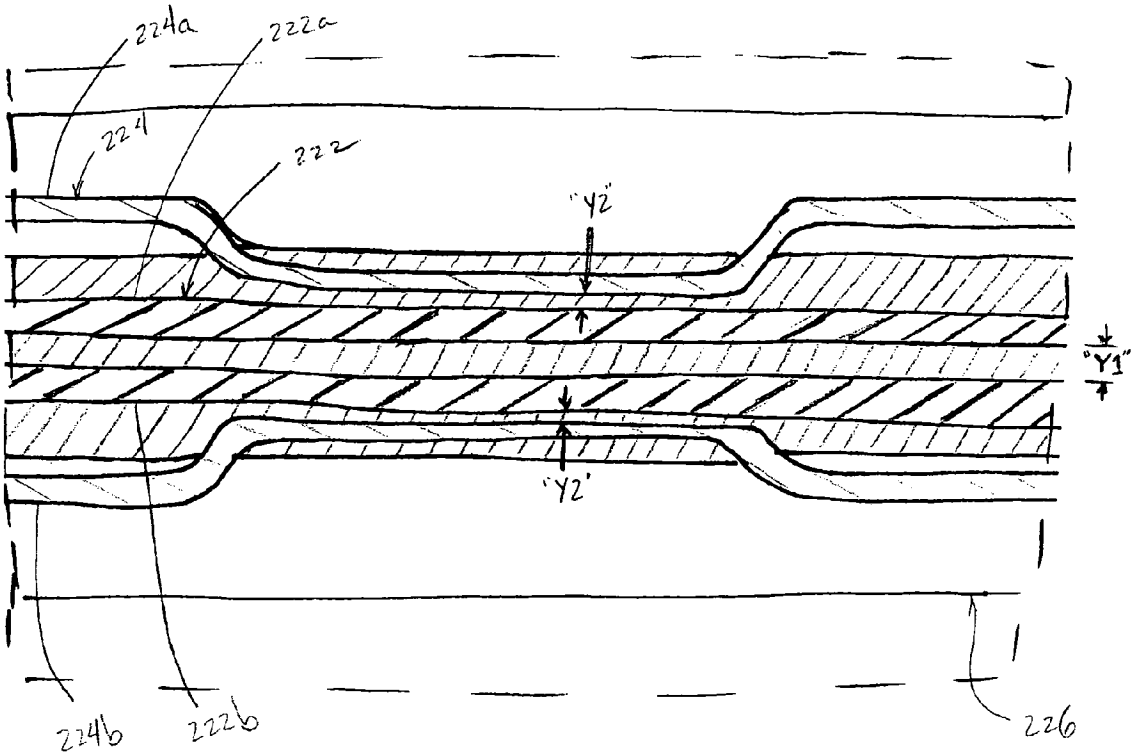


Fig. 2A

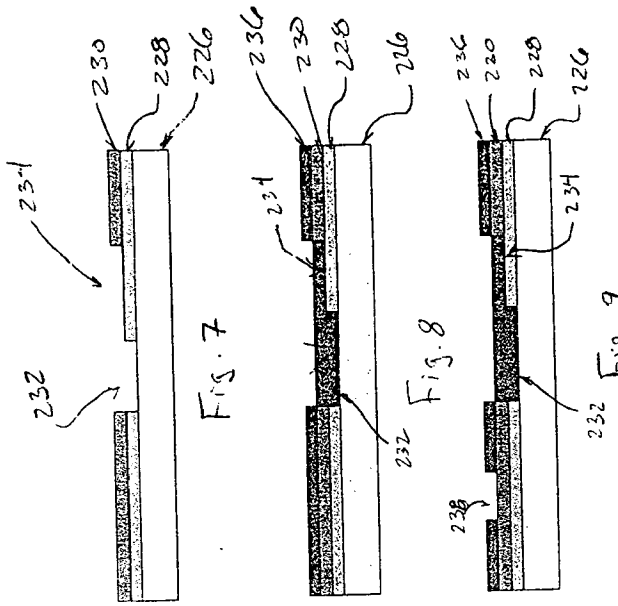


Fig. 7

Fig. 8

Fig. 9

Fig. 3

Fig. 4

Fig. 5

Fig. 6

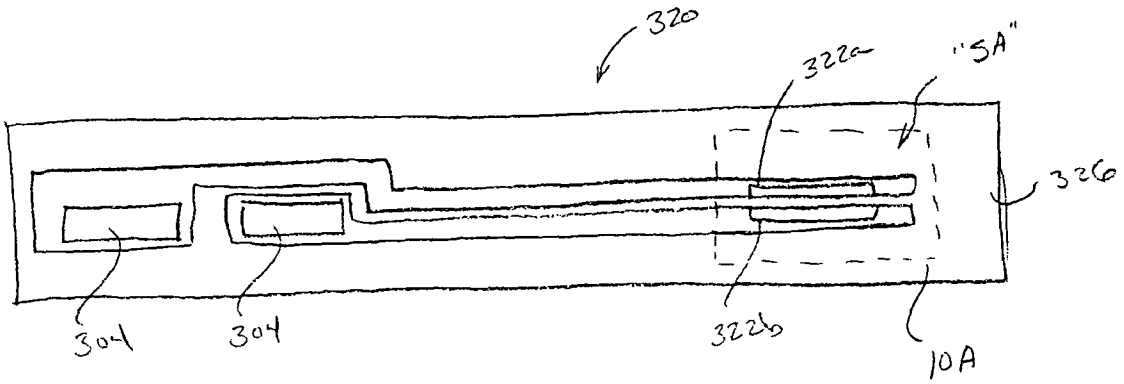


Fig. 10

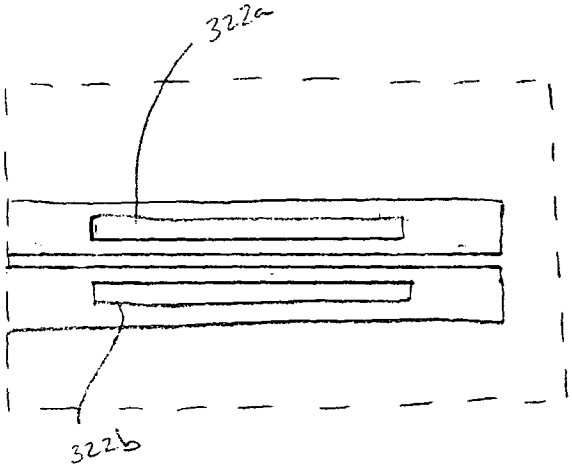


Fig. 10A

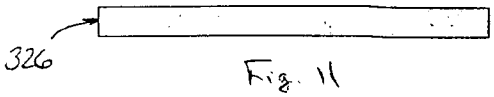
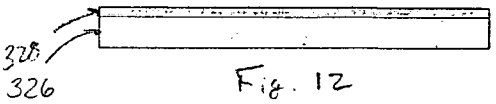


Fig. 11



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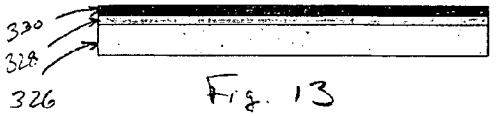

Fig. 13

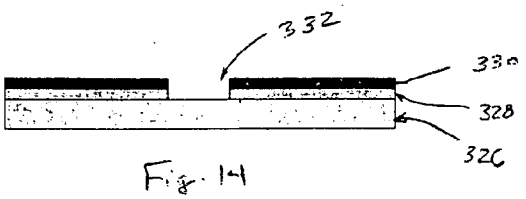

Fig. 14

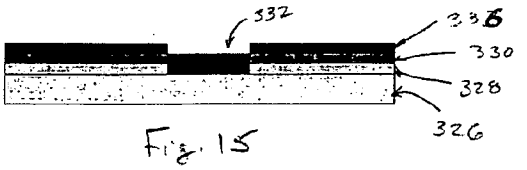

Fig. 15

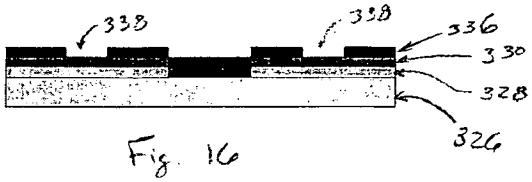

Fig. 16

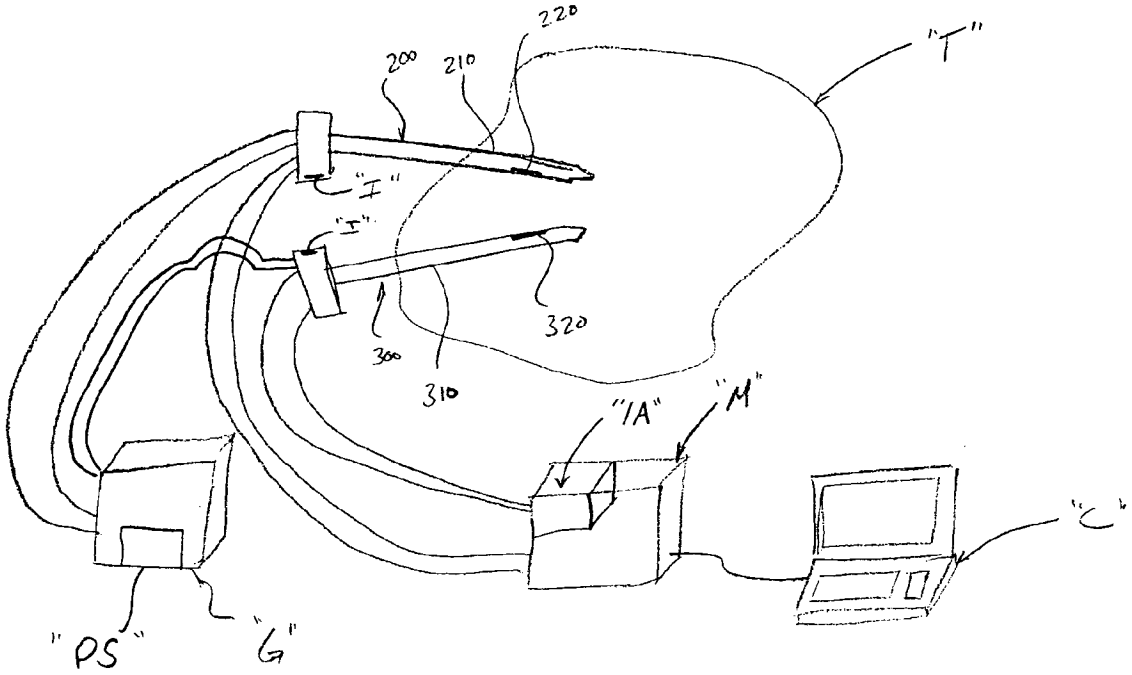
220
200
210
"T"
"I"
"I"
320
300
310
"IA"
"M"
"C"
"PS"
"G"

Fig. 17

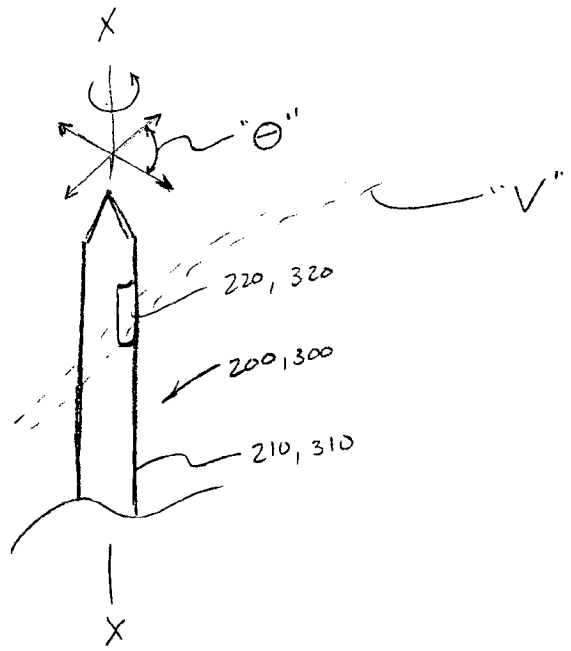
X
"θ"
"V"
220, 320
200, 300
210, 310
X

Fig. 18

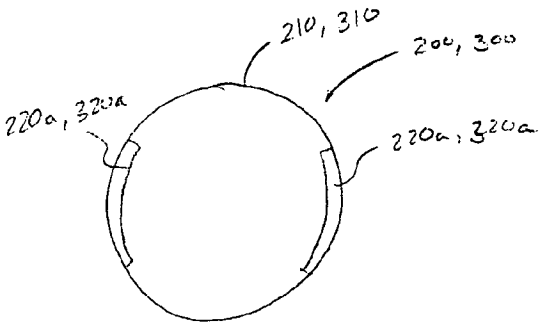

Fig. 19

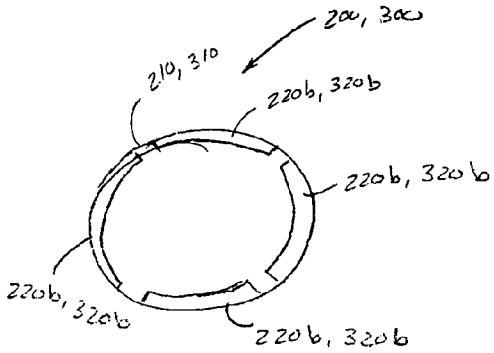

Fig. 20

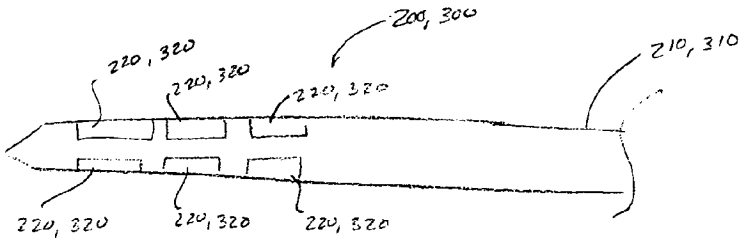

Fig. 21

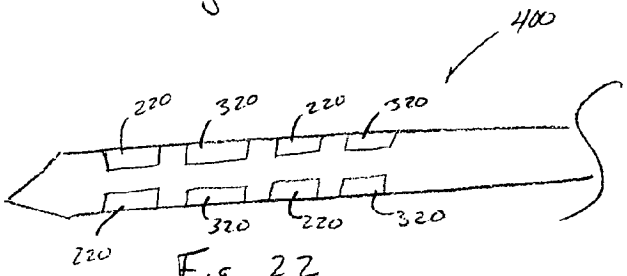

Fig. 22

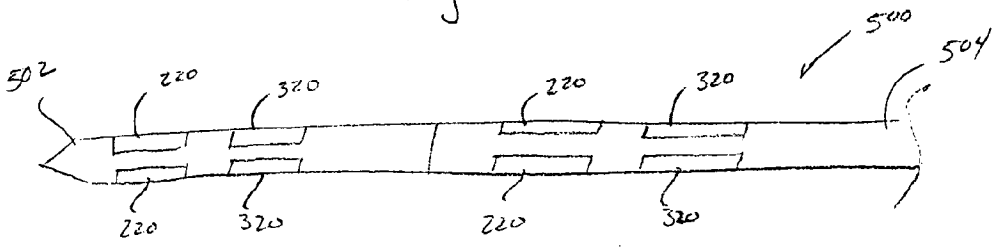

Fig. 23

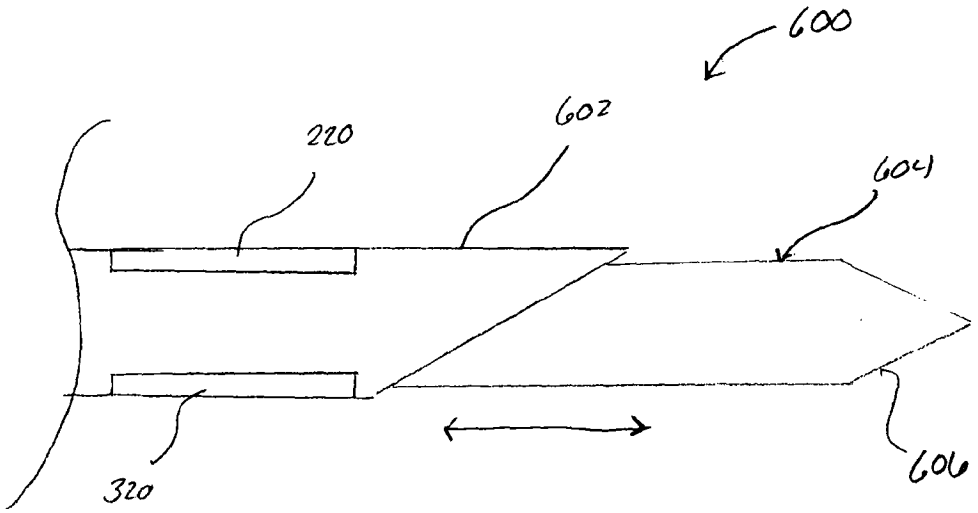

FIG. 24

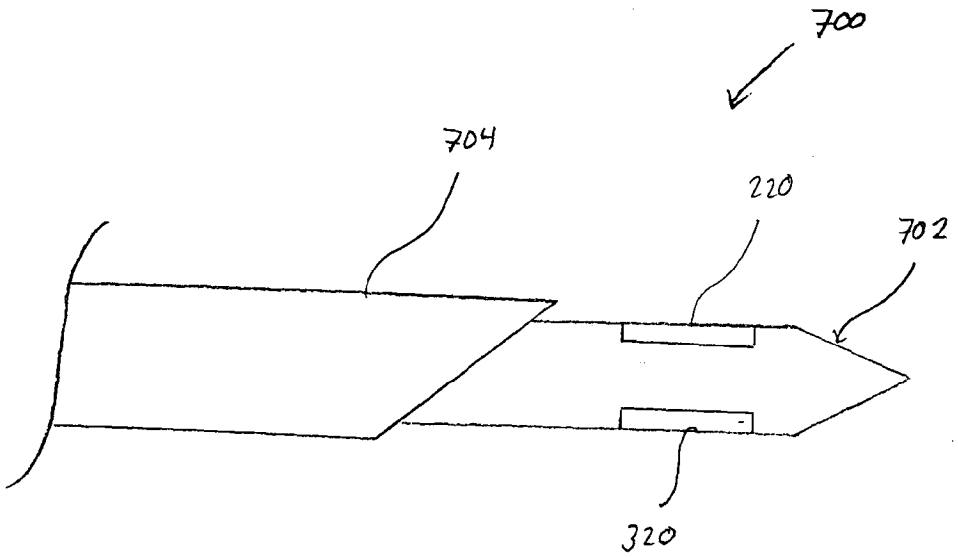

FIG. 25

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 88123807 P **[0001]**

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 **[0049]**

专利名称(译)	导热和导电探针及其制造方法		
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申请(专利权)人(译)	泰科医疗集团，LP		
当前申请(专利权)人(译)	泰科医疗集团，LP		
[标]发明人	PODHAJSKY RONALD J		
发明人	PODHAJSKY, RONALD J.		
IPC分类号	A61B5/053 A61B5/00 G01N27/04 G01N25/18 A61B5/01 A61B18/12 G01N27/18		
CPC分类号	A61B5/01 A61B5/053 A61B18/12 A61B34/10 A61B2017/00026 A61B2018/00875 G01N25/18 G01N27/045 G01N27/18 Y10T29/49 Y10T29/49002 Y10T29/49007 A61B5/0538 A61B5/055 A61B6/032 A61B6/487 A61B6/5211 A61B8/5215 A61B18/02 A61B18/1815 A61B18/20		
优先权	60/881238 2007-01-19 US		
其他公开文献	EP1946700B1 EP1946700A3		
外部链接	Espacenet		

摘要(译)

根据本公开，提供了一种用于在至少一个方向上感测组织属性的系统。该系统包括导热探针，该导热探针具有被配置为在至少一个方向上测量目标组织中的导热率的传感器，以及具有传感器的导电探针，该传感器被配置为在至少一个方向上测量目标组织中的导电率，功率供应可操作地耦合到导热探针并被配置为向导热探针供电，阻抗分析器可操作地耦合到导电探针，以及计算机可操作地耦合到电源，万用表和阻抗中的至少一个分析仪。

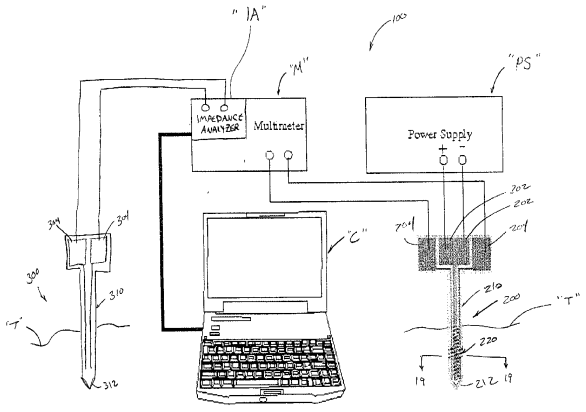

Fig. 1