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(54) Thermal and electrical conductivity probes

Wärme- und Stromleitfähigkeitssonden

Sondes à conductivité thermique et électrique

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Description

BACKGROUND

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.

2. *Discussion of Related Art*

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

[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 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.

[0006] US2004/0015162 discloses an electrosurgical probe including first and second needle electrodes having a thermocouple. WO/0070333 discloses a plane heat sensor in the form of a double spiral sandwiched between two thin electrically insulating sheets. US6190378 discloses a probe using thermistors at different locations to determine thermal conductivity at those locations. The preamble of independent claim 1 is based on US2004/0015162.

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] The present invention provides a system for sensing attributes of tissue in at least one direction. 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] The thermal conductivity probe includes a body and a sensor operably connected to the body. The sensor includes a line heater having a pair of inner resistive heating elements, a detector having a pair of outer 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 disclosed. 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 may be 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 disclosed. 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 disclosure 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 disclosure 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 disclosure of the present disclosure;

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

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

[0030] FIG. 25 is a schematic illustration of a distal end of an electrosurgical device according to still another disclosure 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 disclosure, 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 disclosure, 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 disclosure, microprobe sensor 220 may include a substrate 226 having a thickness approximately equal to 300μm to 1000μm, and in a further disclosure 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 disclosure, 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 a disclosure, substrate 326 may have a thickness between approximately 300μm and 1,000μm, and in a further disclosure 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 disclosures 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 disclosure 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 disclosure, 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 disclosure, 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 of the claims appended hereto.

Claims

1. A system (100) for sensing attributes of tissue, the system comprising:

a thermal conductivity probe (200) including a sensor (220) configured to measure a thermal conductivity in the target tissue in at least one direction;

an electrical conductivity probe (300) including a sensor (320) configured to measure an electrical conductivity in the target tissue in at least one direction;

a power supply (PS) operatively coupled to the thermal conductivity probe and configured to supply power to the thermal conductivity probe;

a multimeter (M) operatively coupled to the thermal conductivity probe;

a computer (C) operatively coupled to at least one of the power supply, the multimeter and an impedance

analyzer;
wherein the thermal conductivity probe comprises:

a body (210) defining a catheter configured for insertion into tissue; and
the sensor operably coupled to the body, **characterized in that** the sensor includes:

a line heater (222) having a pair of inner resistive heating elements (222a, b);
a detector (224) having a pair of outer detector elements (224a, b); and
a substrate (226) for supporting the line heater and the detector, wherein the substrate provides a thermal conductivity contrast.

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. The system of claim 1, 2 or 3, wherein the pair of outer detector elements are resistance temperature detector elements (RTD).

5. The system of claim 1, 2, 3 or 4, wherein the pair of inner heating elements are substantially parallel.

6. The system of any one of the preceding claims, wherein the thermal conductivity probe includes an array of sensors.

7. The system of any one of the preceding claims, wherein the electrical conductivity probe comprises:

a body (310); and
the sensor for sensing electrical conductivity, wherein the sensor includes:

a pair of electrodes (322a, 322b);
a pair of bonding pads (304) coupled to the pair of electrodes by a pair of electrical leads; and
a substrate (326) for supporting the electrodes, bonding pads and leads.

8. The probe of claim 7, wherein the pair of electrodes are parallel.

9. The probe of claim 7 or 8, wherein the body of the electrical conductivity probe defines a catheter configured for insertion into tissue.

10. The probe of claim 7, 8 or 9, 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.

11. The system of any one of the preceding claims, wherein the thermal conductivity probe is a thin-film thermal conductivity probe configured to measure thermal conductivity based on the principle of the hot-wire method.

12. The system of any one of the preceding claims, wherein the thermal conductivity probe and/or the electrical conductivity probe include at least two or multiple sensors disposed around a circumference thereof.

Patentansprüche

1. System (100) zum Erfassen von Gewebeattributen, mit:

einer Wärmeleitfähigkeitssonde (200) mit einem Sensor (220), der eingerichtet ist, in mindestens einer Richtung eine Wärmeleitfähigkeit in dem Zielgewebe zu messen;
einer elektrischen Leitfähigkeitssonde (300) mit einem Sensor (320), der eingerichtet ist, eine elektrische Leitfähigkeit in dem Zielgewebe in mindestens einer Richtung zu messen;
einer Leistungsversorgung (PS), die betriebsfähig mit der thermischen Leitfähigkeitssonde gekoppelt ist und eingerichtet ist, der Wärmeleitfähigkeitssonde Leistung zuzuführen;
einem Multimeter (M), das betriebsfähig mit der Wärmeleitfähigkeitssonde gekoppelt ist;

einem Computer (C), der betriebsfähig mit der Leistungsversorgung, dem Multimeter und/oder einem Impedanzanalysator gekoppelt ist;
wobei die Wärmeleitfähigkeitssonde aufweist:

einen Körper (210), der einen Katheter definiert, der zum Einführen in Gewebe eingerichtet ist; und der Sensor betriebsfähig mit dem Körper gekoppelt ist,

dadurch gekennzeichnet, dass der Sensor aufweist:

einen Linienheizer (222), der ein Paar innere Widerstandsheizelemente (222a, b) aufweist;
einen Detektor (224), der ein paar äußere Detektorelemente (224a, b) aufweist; und
ein Substrat (226) zum Unterstützen des Linienheizers und des Detektors, wobei das Substrat einen Wärmeleitfähigkeitskontrast bereitstellt.

2. System nach Anspruch 1, bei dem die Wärmeleitfähigkeitssonde und die elektrische Leitfähigkeitssonde in einer einzigen Sonde integriert sind.

3. System nach Anspruch 1, bei dem der Impedanzanalysator betriebsfähig mit der elektrischen Leitfähigkeitssonde gekoppelt ist.

4. System nach Anspruch 1, 2 oder 3, bei dem das Paar äußere Detektorelemente Widerstandstemperaturdetektorelemente (RTD) sind.

5. System nach Anspruch 1, 2, 3 oder 4, bei dem das Paar innere Heizelemente im Wesentlichen parallel zueinander sind.

6. System nach einem der vorstehenden Ansprüche, bei dem die Wärmeleitfähigkeitssonde einen Sensorarray aufweist.

7. System nach einem der vorstehenden Ansprüche, bei dem die elektrische Leitfähigkeitssonde aufweist:

einen Körper (310); und
den Sensor zum Erfassen elektrischer Leitfähigkeit, wobei der Sensor aufweist:

ein Paar Elektroden (322a, 322b);
ein Paar Kontaktpads (304), das durch ein Paar elektrische Leitungen mit einem Paar Elektroden gekoppelt ist; und
ein Substrat (326) zum Unterstützen der Elektroden, Kontaktpads und Leitungen.

8. Sonde nach Anspruch 7, bei der das Paar Elektroden parallel zueinander sind.

9. Sonde nach Anspruch 7 oder 8, bei der der Körper der elektrischen Leitfähigkeitssonde einen Katheter definiert, der zum Einführen in Gewebe eingerichtet ist.

10. Sonde nach Anspruch 7, 8 oder 9, bei der der Sensor ein Isolationsmaterial aufweist, das zumindest teilweise das Paar Elektroden überdeckt und einen freigestellten Bereich, der in der Isolation ausgebildet ist und mit jeder Elektrode verknüpft ist.

11. System nach einem der vorstehenden Ansprüche, bei dem die Wärmeleitfähigkeitssonde eine Dünnfilm-Wärmeleitfähigkeitssonde ist, die eingerichtet ist, die Wärmeleitfähigkeit auf Grundlage des Prinzips der Heißdrahtmethode zu messen.

12. System nach einem der vorstehenden Ansprüche, bei dem die Wärmeleitfähigkeitssonde und/oder die elektrische Leitfähigkeitssonde mindestens zwei oder mehr Sensoren aufweist, die um ihren Umfang angeordnet sind.

Revendications

1. Système (100) pour détecter des attributs de tissu, le système comprenant:

une sonde à conductivité thermique (200) incluant un capteur (220) configuré pour mesurer une conductivité thermique dans le tissu cible dans au moins une direction;
une sonde à conductivité électrique (300) incluant un capteur (320) configuré pour mesurer une conductivité électrique dans le tissu cible dans au moins une direction;
une alimentation (PS) fonctionnellement couplée à la sonde à conductivité thermique et configurée pour fournir de la puissance à la sonde à conductivité thermique;
un mulimètre (M) fonctionnellement couplé à la sonde à conductivité thermique;
un ordinateur (C) fonctionnellement couplé à au moins un parmi l'alimentation, le multimètre et un analyseur d'impédance;
où la sonde à conductivité thermique comprend:

un corps (210) définissant un cathéter configuré pour l'insertion dans le tissu; et
le capteur étant fonctionnellement couplé au corps, **caractérisé en ce que** le capteur comprend:

un organe de chauffage de ligne (222) comportant une paire d'éléments chauffants résistifs intérieurs (222a, b);
un détecteur (224) comportant une paire d'éléments de détecteur extérieurs (224a, b); et
un substrat (226) pour supporter l'organe de chauffage de ligne et le détecteur, où le substrat fournit un contraste de conductivité thermique.

2. Système selon la revendication 1, où la sonde à conductivité thermique et la sonde à conductivité électrique sont intégrées en une seule sonde.

3. Système selon la revendication 1, où l'analyseur d'impédance est fonctionnellement couplée à la sonde à conductivité électrique.

4. Système selon la revendication 1, 2 ou 3, où la paire d'éléments de détecteur extérieurs sont des éléments de détecteur de température à résistance (RTD).

5. Système selon la revendication 1, 2, 3 ou 4, où les deux éléments de chauffage intérieurs sont sensiblement parallèles.

6. Système selon l'une quelconque des revendications précédentes, où la conductivité thermique comprend un groupement de capteurs.

7. Système selon l'une quelconque des revendications précédentes, où la sonde à conductivité électrique comprend:

un corps (310); et
le capteur pour détecter la conductivité électrique, où le capteur comprend:

deux électrodes (322a, 322b);
deux plots de connection (304) couplés aux deux électrodes par deux conducteurs électriques; et
un substrat (326) pour supporter les électrodes, les plots de connection et les conducteurs.

8. Sonde selon la revendication 7, où les deux électrodes sont parallèles.

9. Sonde selon la revendication 7 ou 8, où le corps de la sonde à conductivité électrique définit un cathéter configuré pour l'insertion dans le tissu.

10. Sonde selon la revendication 7, 8 ou 9, où le capteur comprend un matériau d'isolation recouvrant au moins partiellement les deux électrodes, et une région exposée formée dans l'isolation et associée à chaque électrode.

11. Système selon l'une quelconque des revendications précédentes, où la sonde à conductivité thermique est une sonde à conductivité thermique à film mince configurée pour mesurer la conductivité thermique sur la base du

principe de la méthode à fil-chaud.

12. Système selon l'une quelconque des revendications précédentes, où la sonde à conductivité thermique et/ou à conductivité électrique comprennent au moins deux ou plusieurs capteurs disposés autour de leur circonférence.

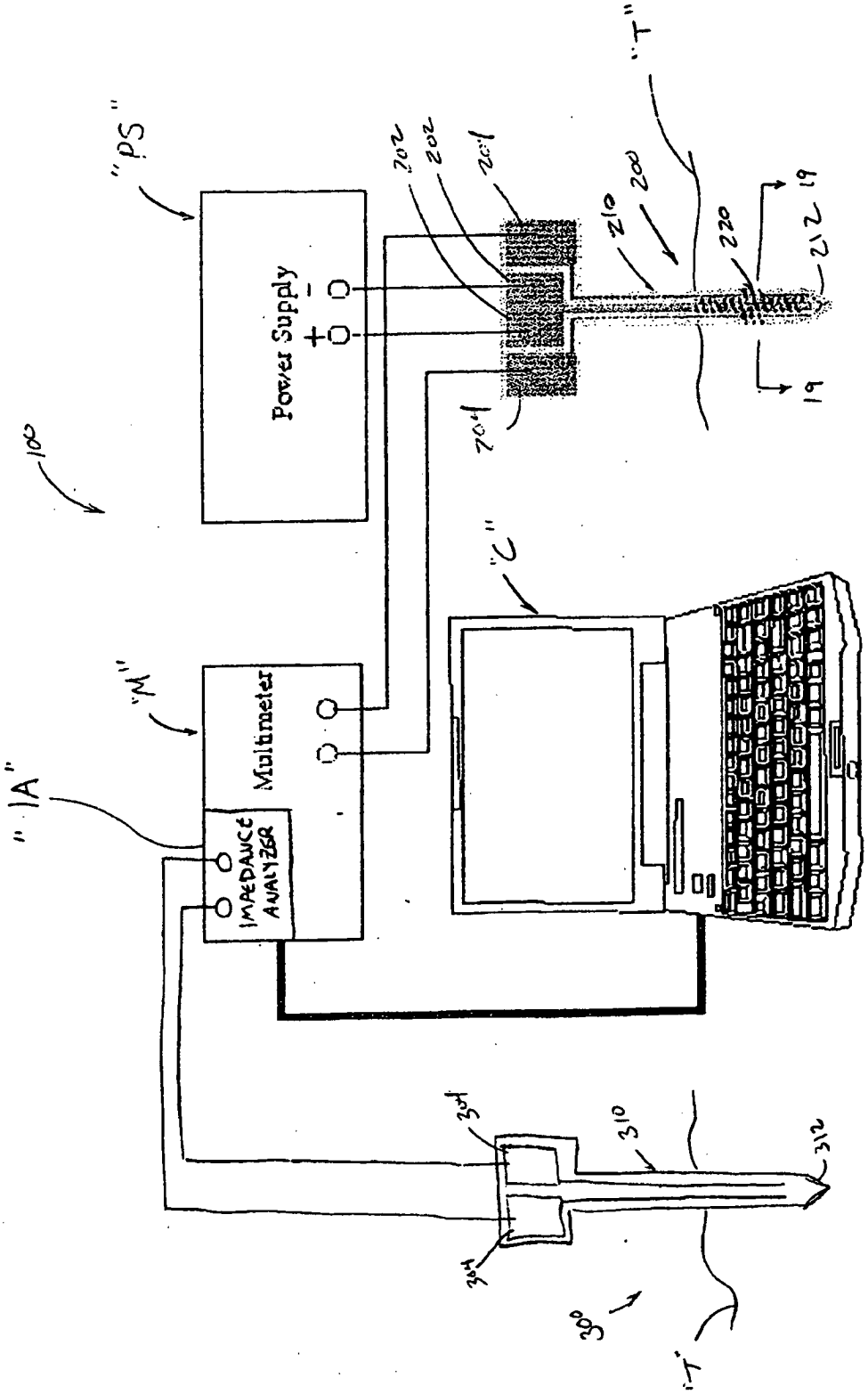
"PS"
Power Supply
-
+
202
202
204
204
"T"
210
200
220
212
19
19
100
"C"
"M"
Multimeter
IMPEDANCE ANALYZER
"IA"
304
310
312
304
300
"T"

Fig. 1

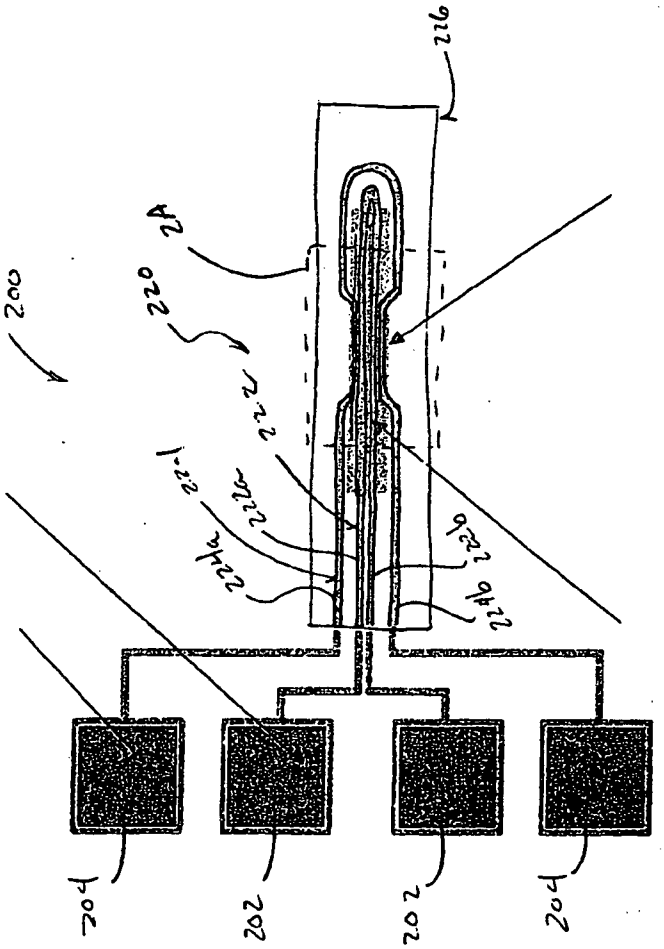

Fig. 2

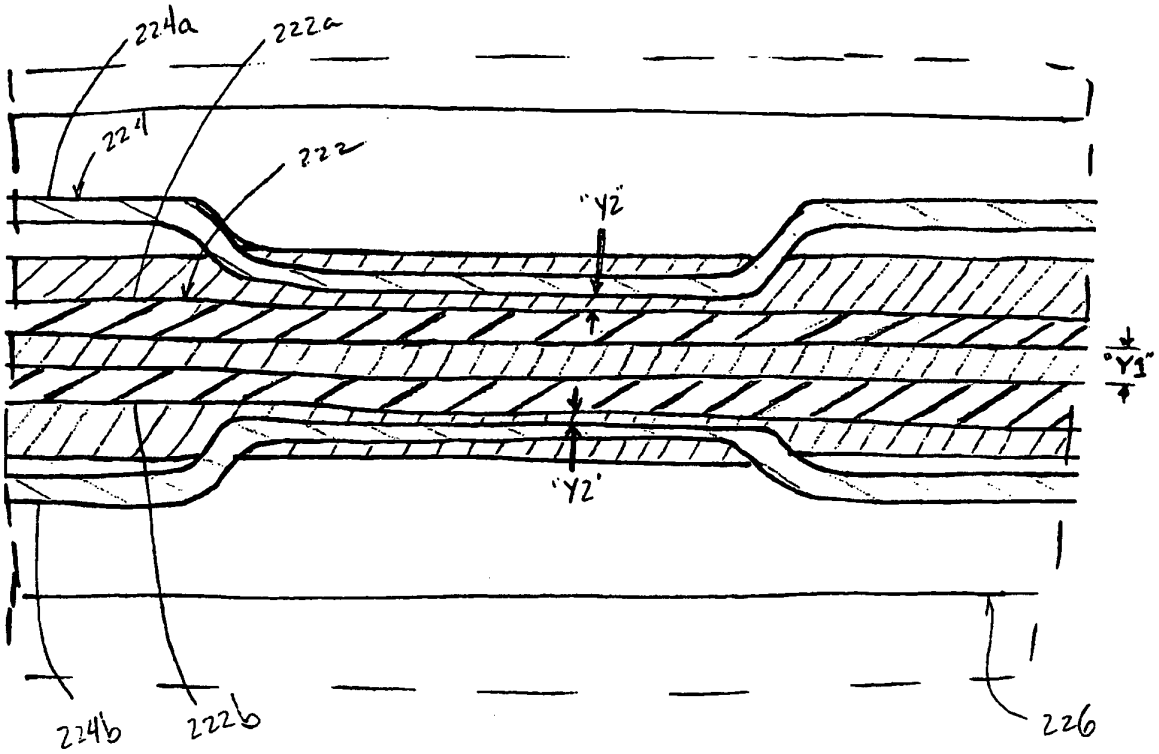

Fig. 2A

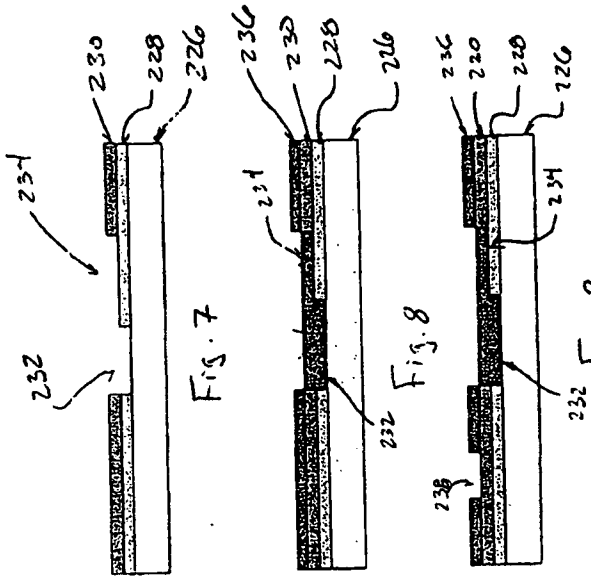

Fig. 7 Fig. 8 Fig. 9

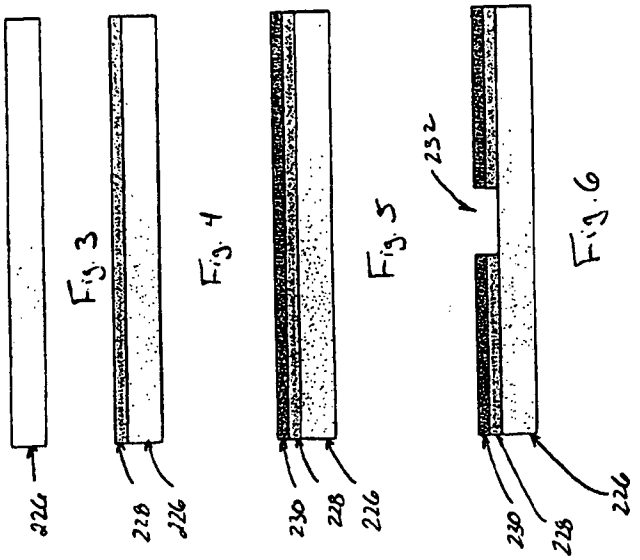

Fig. 3 Fig. 4 Fig. 5 Fig. 6

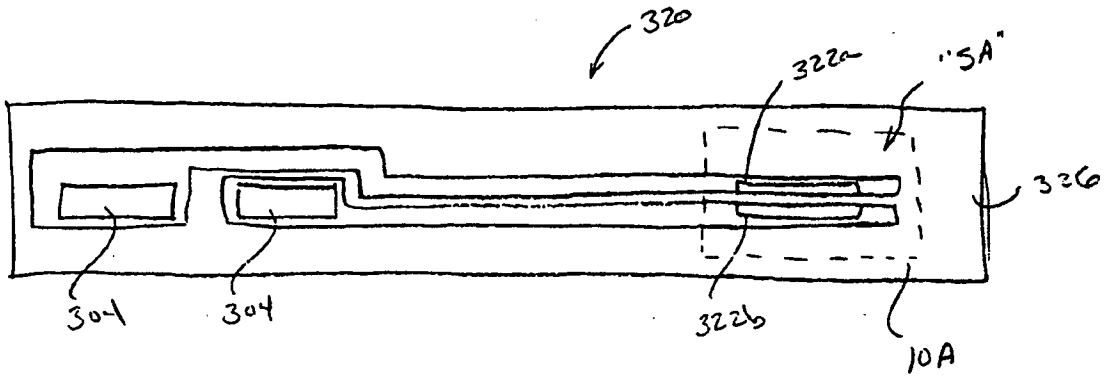

Fig. 10

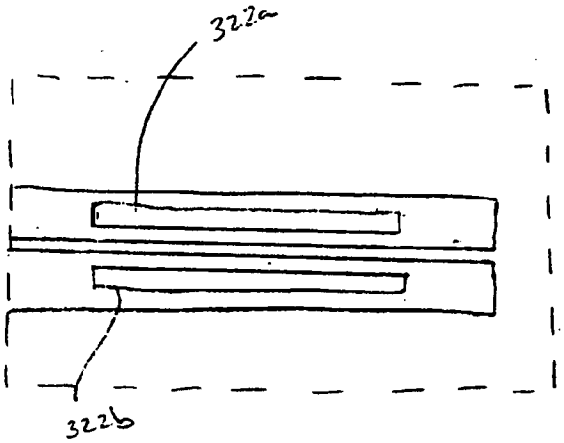

Fig. 10A

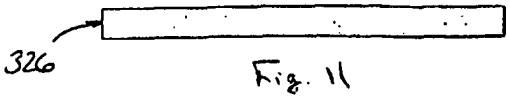

Fig. 11

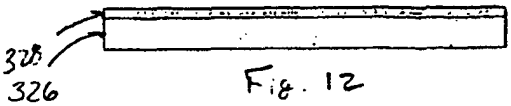

Fig. 12

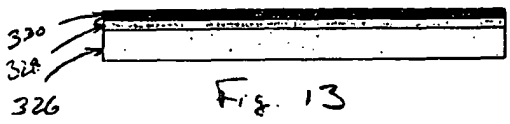

Fig. 13

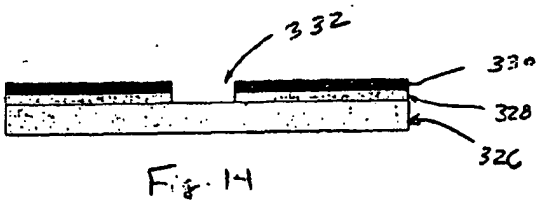

Fig. 14

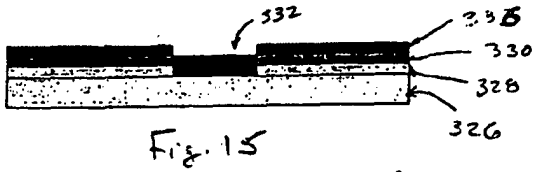

Fig. 15

Fig. 16

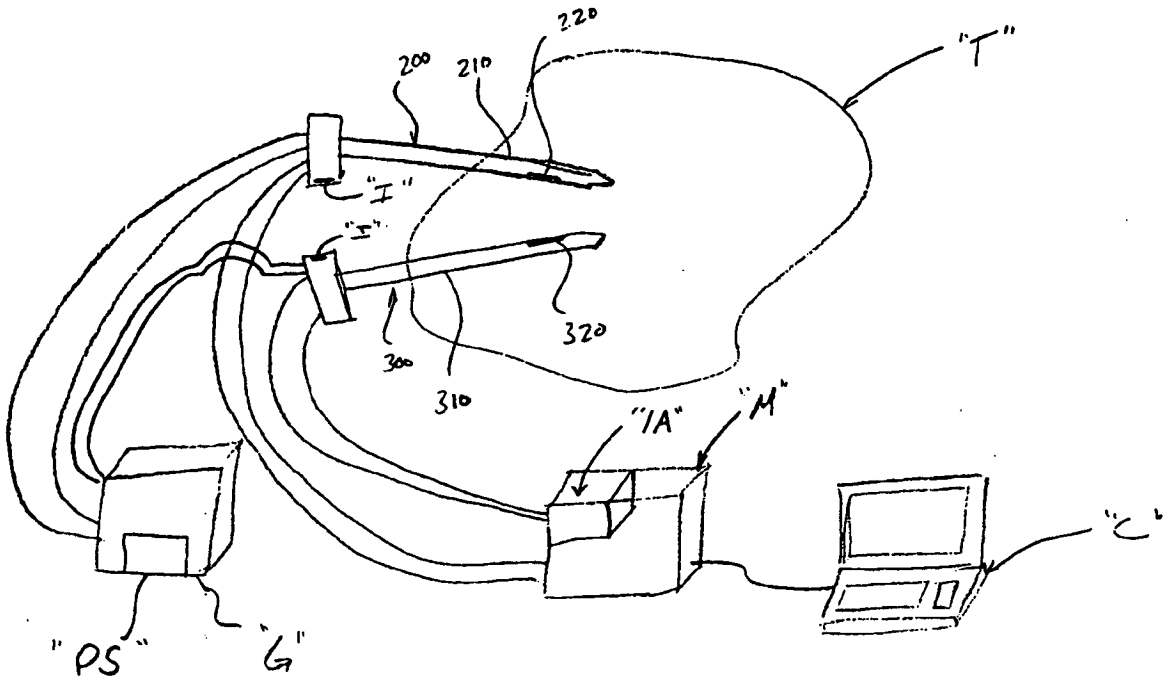
220
200
210
"T"
"I"
"I"
320
300
310
"IA"
"M"
"C"
"PS"
"G"

Fig. 17

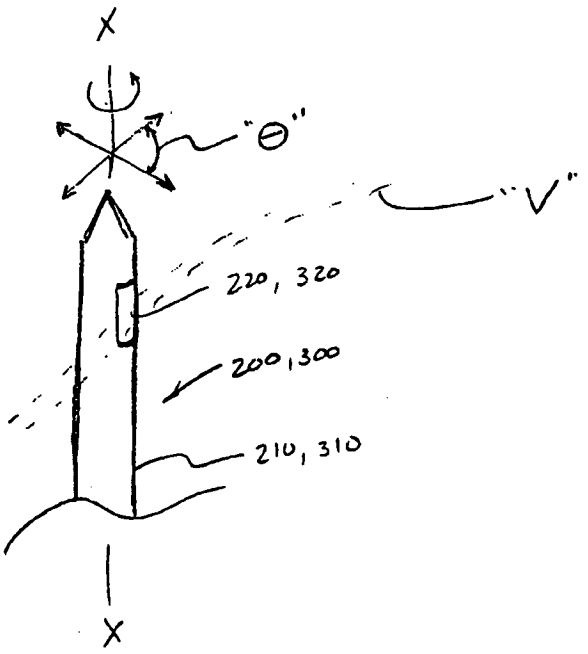
X
"θ"
"V"
220, 320
200, 300
210, 310
X

Fig. 18

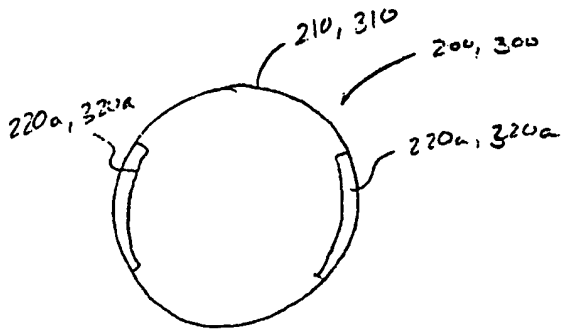

Fig. 19

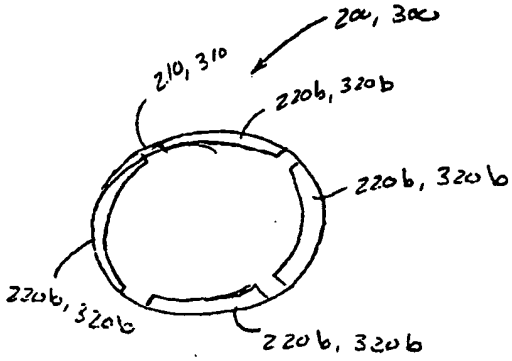

Fig. 20

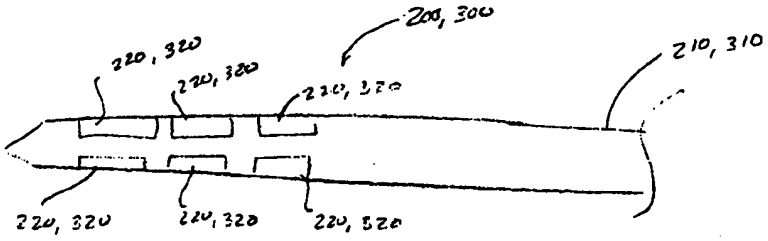

Fig. 21

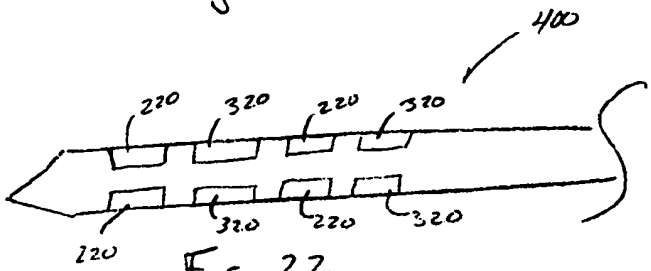

Fig. 22

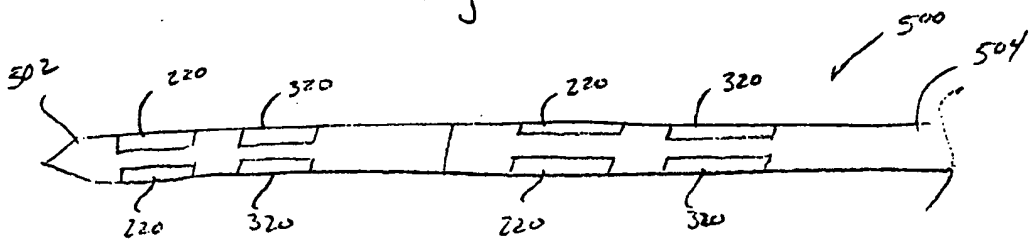

Fig. 23

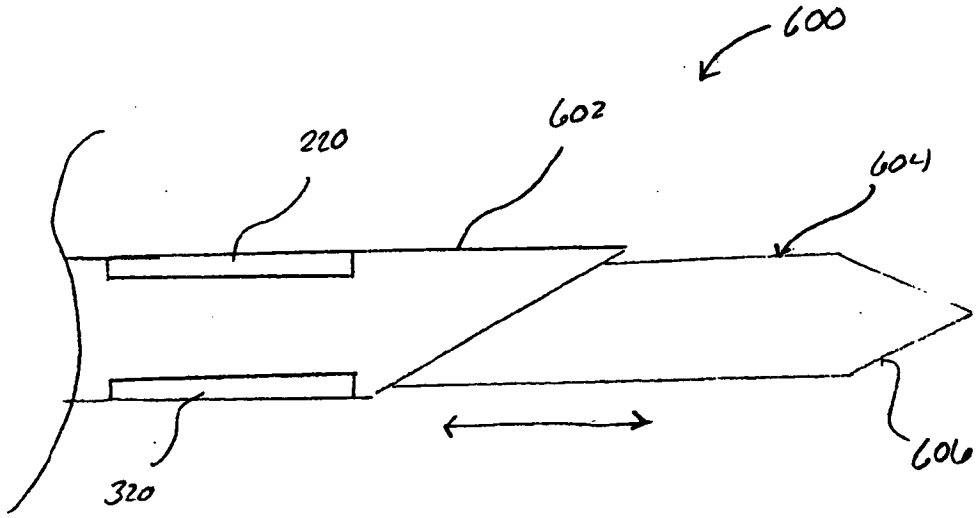

FIG. 24

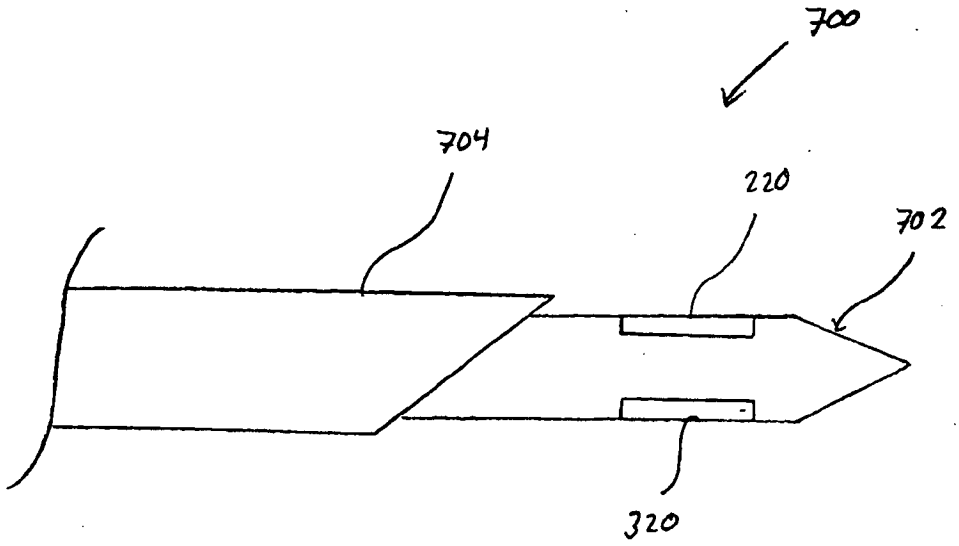

FIG. 25

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20040015162 A **[0006]**
- WO 0070333 A **[0006]**
- US 6190378 B **[0006]**

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]**

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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		
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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	EP1946700A2 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。