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(54) **ULTRASOUND MEDICAL SYSTEM**

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(51) **Int. Cl.**
A61N 7/02 (2006.01)

(52) **U.S. Cl.** **601/3**; 600/549

(58) **Field of Classification Search** 600/437, 600/438, 442, 459, 439, 472, 407, 457, 470; 607/2, 3, 6; 601/2, 3

See application file for complete search history.

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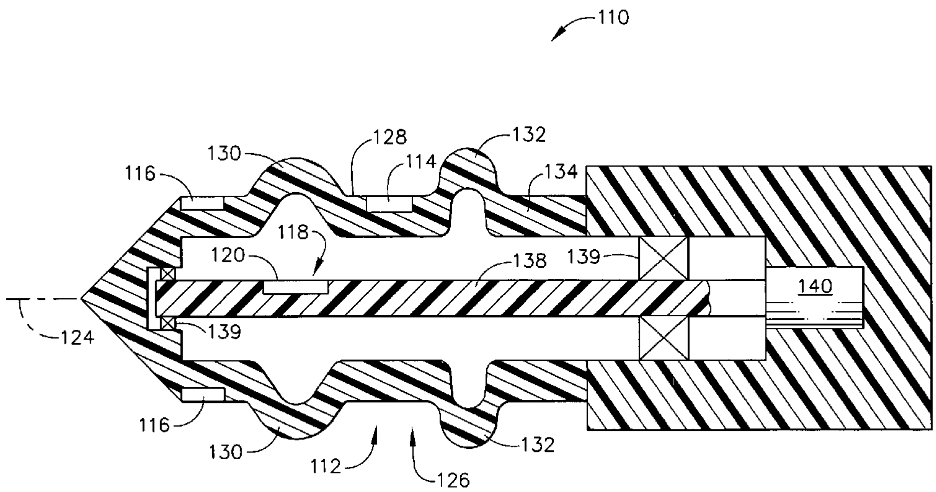
Primary Examiner — Eric F Winakur
Assistant Examiner — Vani Gupta

(57) **ABSTRACT**

An ultrasound medical system includes an ultrasound end effector and at least one non-ultrasound tissue-property-measuring sensor. The ultrasound end effector includes a medical ultrasound transducer assembly having at least one medical-treatment ultrasound transducer. The at-least-one non-ultrasound tissue-property-measuring sensor is supported by the ultrasound end effector and is positionable in contact with patient tissue.

13 Claims, 6 Drawing Sheets



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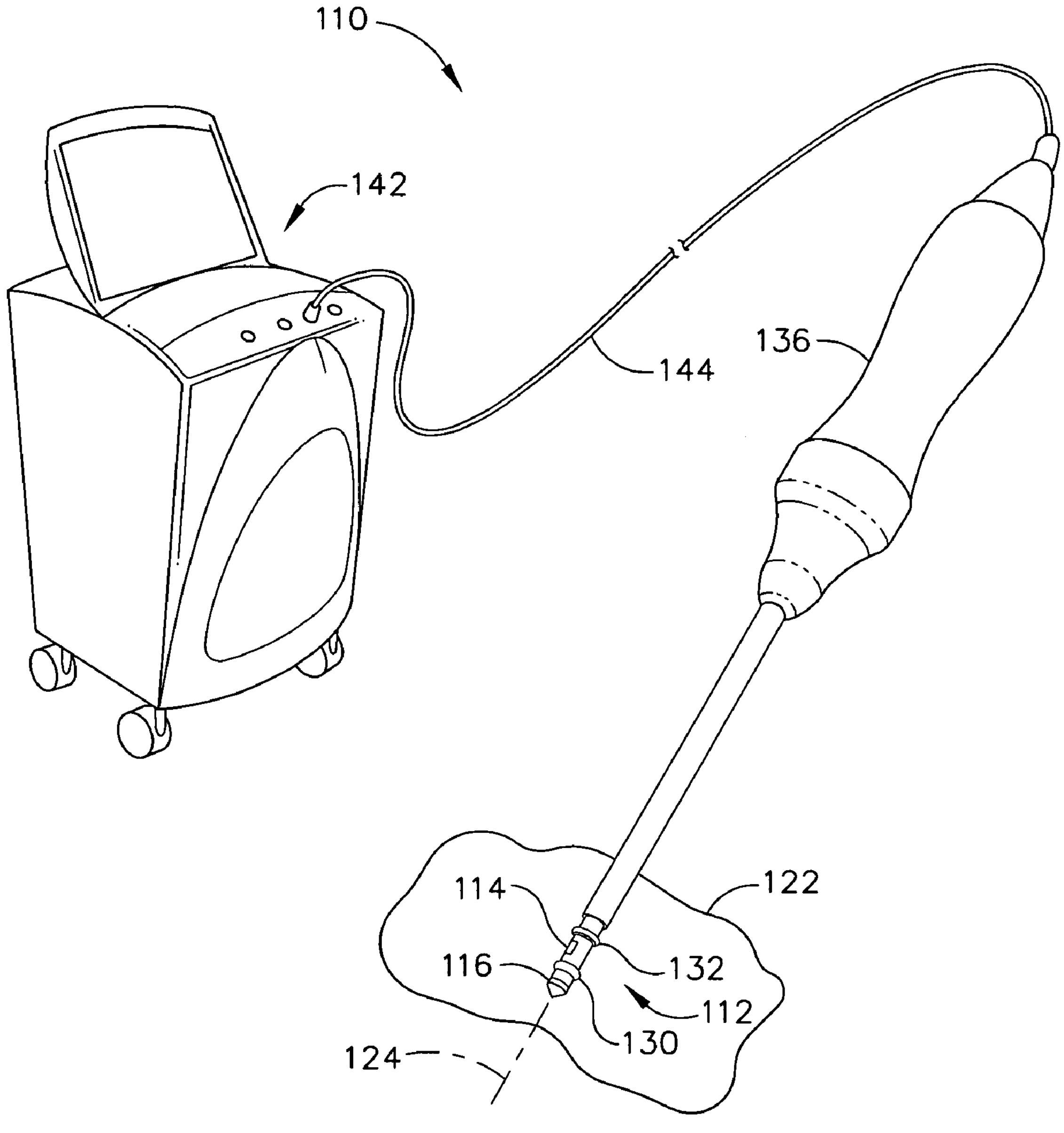

FIG. 1

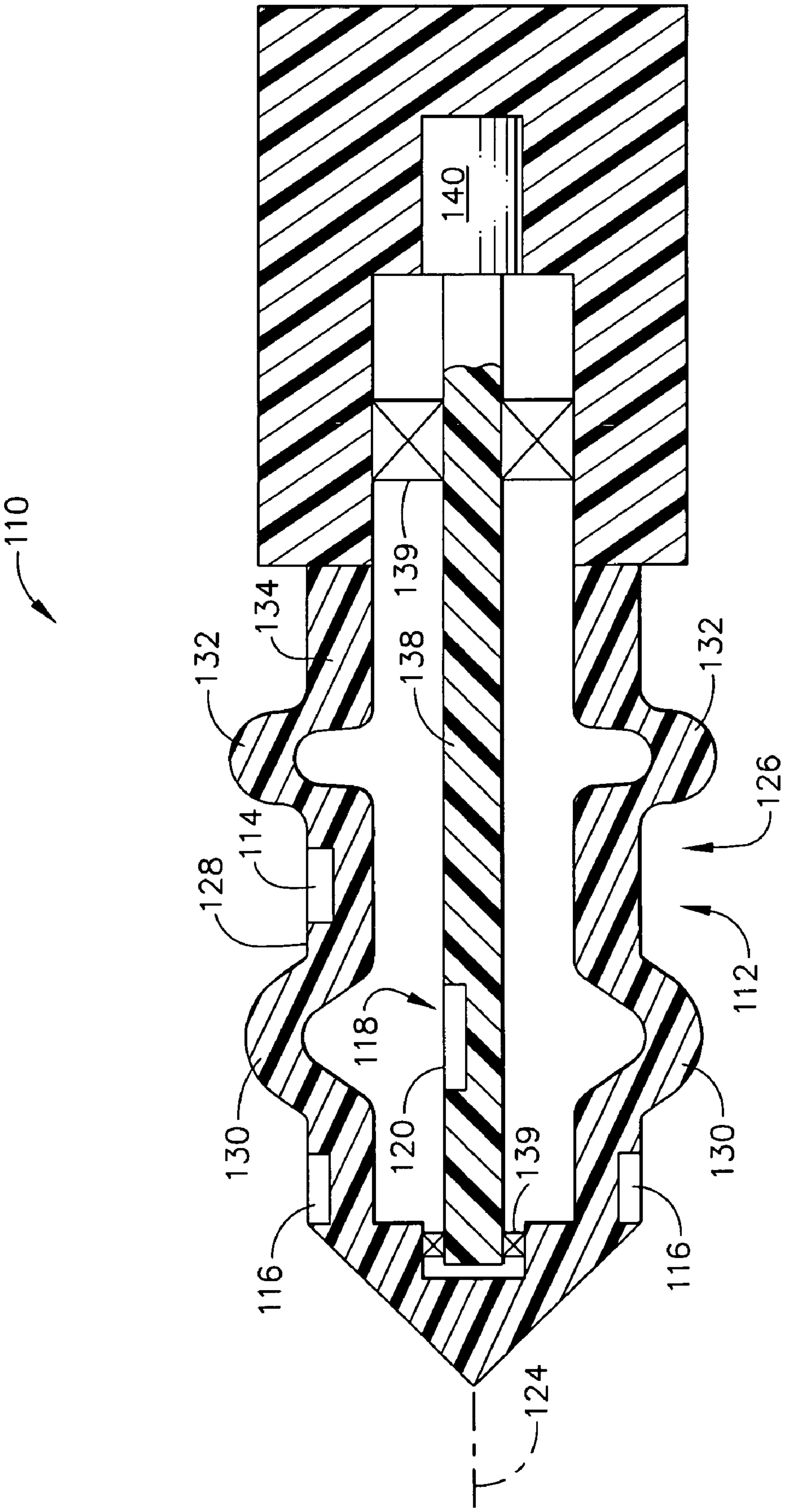
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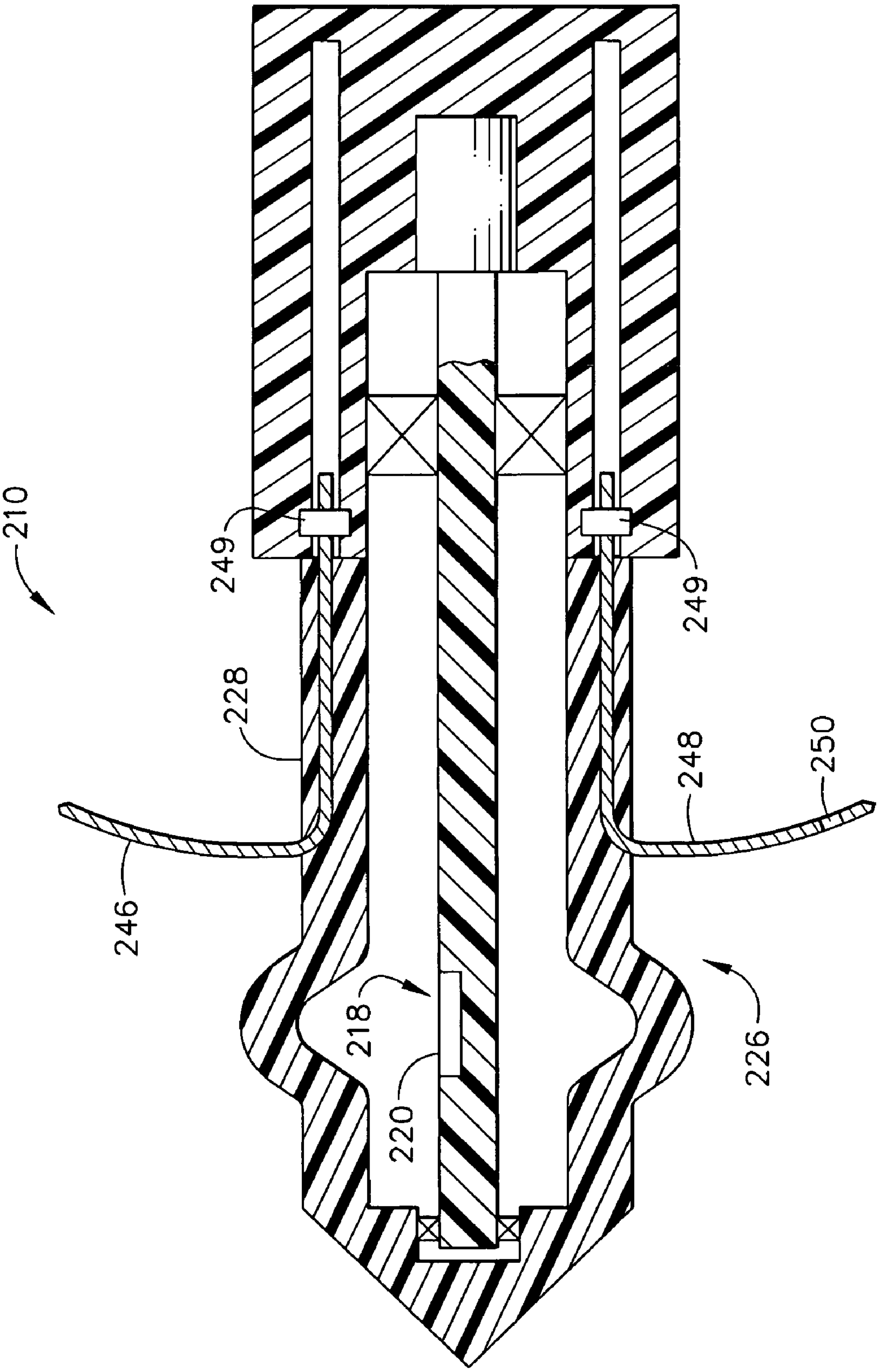
FIG. 2



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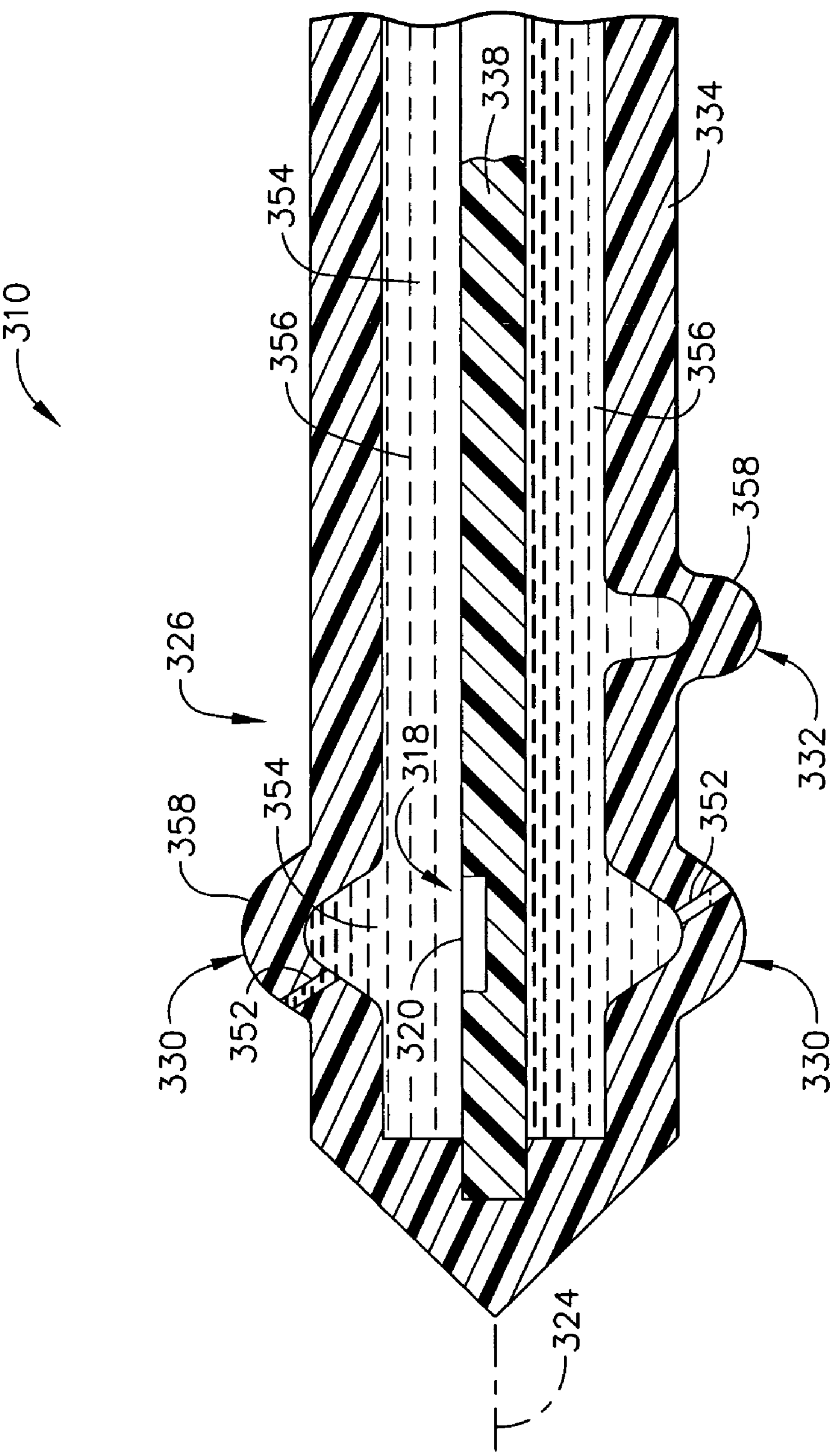
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FIG. 4

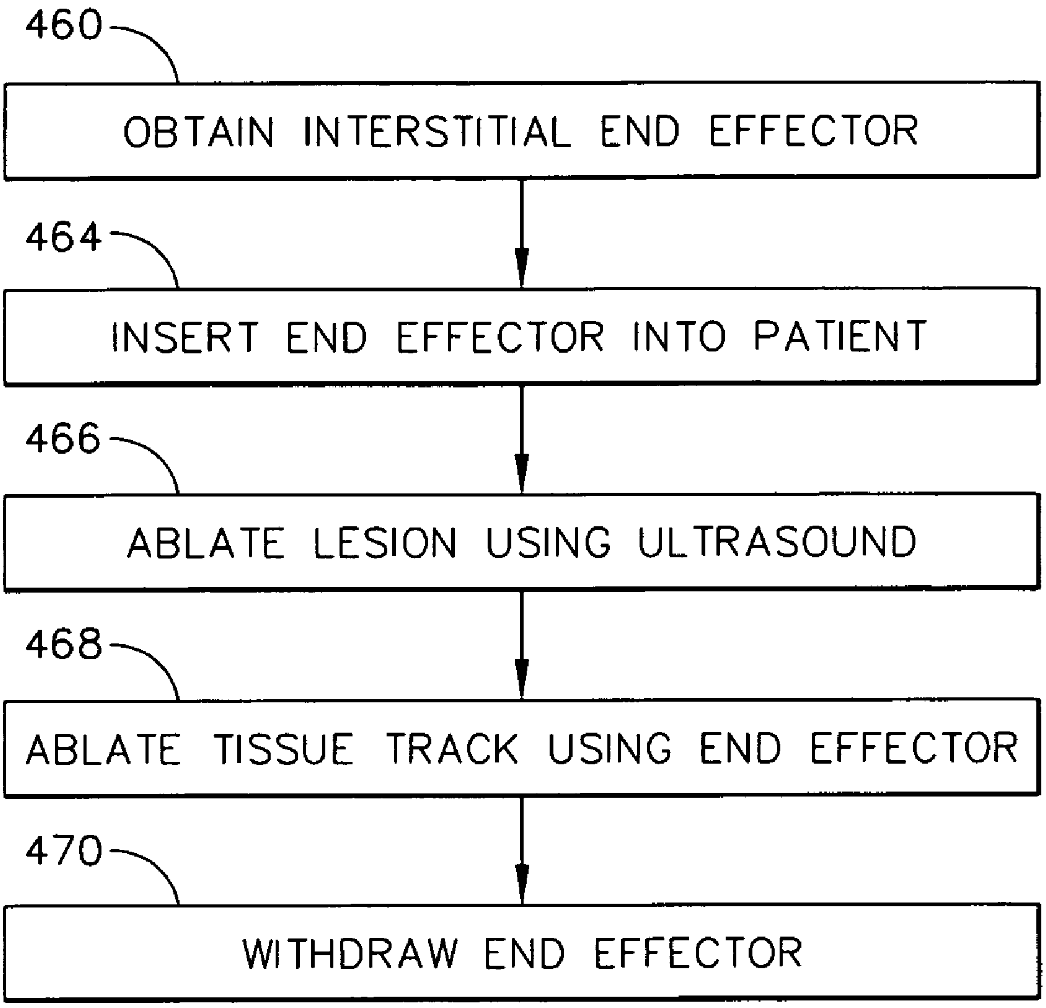
460
OBTAIN INTERSTITIAL END EFFECTOR
464
INSERT END EFFECTOR INTO PATIENT
466
ABLATE LESION USING ULTRASOUND
468
ABLATE TISSUE TRACK USING END EFFECTOR
470
WITHDRAW END EFFECTOR

FIG. 5

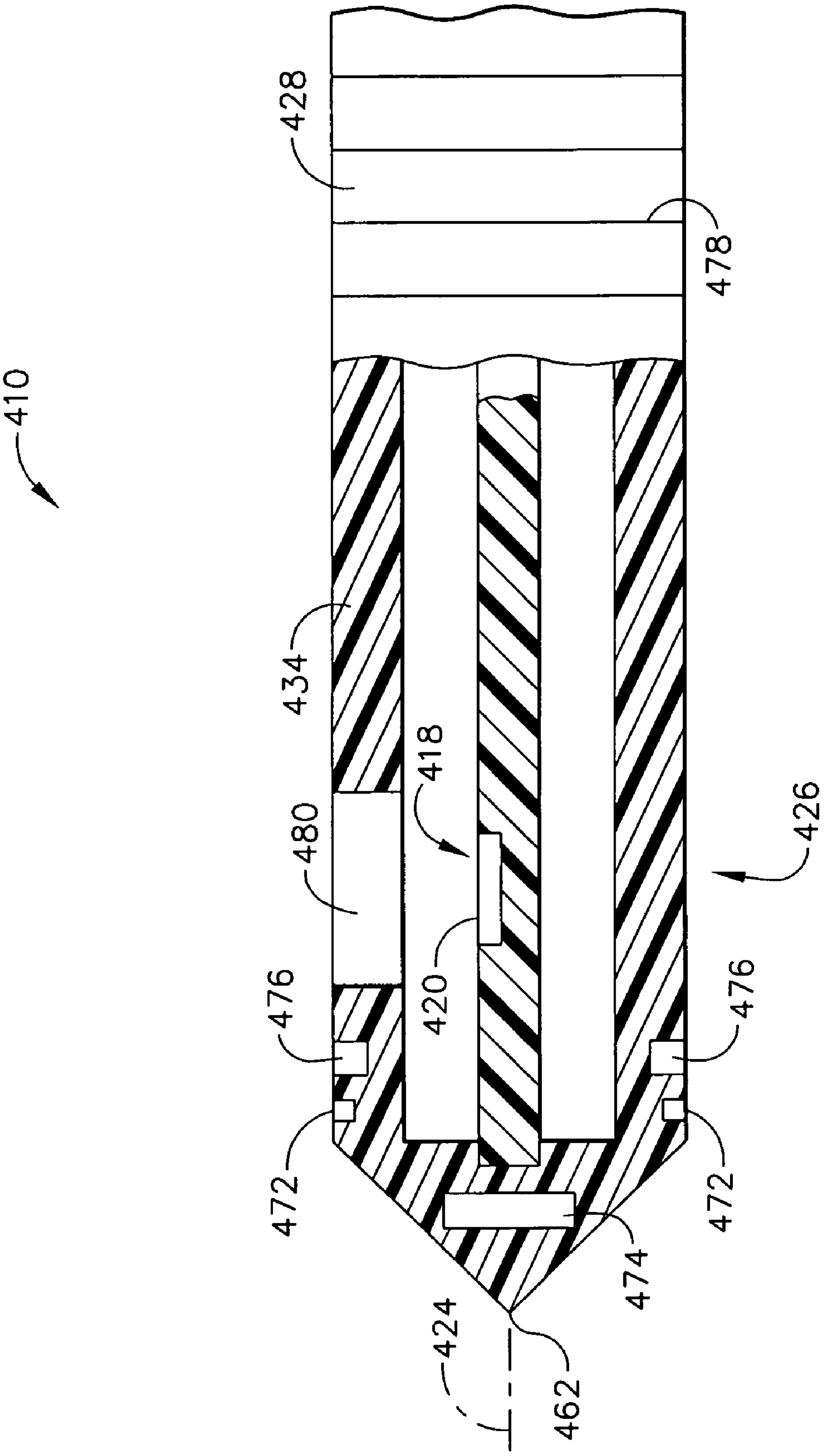

FIG. 6

ULTRASOUND MEDICAL SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to ultrasound, and more particularly to ultrasound medical systems and methods.

BACKGROUND OF THE INVENTION

Known medical methods include using ultrasound imaging (at low power) of patients to identify patient tissue for medical treatment and include using ultrasound (at high power) to ablate identified patient tissue by heating the tissue.

Known ultrasound medical systems and methods include deploying an ultrasound end effector having an ultrasound transducer outside the body to break up kidney stones inside the body, endoscopically inserting an ultrasound end effector having an ultrasound transducer in the rectum to medically destroy prostate cancer, laparoscopically inserting an ultrasound end effector having an ultrasound transducer in the abdominal cavity to medically destroy a cancerous liver tumor, intravenously inserting a catheter ultrasound end effector having an ultrasound transducer into a vein in the arm and moving the catheter to the heart to medically destroy diseased heart tissue, and interstitially inserting a needle ultrasound end effector having an ultrasound transducer needle into the tongue to medically destroy tissue to reduce tongue volume to reduce snoring.

Rotatable ultrasound end effectors are known wherein an ultrasound transducer is non-rotatably attached to a shaft whose distal end is circumferentially and longitudinally surrounded by a sheath having a longitudinal axis and having an acoustic window. Water between the shaft and the sheath provides acoustic coupling between the ultrasound transducer and the acoustic window. The shaft is rotatable about the longitudinal axis with respect to the sheath. The sheath is non-rotatably attached to a handpiece.

Known medical systems and methods include deploying a radio-frequency (RF) end effector having an RF electrode to thermally ablate patient tissue and to take tissue electric impedance and tissue temperature measurements using electrodes integrated into the shaft or into a tine which also helps stabilize the RF end effector in patient tissue.

Still, scientists and engineers continue to seek improved ultrasound medical systems and methods.

SUMMARY OF THE INVENTION

An embodiment of the invention is an ultrasound medical system including an ultrasound end effector and including at least one non-ultrasound tissue-property-measuring sensor. The ultrasound end effector includes a medical ultrasound transducer assembly having at least one medical-treatment ultrasound transducer. The at-least-one non-ultrasound tissue-property-measuring sensor is supported by the ultrasound end effector and is positionable in contact with patient tissue.

Several benefits and advantages are obtained from one or more of the embodiments and methods of the invention. In one example, having a non-ultrasound tissue-property-measuring sensor (such as a tissue temperature sensor and/or a tissue electric impedance sensor) allows ultrasound tissue ablation with feedback from the sensor used to evaluate the tissue ablation and/or modify the ultrasound treatment.

The present invention has, without limitation, application in conventional interstitial, endoscopic, laparoscopic, and open surgical instrumentation as well as application in robotic-assisted surgery.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a perspective view of a first embodiment of the present invention showing an ultrasound medical system which includes an end effector, a handpiece, and a controller;

FIG. **2** is a schematic cross-sectional view of a first embodiment of the end effector and the handpiece of the ultrasound medical system of FIG. **1** showing a medical ultrasound transducer assembly and two non-ultrasound tissue-property-measuring sensors;

FIG. **3** is a view, as in FIG. **2**, but of a second embodiment of a handpiece and of an end effector having a medical ultrasound transducer assembly and two tines;

FIG. **4** is a view, as in FIG. **2**, but of a third embodiment of an end effector having a medical ultrasound transducer assembly supported by a shaft and having a surrounding sheath, wherein the sheath includes two balloon portions;

FIG. **5** is a block diagram view of a method of the invention for ultrasonically treating a lesion in a patient; and

FIG. **6** is a schematic view, partially in cross-section, of a fourth embodiment of an end effector which has a medical-treatment ultrasound transducer and three end-effector-tissue-track ablation devices and which can be used in one employment of the method of FIG. **5**.

DETAILED DESCRIPTION OF THE INVENTION

Before explaining the present invention in detail, it should be noted that the invention is not limited in its application or use to the details of construction and arrangement of parts and/or steps illustrated in the accompanying drawings and description. The illustrative embodiments and methods of the invention may be implemented or incorporated in other embodiments, methods, variations and modifications, and may be practiced or carried out in various ways. Furthermore, unless otherwise indicated, the terms and expressions employed herein have been chosen for the purpose of describing the illustrative embodiments and methods of the present invention for the convenience of the reader and are not for the purpose of limiting the invention.

It is understood that any one or more of the following-described embodiments, methods, examples, etc. can be combined with any one or more of the other following-described embodiments, methods, examples, etc.

Referring now to FIGS. **1-2** of the drawings, a first embodiment of the present invention is an ultrasound medical system **110** comprising an ultrasound end effector **112** and at least one non-ultrasound tissue-property-measuring sensor **114** and **116**. The ultrasound end effector **112** includes a medical ultrasound transducer assembly **118** having at least one medical-treatment ultrasound transducer **120**. The at-least-one non-ultrasound tissue-property-measuring sensor **114** and **116** is supported by the ultrasound end effector **112** and is disposable in contact with patient tissue **122**.

It is noted that a medical-treatment ultrasound transducer includes a medical-treatment-only ultrasound transducer and a medical-imaging-and-treatment ultrasound transducer. In one arrangement, an ultrasound transducer has a single transducer element, and in another arrangement, an ultrasound transducer has a plurality (also called an array) of transducer elements. It is also noted that a medical ultrasound transducer assembly having at least one medical-treatment ultrasound transducer can also have at least one medical-imaging ultrasound transducer.

In one example of the embodiment of FIGS. **1-2**, the ultrasound end effector **112** includes a longitudinal axis **124**. In this example, the at-least-one non-ultrasound tissue-property-measuring sensor **114** and **116** includes a first non-ultrasound tissue-property-measuring sensor **114** and a second non-ultrasound tissue-property-measuring sensor **116**. The at-least-one medical-treatment ultrasound transducer **120** is disposed longitudinally between the first and second non-ultrasound tissue-property-measuring sensors **114** and **116**.

In one variation of the embodiment of FIGS. **1-2**, the at-least-one non-ultrasound tissue-property-measuring sensor (e.g., **114**) measures tissue temperature. In one modification, the at-least-one non-ultrasound tissue-property-measuring sensor (e.g., **114**) is chosen from the group consisting of a thermistor, a thermocouple, and combinations thereof. In another variation, the at-least-one non-ultrasound tissue-property-measuring sensor (e.g., **116**) measures tissue electric impedance. In one modification, the at-least-one non-ultrasound tissue-property-measuring sensor (e.g., **116**) is chosen from the group consisting of a monopolar electrode, a bipolar electrode, and combinations thereof. It is noted that tissue temperature and/or tissue electric impedance is a measure of the degree of ultrasonic ablation of patient tissue, as can be appreciated by those skilled in the art.

In one construction of the embodiment of FIGS. **1-2**, the ultrasound end effector **112** is an ultrasound interstitial end effector **126** which is interstitially insertable into patient tissue **122** and which has an exterior surface **128**. The at-least-one non-ultrasound tissue-property-measuring sensor **114** and **116** is attached to the ultrasound interstitial end effector **126** and is fixedly disposed substantially flush with the exterior surface **128**. In one arrangement, the exterior surface **128** includes at least one balloon portion **130** and **132** which is expandable and contractible and which is expandable against patient tissue **122** to provide at least some stabilization of the ultrasound interstitial end effector **126** with respect to patient tissue **122**. In one variation, the exterior surface **128** is the exterior surface of a sheath **134** and has first and second balloon portions **130** and **132**, wherein the first balloon portion **130** surrounds the medical ultrasound transducer assembly **118** and acts as an acoustic window, and wherein the second balloon portion **132** is longitudinally spaced apart from the medical ultrasound transducer assembly **118**. An acoustic coupling medium, such as water, is disposable between the medical ultrasound transducer assembly **118** and the first balloon portion **130** and has been omitted from FIG. **2** for clarity. In one modification, the first balloon portion **130** is omitted and the sheath **134** terminates before the medical ultrasound transducer assembly **118** which is exposed to patient tissue. In another modification, the second balloon portion **132** is omitted. In one employment, the at-least-one balloon portion **130** and **132** is contracted during tissue insertion and withdrawal of the ultrasound interstitial end effector **126**. Other constructions, arrangements, variations, and modifications are left to the artisan.

In one enablement of the embodiment of FIGS. **1-2**, the ultrasound end effector **112** is an ultrasound interstitial end effector **126** which is interstitially insertable into patient tissue **122** and which has an exterior surface **128**. In this enablement, the at-least-one non-ultrasound tissue-property-measuring sensor **114** and **116** is deployable to extend away from the exterior surface into patient tissue **128** to provide at least some stabilization of the ultrasound interstitial end effector **126** with respect to patient tissue **122** and is retrievable to retract back toward the exterior surface **128**. In one arrangement, the at-least-one non-ultrasound tissue-property-measuring sensor **114** and **116** is storable inside the exterior surface.

In one implementation of the embodiment of FIGS. **1-2**, the ultrasound medical system **110** also includes a handpiece **136** operatively connected to the ultrasound end effector **112**, The ultrasound end effector **112** has a longitudinal axis **124** and a shaft **138**, and the medical ultrasound transducer assembly **118** is supported by the shaft **138**. The shaft **138** is rotatable with respect to the handpiece **136** about the longitudinal axis **124** and is supported by bearings **139**. In one variation, a motor **140** rotates the shaft **138**. In one arrangement, the ultrasound medical system **110** includes a controller **142** operatively connected to the handpiece **136** via a cable **144**.

A second embodiment of the present invention, shown in FIG. **3**, is an ultrasound medical system **210** comprising an ultrasound end effector **226**. The ultrasound end effector **226** has an exterior surface **228**. The ultrasound end effector **226** includes a medical ultrasound transducer assembly **218** having at least one medical-treatment ultrasound transducer **220**, and includes at least one tine **246** and **248**. The at-least-one tine **246** and **248** is deployable to extend away from the exterior surface into patient tissue to provide at least some stabilization of the ultrasound end effector **226** with respect to patient tissue and is retrievable to retract back toward the exterior surface **228**.

In one example of the embodiment of FIG. **3**, the ultrasound end effector **226** is insertable into a patient. In one variation, the ultrasound end effector **226** is an ultrasound interstitial end effector which is interstitially insertable into patient tissue. In other variations, the ultrasound end effector is insertable into a patient in an endoscopic, laparoscopic, and/or open surgical manner. In another example, the ultrasound end effector is disposable on the outside of a patient. Other examples and variations are left to the artisan.

In one enablement of the embodiment of FIG. **3**, the at-least-one tine **246** and **248** includes a plurality of tines. In one example of the embodiment of FIG. **3**, the at-least-one tine **246** and **248** is storable inside the exterior surface. It is noted that construction of deployable tines **246** and **248** in an ultrasound end effector **226** is within the level of skill of the artisan. In one arrangement, such deployment is accomplished using one or more of cables, levers, motors **249**, gearing, push rods and the like to move a tine partially out of, and back into, a lumen in the end effector. In one choice of materials, the tine comprises or consists essentially of Nitinol wire or nichrome wire.

In one employment of the embodiment of FIG. **3**, the at-least-one tine (e.g., **246**) acts as an element chosen from the group consisting of an electrode, a thermistor, a thermocouple, an acoustic reflector, an acoustic absorber, an acoustic emitter, an acoustic receiver, a radio-frequency (RF) heater, a resistive heater, and combinations thereof. In another employment, the at-least-one tine (e.g., **248**) includes a component **250** chosen from the group consisting of an electrode, a thermistor, a thermocouple, an acoustic reflector, an acoustic absorber, an acoustic emitter, an acoustic receiver, a radio-frequency (RF) heater, a resistive heater, and combinations thereof.

The embodiment, examples, constructions, implementations, etc. of the embodiment of FIGS. **1-2** are equally applicable to the embodiment, constructions, implementations, etc. of FIG. **3**. In one construction of the embodiment of FIG. **3**, the exterior surface **228** is like the exterior surface **128** of a previously-illustrated and described construction of the embodiment of FIGS. **1-2** including at least one balloon portion which is expandable and contractible, and which is expandable against patient tissue to provide at least some stabilization of the ultrasound end effector with respect to patient tissue. In one implementation of the embodiment of FIG. **3**, the ultrasound medical system **210** also includes, like a previously-illustrated and described implementation of the embodiment of FIGS. **1-2**, a handpiece operatively connected to the ultrasound end effector, wherein the ultrasound end effector has a longitudinal axis and a shaft, wherein the medical ultrasound transducer assembly is supported by the shaft, and wherein the shaft is rotatable with respect to the handpiece about the longitudinal axis.

One method, using the embodiment of FIG. **3** and enablements, examples, employments, and constructions thereof, is for ultrasonically treating a lesion in a patient and includes steps a) through f). Step a) includes obtaining the ultrasound medical system **210**. Step b) includes inserting the ultrasound end effector **226** into patient tissue. Step c) includes deploying the plurality of tines **246** and **248** to extend sway from the exterior surface **228** into the patient tissue. Step d) includes ultrasonically ablating the lesion using the at-least-one medical-treatment ultrasound transducer **220**. Step e) includes retrieving the plurality of tines **246** and **248** to retract back toward the exterior surface and storing the plurality of tines **246** and **248** inside the exterior surface **228**. Step f) includes withdrawing the ultrasound end effector **226** from the patient tissue. Another method also includes the step of employing the plurality of tines **246** and **248** to each act as the element or using each component **250**. An additional method also includes the step of expanding the at-least-one balloon portion against patient tissue and contracting the at-least-one balloon portion.

A third embodiment of the present invention, shown in FIG. **4**, is an ultrasound medical system **310** comprising an ultrasound end effector **326** including a shaft **338**, a sheath **334**, and a medical ultrasound transducer assembly **318**. The medical ultrasound transducer assembly **318** is supported by the shaft **338** and has at least one medical-treatment ultrasound transducer **320**. The sheath **334** surrounds the shaft **338**. The sheath **334** includes at least one balloon portion **330** and **332** which is expandable against patient tissue to provide at least some stabilization of the ultrasound end effector **326** with respect to patient tissue.

In one example of the embodiment of FIG. **4**, the ultrasound end effector **326** is insertable into a patient. In one variation, the ultrasound end effector **326** is an ultrasound interstitial end effector which is interstitially insertable into patient tissue. In other variations, the ultrasound end effector is insertable into a patient in an endoscopic, laparoscopic, and/or open surgical manner. In another example, the ultrasound end effector is disposable on the outside of a patient. Other examples and variations are left to the artisan.

In one construction of the embodiment of FIG. **3**, the ultrasound end effector **326** has a longitudinal axis **324**, and the at-least-one balloon portion (e.g., **330**) acts as an acoustic window and is disposed to longitudinally overlap the at-least-one medical-treatment ultrasound transducer **320**. In one variation of this construction, the at-least-one balloon portion (e.g., **330**) includes at least one through hole **352**. In one modification, the at-least-one balloon portion (e.g., **330**) includes a plurality of through holes **352** creating a "weeping" balloon portion, wherein some of the acoustic coupling medium inside the sheath **334** extends and/or flows outside the sheath acoustic window providing improved acoustic coupling between the at-least-one medical-treatment ultrasound transducer **320** and patient tissue.

In one arrangement of the embodiment of FIG. **3**, the at-least-one balloon portion (e.g., **330**) includes at least one through hole **352** and the ultrasound end effector **326** is adapted to dispense a drug **354** through the at-least-one through hole **352** to patient tissue. In one variation, the drug **354** is carried in a liquid acoustic coupling medium **356**, such as water, disposed between the medical ultrasound transducer assembly **318** and the at-least-one balloon portion **330** whose pressure is controlled (such as by a pump in a handpiece operatively connected to the ultrasound end effector) to expand and contract the at-least-one balloon portion **330**. In one variation, the drug **354** is at least potentiated (i.e., has its medical effect increased and/or activated) by ultrasound emitted from the at-least-one medical-treatment ultrasound transducer **320**.

In the same or another arrangement of the embodiment of FIG. **3**, the ultrasound end effector **326** has a longitudinal axis **324**, and the at-least-one balloon portion (e.g., **332**) is disposed longitudinally apart from the at-least-one medical-treatment ultrasound transducer **320**. In one variation of the embodiment of FIG. **3**, the at-least-one balloon portion (e.g., **330**) is a fully-circumferential balloon portion. In a different variation, the at-least-one balloon portion (e.g., **332**) is a blister balloon portion. In one example of the embodiment of FIG. **3**, the at-least-one balloon portion **330** and **332** includes an outside surface **358** having a roughness average at least equal to 0.005-inch. In one variation, the outside surface includes ribs. Such surface roughness improves stabilization of the ultrasound end effector **326** with respect to patient tissue when the at-least-one balloon portion **330** and **332** is expanded against the patient tissue.

The embodiments, constructions, implementations, etc. of the embodiments of FIGS. **1-2** and **3** are equally applicable to the embodiment, constructions, implementations, etc. of the embodiment of FIG. **4**. In one implementation of the embodiment of FIG. **3**, the ultrasound medical system **310** also includes a controller, like the controller of the previously-illustrated and described arrangement of the embodiment of FIGS. **1-2**, wherein the controller is operatively connected to the medical ultrasound transducer assembly, wherein the medical ultrasound transducer assembly is a medical-imaging-and-treatment ultrasound transducer assembly, and wherein the controller determines if the at-least-one balloon portion is acoustically coupled to, or acoustically decoupled from, patient tissue from ultrasonically imaging a balloon-tissue area using the medical-imaging-and-treatment ultrasound transducer assembly.

One method of the invention for ultrasonically treating a lesion in a patient is shown in block diagram form in FIG. **5**, and an embodiment of an ultrasound medical system which can be used in performing the method is shown in FIG. **6**. The method includes steps a) through e). Step a) is labeled as "Obtain Interstitial End Effector" in block **460** of FIG. **5**. Step a) includes obtaining an interstitial end effector **426** including a distal end **462** and including a medical ultrasound transducer assembly **418** having at least one medical-treatment ultrasound transducer **420** and at least one end-effector-tissue-track ablation device **472**, **474** and **476**; It is noted that the distal end of an interstitial end effector is an end having a tissue-piercing tip. Step b) is labeled as "Insert End Effector Into Patient" in block **464** of FIG. **5**. Step b) includes inserting the interstitial end effector **426** into the patient creating a tissue track which is surrounded by patient tissue and which ends at the distal end **462** of the inserted interstitial end effector **426**. Step c) is labeled as "Ablate Lesion Using Ultrasound" in block **466** of FIG. **5**. Step c) includes ultrasonically ablating the lesion using the at-least-one medical-treatment ultrasound transducer **420**. Step d) is labeled as "Ablate Tissue Track Using End Effector" in block **468** of FIG. **5**. Step d) includes using the at-least-one end-effector-tissue-track ablation device **472**, **474** and **476** to ablate the patient tissue surrounding the tissue track along substantially the entire tissue track. Step e) is labeled as "Withdraw End Effector" in block **470** of FIG. **5**. Step e) includes withdrawing the interstitial end effector **426** from the patient.

It is noted that creating a tissue track requires that the interstitial end effector **426** be interstitially inserted into patient tissue. It is also noted that the interstitial end effector **426** can be equipped with a retractable tip shield (not shown) for initial endoscopic or laparoscopic patient entry followed by interstitial insertion into patient tissue.

In one extension of the method of FIG. **5**, there is included the step of using the at-least-one end-effector-tissue-track ablation device (e.g., **474**) to ablate the patient tissue at the distal end **462** of the inserted interstitial end effector **426**.

In one implementation of the method of FIG. **5**, the at-least-one end-effector-tissue-track ablation device (e.g., **474**) includes a non-ultrasound energy source, and step d) uses the non-ultrasound energy source to ablate the patient tissue surrounding the tissue track. In one variation, the non-ultrasound energy source is chosen from the group consisting of a resistive heat energy source, a hot liquid energy source, a monopolar radio-frequency (RF) energy source, a bipolar radio-frequency (RF) energy source, a capacitive heat energy source, a microwave energy source, and combinations thereof.

In another implementation of the method, the at-least-one end-effector-tissue-track ablation device (e.g., **476**) includes a tissue-ablating chemical agent, and step d) uses the tissue-ablating chemical agent to ablate the patient tissue surrounding the tissue track. In one variation, the tissue-ablating chemical agent is chosen from the group consisting of fibrin, alcohol, an acidic fluid, a chemotherapeutic agent, and combinations thereof.

In a further implementation of the method, step d) uses the medical ultrasound transducer assembly **418** to ultrasonically ablate the patient tissue surrounding the tissue track. In one variation, step d) ultrasonically ablates at a higher ultrasound frequency than does step c).

In the same or another extension of the method of FIG. **5**, there is included the step of monitoring (such as for acoustic coupling and/or for tissue ablation) the patient tissue surrounding the tissue track during step d). In one variation, the monitoring is chosen from the group consisting of B-mode ultrasonic image monitoring, tissue temperature monitoring, tissue electric impedance, and combinations thereof.

In the same or another extension of the method of FIG. **5**, there are included, after step b) and before step c), the step of stabilizing (such as by using a balloon, a tine and/or suction) the interstitial end effector **426** with respect to the patient tissue surrounding the tissue track and, after step c) and before step d), the step of releasing the stabilizing of the interstitial end effector **426** with respect to the patient tissue surrounding the tissue track.

In one application of the method of FIG. **5**, step e) includes stepwise withdrawing the interstitial end effector **426** from the patient using a plurality of positional steps, and step d) includes ablating the patient tissue surrounding the tissue track for a predetermined time with the interstitial end effector at each positional step.

A fourth embodiment of the present invention, shown in FIG. **6**, is an ultrasound medical system **410** comprising an interstitial end effector **426** which is interstitially insertable into patient tissue, which includes at least one medical-treatment ultrasound transducer **420**, and which includes at least one end-effector-tissue-track ablation device **472**, **474** and **476**.

In one enablement of the embodiment of FIG. **6**, the ultrasound medical system **410** includes a controller (such as the controller **142** illustrated in FIG. **1**) which is operatively connected to the at-least-one medical-treatment ultrasound transducer **420** to ultrasonically ablate a lesion in patient tissue of the patient and which is operatively connected to the at-least-one end-effector-tissue-track ablation device **472**, **474** and **476** to ablate patient tissue surrounding the interstitial end effector **426** during withdrawal of the interstitial end effector **426** from the patient.

In one application of the embodiment of FIG. **6**, the at-least-one end-effector-tissue-track ablation device **472**, **474**, **476** includes a cylindrical ultrasound transducer **472**. In the same or a different application, the at-least-one end-effector-tissue-track ablation device and the at-least-one medical-treatment ultrasound transducer are a single rotatable ultrasound transducer (such as ultrasound transducer **420** made rotatable such as in a previously illustrated and described implementation of the embodiment of FIGS. **1-2**). Other applications of an end-effector-tissue-track ablation device involving ultrasound are left to the artisan.

In another application of the embodiment of FIG. **6**, the at-least-one end-effector-tissue-track ablation device **472**, **474** and **476** includes a device **474** which uses a non-ultrasound energy source. In one variation, the non-ultrasound energy source is chosen from the group consisting of a resistive heat energy source, a hot liquid energy source, a monopolar radio-frequency (RF) energy source, a bipolar radio-frequency (RF) energy source, a capacitive heat energy source, a microwave energy source, and combinations thereof.

In a further application of the embodiment of FIG. **6**, the at-least-one end-effector-tissue-track ablation device **472**, **474** and **476** includes a device **476** which releases a tissue-ablating chemical agent. In one variation, the tissue-ablating chemical agent is chosen from the group consisting of fibrin, alcohol, an acidic fluid, a chemotherapeutic agent, and combinations thereof.

In one construction of the embodiment of FIG. **6**, the interstitial end effector **426** has a length and an exterior surface **428** and includes position markings **478** on the exterior surface **428** along at least a portion of its length. Such position markings allow a user to withdraw the interstitial end effector **426** from patient tissue in positional steps while ablating patient tissue surrounding the end-effector tissue track for a predetermined dwell time at each positional step. In the same or a different construction, the interstitial end effector **426** has a longitudinal axis **424** and a distal end **462**, and wherein the at-least-one end-effector-tissue-track ablation device **472**, **474** and **476** includes an end-effector-tissue-track ablation device (such as **474**) which is disposed proximate the distal end **462**. It is noted that the distal end of an interstitial end effector is an end having a tissue-piercing tip. In the same or a different construction, the interstitial end effector **426** includes a tissue-ablating component (such as **474**) adapted (such as by having a resistive heat energy source) to ablate (such as to thermally ablate) patient tissue longitudinally forward of the distal end **462**.

In one variation, the ultrasound interstitial end effector includes a sheath **434** surrounding the medical-treatment ultrasound transducer **120** and having an acoustic window **480**. In one modification, the entire sheath acts as an acoustic window. In another modification, the acoustic window is a thinner portion of the sheath. In a further modification, the acoustic window is a separate material(s) from the material(s) of the non-acoustic-window portion(s) of the sheath. Acoustic window component materials are known to those skilled in the art. Other modifications are left to the artisan.

It is noted that the embodiments, constructions, implementations, etc. of the embodiments of FIGS. **1-2**, **3** and **4** are equally applicable to the embodiment, constructions, implementations, etc. of the embodiment of FIG. **6**.

Several benefits and advantages are obtained from one or more of the embodiments and methods of the invention. In one example, having a non-ultrasound tissue-property-measuring sensor (such as a tissue temperature sensor and/or a tissue electric impedance sensor) allows ultrasound tissue ablation with feedback from the sensor used to evaluate the tissue ablation and/or modify the ultrasound treatment.

While the present invention has been illustrated by a description of several embodiments and methods, it is not the intention of the applicants to restrict or limit the spirit and scope of the appended claims to such detail. Numerous other variations, changes, and substitutions will occur to those skilled in the art without departing from the scope of the invention. For instance, the ultrasound medical system of the invention has application in robotic assisted surgery taking into account the obvious modifications of such systems, components and methods to be compatible with such a robotic system. It will be understood that the foregoing description is provided by way of example, and that other modifications may occur to those skilled in the art without departing from the scope and spirit of the appended claims.

What is claimed is:

1. An ultrasound medical system comprising:

an ultrasound end effector, wherein the ultrasound end effector includes a sheath having an exterior surface, and wherein the ultrasound end effector is an ultrasound interstitial end effector which is interstitially insertable into patient tissue;

at least one non-ultrasound tissue-property-measuring sensor, wherein the at-least-one non-ultrasound tissue-property-measuring sensor is attached to the ultrasound interstitial end effector and is fixedly disposed substantially flush with the exterior surface; and

a medical ultrasound transducer assembly having at least one medical-treatment ultrasound transducer, wherein the medical ultrasound transducer assembly including the medical-treatment ultrasound transducer is surrounded by the sheath;

wherein the at-least-one non-ultrasound tissue-property-measuring sensor is supported by the ultrasound interstitial end effector and is disposable in contact with patient tissue; and

wherein the exterior surface includes at least one balloon portion which is expandable and contractible and which is expandable against patient tissue to provide at least some stabilization of the ultrasound interstitial end effector with respect to patient tissue, wherein a first balloon portion surrounds the medical ultrasound transducer assembly and acts as an acoustic window and longitudinally overlaps the medical-treatment ultrasound transducer, and wherein an acoustic coupling medium is disposable between the medical ultrasound transducer assembly and the first balloon portion.

2. The ultrasound medical system of claim **1**, wherein the ultrasound interstitial end effector includes a longitudinal axis, wherein the at-least-one non-ultrasound tissue-property-measuring sensor includes a first non-ultrasound tissue-property-measuring sensor and a second non-ultrasound tissue-property-measuring sensor, and wherein the at-least-one medical-treatment ultrasound transducer is disposed longitudinally between the first and second non-ultrasound tissue-property-measuring sensors.

3. The ultrasound medical system of claim **1**, wherein the at-least-one non-ultrasound tissue-property-measuring sensor measures tissue temperature.

4. The ultrasound medical system of claim **1**, wherein the at-least-one non-ultrasound tissue-property-measuring sensor measures tissue electric impedance.

5. The ultrasound medical system of claim **1**, wherein the exterior surface includes a second balloon portion longitudinally spaced apart from the medical ultrasound transducer assembly.

6. The ultrasound medical system of claim **1**, also including a handpiece operatively connected to the ultrasound interstitial end effector, wherein the ultrasound interstitial end effector has a longitudinal axis and a shaft, wherein the medical ultrasound transducer assembly is supported by the shaft, and wherein the shaft is rotatable with respect to the handpiece about the longitudinal axis.

7. An ultrasound medical system comprising:

an ultrasound interstitial end effector, wherein the ultrasound interstitial end effector includes a sheath having an exterior surface;

at least one non-ultrasound tissue-property-measuring sensor, wherein the at-least-one non-ultrasound tissue-property-measuring sensor is deployable to extend away from the exterior surface into patient tissue to provide at least some stabilization of the ultrasound interstitial end effector with respect to patient tissue and is retrievable to retract back toward the exterior surface; and

a medical ultrasound transducer assembly having at least one medical-treatment ultrasound transducer, wherein the medical ultrasound transducer assembly including the medical-treatment ultrasound transducer is surrounded by the sheath;

wherein the at-least-one non-ultrasound tissue-property-measuring sensor is supported by the ultrasound interstitial end effector and is disposable in contact with patient tissue; and

wherein the exterior surface includes at least one balloon portion which is expandable and contractible and which is expandable against patient tissue to provide at least some stabilization of the ultrasound interstitial end effector with respect to patient tissue, wherein a first balloon portion surrounds the medical ultrasound transducer assembly and acts as an acoustic window and longitudinally overlaps the medical-treatment ultrasound transducer, and wherein an acoustic coupling medium is disposable between the medical ultrasound transducer assembly and the first balloon portion.

8. The ultrasound medical system of claim **7**, wherein the at-least-one non-ultrasound tissue-property-measuring sensor is storable inside the exterior surface.

9. The ultrasound medical system of claim **7**, wherein the ultrasound interstitial end effector includes a longitudinal axis, wherein the at-least-one non-ultrasound tissue-property-measuring sensor includes a first non-ultrasound tissue-property-measuring sensor and a second non-ultrasound tissue-property-measuring sensor, and wherein the at-least-one medical-treatment ultrasound transducer is disposed longitudinally between the first and second non-ultrasound tissue-property-measuring sensors.

10. The ultrasound medical system of claim **7**, wherein the at-least-one non-ultrasound tissue-property-measuring sensor measures tissue temperature.

11. The ultrasound medical system of claim **7**, wherein the at-least-one non-ultrasound tissue-property-measuring sensor measures tissue electric impedance.

12. The ultrasound medical system of claim **7**, wherein the exterior surface includes a second balloon portion longitudinally spaced apart from the medical ultrasound transducer assembly.

13. The ultrasound medical system of claim **7**, also including a handpiece operatively connected to the ultrasound interstitial end effector, wherein the ultrasound end effector has a longitudinal axis and a shaft, wherein the medical ultrasound transducer assembly is supported by the shaft, and wherein the shaft is rotatable with respect to the handpiece about the longitudinal axis.

* * * * *

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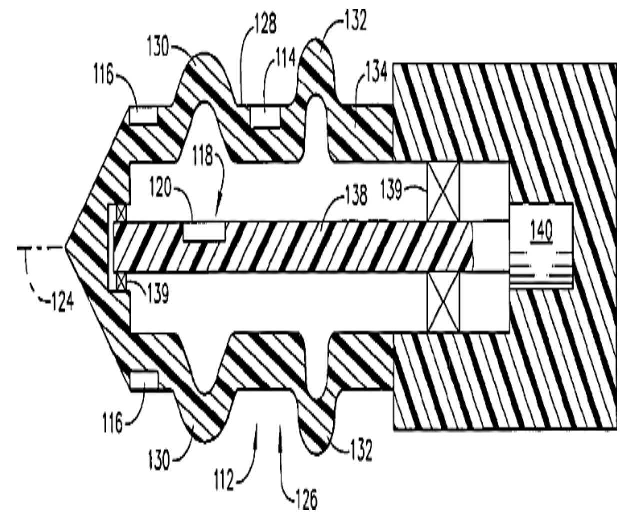
外部链接	Espacenet USPTO		

摘要(译)

超声医疗系统包括超声末端执行器和至少一个非超声组织特性测量传感器。超声末端执行器包括具有至少一个医疗超声换能器的医疗超声换能器组件。至少一个非超声组织特性测量传感器由超声末端执行器支撑，并且可定位成与患者组织接触。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