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(54) **ULTRASONIC SURGICAL INSTRUMENTS**

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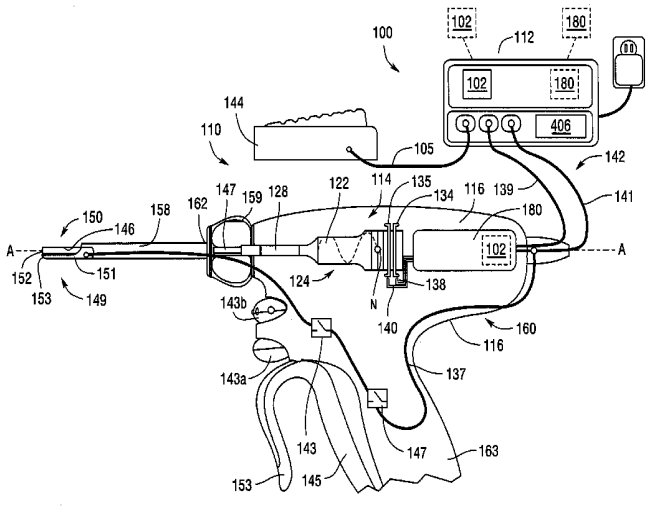
(57) **ABSTRACT**

A surgical instrument comprising a housing, an acoustic assembly configured to produce vibrations, and a waveguide coupled to the acoustic assembly is disclosed. The surgical instrument further comprises an ultrasonic blade extending from the waveguide and a clamp movable between an open position and a closed position relative to the waveguide. The clamp comprises an electrically non-conductive pad, a first electrode embedded in the electrically non-conductive pad, and a second electrode embedded in the electrically non-conductive pad, wherein the first electrode and the second electrode longitudinally overlap a tissue treatment area of the ultrasonic blade when the clamp is in the closed position. The surgical instrument further comprises a first conductor and a second conductor, wherein the first conductor and the second conductor are configured to be placed in electrical communication with a power source such that current can flow from the first electrode to the second electrode.

10 Claims, 15 Drawing Sheets



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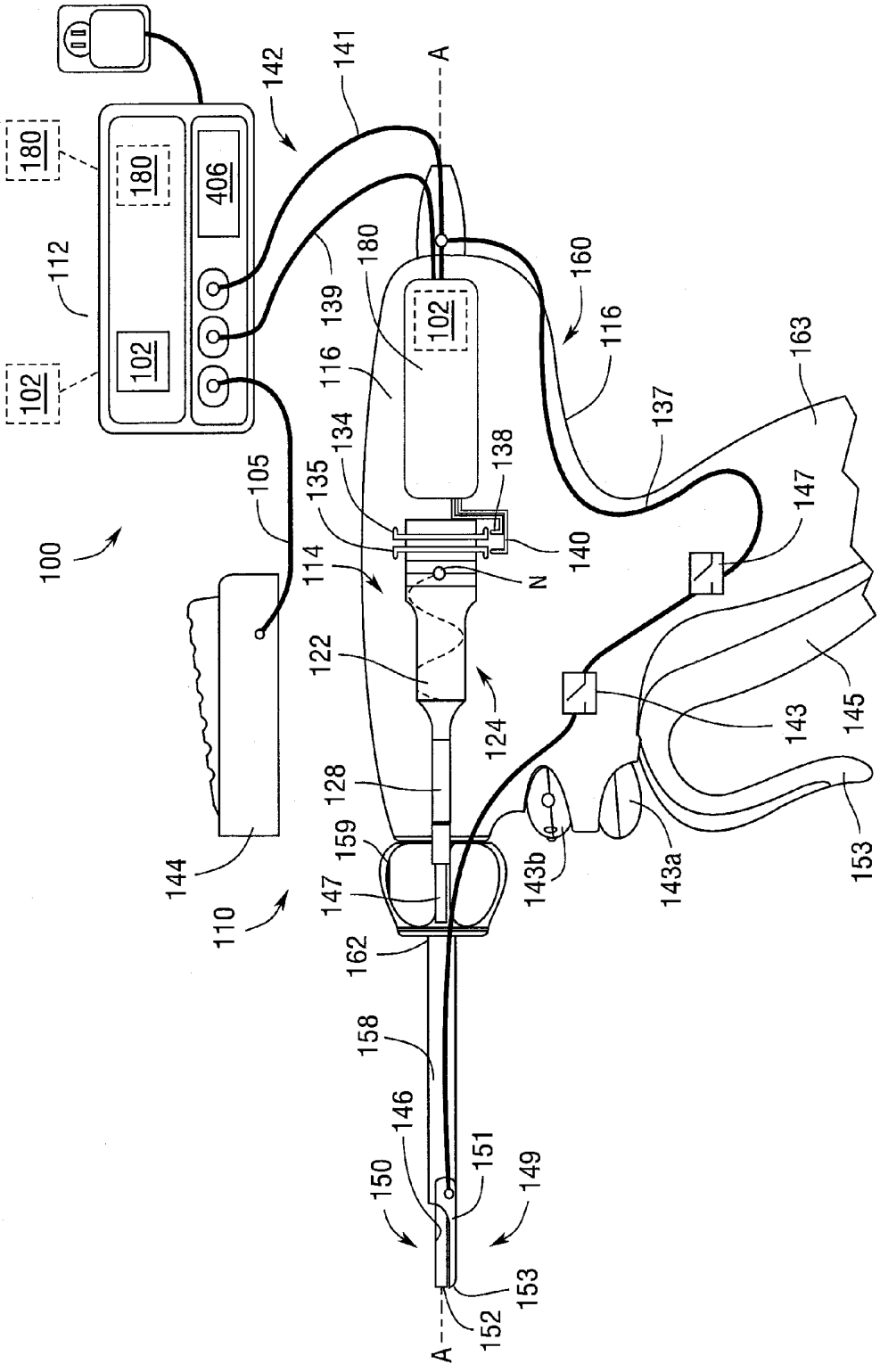
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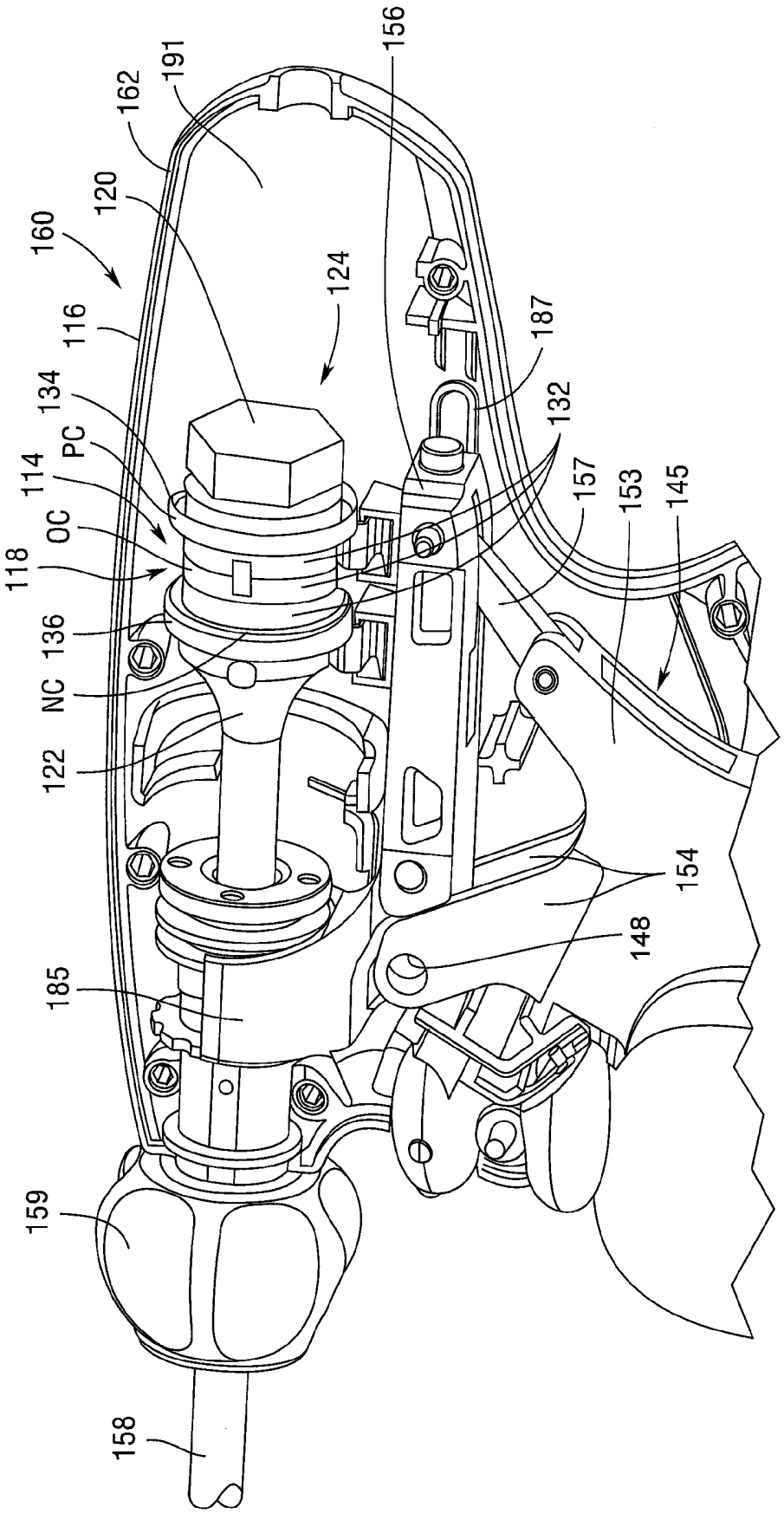
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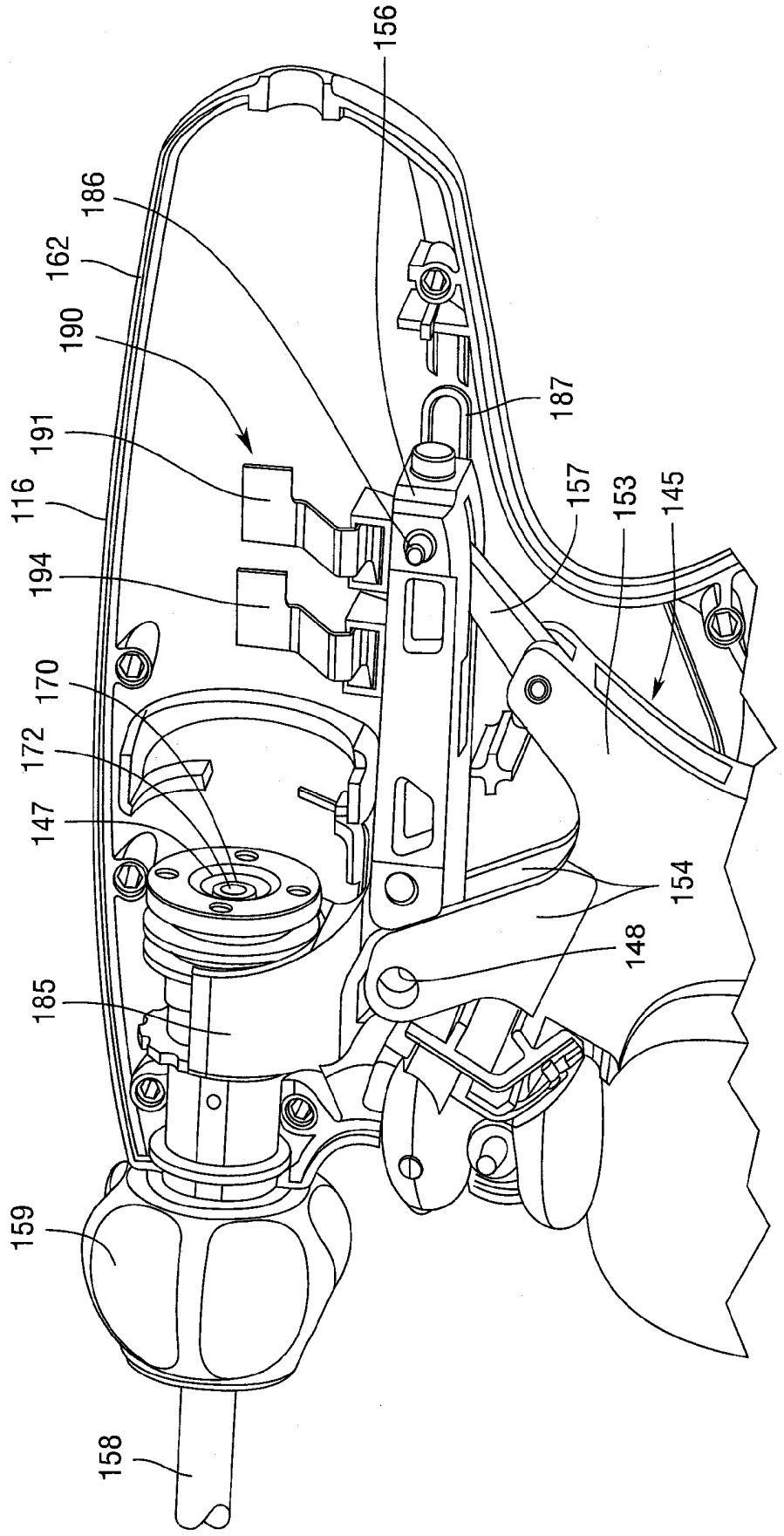
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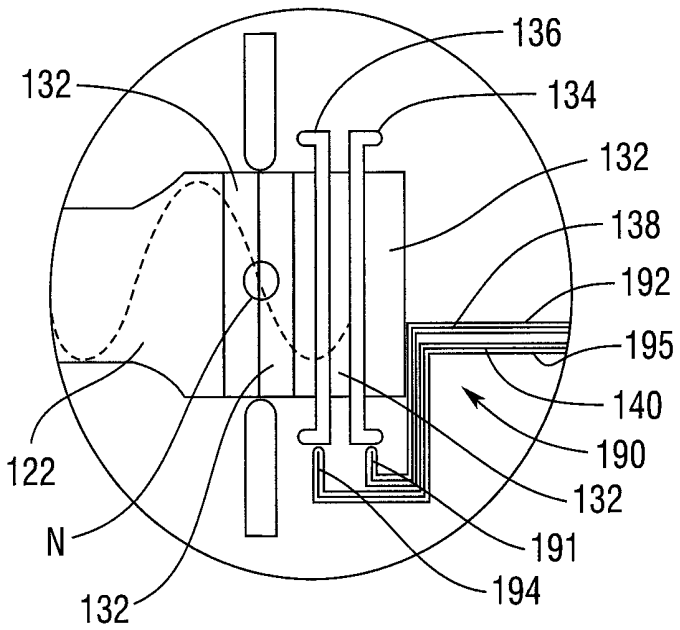

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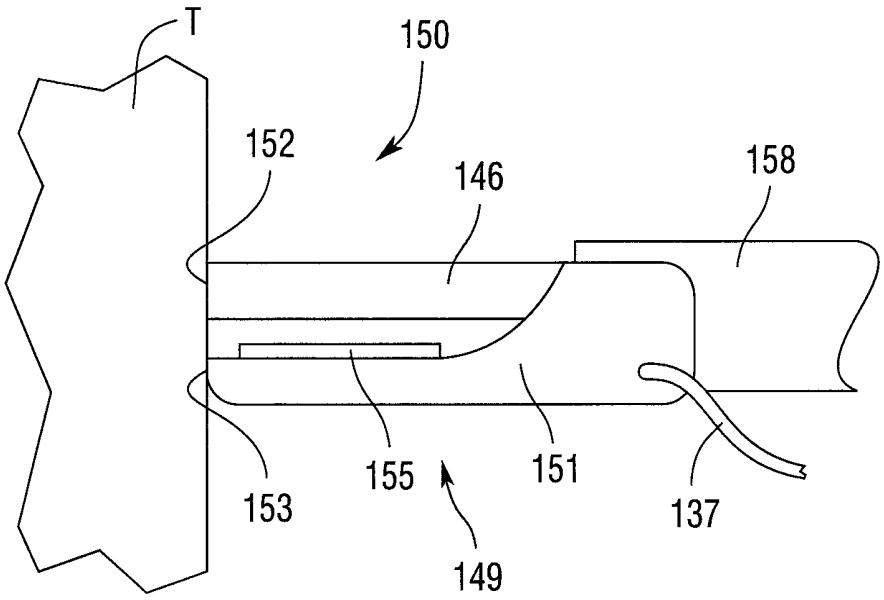

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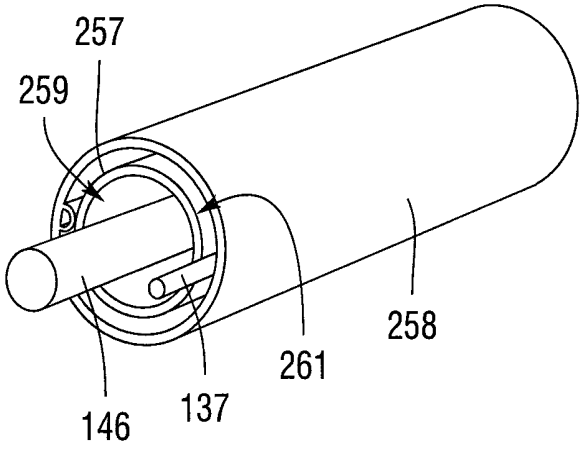

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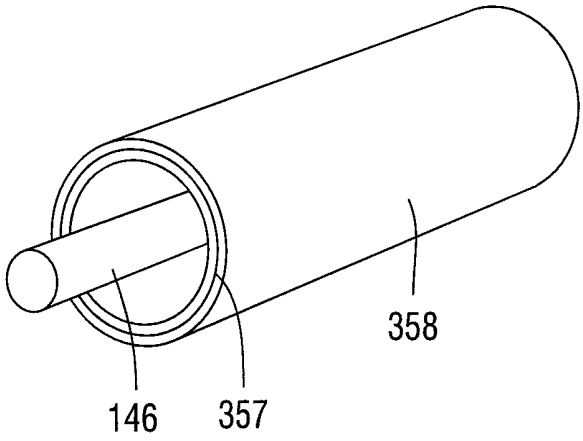

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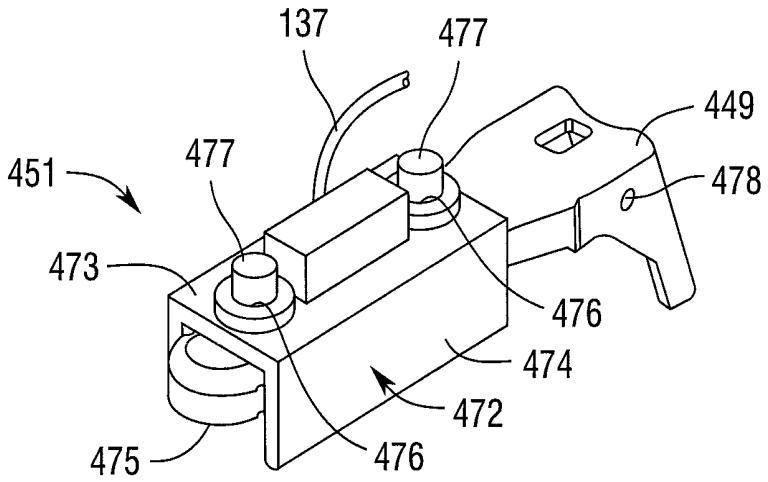
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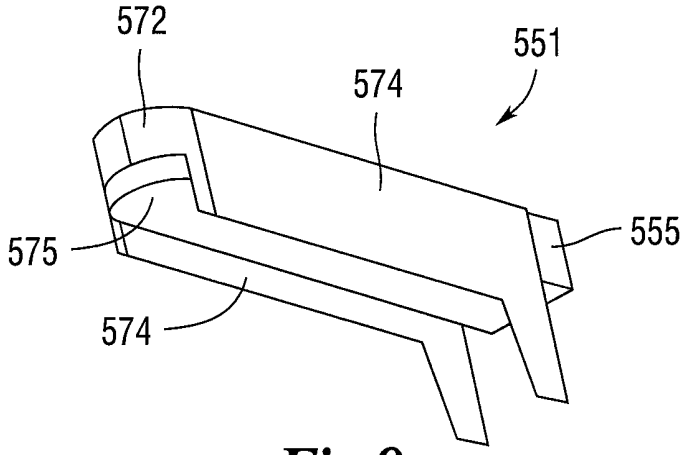
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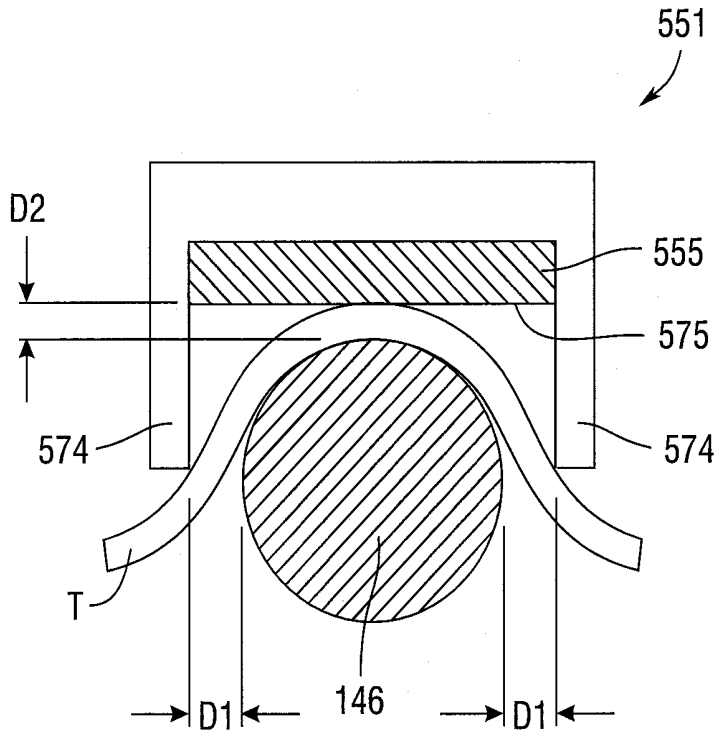

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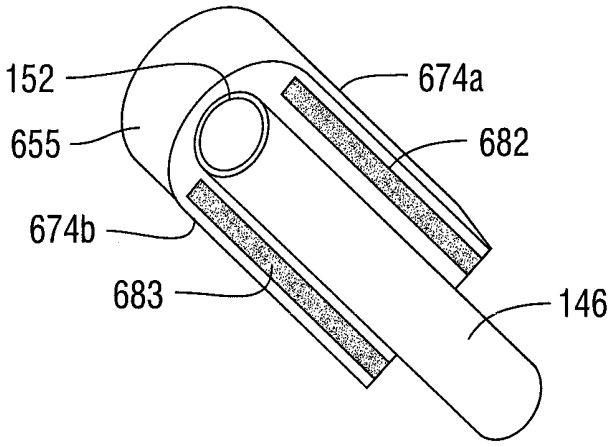

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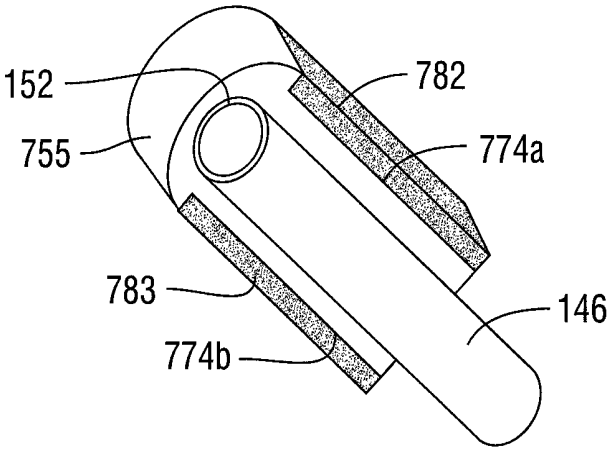

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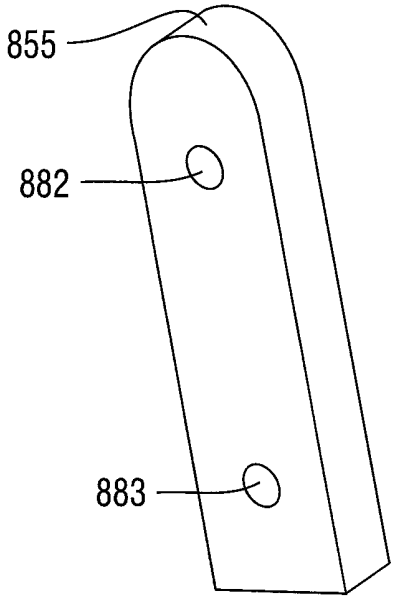

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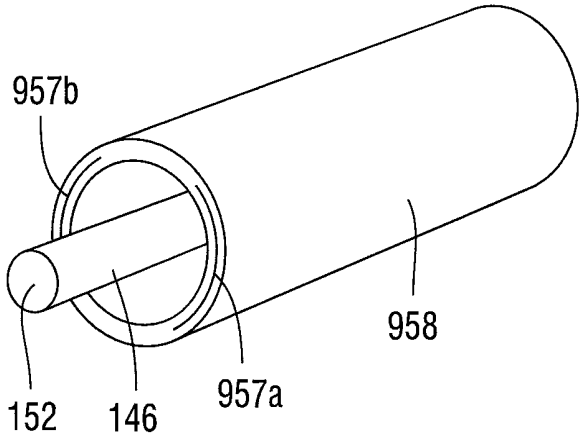

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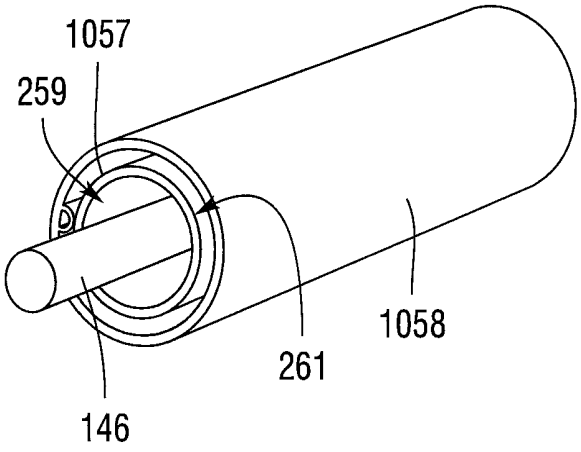

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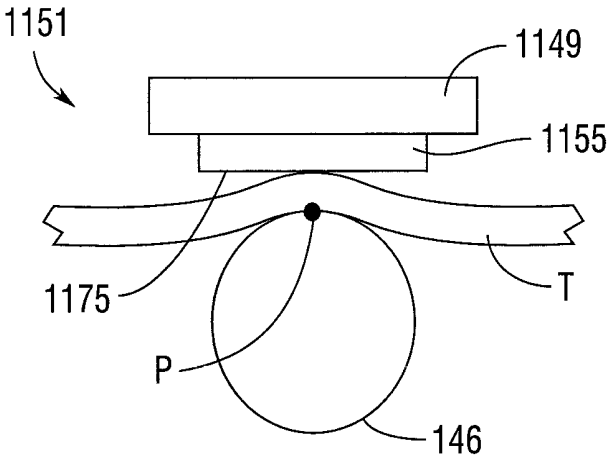
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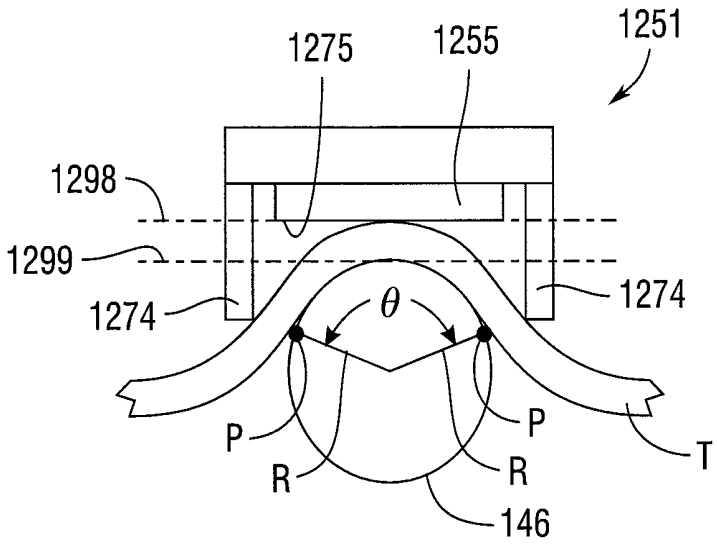
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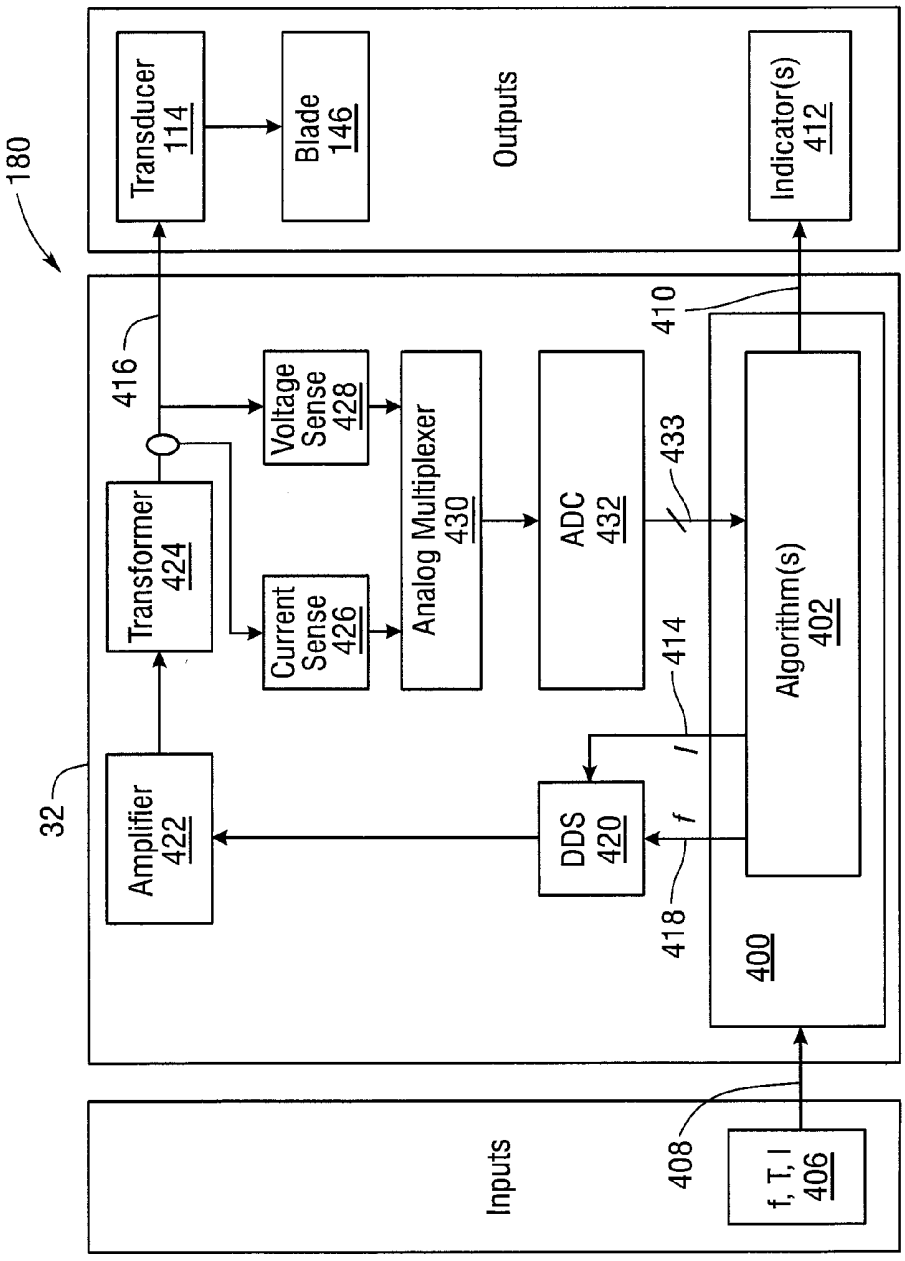
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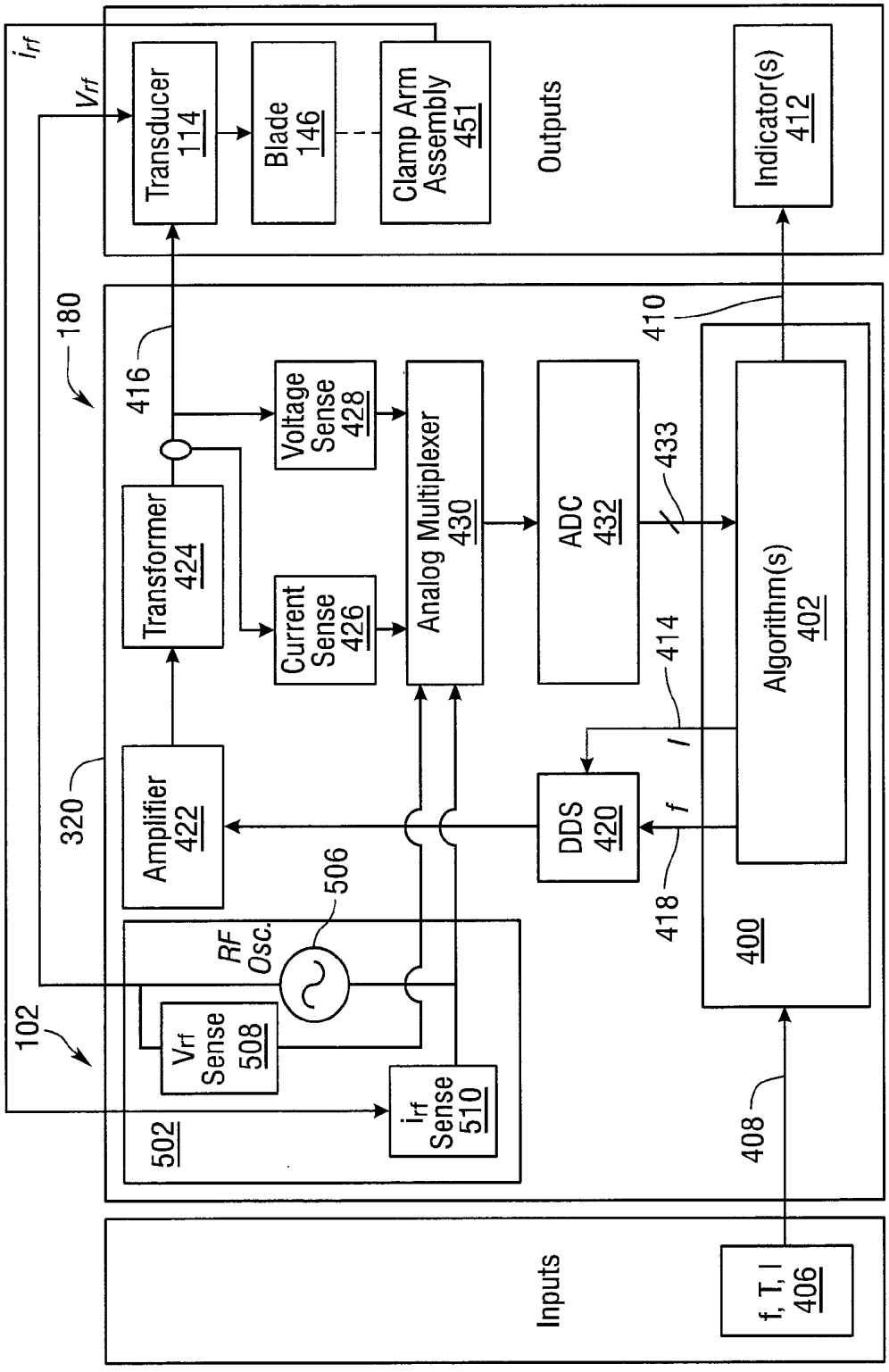
f, T, I 406

Fig. 18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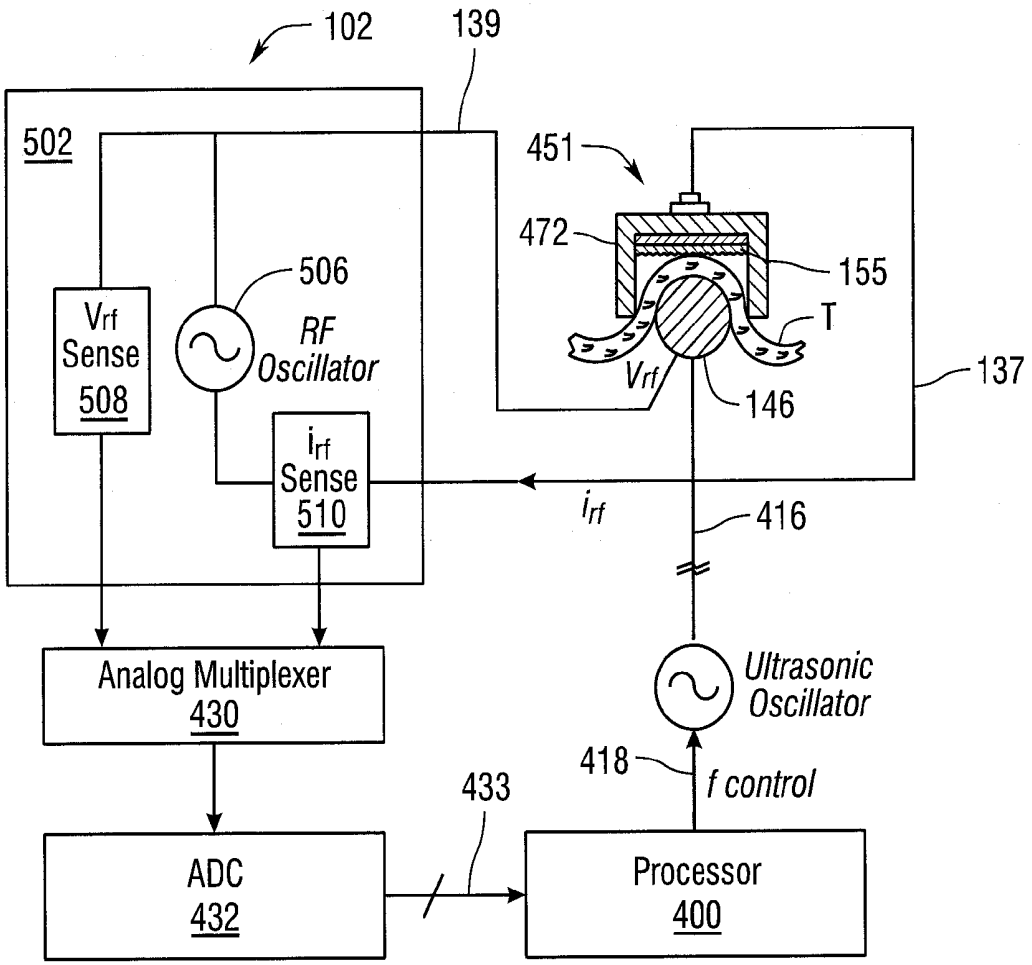
Vrf

Fig. 19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Analog Multiplexer
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Ultrasonic
Oscillator
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f control
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ADC
432
Processor
400

Fig.20

ULTRASONIC SURGICAL INSTRUMENTS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional application under 35 U.S.C. §121 of co-pending U.S. patent application Ser. No. 12/503,769, filed on Jul. 15, 2009, entitled ULTRASONIC SURGICAL INSTRUMENTS, now U.S. Pat. No. 8,663,220, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

The present disclosure generally relates to ultrasonic surgical systems and, more particularly, to ultrasonic systems that allow surgeons to perform cutting and coagulation.

Ultrasonic surgical instruments are finding increasingly widespread applications in surgical procedures by virtue of the unique performance characteristics of such instruments. Depending upon specific instrument configurations and operational parameters, ultrasonic surgical instruments can provide substantially simultaneous cutting of tissue and homeostasis by coagulation, desirably minimizing patient trauma. The cutting action is typically realized by an-end effector, or blade tip, at the distal end of the instrument, which transmits ultrasonic energy to tissue brought into contact with the end effector. Ultrasonic instruments of this nature can be configured for open surgical use, laparoscopic, or endoscopic surgical procedures including robotic-assisted procedures.

Some surgical instruments utilize ultrasonic energy for both precise cutting and controlled coagulation. Ultrasonic energy cuts and coagulates by using lower temperatures than those used by electrosurgery. Vibrating at high frequencies (e.g., 55,500 times per second), the ultrasonic blade denatures protein in the tissue to form a sticky coagulum. Pressure exerted on tissue with the blade surface collapses blood vessels and allows the coagulum to form a hemostatic seal. The precision of cutting and coagulation is controlled by the surgeon's technique and adjusting the power level, blade edge, tissue traction, and blade pressure.

A primary challenge of ultrasonic technology for medical devices, however, continues to be sealing of blood vessels. Work done by the applicant and others has shown that optimum vessel sealing occurs when the inner muscle layer of a vessel is separated and moved away from the adventitia layer prior to the application of standard ultrasonic energy. Current efforts to achieve this separation have involved increasing the clamp force applied to the vessel.

Furthermore, the user does not always have visual feedback of the tissue being cut. Accordingly, it would be desirable to provide some form of feedback to indicate to the user that the cut is complete when visual feedback is unavailable. Moreover, without some form of feedback indicator to indicate that the cut is complete, the user may continue to activate the harmonic instrument even though the cut is complete, which cause possible damage to the harmonic instrument and surrounding tissue by the heat that is generated exponentially when activating a harmonic instrument with nothing between the jaws.

It would be desirable to provide an ultrasonic surgical instrument that overcomes some of the deficiencies of current instruments. The ultrasonic surgical instrument described herein overcomes those deficiencies.

SUMMARY

In various embodiments, a surgical instrument comprising a handpiece housing, an acoustic assembly supported within the handpiece housing, wherein the acoustic assembly is configured to produce vibrations, and a waveguide comprising a proximal end and a distal end, wherein the proximal end is mounted to the acoustic assembly such that vibrations produced by the acoustic assembly are transmitted to the waveguide is disclosed. The surgical instrument further comprises an ultrasonic blade coupled to the distal end of the waveguide, wherein the ultrasonic blade comprises a tissue treatment portion configured to cut and coagulate tissue, a clamp movable between an open position and a closed position relative to the waveguide, wherein the clamp comprises a first electrode and a second electrode, and wherein the first electrode and the second electrode longitudinally overlap the tissue treatment portion of the ultrasonic blade when the clamp is in the closed position, a first conductor in electrical communication with the first electrode, and a second conductor in electrical communication with the second electrode, wherein the first conductor and the second conductor are configured to be placed in electrical communication with a power source such that current can flow from the first electrode to the second electrode through tissue positioned intermediate the first electrode and the second electrode.

In various embodiments, a surgical instrument comprising a housing, an acoustic assembly supported within the housing, wherein the acoustic assembly is configured to produce vibrations, and a waveguide coupled to the acoustic assembly is disclosed. The surgical instrument further comprises an ultrasonic blade extending from the waveguide, wherein the ultrasonic blade comprises a tissue treatment area configured to cut and coagulate tissue, and a clamp movable between an open position and a closed position relative to the waveguide. The clamp comprises an electrically non-conductive pad, a first electrode embedded in the electrically non-conductive pad, and a second electrode embedded in the electrically non-conductive pad, wherein the first electrode and the second electrode longitudinally overlap the tissue treatment area of the ultrasonic blade when the clamp is in the closed position. The surgical instrument further comprises a first conductor in electrical communication with the first electrode and a second conductor in electrical communication with the second electrode, wherein the first conductor and the second conductor are configured to be placed in electrical communication with a power source such that current can flow from the first electrode to the second electrode through tissue positioned intermediate the first electrode and the second electrode.

FIGURES

The features of various embodiments are set forth with particularity in the appended claims. The various embodiments, however, both as to organization and methods of operation, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in conjunction with the accompanying drawings as follows.

FIG. **1** illustrates a surgical instrument comprising an ultrasonic surgical instrument system and an electrosurgery surgical instrument system.

FIG. **2** illustrates a portion of a handpiece assembly of the surgical instrument of FIG. **1** with a portion of the handpiece housing removed and an acoustic assembly operably engaged with a waveguide of the surgical instrument.

FIG. **3** illustrates the handpiece assembly of FIG. **2** with the acoustic assembly removed to illustrate positive and negative electrode contacts configured to supply the acoustic assembly with power.

FIG. **4** is a detail view of a portion of the acoustic assembly of FIG. **2**.

FIG. **5** is a detail view of the end effector of the ultrasonic surgical instrument of FIG. **1**.

FIG. **6** is a perspective view of an embodiment of a sheath assembly comprising an inner sheath and an outer sheath which can define a first passageway for a waveguide of an ultrasonic instrument and a second passageway for a return conductor.

FIG. **7** is a perspective view of an embodiment of a sheath configured to surround at least a portion of a waveguide of an ultrasonic surgical instrument, wherein a conductor can be embedded in at least a portion of a sheath.

FIG. **8** is a perspective view of an embodiment of a clamp arm assembly configured to hold tissue against a waveguide of an ultrasonic surgical instrument.

FIG. **9** is a perspective view of another embodiment of a clamp arm assembly having downwardly-extending walls which extend below a tissue-contacting surface.

FIG. **10** is a cross-sectional end view of the clamp arm assembly of FIG. **9** positioned in a closed position relative to a waveguide of an ultrasonic surgical instrument.

FIG. **11** is a perspective view of a tissue-contacting pad of a clamp arm assembly, wherein the pad includes first and second electrodes embedded therein and positioned relative to a waveguide of an ultrasonic surgical instrument.

FIG. **12** is a perspective view of another embodiment of a tissue-contacting pad of a clamp arm assembly, wherein the pad includes first and second electrodes mounted thereto and positioned relative to a waveguide of an ultrasonic surgical instrument.

FIG. **13** is a perspective view of another embodiment of a tissue-contacting pad of a clamp arm assembly, wherein the pad includes first and second point electrodes embedded therein.

FIG. **14** is a perspective view of an embodiment of a sheath configured to surround at least a portion of a waveguide of an ultrasonic surgical instrument, wherein first and second conductors can be embedded in at least a portion of a sheath.

FIG. **15** is a perspective view of an embodiment of a sheath assembly comprising an inner sheath and an outer sheath, wherein the inner sheath and the outer sheath may comprise first and second conductors.

FIG. **16** is an end view of a clamp arm assembly holding tissue against a waveguide.

FIG. **17** is an end view of an alternative embodiment of a clamp arm assembly holding tissue against a waveguide.

FIG. **18** illustrates one embodiment of a drive system of an ultrasonic generator module, which creates the ultrasonic electrical signal for driving an ultrasonic transducer.

FIG. **19** illustrates one embodiment of a drive system of a generator comprising a tissue impedance module.

FIG. **20** is a schematic diagram of a tissue impedance module coupled to a blade and a clamp arm assembly with tissue located therebetween.

DESCRIPTION

Before explaining various embodiments of ultrasonic surgical instruments in detail, it should be noted that the illustrative embodiments are not limited in application or use to the details of construction and arrangement of parts illustrated in the accompanying drawings and description. The illustrative embodiments may be implemented or incorporated in other embodiments, variations and modifications, and may be practiced or carried out in various ways. Further, unless otherwise indicated, the terms and expressions employed herein have been chosen for the purpose of describing the illustrative embodiments for the convenience of the reader and are not for the purpose of limitation thereof.

Further, it is understood that any one or more of the following-described embodiments, expressions of embodiments, examples, can be combined with any one or more of the other following-described embodiments, expressions of embodiments, and examples.

Various embodiments are directed to improved ultrasonic surgical instruments configured for effecting tissue dissecting, cutting, and/or coagulation during surgical procedures. In one embodiment, an ultrasonic surgical instrument apparatus is configured for use in open surgical procedures, but has applications in other types of surgery, such as laparoscopic, endoscopic, and robotic-assisted procedures. Versatile use is facilitated by selective use of ultrasonic energy.

It will be appreciated that the terms "proximal" and "distal" are used herein with reference to a clinician gripping a handpiece assembly. Thus, an end effector is distal with respect to the more proximal handpiece assembly. It will be further appreciated that, for convenience and clarity, spatial terms such as "top" and "bottom" also are used herein with respect to the clinician gripping the handpiece assembly. However, surgical instruments are used in many orientations and positions, and these terms are not intended to be limiting and absolute.

The various embodiments will be described in combination with an ultrasonic instrument as described herein. Such description is provided by way of example, and not limitation, and is not intended to limit the scope and applications thereof. For example, any one of the described embodiments is useful in combination with a multitude of ultrasonic instruments including those described in, for example, U.S. Pat. Nos. 5,322,055; 5,449,370; 5,630,420; 5,935,144; 5,938,633; 5,944,737; 5,954,736; 6,278,218; 6,283,981; 6,309,400; 6,325,811; and 6,436,115, wherein the disclosure of each of the patents is herein incorporated by reference. Also incorporated by reference in its entirety is commonly-owned, co-pending U.S. patent application Ser. No. 11/726,625, entitled ULTRASONIC SURGICAL INSTRUMENTS, filed on Mar. 22, 2007, now U.S. Patent Application Publication No. 2008/0234710. The disclosure of each the following commonly-owned U.S. Patent Applications is incorporated herein by reference in its entirety:

(1) U.S. patent application Ser. No. 12/503,770, entitled "ROTATING TRANSDUCER MOUNT FOR ULTRASONIC SURGICAL INSTRUMENTS", now U.S. Pat. No. 8,461,744; and

(2) U.S. patent application Ser. No. 12/503,766, entitled "IMPEDENCE MONITORING APPARATUS, SYSTEM, AND METHOD FOR ULTRASONIC SURGICAL INSTRUMENTS", now U.S. Patent Application Publication No. 2011/0015627;

(3) U.S. patent application Ser. No. 12/503,775, entitled "ULTRASONIC DEVICE FOR CUTTING AND COAGULATING WITH STEPPED OUTPUT", now U.S. Pat. No. 8,058,771.

As will become apparent from the following description, it is contemplated that embodiments of the surgical instrument described herein may be used in association with an oscillator module of a surgical system, whereby ultrasonic

energy from the oscillator module provides the desired ultrasonic actuation for the present surgical instrument. It is also contemplated that embodiments of the surgical instrument described herein may be used in association with a signal generator module of a surgical system, whereby electrical energy in the form of radio frequencies (RF), for example, is used to provide feedback to the user regarding the surgical instrument. The ultrasonic oscillator and/or the signal generator modules may be non-detachably integrated with the surgical instrument or may be provided as separate components, which can be electrically attachable to the surgical instrument.

One embodiment of the present surgical apparatus is particularly configured for disposable use by virtue of its straightforward construction. However, it is also contemplated that other embodiments of the present surgical instrument can be configured for non-disposable or multiple uses. Detachable connection of the present surgical instrument with an associated oscillator and signal generator unit is presently disclosed for single-patient use for illustrative purposes only. However, non-detachable integrated connection of the present surgical instrument with an associated oscillator and/or signal generator unit is also contemplated. Accordingly, various embodiments of the presently described surgical instruments may be configured for single use and/or multiple uses and with either detachable and/or non-detachable integral oscillator and/or signal generator modules, without limitation. All combinations of such configurations are contemplated to be within the scope of the present disclosure.

FIG. **1** illustrates one embodiment of a surgical system **100**. The surgical system **100** includes a generator **112** and an ultrasonic surgical instrument **110**. The generator **112** is connected to an ultrasonic transducer **114** portion of the ultrasonic surgical instrument **110** via a suitable transmission medium such as a cable **142**. In one embodiment, the generator **112** is coupled to an ultrasonic generator module **180** and a signal generator module **102**. In various embodiments, the ultrasonic generator module **180** and/or the signal generator module **102** each may be formed integrally with the generator **112** or may be provided as a separate circuit modules electrically coupled to the generator **112** (shown in phantom to illustrate this option). In one embodiment, the signal generator module **102** may be formed integrally with the ultrasonic generator module **180**. Although in the presently disclosed embodiment, the generator **112** is shown separate from the surgical instrument **110**, in one embodiment, the generator **112** may be formed integrally with the surgical instrument **110** to form a unitary surgical system **100**. The generator **112** comprises an input device **406** located on a front panel of the generator **112** console. The input device **406** may comprise any suitable device that generates signals suitable for programming the operation of the generator **112** as subsequently described with reference to FIG. **18**. Still with reference to FIG. **1**, the cable **142** may comprise multiple electrical conductors **139**, **141** for the application of electrical energy to positive (+) and negative (−) electrodes of the ultrasonic transducer **114**. It will be noted that, in some applications, the ultrasonic transducer **114** may be referred to as a "handle assembly" because the surgical instrument **110** of the surgical system **100** may be configured such that a surgeon may grasp and manipulate the ultrasonic transducer **114** during various procedures and operations.

In one embodiment, the generator **112** may be implemented as an electrosurgery unit (ESU) capable of supplying power sufficient to perform bipolar electrosurgery using radio frequency (RF) energy. In one embodiment, the ESU can be a bipolar ERBE ICC 350 sold by ERBE USA, Inc. of Marietta, Ga. In bipolar electrosurgery applications, as previously discussed, a surgical instrument having an active electrode and a return electrode can be utilized, wherein the active electrode and the return electrode can be positioned against, or adjacent to, the tissue to be treated such that current can flow from the active electrode to the return electrode through the tissue. Accordingly, the generator **112** may be configured for therapeutic purposes by applying electrical energy to the tissue T sufficient for treating the tissue (e.g., cauterization).

In one embodiment, the signal generator module **102** may be configured to deliver a subtherapeutic RF signal to implement a tissue impedance measurement module. In one embodiment, the signal generator module **102** comprises a bipolar radio frequency generator as described in more detail below. In one embodiment, signal generator module **102** may be configured to monitor the electrical impedance Z_t of tissue T (FIG. **5**) and to control the characteristics of time and power level based on the tissue impedance Z_t. The tissue impedance Z_t may be determined by applying the subtherapeutic RF signal to the tissue T and measuring the current through the tissue T (FIGS. **5**, **10**, **16**, **17**) by way of a return electrode on provided on a clamp member **151**, as discussed in more detail below. Accordingly, the signal generator module **102** may be configured for subtherapeutic purposes for measuring the impedance or other electrical characteristics of the tissue T. Techniques and circuit configurations for measuring the impedance or other electrical characteristics of the tissue T are discussed in more detail below with reference to FIGS. **18-20** below.

A suitable ultrasonic generator module **180** may be configured to functionally operate in a manner similar to the GEN 300 sold by Ethicon Endo-Surgery, Inc. of Cincinnati, Ohio as is disclosed in one or more of the following U.S. Patents, all of which are incorporated by reference herein: U.S. Pat. No. 6,480,796 (Method for Improving the Start Up of an Ultrasonic System Under Zero Load Conditions); U.S. Pat. No. 6,537,291 (Method for Detecting a Loose Blade in a Handle Connected to an Ultrasonic Surgical System); U.S. Pat. No. 6,626,926 (Method for Driving an Ultrasonic System to Improve Acquisition of Blade Resonance Frequency at Startup); U.S. Pat. No. 6,633,234 (Method for Detecting Blade Breakage Using Rate and/or Impedance Information); U.S. Pat. No. 6,662,127 (Method for Detecting Presence of a Blade in an Ultrasonic System); U.S. Pat. No. 6,678,621 (Output Displacement Control Using Phase Margin in an Ultrasonic Surgical Handle); U.S. Pat. No. 6,679,899 (Method for Detecting Transverse Vibrations in an Ultrasonic Handle); U.S. Pat. No. 6,908,472 (Apparatus and Method for Altering Generator Functions in an Ultrasonic Surgical System); U.S. Pat. No. 6,977,495 (Detection Circuitry for Surgical Handpiece System); U.S. Pat. No. 7,077,853 (Method for Calculating Transducer Capacitance to Determine Transducer Temperature); U.S. Pat. No. 7,179,271 (Method for Driving an Ultrasonic System to Improve Acquisition of Blade Resonance Frequency at Startup); and U.S. Pat. No. 7,273,483 (Apparatus and Method for Alerting Generator Function in an Ultrasonic Surgical System).

In accordance with the described embodiments, the ultrasonic generator module **180** produces electrical signals of a particular voltage, current, and frequency, e.g. 55,500 cycles per second (Hz). The generator is **112** connected by the cable **142** to the ultrasonic generator module **180** in the handpiece assembly **160**, which contains piezoceramic elements forming the ultrasonic transducer **114**. In response to a switch **143**

on the handpiece assembly **160** or a foot switch **144** connected to the generator **112** by another cable **105** the generator signal is applied to the transducer **114**, which causes a longitudinal vibration of its elements. A structure connects the transducer **114** to a surgical blade **146**, which is thus vibrated at ultrasonic frequencies when the generator signal is applied to the transducer **114**. The structure is designed to resonate at the selected frequency, thus amplifying the motion initiated by the transducer **114**. In one embodiment, the generator **112** is configured to produce a particular voltage, current, and/or frequency output signal that can be stepped with high resolution, accuracy, and repeatability.

Referring now to FIGS. **1-4**, the handpiece assembly **160** of the surgical instrument system **110** may include a handpiece housing **116** that operably supports the end effector **150**. The handpiece housing **116** rotatably supports an acoustic assembly **124** therein. The acoustic assembly **124** includes the ultrasonic transducer **114** that generally includes a transduction portion **118**, a first resonator or end-bell **120**, a second resonator or fore-bell **122**, and ancillary components as shown in FIG. **2**. In various embodiments, the ultrasonic energy produced by the transducer **114** can be transmitted through the acoustic assembly **124** to the end effector **150** via the ultrasonic transmission waveguide **147** as shown in FIGS. **1** and **3**. In order for the acoustic assembly **124** to deliver energy to the waveguide **147**, and ultimately to the end effector **150**, the components of the acoustic assembly **124** are acoustically coupled to the blade **146**. For example, the distal end of the ultrasonic transducer **114** may be acoustically coupled to the proximal end **170** of the waveguide **147** by a coupling assembly that enables the acoustic assembly **124** to freely rotate relative to the waveguide **147** while transmitting ultrasonic energy thereto.

As shown in FIG. **3**, the proximal end **170** of the waveguide **147** may be provided with an aperture **172** therein that is sized to receive a stem (not shown) that protrudes distally from the fore-bell **122**. In various embodiments, piezoelectric elements **132**, for example, can be compressed between the end-bell **120** and the fore-bell **122** to form a stack of piezoelectric elements when the end-bell **120** and the fore-bell **122** are assembled together as illustrated in FIGS. **2-4**. The piezoelectric elements **132** may be fabricated from any suitable material, such as, for example, lead zirconate-titanate, lead meta-niobate, lead titanate, and/or any suitable piezoelectric crystal material, for example. As shown in FIGS. **2** and **4**, the transducer **114** may comprise electrodes, such as at least one positive electrode **134** and at least one negative electrode **136**, for example, which can be configured to create a voltage potential across the one or more piezoelectric elements **132**. As shown in FIG. **2**, the positive electrode **134** and the negative electrode **136**, and the piezoelectric elements **132** can each be configured with a bore (not shown) that cooperates to form a passageway that can receive a threaded portion of the end-bell **120**. In one embodiment, the positive electrode **134** is provided in the form of an annular ring that has a first circumference "PC" and the negative electrode **136** is also provided in the form of an annular ring that has a second circumference "NC." As shown in FIG. **2**, in various embodiments, the stack of piezoelectric elements **132** may have an outer circumference "OC" that is less than the first and second circumferences "PC" and "NC."

In various embodiments, the handpiece housing **116** may support the ultrasonic generator module **180** and/or the signal generator module **102**. In one embodiment, the ultrasonic generator module **180** may be electrically coupled to an electrical contact assembly **190** that may comprise a positive slip ring contact **191** that is mounted within handpiece housing **116** for rotatable contact with the positive electrode **134**. The positive slip ring contact **191** is electrically coupled to the ultrasonic generator module **180** by a positive ultrasonic supply cable/conductor **192**. The electrical contact assembly **190** may further comprise a negative slip ring contact **194** that is mounted within handpiece housing **116** for rotatable contact with the negative electrode **136**. The negative slip ring contact **194** is electrically coupled to the ultrasonic generator module **180** by a negative ultrasonic supply cable **195**. It will be appreciated that such arrangement enables the acoustic assembly **124** to freely rotate relative to the ultrasonic generator module **180** while remaining in full electrical contact therewith.

In various embodiments, the ultrasonic transmission waveguide **147** may comprise a plurality of stabilizing silicone rings or compliant supports (not shown) positioned at, or at least near, a plurality of nodes. As was discussed above, the silicone rings can dampen undesirable vibration and isolate the ultrasonic energy from the sheath **158** that at least partially surrounds the waveguide **147**, thereby assuring the flow of ultrasonic energy in a longitudinal direction to the distal end **152** of the end effector **150** with maximum efficiency.

As shown in FIGS. **2** and **3**, the sheath **158** can be coupled to a rotation wheel **159** that is rotatably attached to the distal end of the handpiece assembly **160**. The rotation wheel **159** facilitates selective rotation of the sheath **158** and the waveguide **147** relative to the handpiece assembly **160**. The sheath **158** may have an adapter portion **162** that may be threaded or snapped onto the rotation wheel **159**. The rotation wheel **159** may include a flanged portion (not shown) that is snapped into an annular groove in the handpiece assembly **160** to facilitate rotation of the sheath **158** and waveguide **147** relative to the handpiece assembly **160** about axis A-A. In one embodiment, the sheath **158** also includes a hollow tubular portion **164** through which the waveguide **147** extends in the manner described in further detail above. In various embodiments, the adapter **162** of the sheath **158** may be constructed from ULTEM®, for example, and the tubular portion **164** may be fabricated from stainless steel, for example. In at least one embodiment, the ultrasonic transmission waveguide **147** may have polymeric material, for example, surrounding it in order to isolate it from outside contact.

In the embodiment, as shown in FIG. **1**, the ultrasonic generator module **180** is electrically coupled to the electronic signal/radio frequency generator **112** by the cables **139**, **141** which may be housed in a sheath to form the cable **142**. Because the acoustic assembly **124** can freely rotate relative to the ultrasonic generator module **180**, the waveguide **147** and the end effector **150** may be freely rotated about axis A-A relative to the handpiece assembly **160** without causing the cable **142** to undesirably twist and tangle.

As illustrated in FIGS. **2** and **3**, the handpiece assembly **160** may have a pistol grip configuration and operably support a movable trigger assembly **145** that is pivotally supported within the handpiece assembly **160**. To facilitate easy assembly, the handpiece assembly **160** may comprise two housing segments **162** that are coupled together by threaded fasteners, snap features, adhesive. The movable trigger assembly **145** includes a trigger portion **153** that has a pair of spaced attachment arms **154** that each has a hole **155** therethrough. Holes **155** are each sized to receive a

corresponding pivot pin (not shown) that protrudes from each of the housing segments **162**. Such arrangement permits the trigger portion **153** to pivot relative to the handpiece assembly **160** about an axis that is substantially transverse to axis A-A.

As shown in FIGS. **2** and **3**, the trigger assembly **145** may comprise an actuation arm **156** that is attached to the trigger portion **153** via an intermediate link **157**. The actuation arm **156** is pivotally coupled (pinned) to the trigger yoke **185**. The arm **156** has a mounting pin **186** extending transversely therethrough that is sized to be slidably received in corresponding elongated cavities **187** formed in the housing segments **162**. See FIGS. **2** and **3**. Such arrangement facilitates the axial movement of the actuation arm **156** within the handpiece assembly **160** in response to pivoting the trigger portion **153**.

In the embodiment illustrated in FIG. **1**, the end effector **150** portion of the surgical system **100** comprises a clamp arm assembly **149** connected at a distal end of the surgical instrument **110**. The blade **146** forms a first (e.g., energizing) electrode and the clamp arm assembly **149** comprises an electrically conductive portion that forms a second (e.g., return) electrode. The signal generator module **102** is coupled to the blade **146** and the clamp arm assembly **149** through a suitable transmission medium such as a cable **137**. The cable **137** comprises multiple electrical conductors for applying a voltage to the tissue and providing a return path for current flowing through the tissue back to the signal generator module **102**. In various embodiments, the signal generator module **102** may be formed integrally with the generator **112** or may be provided as a separate circuit coupled to the generator **112** and, in one embodiment, may be formed integrally with the ultrasonic generator module **180** (shown in phantom to illustrate these options).

In one embodiment, the surgical system **100** illustrated in FIG. **1** may comprise components for selectively energizing an end effector **150** and transmitting mechanical energy thereto and, in addition, selectively energizing the end effector **150** with therapeutic and/or subtherapeutic electrical energy. The surgical instrument **110** may be switchable between a first operating mode in which mechanical energy, or vibrations at ultrasonic frequencies (e.g., 55.5 kHz), are transmitted to the end effector **150** and a second operating mode in which electrical energy (e.g., therapeutic and/or subtherapeutic), or current, is permitted to flow through the end effector **150**. In certain embodiments, referring to FIG. **1**, in a first operating mode of the surgical instrument **110**, for example, the transducer **114** converts electrical energy supplied thereto by the ultrasonic generator module **180** (e.g., an ultrasonic oscillator) of the generator **112** into mechanical vibrations and transmit the vibrations into a waveguide **147** to the blade **146** portion of the end effector **150**, for example. Such mechanical vibrations can be generated at ultrasonic frequencies, although any suitable frequency, or frequencies, can be used. In the second operating mode of the surgical instrument **110**, an electrical current may be supplied by the generator **112** that can flow through the transducer **114**, the waveguide **147**, and the end effector **150**. The current flowing through the waveguide **147** and end effector **150** can be an alternating current (AC current), wherein, in various embodiments, the wave form of the AC current can be sinusoidal and/or may comprise a series of step intervals, for example.

In one embodiment, the current supplied by the signal generator module **102** is an RF current. In any event, the surgical instrument **110** may comprise a supply path and a return path, wherein the tissue T (FIG. **5**) being treated completes, or closes, an electrical circuit, or loop, comprising a supply path through the transducer **114**, the waveguide **147**, and the blade **146** and a return path through conductor cable **137**. In one embodiment, the patient can be positioned on a conductive pad wherein the current can flow from a supply path of the surgical instrument, through the patient, and into the conductive pad in order to complete the electrical circuit.

Still referring to FIG. **1**, as previously discussed, in one embodiment the surgical instrument system **110** may be energized by the generator **112** by way of the foot switch **144** in order to energize the end effector **150**. When actuated, the foot switch **144** triggers the generator **112** to deliver electrical energy to the handpiece assembly **160**, for example. Although the foot switch **144** may be suitable in many circumstances, other suitable switches can be used. In various embodiments, the surgical instrument system **110** may comprise at least one supply conductor **139** and at least one return conductor **141**, wherein current can be supplied to handpiece assembly **160** via the supply conductor **139** and wherein the current can flow back to the generator **112** via return conductor **141**. In various embodiments, the supply conductor **139** and the return conductor **141** may comprise insulated wires and/or any other suitable type of conductor. In certain embodiments, as described below, the supply conductor **139** and the return conductor **141** may be contained within and/or may comprise a cable extending between, or at least partially between, the generator **112** and the transducer **114** portion of the handpiece assembly **160**. In any event, the generator **112** can be configured to apply a sufficient voltage differential between the supply conductor **139** and the return conductor **141** such that sufficient current can be supplied to the transducer **114**.

In various embodiments, still referring to FIG. **1**, the supply conductor **139** and the return conductor **141** may be operably connected to a transducer drive unit **135**, wherein the drive unit **135** can be configured to receive current from the generator **112** via the supply conductor **139**. In certain embodiments, the handpiece assembly **160** may comprise a switch, such as a toggle switch **143**, for example, which can be manipulated to place the surgical instrument **110** in one of a first operating mode and a second operating mode. In one embodiment, as described below, the toggle switch **143** may comprise a first toggle button **143***a* which can be depressed to place the surgical instrument **110** in the first operating mode and, in addition, a second toggle button **143***b* which can be depressed to place the surgical instrument in the second operating mode. Although a toggle switch is illustrated and described herein, any suitable switch, or switches, can be used. When the first toggle button **143***a* is depressed, the transducer drive unit **135** can operate a transducer, such as the transducer **114**, for example, such that the transducer **114** produces vibrations. The transducer **114** may comprise one or more piezoelectric elements **132**, wherein the drive unit **135** can be configured to apply a voltage differential, and/or a series of voltage differentials, across the piezoelectric elements **132** such that they mechanically vibrate in a desired manner. Also, the transducer **114** may comprise one or more electrodes, such as a positive electrode **134** and a negative electrode **136**, for example, positioned intermediate and/or adjacent to the piezoelectric elements **132**. In one embodiment, the surgical instrument **110** may comprise a positive polarizing conductor **192** operably connected to the drive unit **135** and a positive electrode **134** and, in addition, a negative polarizing conductor **195** operably connected to the drive unit **135** and the negative electrode **136**, wherein the drive unit **135** can be

configured to polarize the electrodes **134**, **136** via the polarizing conductors **192**, **195**, respectively.

In various embodiments, the transducer **114** may comprise a fore-bell **122** and a velocity transformer **128** which can be configured to conduct the vibrations produced by the piezoelectric elements **132** into the transmission waveguide **147**. In certain embodiments, referring still to FIG. **1**, the transmission waveguide **147** may comprise an elongate shaft portion surrounded, or at least partially surrounded, by a sheath **158**, for example, wherein the waveguide **147** may comprise a distal end **152**. The distal end **152** of the waveguide **147** may comprise part of the end effector **150**, wherein the end effector **150** may comprise the clamp member **151** having a rotatable clamp arm, or jaw, which can be pivoted between an open position in which tissue can be positioned intermediate the blade **146** and the clamp member **151** and a closed position in which clamp member **151** can position and/or compress the tissue T (FIG. **5**) against the blade **146**. In various embodiments, a surgical instrument may comprise a lever or actuator, such as a jaw closure trigger **145**, for example, which can be actuated by a surgeon in order to pivot the clamp member **151** between its open and closed positions. In at least one embodiment, the jaw closure trigger **145** can be operably engaged with a push/pull rod operably engaged with the clamp member **151** wherein, when the jaw closure trigger **145** is closed or moved toward the handpiece assembly **160**, the closure trigger **145** can push the push/pull rod distally and pivot the clamp member **151** toward the blade **146** into its closed position. Correspondingly, the jaw closure trigger **145** can be pivoted into its open position in order to pull the rod proximally and pivot the clamp member **151** away from the blade **146** into its open position.

In any event, once the tissue T (FIG. **5**) has been suitably positioned within the jaws of the end effector **150**, the transducer **114** can be operated by the drive unit **135** in order to transmit mechanical energy, or vibrations, into the targeted tissue T. In some embodiments, the actuation of the foot switch **144** may be sufficient to actuate the transducer **114**. In certain other embodiments, the actuation of a different switch may be required in addition to or in lieu of the actuation of the foot switch **144**. In one embodiment, the actuation of the foot switch **144** can supply power to the drive unit **135**, although the actuation of the jaw closure trigger **145**, and the trigger closure switch **147**, may be required before the drive unit **135** can drive the transducer **114**. In various embodiments, the jaw closure trigger **145** can be moved between a first, or open, position in which the trigger closure switch **147** is in an open state, or condition, and a second, or closed, position in which the trigger closure switch **147** is in a closed state, or condition. When the trigger closure switch **147** is in its closed condition, in various embodiments, a circuit within the drive unit **135**, for example, can be closed such that the drive unit **135** can drive the transducer **114**.

Referring still to FIG. **1**, In various applications, a surgeon may desire to treat tissue using mechanical energy, or vibrations, transmitted through the blade **146**, for example. In various other applications, the surgeon may desire to treat the tissue using therapeutic electrical energy transmitted through the blade **146**. In various other applications, the surgeon may desire to obtain feedback in regards to a state of the tissue T (FIG. **5**) by measuring the electrical properties of the tissue T (e.g., impedance) using subtherapeutic electrical energy transmitted through the blade **146**. In various embodiments, the toggle switch **143** can be manipulated to place the surgical instrument **110** in the second operating mode. In at least one such embodiment, the second toggle button **143***b* of the toggle switch **143** can be depressed in order to switch the surgical instrument **110** from the first operating mode into the second operating mode. As described below, the depression of the second toggle button **143***b* can configure the handpiece assembly **160** such that the drive unit **135** does not drive the transducer **114** but rather, the power supplied to the handpiece assembly **160** from generator **112** can flow into the blade **146** without being converted into mechanical energy, or vibrations. In one embodiment, referring now to FIG. **5**, the distal end **152** of the blade **146** can be positioned against the targeted tissue "T" and, in addition, the distal end **153** of the clamp member **151** can also be positioned against the tissue T such that current can flow from the supply conductor **139** into the blade **136**, through the tissue T, and return back to the generator **112** via the clamp member **151**, the return conductors **137**, **141**. As shown in FIG. **5**, the clamp member **151** can be configured such that it is not in contact with the blade **146** when the clamp member **151** is in the closed position.

With reference now back to FIG. **1**, in various embodiments, the return conductor **137** may comprise an insulated wire having a first end operably coupled with the clamp member **151** and a second end operably coupled with the return conductor **141**, wherein current can flow through the return conductor **137** when the toggle switch **143** is in the second configuration and the trigger closure switch **147** has been closed by the trigger **145**. In one embodiment, current will not flow through the return conductor **137** when the trigger closure switch **147** is in an open condition and/or when the toggle switch **143** is in the first configuration, i.e., when the first toggle button **143***a* is depressed, as described above. In any event, in various circumstances, the current flowing through the tissue T (FIG. **5**) from the distal end **152** of the blade **146** to the distal end **153** of the clamp member **151** can treat the tissue positioned intermediate, and/or surrounding, the distal ends **152**, **153**. In another embodiment, the current may be subtherapeutic for measuring the electrical state of the tissue T (FIG. **5**).

The distal end **152** of the blade **146** may comprise a supply electrode while the distal end **153** of the clamp member **151** may comprise a return electrode. In various other embodiments, current can be supplied to the conductor **137** such that the distal end **153** of the clamp member **151** may comprise the supply electrode and the distal end **152** of the blade **146** may comprise the return electrode. In one embodiment, the current can return to the generator **112** via the blade **146**, the waveguide **147**, and the conductor **139**. In either event, referring again to FIG. **1**, at least a portion of the return conductor **137** can extend along the outside of the sheath **158**, wherein at least another portion of the return conductor **137** can extend through the handpiece assembly **160**. In certain embodiments, although not illustrated, at least a portion of the return conductor **137** can be positioned within the sheath **158** and can extend alongside the blade **146**.

A s shown in FIG. **6**, in some embodiments, the surgical instrument **110** may comprise an inner sheath **257** and an outer sheath **258**, wherein the inner sheath **257** can define a first, or inner, passageway **259**, and wherein the inner sheath **257** and the outer sheath **258** can define a second, or outer, passageway **261** therebetween. In one embodiment, the blade **146** can extend through the inner passageway **259** and the return conductor **137**, and/or any other suitable conductor, can extend through the outer passageway **261**. In various

other embodiments, a conductor can be embedded in at least a portion of the inner sheath **257** or the outer sheath **258**.

As shown in FIG. **7**, in one embodiment, a sheath may comprise a non-electrically conductive or insulative material **358**, such as plastic and/or rubber, for example, overmolded onto a conductive insert **357**, which can be comprised of copper, for example, wherein the conductive insert **357** can allow current flowing through the blade **146** to return to the generator **112** after it has passed through the targeted tissue T (FIG. **5**) as described above. In various embodiments, the insulative material **358** can entirely, or at least substantially, surround the conductive insert **357** such that current flowing through the conductive insert **357** does not unintentionally short to non-targeted tissue, for example. In at least one embodiment, the insulative material **358** can cover the inside surface and the outside surface of the conductive insert **357**. In certain embodiments, although not illustrated, an insulative material of a sheath may cover only the outer surface of a conductive insert, for example.

In various embodiments, as described above, a first end of the return conductor **137** can be operably coupled to the clamp member **151** such that current can flow therethrough. In certain embodiments, the first end of the return conductor **137** can be soldered and/or welded to the clamp member **151**. In one embodiment, although not illustrated, the clamp member **151** may comprise an aperture configured to receive the first end of the return conductor **137** wherein a fastener can be inserted into the aperture in order to secure the first end therein. In at least one such embodiment, the sidewalls of the aperture can be at least partially threaded and the fastener can be threadably received in the threaded aperture.

As shown in FIG. **8**, in one embodiment, a clamp arm assembly **451** may comprise a conductive jacket **472** mounted to a base **449**. In one embodiment, the first end of the return conductor **137** may be mounted to the conductive jacket **472** such that current can flow from the blade **146**, through tissue positioned intermediate the jacket **472** and the blade **146**, and then into the jacket **472** and to the return conductor **137**. In various embodiments, the conductive jacket **472** may comprise a center portion **473** and at least one downwardly-extending sidewall **474** which can extend below bottom the surface **475** of the base **449**. In the illustrated embodiment, the conductive jacket **472** has two sidewalls **474** extending downwardly on opposite sides of the base **449**. In certain embodiments, the center portion **473** may comprise at least one aperture **476** which can be configured to receive a projection **477** extending from the base **449**. In one embodiment, the projections **477** can be press-fit within the apertures **476** in order to secure the conductive jacket **472** to the base **449** although, in some embodiments, the projections **477** can be deformed after they have been inserted into the apertures **476**. In various embodiments, fasteners can be used to secure the conductive jacket **472** to the base **449**.

In various embodiments, the clamp arm assembly **451** may comprise a non-electrically conductive or insulative material, such as plastic and/or rubber, for example, positioned intermediate the conductive jacket **472** and the base **449**. The insulative material can prevent current from flowing, or shorting, between the conductive jacket **472** and the base **449**. In various embodiments, referring again to FIG. **8**, the base **449** may comprise at least one aperture **478**, for example, which can be configured to receive a pivot pin (not illustrated), wherein the pivot pin can be configured to pivotably mount the base **449** to the sheath **158**, for example, such that the clamp arm assembly **451** can be rotated between open and closed positions relative to the sheath **158**. In the embodiment illustrated in FIG. **8**, the base **449** includes two apertures **478** positioned on opposite sides of the base **449**. In one embodiment, the pivot pin can be comprised of a non-electrically conductive or insulative material, such as plastic and/or rubber, for example, which can be configured to prevent current from flowing into the sheath **158** even if the base **449** is in electrical contact with the conductive jacket **472**, for example.

In various embodiments, as described above, the surgical instrument system **110** can be configured such that current can flow from the distal tip of the blade **146**, through the tissue T (FIG. **5**), and then to the distal tip of the clamp member **151**. In one embodiment, as shown in to FIG. **5**, the clamp member **151** may comprise a tissue engaging pad or clamp pad **155**, for example, mounted thereto, wherein the pad **155** can be configured to contact tissue positioned intermediate the clamp member **151** and the waveguide **147**. In one expression of the embodiment, the pad **155** may be formed of a non-electrically conductive or insulative material, such as polytetrafluoroethylene (PTFE), such as for example TEFLON® a trademark name of E. I. Du Pont de Nemours and Company, a low coefficient of friction polymer material, or any other suitable low-friction material. The non-electrically conductive or insulative material can also server to prevent current from flowing between the clamp member **151** and the blade **146** without first passing through the distal end **152** of the blade **146**, the targeted tissue T, and the distal end **153** of the clamp member **151**. In various embodiments, the pad **155** can be attached to the clamp member **151** utilizing an adhesive, for example. The clamp pad **155** mounts on the clamp member **151** for cooperation with the blade **146**, with pivotal movement of the clamp member **151** positioning the clamp pad **155** in substantially parallel relationship to, and in contact with, the blade **146**, thereby defining a tissue treatment region. By this construction, tissue is grasped between the clamp pad **155** and the blade **146**. The clamp pad **155** may be provided with a non-smooth surface, such as a saw tooth-like configuration to enhance the gripping of tissue in cooperation with the blade **146**. The saw tooth-like configuration, or teeth, provide traction against the movement of the blade **146**. The teeth also provide counter traction to the blade **146** and clamping movement. It will be appreciated that the saw tooth-like configuration is just one example of many tissue engaging surfaces to prevent movement of the tissue relative to the movement of the blade **146**. Other illustrative examples include bumps, criss-cross patterns, tread patterns, a bead, or sand blasted surface.

In various other embodiments, the surgical instrument **110** can be configured such that current can flow through tissue clamped between the blade **146**, for example, and the clamp member **151** without having to first pass through the distal ends thereof. In at least one embodiment, referring now to FIG. **9**, a clamp arm assembly **551** may comprise an electrically-conductive member **572** and a pad **555** attached thereto, wherein the electrically-conductive member **572** may comprise at least one sidewall **574** extending downwardly therefrom. In one embodiment, current can flow between the blade **146**, for example, through tissue positioned between the blade **146** and the sidewalls **574** of the clamp arm assembly **551**, and into the sidewalls **574**. In various embodiments, gaps can be defined between each sidewall **574** and the blade **146** and, in addition, a gap can be defined between the tissue-contacting surface **575** of the pad **555** and the blade **146**.

In one embodiment, referring now to FIG. **10**, the gaps between each sidewall **574** and the waveguide **147** can be

defined by a distance "D1," wherein the distance D1 can be selected such that, when the clamp arm assembly **551** is positioned in a closed position, the tissue positioned intermediate each of the sidewalls **574** and the blade **146** can be compressed. Although these gaps are illustrated as having the same distance D1, other embodiments are envisioned in which the gaps have different distances. A gap between the tissue-contacting surface **575** and the blade **146** can be defined by a distance "D2," wherein the distance D2 also may be selected such that, when the clamp arm assembly **551** is positioned in a closed position, the tissue-contacting surface **575** can be contact and/or compress the tissue against blade **146**.

In various embodiments, a clamp arm assembly may comprise an electrically-conductive pad mounted thereto. In at least one such embodiment, such a pad can be configured to contact and/or compress tissue positioned intermediate the clamp arm assembly and a waveguide, such as the blade **146**, for example, such that current can flow from the blade **146** into the pad. In certain embodiments, the electrically conductive pad can be comprised of a typically conductive material, such as copper, for example. In at least one embodiment, the pad can be comprised of a typically non-conductive material, such as PTFE, for example, which can be impregnated with electrically conductive particles, such as medical grade stainless steel, for example, such that the pad is sufficiently conductive to permit current to flow between the blade **146** and the clamp arm.

In one embodiment, as previously discussed, the surgical instrument **110** comprises the blade **146**, for example, which may comprise a first electrode and, in addition, a clamp arm, such as the clamp member **151**, for example, which may comprise a second electrode. In various embodiments, as also discussed above, the blade **146** may comprise a supply electrode whereas the clamp member **151** may comprise a return electrode. Alternatively, the clamp member **151** may comprise the supply electrode while the blade **146** may comprise the return electrode. In various other embodiments, a clamp arm may comprise both the supply electrode and the return electrode. In certain embodiments, referring now to FIG. **11**, a clamp arm may comprise a pad **655** and two or more electrodes, such as a first electrode **682** and a second electrode **683**, for example. In one embodiment, the pad **655** can be comprised of a non-electrically conductive or insulative material, such as PTFE, for example, as previously discussed with reference to the clamp pad **155** (FIG. **5**), whereas the electrodes **682**, **683** can be comprised of an electrically conductive material, such as copper and/or a PTFE material having electrically conductive particles mixed therein, for example. In various embodiments, the first electrode **682** and/or the second electrode **683** can be embedded within the pad **655**. In at least one such embodiment, the pad **655** can be molded onto the electrodes **682**, **683** whereas, in certain embodiments, the electrodes **682**, **683** can be inserted and/or press-fit into openings formed in the pad **655**.

In various embodiments, the first electrode **682** can be positioned adjacent to a first side **674***a* of the pad **655** while the second electrode **683** can be positioned adjacent to a second side **674***b* of the pad **655**. In use, the first electrode **682** may comprise a supply electrode and the second electrode **683** may comprise a return electrode, wherein current can flow from the supply electrode **682**, through tissue clamped or positioned between the pad **655** and the blade **146**, for example, and into the return electrode **683**. In one embodiment, a supply wire can be operably coupled with the first electrode **682** and a return wire can be operably coupled with the second electrode **683** such that current can be supplied thereto from a power source, such as the generator **112**, for example. In various embodiments, referring still to FIG. **11**, the electrodes **682**, **683** can be positioned within the pad **655** such that the electrodes **682**, **683** do not contact the blade **146** when the clamp member **151** (FIG. **5**) is in a closed position and short to the blade **146**. Although the illustrated embodiment comprises one supply electrode and one return electrode positioned within a pad, embodiments are envisioned in which a pad includes more than one supply electrode and/or more than one return electrode.

As discussed above, electrodes can be embedded within the pad of a clamp arm assembly. In various embodiments, first and second electrodes can be mounted to the sides of a clamp arm pad. Referring now to FIG. **12**, a clamp arm may comprise a pad **755**, for example, which can be configured to hold tissue against the blade **146**, for example, wherein a first electrode **782** can be mounted to a first side **774***a* of the pad **755** and wherein a second electrode **783** can be mounted to a second side **774***b* of the pad **755**. In various embodiments, the electrodes **782**, **783** can be positioned within cut-outs in the sides of the pad **755** wherein, in certain embodiments, the electrodes **782**, **783** can be adhered and/or fastened, for example, to the pad **755**. The first electrode **782** may comprise a supply electrode and the second electrode **783** may comprise a return electrode, wherein current can flow from the supply electrode **782**, through tissue clamped or positioned between the pad **755** and the blade **146**, for example, and into the return electrode **783**. In one embodiment, a supply wire can be operably coupled with the first electrode **782** and a return wire can be operably coupled with the second electrode **783** such that current can be supplied thereto from a power source, such as the generator **112**, for example. Furthermore, the electrodes **782**, **783** can be mounted to the pad **755** such that the electrodes **782**, **783** do not contact the blade **146** and create an electrical short thereto. Although the illustrated embodiment comprises one supply electrode and one return electrode mounted to a pad, embodiments are envisioned in which a pad includes more than one supply electrode and/or more than one return electrode.

Still referring to FIG. **12**, various electrodes can be configured such that they extend in a longitudinal direction which is parallel, or at least substantially parallel, to the longitudinal axis of the blade **146**, for example. In various embodiments, the electrodes can extend along an end effector such that the entire length of the tissue positioned within the end effector can be treated. In various embodiments, referring now to FIG. **13**, a clamp arm may comprise a pad **885** having two point electrodes. More particularly, in one embodiment, the pad **855** may comprise a first point electrode **882** and a second point electrode **883** positioned therein, wherein current can flow through tissue positioned intermediate the first point electrode **882** and the second point electrode **883**. In at least one such embodiment, the pad **855** can be comprised of a non-electrically conductive material, the first point electrode **882** may comprise a supply electrode, and the second point electrode **883** may comprise a return electrode. In various embodiments, the electrodes **882**, **883** can be embedded within the pad **885** and, in one embodiment the pad **885** can be molded around the electrodes **882**, **883**. In certain embodiments, the electrodes **882**, **883** can be inserted into apertures within the pad **855**. A supply wire can be operably coupled with the first electrode **882** and a return wire can be operably coupled with the second electrode **883** such that current can be supplied thereto from a power source, such as the generator **112**, for

example. Furthermore, the electrodes **882**, **883** can be positioned within the pad **855** such that the electrodes **882**, **883** do not contact the blade **146** and create an electrical short thereto. In one embodiment, the clamp arm supporting pad **885**, and/or a sheath rotatably supporting the clamp arm, may further comprise a stop which can be configured to prevent the pad **855** from rotating into a position in which the electrodes **882**, **883** contact the blade **146**. Although the illustrated embodiment comprises one supply point electrode and one return point electrode positioned within a pad, other embodiments are envisioned in which a pad includes more than one supply point electrode and/or more than one return point electrode. Various embodiments are envisioned in which a pad includes an array of supply point electrodes and/or an array of return point electrodes.

In various embodiments, as described above, a surgical instrument may comprise a clamp arm including both a supply electrode and a return electrode. In one embodiment, the surgical instrument may comprise a waveguide which does not comprise an electrode. In certain embodiments, a supply electrode and a return electrode can be configured such that current can flow therebetween along a predetermined path. In various embodiments, such a path can be one-dimensional. Embodiments having two point electrodes, for example, can permit such a path. In other embodiments, such a path can be two-dimensional. Embodiments having an array of point electrodes, for example, can permit such a path. A two-dimensional path can be referred to as a field. In certain embodiments, a path can be three-dimensional. In at least one such embodiment, a clamp arm assembly can have a supply electrode and a return electrode while the waveguide may comprise one of a supply electrode or a return electrode. In embodiments where the waveguide comprises a return electrode, current can flow from the supply electrode of the clamp arm assembly to the return electrode of the clamp arm assembly and the return electrode of the waveguide. In one such embodiment, the return electrodes may comprise a common ground. In embodiments where the waveguide comprises a supply electrode, current can flow from the waveguide and the supply electrode of the clamp arm assembly to the return electrode of the clamp arm assembly. Such arrangements can permit the current to flow in a three-dimensional path, or field.

In various embodiments, referring now to FIG. **14**, the surgical instrument **110** may comprise a sheath encompassing, or at least partially encompassing, a portion of the blade **146** wherein a sheath may comprise both at least one supply conductor and at least one return conductor. In one embodiment, a sheath may comprise a plurality of conductive inserts, such as a first conductive insert **957***a* and a second conductive inserts **957***b*, for example, wherein the first conductive insert **957***a* may comprise a supply conductor and wherein the second conductive insert **957***b* may comprise a return conductor. In various embodiments, a non-electrically conductive or insulative material **958**, such as plastic and/or rubber, for example, can be overmolded onto the first and second conductive inserts **957***a*, **957***b* in order to comprise the sheath. In various other embodiments, the surgical instrument **110** may comprise, referring now to FIG. **15**, a sheath assembly encompassing, or at least partially encompassing, a portion of a waveguide wherein the sheath assembly may comprise an inner sheath, such as an inner sheath **1057**, for example, and an outer sheath, such as an outer sheath **1058**, for example. In one embodiment, the inner sheath **1057** may comprise a supply conductor operably coupled with a supply electrode in a clamp arm assembly, wherein the outer sheath **1058** may comprise a return conductor operably coupled with a return electrode in the clamp arm assembly. In certain embodiments, the inner sheath **1057** and/or the outer sheath **1058** may be comprised of an electrically conductive material, such as medical grade stainless steel, for example, wherein, in one embodiment, one or more surfaces of the inner sheath **1057** and/or the outer sheath **1058** can be coated, or at least partially coated, in a non-conductive material, such as a material comprising poly(p-xylylene) polymers, for example. Materials comprised of poly(p-xylylene) polymers are often sold under the tradename of Parylene™.

In various embodiments, a clamp arm can be moved between open and closed positions in order position and/or compress tissue T against a blade. In one embodiment, referring to FIG. **16**, a clamp arm **1151** may comprise a base **1149** and a pad **1155** mounted to the base **1149**, wherein the pad **1155** can be configured to contact and compress tissue T against the blade **146**, for example. As illustrated in FIG. **16**, the pad **1155** may comprise a tissue-contacting surface **1175** which, although it may include various serrations, ridges, and/or surface texturing, is planar, or at least substantially planar. In such embodiments, especially when the blade **146** has a round or arcuate cross-section, only a small portion of the tissue T positioned intermediate the blade **146** and the pad **1155** may contact the surface area, or perimeter, of the blade **146**. As illustrated in FIG. **16**, the tissue T may contact the blade **146** at a contact point P. Various alternative embodiments are envisioned in which the clamp arm **1251**, for example, may comprise downwardly-extending sidewalls **1274** which extend below a tissue-contacting surface **1275** of the pad **1255**, for example, although a clamp arm may comprise a tissue-contacting surface with or without a pad. In one embodiment, referring to FIG. **17**, the sidewalls **1274** can be configured to contact the tissue T positioned laterally with respect to the blade **146** and push the tissue T downwardly. As illustrated in FIG. **17**, the sidewalls **1274** can push the tissue T downwardly such that the tissue T positioned intermediate the sidewalls **1274** contacts a larger surface area, or perimeter, on the blade **146** as compared to the embodiment illustrated in FIG. **16**. Owing to the larger contact area, the blade **146** may be more efficient in cutting, coagulating, and/or otherwise treating the tissue. In embodiments where the blade **146** may comprise a circular or arcuate cross-section, the perimeter contact distance, i.e., the distance in which the tissue is in contact with the perimeter of the blade **146**, may comprise an arclength (s) which can equal the product of the radius of curvature of the arc R and the sweep angle θ defined between the two contact points P. As illustrated in FIG. **17**, the contact points P can represent the endpoints of the perimeter in which the tissue T contacts the blade **146**. Although the illustrated blade **146** is depicted as having a curved or arcuate cross-section, any other suitable cross-section may be used.

In various embodiments, the tissue-contacting surface **1275** of the clamp arm **1251** can define a plane **1298** which can represent the portions of the pad **1255** which contact the tissue T positioned within the end effector when the clamp arm **1251** is rotated between its open and closed positions. As illustrated in FIG. **17**, the sidewalls **1274** of the clamp arm **1251** can extend through the plane **1298**, wherein, when the clamp arm **1251** is rotated from an open position into a closed position, the sidewalls **1274** can be positioned laterally along the opposite sides of the blade **146** and, in addition, the tissue-contacting surface **1275** can be positioned against, or adjacent to, the top surface of the blade **146** such that the plane **1298** is aligned with, or respect to,

a plane **1299** extending through the top surface of the blade **146**. In one embodiment, the plane **1299** can be defined as a tangential plane which is tangential to the perimeter of the blade **146**. In one embodiment, the plane **1299** can be tangential to the top tissue-contacting surface of the blade **146**, for example, wherein the top tissue-contacting surface of the **146** may comprise the surface closest to the clamp tissue-contacting surface **1275** when the clamp arm **1271** is in its closed position. In the illustrated embodiment, still referring to FIG. **17**, the planes **1298**, **1299** can be parallel, or at least substantially parallel, to one another when the tissue-contacting surface **1275** is positioned adjacent to the blade **146**, while the planes **1298**, **1299** can be co-planar, or at least substantially co-planar, with one another when the tissue-contacting surface **1275** is in contact with the blade **146**. The sidewalls **1274** can be sized and configured such that they extend through the blade plane **1299** when the clamp arm **1271** is in the closed position. In various embodiments, the sidewalls **1274** may not extend through the plane **1299** when the clamp arm **1251** is in the open position. In one embodiment, the sidewalls **1274** may "break" the plane **1299** as the clamp arm **1251** is being closed, but before it is completely closed. In one embodiment, the sidewalls **1274** may break the plane **1299** just before the clamp arm **1251** reaches its completely closed position.

FIG. **18** illustrates one embodiment of a drive system **32** of the ultrasonic generator module **180** shown in FIG. **1**, which creates an ultrasonic electrical signal for driving an ultrasonic transducer. With reference now to FIGS. **1** and **18**, the drive system **32** is flexible and can create an ultrasonic electrical drive signal **416** at a desired frequency and power level setting for driving the ultrasonic transducer **114**. In various embodiments, the generator **112** may comprise several separate functional elements, such as modules and/or blocks. Although certain modules and/or blocks may be described by way of example, it can be appreciated that a greater or lesser number of modules and/or blocks may be used and still fall within the scope of the embodiments. Further, although various embodiments may be described in terms of modules and/or blocks to facilitate description, such modules and/or blocks may be implemented by one or more hardware components, e.g., processors, Digital Signal Processors (DSPs), Programmable Logic Devices (PLDs), Application Specific Integrated Circuits (ASICs), circuits, registers and/or software components, e.g., programs, subroutines, logic and/or combinations of hardware and software components.

In one embodiment, the ultrasonic generator module **180** drive system **32** may comprise one or more embedded applications implemented as firmware, software, hardware, or any combination thereof. The ultrasonic generator module **180** drive system **32** may comprise various executable modules such as software, programs, data, drivers, application program interfaces (APIs), and so forth. The firmware may be stored in nonvolatile memory (NVM), such as in bit-masked read-only memory (ROM) or flash memory. In various implementations, storing the firmware in ROM may preserve flash memory. The NVM may comprise other types of memory including, for example, programmable ROM (PROM), erasable programmable ROM (EPROM), electrically erasable programmable ROM (EEPROM), or battery backed random-access memory (RAM) such as dynamic RAM (DRAM), Double-Data-Rate DRAM (DDRAM), and/or synchronous DRAM (SDRAM).

In one embodiment, the ultrasonic generator module **180** drive system **32** comprises a hardware component implemented as a processor **400** for executing program instructions for monitoring various measurable characteristics of the ultrasonic surgical instrument **110** and generating a corresponding output control signal for operating the surgical instrument **110**. In various embodiments, the output control signal is for driving the ultrasonic transducer **114** in cutting and/or coagulation operating modes, measuring electrical characteristics of the surgical instrument **110** and/or the tissue T, and providing feedback to use. It will be appreciated by those skilled in the art that the ultrasonic generator module **180** and the drive system **32** may comprise additional or fewer components and only a simplified version of the ultrasonic generator module **180** and the drive system **32** are described herein for conciseness and clarity. In various embodiments, as previously discussed, the hardware component may be implemented as a DSP, PLD, ASIC, circuits, and/or registers. In one embodiment, the processor **400** may be configured to store and execute computer software program instructions to generate the step function output signals for driving various components of the ultrasonic surgical instrument **110**, such as the transducer **114**, the end effector **150**, and/or the blade **146**.

In one embodiment, under control of one or more software program routines, the processor **400** executes the methods in accordance with the described embodiments to perform a variety of functions, such as, for example, generating a step function formed by a stepwise waveform of drive signals comprising current (I), voltage (V), and/or frequency (f) for various time intervals or periods (T), driving the ultrasonic transducer **114**, driving the end effector **150** using therapeutic and/or subtherapeutic electrical signals (e.g., RF signal), measuring the impedance (Z) of the transducer **114**, measuring the impedance (Z_1) of the tissue T, and/or providing feedback to the user. In one embodiment, stepwise waveforms of the drive signals may be generated by forming a piecewise linear combination of constant functions over a plurality of time intervals created by stepping the ultrasonic generator module **180** drive signals, e.g., output drive current (I), voltage (V), and/or frequency (f). The time intervals or periods (T) may be predetermined (e.g., fixed and/or programmed by the user) or may be variable. Variable time intervals may be defined by setting the drive signal to a first value and maintaining the drive signal at that value until a change is detected in a monitored characteristic. Examples of monitored characteristics may comprise, for example, transducer impedance, tissue impedance, tissue heating, tissue transection, tissue coagulation, and the like. The ultrasonic drive signals generated by the ultrasonic generator module **180** include, without limitation, ultrasonic drive signals that excite various vibratory modes of the ultrasonic transducer **114** such as the primary longitudinal mode and harmonics thereof as well flexural and torsional vibratory modes.

In one embodiment, the executable modules comprise one or more algorithm(s) **402** stored in memory that when executed causes the processor **400** to perform a variety of functions, such as, for example, generating a step function formed by a stepwise waveform of drive signals comprising current (I), voltage (V), and/or frequency (f) for various time intervals or periods (T), driving the ultrasonic transducer **114**, driving the end effector **150** using a therapeutic and/or subtherapeutic electrical signal (e.g., RF signal), measuring the impedance (Z) of the transducer **114**, measuring the impedance (Z_t) of the tissue T, and/or providing feedback in accordance with a state of the tissue T. In one embodiment, an algorithm **402** is executed by the processor **400** to generate a step function formed by a stepwise waveform of drive signals comprising current (I), voltage (V), and/or

frequency (f) for various time intervals or periods (T). The stepwise waveforms of the drive signals may be generated by forming a piecewise linear combination of constant functions over two or more time intervals created by stepping the generator's **30** output drive current (I), voltage (V), and/or frequency (f). The drive signals may be generated either for predetermined fixed time intervals or periods (T) of time or variable time intervals or periods of time in accordance with the one or more stepped output algorithm(s) **402**. Under control of the processor **400**, the ultrasonic generator module **180** steps (e.g., increment or decrement) the current (I), voltage (V), and/or frequency (f) up or down at a particular resolution for a predetermined period (T) or until a predetermined condition is detected, such as a change in a monitored characteristic (e.g., transducer impedance, tissue impedance). The steps can change in programmed increments or decrements. If other steps are desired, the ultrasonic generator module **180** can increase or decrease the step adaptively based on measured system characteristics. In other embodiments, algorithms **402** may be executed by the processor **400** to drive the ultrasonic transducer **114**, drive the end effector **150** using a therapeutic and/or subtherapeutic electrical signal (e.g., RF signal), measure the impedance (Z) of the transducer **114**, measure the impedance (Z_t) of the tissue T, and/or to provide feedback in accordance with a state of the tissue T.

In operation, the user can program the operation of the ultrasonic generator module **180** using the input device **406** located on the front panel of the ultrasonic generator module **180** console. The input device **406** may comprise any suitable device that generates signals **408** that can be applied to the processor **400** to control the operation of the ultrasonic generator module **180**. In various embodiments, the input device **406** includes buttons, switches, thumbwheels, keyboard, keypad, touch screen monitor, pointing device, remote connection to a general purpose or dedicated computer. In other embodiments, the input device **406** may comprise a suitable user interface. Accordingly, by way of the input device **406**, the user can set or program the current (I), voltage (V), frequency (f), and/or period (T) for programming the step function output of the ultrasonic generator module **180**. The processor **400** then displays the selected power level by sending a signal on line **410** to an output indicator **412**.

In various embodiments, the output indicator **412** may provide visual, audible, and/or tactile feedback to the surgeon to indicate the status of a surgical procedure, such as, for example, when tissue cutting and coagulating is complete based on a measured characteristic of the ultrasonic surgical instrument **110**, e.g., transducer impedance, tissue impedance, or other measurements as subsequently described. By way of example, and not limitation, visual feedback comprises any type of visual indication device including incandescent lamps or light emitting diodes (LEDs), graphical user interface, display, analog indicator, digital indicator, bar graph display, digital alphanumeric display. By way of example, and not limitation, audible feedback comprises any type of buzzer, computer generated tone, computerized speech, voice user interface (VUI) to interact with computers through a voice/speech platform. By way of example, and not limitation, tactile feedback comprises any type of vibratory feedback provided through the instrument handpiece assembly **160** or simply housing handle assembly.

In one embodiment, the processor **400** may be configured or programmed to generate a digital current signal **414** and a digital frequency signal **418**. These signals **414**, **418** are applied to a direct digital synthesizer (DDS) circuit **420** to adjust the amplitude and the frequency (f) of the current output signal **416** to the transducer **114**. The output of the DDS circuit **420** is applied to an amplifier **422** whose output is applied to a transformer **424**. The output of the transformer **424** is the signal **416** applied to the ultrasonic transducer **114**, which is coupled to the blade **146** by way of the waveguide **147**.

In one embodiment, the ultrasonic generator module **180** comprises one or more measurement modules or components that may be configured to monitor measurable characteristics of the ultrasonic instrument **110**. In embodiment illustrated in FIG. **18**, the processor **400** may be employed to monitor and calculate system characteristics. As shown, the processor **400** measures the impedance Z of the transducer **114** by monitoring the current supplied to the transducer **114** and the voltage applied to the transducer **114**. In one embodiment, a current sense circuit **426** is employed to sense the current flowing through the transducer **114** and a voltage sense circuit **428** is employed to sense the output voltage applied to the transducer **114**. These signals may be applied to the analog-to-digital converter **432** (ADC) via an analog multiplexer **430** circuit or switching circuit arrangement. The analog multiplexer **430** routes the appropriate analog signal to the ADC **432** for conversion. In other embodiments, multiple ADCs **432** may be employed for each measured characteristic instead of the multiplexer **430** circuit. The processor **400** receives the digital output **433** of the ADC **432** and calculates the transducer impedance Z based on the measured values of current and voltage. In response to the transducer impedance (Z), the processor **400** controls the operation of the surgical instrument **110**. For example, the processor **400** can adjust the power delivered to the transducer **114**, can shut off the power to the transducer **114**, and/or provide feedback to the user. In one embodiment, the processor **400** adjusts the output drive signal **416** such that it can generate a desired power versus load curve. In one embodiment, in accordance with a programmed step function algorithms **402**, the processor **400** can step the drive signal **416**, e.g., the current or frequency, in any suitable increment or decrement in response to the transducer impedance Z.

With reference back now to FIGS. **1** and **18**, to actually cause the surgical blade **146** to vibrate, e.g., actuate the blade **146**, the user activates the foot switch **144** or the switch **143** on the handpiece assembly **160**, as discussed above. This activation outputs the drive signal **416** to the transducer **114** based on programmed values of current (I), frequency (f), and corresponding time periods (T). After a predetermined fixed time period (T), or variable time period based on a measurable system characteristic such as changes in the impedance Z of the transducer **114**, the processor **400** changes the output current step or frequency step in accordance with the programmed values. The output indicator **412** communicates the particular state of the process to the user.

The operation of the ultrasonic generator module **180** may be programmed to provide a variety of output drive signals to measure electrical properties of current, voltage, power, impedance, and frequency associated with the transducer **114** in an unloaded state, a lightly loaded state, and a heavily loaded state, for example. When the ultrasonic transducer **114** is in an unloaded state, the ultrasonic generator module **180** output may be stepped in a first sequence, for example. In one embodiment, the ultrasonic generator module **180** is initially activated at about time 0 resulting in a drive current rising to a first set point I_1 of about 100 mA. The current is maintained at the first set point I_1, for a first period T_1. At the

end of the first period T_1, e.g., about 1 second, the current set point is changed, e.g., stepped, by the ultrasonic generator module **180** in accordance with the software, e.g., the step function algorithm(s) **402**, to a second set point I_2 of about 175 mA for a second period T_2, e.g., about 2 seconds. At the end of the second period T_2, e.g., at about 3 seconds, the ultrasonic generator module **180** software changes the current to a third set point I_3 of about 350 mA. The voltage, current, power, and frequency respond only slightly because there is no load on the system.

When the ultrasonic transducer **114** is in a lightly loaded state, the ultrasonic generator module **180** is activated at about time 0 resulting in the current rising to the first current set point I_1 of about 100 mA. At about 1 second the current set point is changed within the ultrasonic generator module **180** by the software to I_2 of about 175 mA, and then again at about 3 seconds the ultrasonic generator module **180** changes the current **300** set point to I_3 of about 350 mA. The voltage, current, power, and frequency respond to the light load.

When the ultrasonic transducer **114** is in a heavily loaded state, the ultrasonic generator module **180** is activated at about time 0 resulting in the current rising to the first set point I_1 of about 100 mA. At about 1 second the current set point is changed within the ultrasonic generator module **180** by the software to I_2 of about 175 mA, and then again at about 3 seconds the ultrasonic generator module **180** changes the current **300** set point to I_3 of about 350 mA. The voltage, current, power, and frequency respond to the heavy load.

It will be appreciated by those skilled in the art that the current step function set points (e.g., I_1, I_2, I_3) and the time intervals or periods (e.g., T_1, T_2) of duration for each of the step function set points described above are not limited to the values described herein and may be adjusted to any suitable value as may be desired for a given set of surgical procedures. Additional or fewer current set points and periods of duration may be selected as may be desired for a given set of design characteristics or performance constraints. As previously discussed, the periods may be predetermined by programming or may be variable based on measurable system characteristics. The embodiments are not limited in this context.

Having described operational details of various embodiments of the surgical system **100**, operations for the above surgical system **100** may be further described in terms of a process for cutting and coagulating a blood vessel employing a surgical instrument comprising the input device **406** and the transducer impedance measurement capabilities described with reference to FIG. **18**. Although a particular process is described in connection with the operational details, it can be appreciated that the process merely provides an example of how the general functionality described herein can be implemented by the surgical system **100**. Further, the given process does not necessarily have to be executed in the order presented herein unless otherwise indicated. As previously discussed, the input device **406** may be employed to program the stepped output (e.g., current, voltage, frequency) to the ultrasonic transducer **114**/blade **146** assembly.

Accordingly, one technique for sealing a vessel includes separating and moving the inner muscle layer of the vessel away from the adventitia layer prior to the application of standard ultrasonic energy to transect and seal the vessel. Although conventional methods have achieved this separation by increasing the force applied to the clamp member **151**, disclosed is an alternative apparatus and method for cutting and coagulating tissue without relying on clamp force alone. In order to more effectively separate the tissue layers of a vessel, for example, the ultrasonic generator module **180** may be programmed to apply a frequency step function to the ultrasonic transducer **114** to mechanically displace the blade **146** in multiple modes in accordance with the step function. In one embodiment, the frequency step function may be programmed by way of the user interface **406**, wherein the user can select a stepped-frequency program, the frequency (f) for each step, and the corresponding time period (T) of duration for each step for which the ultrasonic transducer **114** will be excited. The user may program a complete operational cycle by setting multiple frequencies for multiple periods to perform various surgical procedures.

In one embodiment, a first ultrasonic frequency may be set initially to mechanically separate the muscle tissue layer of a vessel prior to applying a second ultrasonic frequency to cut and seal the vessel. By way of example, and not limitation, in accordance with one implementation of the program, initially, the ultrasonic generator module **180** is programmed to output a first drive frequency f_1 for a first period T_1 of time (for example less than approximately 1 second), wherein the first frequency f_1 is significantly off resonance, for example, $f_0/2$, $2f_0$ or other structural resonant frequencies, where f_0 is the resonant frequency (e.g., 55.5 kHz). The first frequency f_1 provides a low level of mechanical vibration action to the blade **146** that, in conjunction with the clamp force, mechanically separates the muscle tissue layer (subtherapeutic) of the vessel without causing significant heating that generally occurs at resonance. After the first period T_1, the ultrasonic generator module **180** is programmed to automatically switch the drive frequency to the resonant frequency f_0 for a second period T_2 to transect and seal the vessel. The duration of the second period T_2 may be programmed or may be determined by the length of time it actually takes to cut and seal the vessel as determined by the user or may be based on measured system characteristics such as the transducer impedance Z as described in more detail below.

In one embodiment, the tissue/vessel transection process (e.g., separating the muscle layer of the vessel from the adventitia layer and transecting/sealing the vessel) may be automated by sensing the impedance Z characteristics of the transducer **114** to detect when the transection of the tissue/vessel occurs. The impedance Z can be correlated to the transection of the muscle layer and to the transection/sealing of the vessel to provide a trigger for the processor **400** to generate the frequency and/or current step function output. As previously discussed with reference to FIG. **18**, the impedance Z of the transducer **114** may be calculated by the processor **400** based on the current flowing through transducer **114** and the voltage applied to the transducer **114** while the blade **146** is under various loads. Because the impedance Z of the transducer **114** is proportional to the load applied to the blade **146**, as the load on the blade **146** increases the impedance Z of the transducer **114** increases and as the load on the blade **146** decreases the impedance Z of the transducer **114** decreases. Accordingly, the impedance Z of the transducer **114** can be monitored to detect the transection of the inner muscle tissue layer of the vessel from the adventitia layer and can also be monitored to detect when the vessel has been transected and sealed.

In one embodiment, the ultrasonic surgical instrument **110** may be operated in accordance with a programmed step function algorithm responsive to the transducer impedance Z. In one embodiment, a frequency step function output may

be initiated based on a comparison of the transducer impedance Z and one or more predetermined thresholds that have been correlated with tissue loads against the blade **146**. When the transducer impedance Z transitions above or below (e.g., crosses) a threshold, the processor **400** applies a digital frequency signal **418** to the DDS circuit **420** to change the frequency of the drive signal **416** by a predetermined step in accordance with the step function algorithm(s) **402** responsive to the transducer impedance Z. In operation, the blade **146** is first located at the tissue treatment site. The processor **400** applies a first digital frequency signal **418** to set a first drive frequency f_1 that is off resonance (e.g., $f_0/2$, $2f_0$ or other structural resonant frequencies, where f_0 is the resonant frequency). The drive signal **416** is applied to the transducer **114** in response to activation of the switch **312***a* on the handpiece assembly **160** or the foot switch **434**. During this period the ultrasonic transducer **114** mechanically activates the blade **146** at the first drive frequency f_1. A force or load may be applied to the clamp member **151** and the blade **146** to facilitate this process. During this period, the processor **400** monitors the transducer impedance Z until the load on the blade **146** changes and the transducer impedance Z crosses a predetermined threshold to indicate that the tissue layer has been transected. The processor **400** then applies a second digital frequency signal **418** to set a second drive frequency f_2, e.g., the resonant frequency f_0 or other suitable frequency for transecting, coagulating, and sealing tissue. Another portion of the tissue (e.g., the vessel) is then grasped between the clamp member **151** and the blade **146**. The transducer **114** is now energized by the drive signal **416** at the second drive frequency f_2 by actuating either the foot switch **434** or the switch **312***a* on the handpiece assembly **160**. It will be appreciated by those skilled in the art that the drive current (I) output also may be stepped as described with reference to FIGS. **6-8** based on the transducer impedance Z.

According to one embodiment of a step function algorithm **402**, the processor **400** initially sets a first drive frequency f_1 that is significantly off resonance to separate the inner muscle layer of the vessel from the adventitia layer. During this period of operation the processor **400** monitors the transducer impedance Z to determine when the inner muscle layer is transected or separated from the adventitia layer. Because the transducer impedance Z is correlated to the load applied to the blade **146**, for example, cutting more tissue decrease the load on the blade **146** and the transducer impedance Z. The transection of the inner muscle layer is detected when the transducer impedance Z drops below a predetermined threshold. When the change in transducer impedance Z indicates that the vessel has been separated from the inner muscle layer, the processor **400** sets the drive frequency to the resonant frequency f_0. The vessel is then grasped between the blade **146** and the clamp member **151** and the transducer **114** is activated by actuating either the foot switch or the switch on the handpiece assembly **160** to transect and seal the vessel. In one embodiment, the impedance Z change may range between about 1.5 to about 4 times a base impedance measurements from an initial point of contact with the tissue to a point just before the muscle layer is transected and sealed.

With reference now to FIGS. **1**, **8**, and **19**, as previously discussed, in one embodiment, the surgical system **100**, and the ultrasonic surgical instrument **110**, comprises the signal generator module **102**. In one embodiment, the signal generator module **102** may be implemented as a tissue impedance module **502**. Although in the presently disclosed embodiment, the signal generator module **102** is shown separate from the surgical instrument **110**, in one embodiment, the signal generator module **102** may be formed integrally with the surgical instrument **110**, as shown in phantom in FIG. **1**, such that the surgical instrument **110** forms a unitary surgical system. In one embodiment, surgical instrument the signal generator module **102** may be configured to monitor the electrical impedance Z_t of the tissue T (FIGS. **5**, **10**, **16**, **17**) to control the characteristics of time and power level based on the impedance Z_t of the tissue T. In one embodiment, the tissue impedance Z_t may be determined by applying a subtherapeutic radio frequency (RF) signal to the tissue T and measuring the current through the tissue T by way of a return electrode on the clamp member **151**, as previously discussed. In the schematic diagram shown in FIG. **19**, an end effector portion of the surgical system **100** comprises the clamp arm assembly **451** (FIG. **8**) connected to the distal end of the outer sheath **158**. The blade **146** forms a first (e.g., energizing) electrode and the clamp arm assembly **451** comprises an electrically conductive portion that forms a second (e.g., return) electrode. The tissue impedance module **502** is coupled to the blade **146** and the clamp arm assembly **451** through a suitable transmission medium such as a cable **137**. The cable **137** comprises multiple electrical conductors for applying a voltage to the tissue T and providing a return path for current flowing through the tissue T back to the impedance module **502**. In various embodiments, the tissue impedance module **502** may be formed integrally with the generator **112** or may be provided as a separate circuit coupled to the generator **112** (shown in phantom to illustrate this option).

Still with reference to FIGS. **1**, **8**, and **19** illustrates one embodiment of an integrated generator module **320** comprising the ultrasonic generator module **180** and the signal generator module **102**. As shown, the signal generator module **102** is configured as a tissue impedance module **502**. The integrated generator module **320** generates the ultrasonic electrical drive signal **416** to drive the ultrasonic transducer **114**. In one embodiment, the tissue impedance module **502** may be configured to measure the impedance Z_t of the tissue T (FIGS. **5**, **10**, **16**, **17**) grasped between the blade **146** and the clamp arm assembly **451**. The tissue impedance module **502** comprises an RF oscillator **506**, a voltage sensing circuit **508**, and a current sensing circuit **510**. The voltage and current sensing circuits **508**, **510** respond to the RF voltage v_{rf} applied to the blade **146** electrode and the RF current i_{rf} flowing through the blade **146** electrode, the tissue, and the conductive portion of the clamp arm assembly **451**. The sensed voltage v_{rf} and current i_{rf} are converted to digital form by the ADC **432** via the analog multiplexer **430**. The processor **400** receives the digitized output **433** of the ADC **432** and determines the tissue impedance Z_t by calculating the ratio of the RF voltage v_{rf} to current i_{rf} measured by the voltage sense circuit **508** and the current sense circuit **510**. In one embodiment, the transection of the inner muscle layer and the tissue may be detected by sensing the tissue impedance Z_t. Accordingly, detection of the tissue impedance Z_t may be integrated with an automated process for separating the inner muscle layer from the outer adventitia layer prior to transecting the tissue without causing a significant amount of heating, which normally occurs at resonance. Additional clamp arm and sheath assemblies comprising an electrode as shown in FIGS. **9-17** may be employed without limitation.

FIG. **20** is a schematic diagram of the signal generator module **102** configured as the tissue impedance module **502** coupled to the blade **146** and the clamp arm assembly **415** with tissue T located therebetween. With reference now to

FIGS. **1**, **8**, and **18-20**, the generator **112** comprises the signal generator module **102** configured as the tissue impedance module **502** configured for monitoring the impedance Z_t of the tissue T located between the blade **146** and the clamp arm assembly **451** during the tissue transection process. The tissue impedance module **502** may is coupled to the ultrasonic surgical instrument **110** by way of the cables **137**, **139**. The cable includes a first "energizing" conductor **139** connected to the blade **146** (e.g., positive [+] electrode) and a second "return" conductor **137** connected to the conductive jacket **472** (e.g., negative [−] electrode) of the clamp arm assembly **451**. In one embodiment, RF voltage v_{rf} is applied to the blade **146** to cause RF current i_{rf} to flow through the tissue T. The second conductor **137** provides the return path for the current i_{rf} back to the tissue impedance module **502**. The distal end of the return conductor **137** is connected to the conductive jacket **472** such that the current i_{rf} can flow from the blade **146**, through the tissue T positioned intermediate the conductive jacket **472** and the blade **146**, and the conductive jacket **472** to the return conductor **137**. The impedance module **502** connects in circuit, by way of the first and second conductors **137**, **139**. In one embodiment, the RF energy may be applied to the blade **146** through the ultrasonic transducer **114** and the waveguide **147**. It is worthwhile noting that the RF energy applied to the tissue T for purposes of measuring the tissue impedance Z_t is a low level subtherapeutic signal that does not contribute in a significant manner, or at all, to the treatment of the tissue T.

Having described operational details of various embodiments of the surgical system **100**, operations for the above surgical system **100** may be further described with reference to FIGS. **1**, **8**, and **18-20** in terms of a process for cutting and coagulating a blood vessel employing a surgical instrument comprising the input device **406** and the tissue impedance module **502**. Although a particular process is described in connection with the operational details, it can be appreciated that the process merely provides an example of how the general functionality described herein can be implemented by the surgical system **100**. Further, the given process does not necessarily have to be executed in the order presented herein unless otherwise indicated. As previously discussed, the input device **406** may be employed to program the step function output (e.g., current, voltage, frequency) to the ultrasonic transducer **114**/blade **146** assembly.

In one embodiment, the ultrasonic surgical instrument **110** may be operated in accordance with a programmed step function algorithm **402** responsive to the tissue impedance Z_t. In one embodiment, a frequency step function output may be initiated based on a comparison of the tissue impedance Z_t and predetermined thresholds that have been correlated with various tissue states (e.g., desiccation, transection, sealing). When the tissue impedance Z_t transitions above or below (e.g., crosses) a threshold, the processor **400** applies a digital frequency signal **418** to the DDS circuit **420** to change the frequency of an ultrasonic oscillator by a predetermined step in accordance with the step function algorithm **402** responsive to the tissue impedance Z_t.

In operation, the blade **146** is located at the tissue treatment site. The tissue T is grasped between the blade **146** and the clamp arm assembly **451** such that the blade **146** and the conductive jacket **472** make electrical contact with the tissue T. The processor **400** applies a first digital frequency signal **418** to set a first drive frequency f_1 that is off resonance (e.g., $f_0/2$, $2f_0$ or other structural resonant frequencies, where f_0 is the resonant frequency). The blade **146** is electrically energized by the low level subtherapeutic RF voltage v_{rf} supplied by the tissue impedance module **502**. The drive signal **416** is applied to the transducer **114**/blade **146** in response to actuation of the switch **143** on the handpiece assembly **160** or the foot switch **144434** until the tissue impedance Z_t of the tissue T changes by a predetermined amount. A force or load is then applied to the clamp arm assembly **451** and the blade **146**. During this period the ultrasonic transducer **114** mechanically activates the blade **146** at the first drive frequency f_1 and as a result, the tissue T begins to desiccate from the ultrasonic action applied between the blade **146** and the one or more clamp pads **155** of the clamp arm assembly **451** causing the impedance Z_t of the tissue T to increase. Eventually, as the tissue T is transected by the ultrasonic action and applied clamp force, the impedance Z_t of the tissue T becomes very high or infinite. It will be appreciated by those skilled in the art that the drive current (I) output also may be stepped as described above based on measured impedance Z_t of the tissue T.

In one embodiment, the impedance Z_t of tissue T may be monitored by the impedance module **502** in accordance with the following process. A measurable RF current i_1 is conveyed through the first energizing conductor **139** to the blade **146**, through the tissue T, and back to the impedance module **502** through the conductive jacket **472** and the second conductor **137**. As the tissue T is desiccated and cut by the ultrasonic action of the blade **146** acting against the one or more clamp pads **155**, the impedance of the tissue **514** increases and thus the current i_1 in the return path, i.e., the second conductor **137**, decreases. The impedance module **502** measures the tissue impedance Z_t and conveys a representative signal to the ADC **432** whose digital output **433** is provided to the processor **400**. The processor **400** calculates the tissue impedance Z_t based on these measured values of v_{rf} and i_{rf}. In response to the transducer impedance (Z_t), the processor **400** controls the operation of the surgical instrument **110**. For example, the processor **400** can adjust the power delivered to the transducer **114**, can shut off the power to the transducer **114**, and/or provide feedback to the user. In one embodiment, the processor **400** steps the frequency by any suitable increment or decrement in response to changes in the impedance Z_t of the tissue T. In other embodiments, the processor **400** controls the drive signals **416** and can make any necessary adjustments in amplitude and frequency in response to the tissue impedance Z_t. In one embodiment, the processor **400** can cut off the drive signal **416** when the tissue impedance Z_t reaches a predetermined threshold value.

Accordingly, by way of example, and not limitation, in one embodiment, the ultrasonic surgical instrument **110** may be operated in accordance with a programmed stepped output algorithm to separate the inner muscle layer of a vessel from the adventitia layer prior to transecting and sealing the vessel. As previously discussed, according to one step function algorithm, the processor **400** initially sets a first drive frequency f_1 that is significantly off resonance. The transducer **114** is activated to separate the inner muscle layer of the vessel from the adventitia layer and the tissue impedance module **502** applies a subtherapeutic RF voltage v_{rf} signal to the blade **146**. During this period T_1 of operation the processor **400** monitors the tissue impedance Z_t to determine when the inner muscle layer is transected or separated from the adventitia layer. The tissue impedance Z_t is correlated to the load applied to the blade **146**, for example, when the tissue becomes desiccated or when the tissue is transected the tissue impedance Z_t becomes extremely high or infinite. The change in tissue impedance

Z_t indicates that the vessel has been separated or transected from the inner muscle layer and the generator **112** is deactivated for a second period of time T_2. The processor **400** then sets the drive frequency to the resonant frequency f_0. The vessel is then grasped between the blade **146** and the clamp arm assembly **451** and the transducer **114** is reactivated to transect and seal the vessel. Continuous monitoring of the tissue impedance Z_t provides an indication of when the vessel is transected and sealed. Also, the tissue impedance Z_t may be monitored to provide an indication of the completeness of the tissue cutting and/or coagulating process or to stop the activation of the generator **112** and/or the ultrasonic generator module **180** when the impedance Z_t of the tissue T reaches a predetermined threshold value. The threshold for the tissue impedance Z_t may be selected, for example, to indicate that the vessel has been transected. In one embodiment, the tissue impedance Z_t may range between about 10 Ohms to about 1000 Ohms from an initial point to a point just before the muscle layer is transected and sealed.

The applicants have discovered that experiments that run varying current set points (both increasing and decreasing) and dwell times indicate that the described embodiments can be used to separate the inner muscle layer from the outer adventitia layer prior to completing the transection resulting in improved hemostasis and potentially lower total energy (heat) at the transection site. Furthermore, although the surgical instrument **110** has been described in regards to impedance threshold detection schemes to determine when the muscle layer is separated from the adventitia, other embodiments that do not employ any detection scheme are within the scope of the present disclosure. For example, embodiments of the surgical instrument **110** may be employed in simplified surgical systems wherein non-resonant power is applied to separate the layers for a predetermined time of approximately 1 second or less, prior to applying a resonant power to cut the tissue. The embodiments are not limited in this context.

In various embodiments, the surgical instrument **110** may be programmed for detecting a change of state of tissue being manipulated by an ultrasonic surgical instrument and providing feedback to the user to indicate that the tissue has undergone such change of state or that there is a high likelihood that the tissue has undergone such change of state. As used herein, the tissue may undergo a change of state when the tissue is separated from other layers of tissue or bone, when the tissue is cut or transected, when the tissue is coagulated, and so forth while being manipulated with an end effector of an ultrasonic surgical instrument, such as, for example, the end effector **150** of the ultrasonic surgical instrument **110**. A change in tissue state may be determined based on the likelihood of an occurrence of a tissue separation event.

With reference to FIGS. **1**, **5**, and **18-20**, in various embodiments, the impedance Z and the tissue Z_t, as well as any other suitable electrical measurements, that can be made with the surgical system **100**, may be used to provide feedback by the output indicator **412** shown in FIGS. **18** and **19**. The output indicator **412** is particularly useful in applications where the tissue being manipulated by the end effector **151** is out of the user's field of view and the user cannot see when a change of state occurs in the tissue T. The output indicator **412** communicates to the user that a change in tissue state has occurred as determined in accordance with the operations described with respect to various logic flows. As previously discussed, the output indicator **412** may be configured to provide various types of feedback to the user including, without limitation, visual, audible, and/or tactile feedback to indicate to the user (e.g., surgeon, clinician) that the tissue has undergone a change of state of the tissue. By way of example, and not limitation, as previously discussed, visual feedback comprises any type of visual indication device including incandescent lamps or LEDs, graphical user interface, display, analog indicator, digital indicator, bar graph display, digital alphanumeric display. By way of example, and not limitation, audible feedback comprises any type of buzzer, computer generated tone, computerized speech, VUI to interact with computers through a voice/speech platform. By way of example, and not limitation, tactile feedback comprises any type of vibratory feedback provided through the instrument housing handpiece assembly **160**.

The processor **400** to determines a change in tissue state in accordance with the operations described above and provides feedback to the user by way of the output indicator **412**. The processor **400** monitors and evaluates the voltage, current, and/or frequency signal samples available from the generator **32**, **320** and according to the evaluation of such signal samples determines whether a change in tissue state has occurred. A change in tissue state may be determined based on the type of ultrasonic instrument and the power level that the instrument is energized at. In response to the feedback, the operational mode of the ultrasonic surgical instrument **110** may be controlled by the user or may be automatically or semi-automatically controlled.

In one embodiment, the processor **400** portion of the drive system **32**, **320** samples the voltage (v), current (i), and frequency (f) signals of the ultrasonic generator module **180** and/or the signal generator module **102**. As previously discussed, the output indicator **412** may provide visual, audible, and/or tactile feedback to alert the user of the ultrasonic surgical instrument **110** that a change in tissue state has occurred. In various embodiments, in response to the feedback from the output indicator **412**, the operational modes of the generator **112**, the ultrasonic generator module **180**, the signal generator module **102**, and/or the ultrasonic instrument **110** may be controlled manually, automatically, or semi-automatically. The operational modes include, without limitation, disconnecting or shutting down the output power, reducing the output power, cycling the output power, pulsing the output power, and/or outputting momentary surge of high-power. In one embodiment, the operational modes include, operating the surgical instrument **110** in a first operating mode in which the transducer **14** produces mechanical energy, or vibrations, that are transmitted to the end effector **151** and a second operating mode in which electrical energy, or current, can flow through the end effector **151** to perform electrosurgery. The operational modes of the ultrasonic instrument **110** in response to the change in tissue state can be selected, for example, to minimize heating effects of the end effector **151**, e.g., of the clamp pad **155**, to prevent or minimize possible damage to the surgical instrument **110**, and/or surrounding tissue. This is advantageous because heat is generated exponentially when the transducer **114** is activated with nothing between the jaws of the end effector **151** as is the case when a change in tissue state occurs.

In various embodiments, the change of state of the tissue may be determined based on transducer and tissue impedance measurements as previously described, or based on voltage, current, and frequency measurements in accordance with the operations described in the disclosure of the following commonly-owned U.S. Patent Application, which is incorporated herein by reference in its entirety: U.S. patent

application Ser. No. 12/503,775, entitled "ULTRASONIC DEVICE FOR CUTTING AND COAGULATING WITH STEPPED OUTPUT," now U.S. Pat. No. 8,058,771.

The devices disclosed herein can be designed to be disposed of after a single use, or they can be designed to be used multiple times. In either case, however, the device can be reconditioned for reuse after at least one use. Reconditioning can include any combination of the steps of disassembly of the device, followed by cleaning or replacement of particular pieces, and subsequent reassembly. In particular, the device can be disassembled, and any number of the particular pieces or parts of the device can be selectively replaced or removed in any combination. Upon cleaning and/or replacement of particular parts, the device can be reassembled for subsequent use either at a reconditioning facility, or by a surgical team immediately prior to a surgical procedure. Those skilled in the art will appreciate that reconditioning of a device can utilize a variety of techniques for disassembly, cleaning/replacement, and reassembly. Use of such techniques, and the resulting reconditioned device, are all within the scope of the present application.

Preferably, the various embodiments described herein will be processed before surgery. First, a new or used instrument is obtained and if necessary cleaned. The instrument can then be sterilized. In one sterilization technique, the instrument is placed in a closed and sealed container, such as a plastic or TYVEK bag. The container and instrument are then placed in a field of radiation that can penetrate the container, such as gamma radiation, x-rays, or high-energy electrons. The radiation kills bacteria on the instrument and in the container. The sterilized instrument can then be stored in the sterile container. The sealed container keeps the instrument sterile until it is opened in the medical facility. Sterilization can also be done by any number of ways known to those skilled in the art including beta or gamma radiation, ethylene oxide, and/or steam.

In various embodiments, an ultrasonic surgical instrument can be supplied to a surgeon with a waveguide and/or end effector already operably coupled with a transducer of the surgical instrument. In at least one such embodiment, the surgeon, or other clinician, can remove the ultrasonic surgical instrument from a sterilized package, plug the ultrasonic instrument into a generator, as outlined above, and use the ultrasonic instrument during a surgical procedure. Such a system can obviate the need for a surgeon, or other clinician, to assemble a waveguide and/or end effector to the ultrasonic surgical instrument. After the ultrasonic surgical instrument has been used, the surgeon, or other clinician, can place the ultrasonic instrument into a sealable package, wherein the package can be transported to a sterilization facility. At the sterilization facility, the ultrasonic instrument can be disinfected, wherein any expended parts can be discarded and replaced while any reusable parts can be sterilized and used once again. Thereafter, the ultrasonic instrument can be reassembled, tested, placed into a sterile package, and/or sterilized after being placed into a package. Once sterilized, the reprocessed ultrasonic surgical instrument can be used once again.

Although various embodiments have been described herein, many modifications and variations to those embodiments may be implemented. For example, different types of end effectors may be employed. Also, where materials are disclosed for certain components, other materials may be used. The foregoing description and following claims are intended to cover all such modification and variations.

Any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated materials does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

What is claimed is:

1. A surgical instrument, comprising:

a handpiece housing;

an acoustic assembly supported within said handpiece housing, wherein said acoustic assembly is configured to produce vibrations;

a waveguide comprising a proximal end and a distal end, wherein said proximal end is mounted to said acoustic assembly such that vibrations produced by said acoustic assembly are transmitted to said waveguide;

an ultrasonic blade coupled to said distal end of said waveguide, wherein said ultrasonic blade comprises a tissue treatment portion configured to cut and coagulate tissue;

a clamp movable between an open position and a closed position relative to said waveguide, wherein said clamp comprises a first electrode and a second electrode, and wherein said first electrode and said second electrode longitudinally overlap said tissue treatment portion of said ultrasonic blade when said clamp is in said closed position;

a first conductor in electrical communication with said first electrode; and

a second conductor in electrical communication with said second electrode, wherein said first conductor and said second conductor are configured to be placed in electrical communication with a power source such that current can flow from said first electrode to said second electrode through tissue positioned intermediate said first electrode and said second electrode.

2. The surgical instrument of claim **1**, wherein said clamp comprises a tissue-contacting pad, and wherein said first electrode and said second electrode are embedded in said tissue-contacting pad.

3. The surgical instrument of claim **2**, wherein said first electrode comprises a first point electrode, wherein said second electrode comprises a second point electrode, and wherein said first point electrode is positioned closer to said distal end of said waveguide than said second point electrode.

4. The surgical instrument of claim **1**, wherein said clamp comprises a tissue-contacting pad, wherein said tissue-contacting pad comprises a first side and a second side, wherein said first electrode is mounted to said first side, and wherein said second electrode is mounted to said second side.

5. A surgical instrument, comprising:

a housing;

an acoustic assembly supported within said housing, wherein said acoustic assembly is configured to produce vibrations;

a waveguide coupled to said acoustic assembly;

an ultrasonic blade extending from said waveguide, wherein said ultrasonic blade comprises a tissue treatment area configured to cut and coagulate tissue;

a clamp movable between an open position and a closed position relative to said waveguide, wherein said clamp comprises:

an electrically non-conductive pad;

a first electrode embedded in said electrically non-conductive pad; and

a second electrode embedded in said electrically non-conductive pad, wherein said first electrode and said second electrode longitudinally overlap said tissue treatment area of said ultrasonic blade when said clamp is in said closed position;

a first conductor in electrical communication with said first electrode; and

a second conductor in electrical communication with said second electrode, wherein said first conductor and said second conductor are configured to be placed in electrical communication with a power source such that current can flow from said first electrode to said second electrode through tissue positioned intermediate said first electrode and said second electrode.

6. The surgical instrument of claim **5**, wherein said first electrode and said second electrode are laterally offset.

7. The surgical instrument of claim **5**, wherein said first electrode comprises a first longitudinal electrode, and wherein said second electrode comprises a second longitudinal electrode.

8. The surgical instrument of claim **7**, wherein said second electrode extends parallel to said first electrode.

9. The surgical instrument of claim **7**, wherein said electrically non-conductive pad comprises a first lateral side and a second lateral side, wherein said first electrode is mounted to said first lateral side, and wherein said second electrode is mounted to said second lateral side.

10. The surgical instrument of claim **5**, wherein said first electrode comprises a first point electrode, and wherein said second electrode comprises a second point electrode.

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专利名称(译)	超声波手术器械		
公开(公告)号	US9764164	公开(公告)日	2017-09-19
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[标]申请(专利权)人(译)	伊西康内外科公司		
申请(专利权)人(译)	爱惜康内镜手术，INC.		
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CPC分类号	A61N7/00 A61B17/320092 A61B18/1445 A61B2017/00367 A61B2017/00393 A61B2018/00702 A61B2018/00875 A61B2018/00916 A61B2017/320093 A61B2017/320094 A61B2017/320095		
其他公开文献	US20140107538A1		
外部链接	Espacenet USPTO		

摘要(译)

本发明公开了一种手术器械，包括壳体，配置成产生振动的声学组件，以及连接到声学组件的波导。手术器械还包括从波导延伸的超声刀和可相对于波导在打开位置和闭合位置之间移动的夹具。夹具包括非导电垫，嵌入非导电垫中的第一电极，以及嵌入非导电垫中的第二电极，其中第一电极和第二电极纵向重叠组织处理区域。当夹具处于关闭位置时，超声波刀片。手术器械还包括第一导体和第二导体，其中第一导体和第二导体被配置为与电源电连通，使得电流可以从第一电极流到第二电极。