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Rankin et al.

(54) ABLATION PROBE WITH FLUID-BASED ACOUSTIC COUPLING FOR ULTRASONIC TISSUE IMAGING

(71) Applicants: **Koninklijke Philips N.V.**, Eindhoven (NL); **Boston Scientific Scimed Inc.**, Maple Grove, MN (US)

(72) Inventors: **Darrell L. Rankin**, Milpitas, MN (US); **Josef V. Koblish**, Sunnyvale, CA (US); **Szabolcs Deladi**, Veldhoven (NL)

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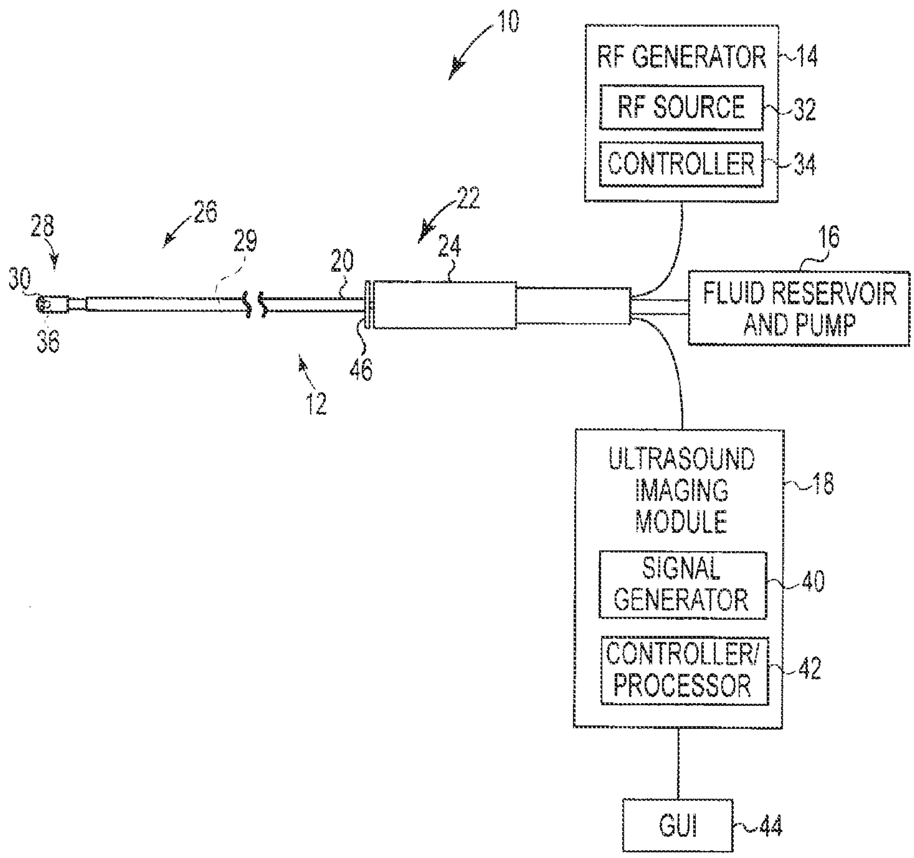
(57) **ABSTRACT**

Devices and systems for ultrasonically imaging tissue and performing ablation therapy are disclosed. An ablation probe for treating and imaging body tissue includes an ablation electrode tip with a number of acoustic openings and a plurality of ultrasonic imaging sensors disposed within an interior lumen of the tip. The ultrasonic imaging sensors are supported within the interior lumen via an insert equipped with a number of recesses that receive the ultrasonic imaging sensors. An acoustically transparent shell disposed between the ultrasonic imaging sensors and the acoustic openings forms a fluid channel in the acoustic pathway of the sensors. During an ablation procedure, cooling fluid from an external fluid source is delivered through the fluid channel, providing an acoustic coupling effect between the ultrasonic imaging sensors and the surrounding body tissue.



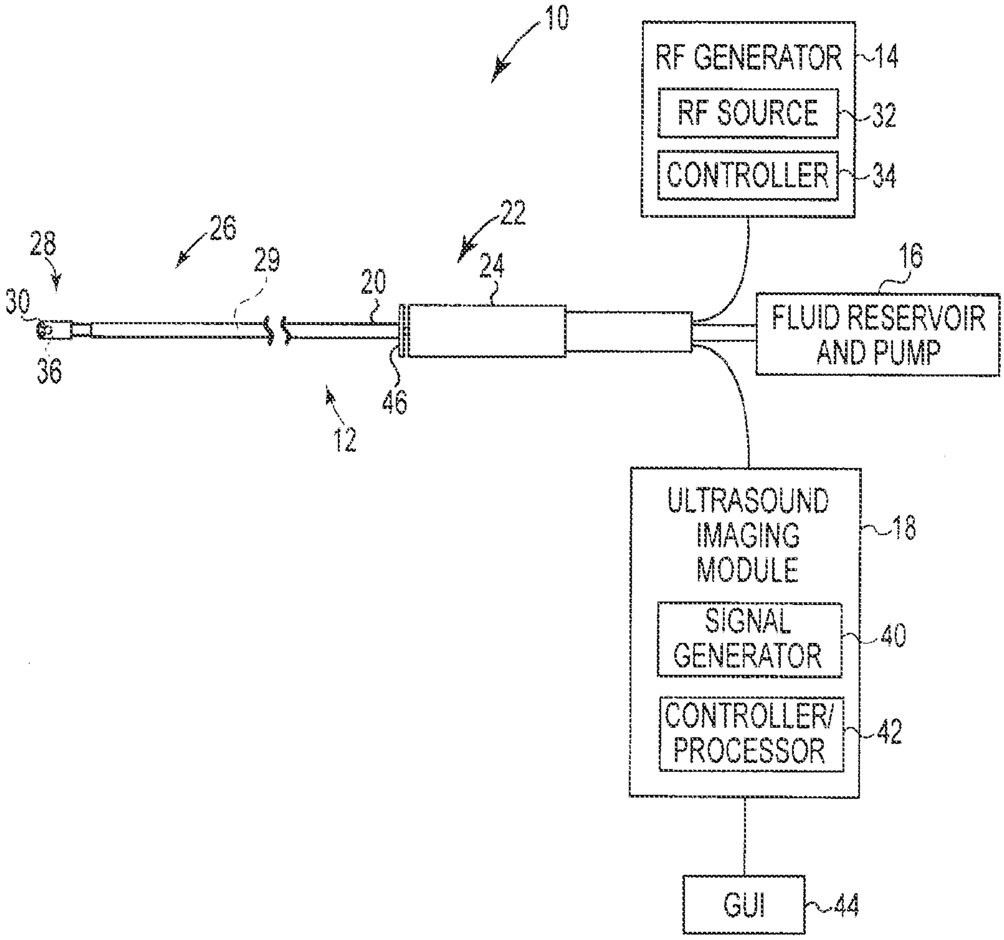

10
RF GENERATOR
14
RF SOURCE
32
CONTROLLER
34
28
26
29
22
24
16
30
20
FLUID RESERVOIR AND PUMP
36
46
12
ULTRASOUND IMAGING MODULE
18
SIGNAL GENERATOR
40
CONTROLLER/ PROCESSOR
42
GUI
44

Figure 1

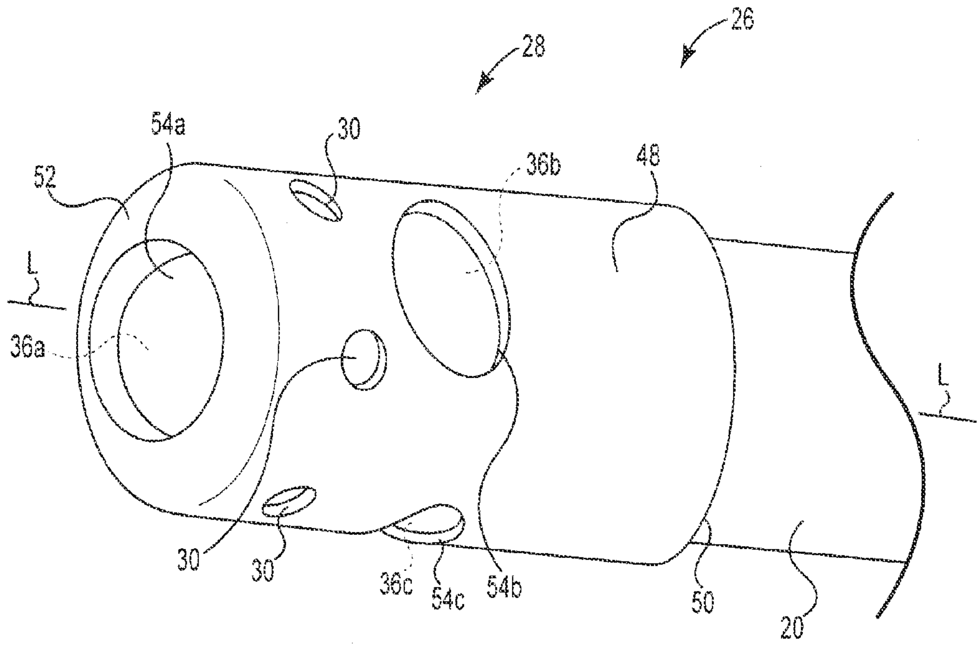


Figure 2

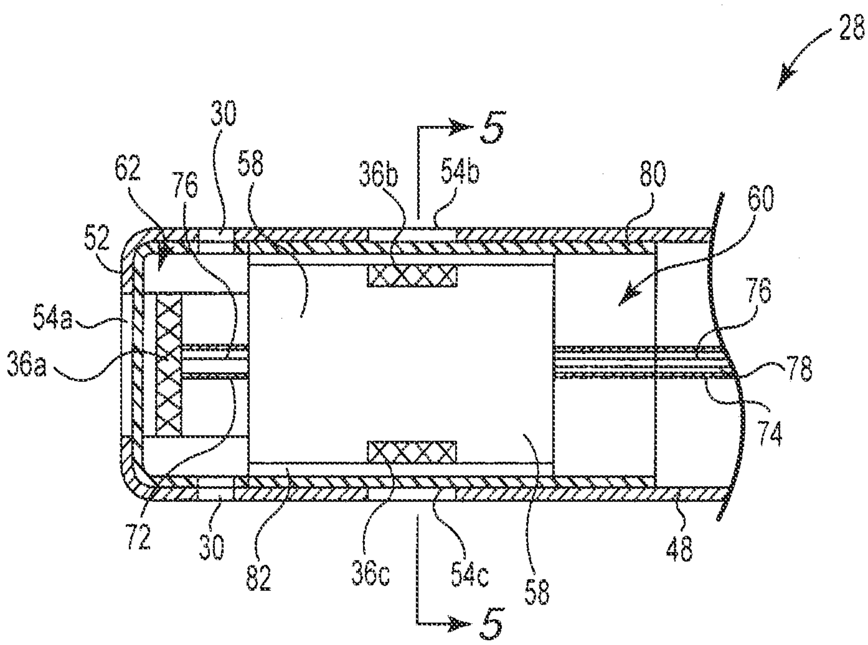


Figure 3

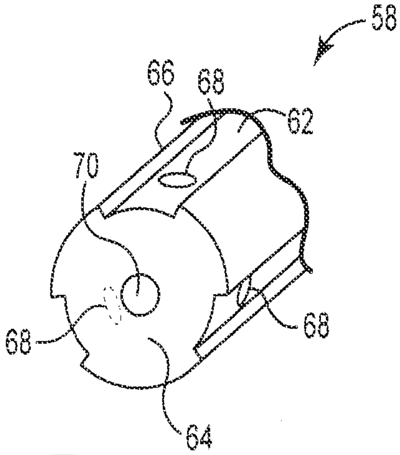


Figure 4

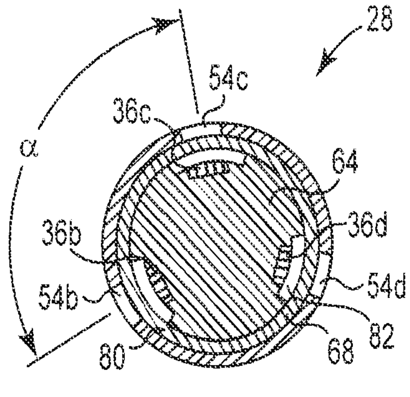


Figure 5

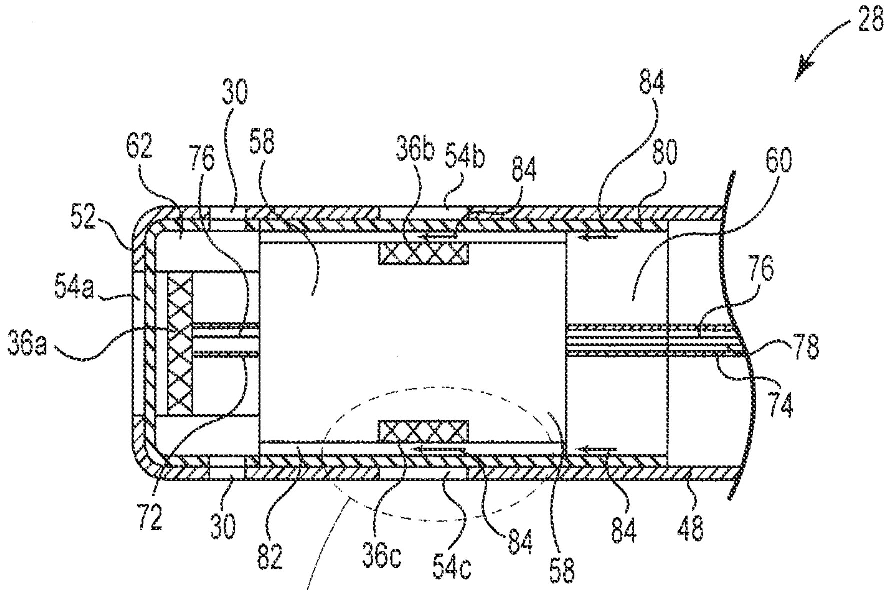


Figure 6

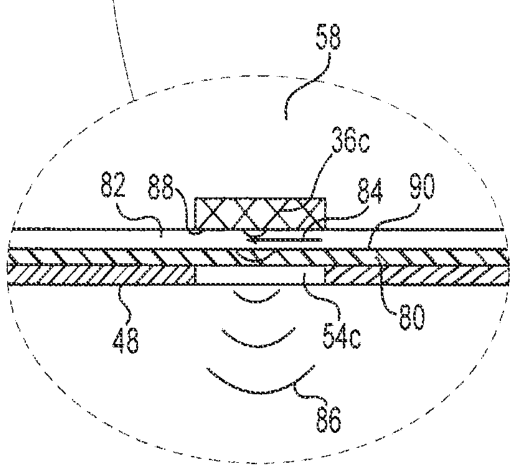


Figure 7

ABLATION PROBE WITH FLUID-BASED ACOUSTIC COUPLING FOR ULTRASONIC TISSUE IMAGING

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a division of U.S. application Ser. No. 13/735,358, filed Jan. 7, 2013, which claims priority to Provisional Application No. 61/592,908, filed Jan. 31, 2012, which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates generally to devices and systems for imaging tissue within the body during an ablation procedure. More specifically, the present disclosure relates to an ablation probe with ultrasonic imaging capabilities.

BACKGROUND

[0003] In ablation therapy, it is often necessary to determine various characteristics of body tissue at a target ablation site within the body. In interventional cardiac electrophysiology (EP) procedures, for example, it is often necessary for the physician to determine the condition of cardiac tissue at a target ablation site in or near the heart. During some EP procedures, the physician may deliver a mapping catheter through a main vein or artery into an interior region of the heart to be treated. Using the mapping catheter, the physician may then determine the source of a cardiac rhythm disturbance or abnormality by placing a number of mapping elements carried by the catheter into contact with the adjacent cardiac tissue and then operate the catheter to generate an electrophysiology map of the interior region of the heart. Once a map of the heart is generated, the physician may then advance an ablation catheter into the heart, and position an ablation electrode carried by the catheter tip near the targeted cardiac tissue to ablate the tissue and form a lesion, thereby treating the cardiac rhythm disturbance or abnormality. In some techniques, the ablation catheter itself may include a number of mapping electrodes, allowing the same device to be used for both mapping and ablation.

[0004] Various ultrasound-based imaging catheters and probes have been developed for directly visualizing body tissue in applications such as interventional cardiology, interventional radiology, and electrophysiology. For interventional cardiac electrophysiology procedures, for example, ultrasound imaging devices have been developed that permit the visualization of anatomical structures of the heart directly and in real-time. In some electrophysiology procedures, for example, ultrasound catheters may be used to image the intra-atrial septum, to guide transseptal crossing of the atrial septum, to locate and image the pulmonary veins, and to monitor the atrial chambers of the heart for signs of a perforation and pericardial effusion.

[0005] Many ultrasound-based imaging systems comprise an imaging probe that is separate from the mapping and ablation catheters used to perform therapy on the patient. As a result, a position tracking system is sometimes used to track the location of each device within the body. In some procedures, it may be difficult for the physician to quickly and accurately determine the condition of tissue to be ablated. Moreover, the images obtained using many ultrasound-based imaging systems are often difficult to read and understand without reference to images obtained from a separate imaging system such as a fluoroscopic imaging system.

SUMMARY

[0006] The present disclosure relates generally to devices and systems for imaging tissue within the body during an ablation procedure.

[0007] In Example 1, an ablation probe for treating and imaging body tissue comprises: an elongate probe body having a proximal section and a distal section; an ablation electrode tip coupled to the distal section of the elongate probe body, the ablation electrode tip configured for delivering ablation energy to body tissue; a plurality of acoustic openings disposed through the ablation electrode tip; a plurality of ultrasonic imaging sensors disposed within an interior lumen of the ablation electrode tip; an acoustically transparent member disposed between the ultrasonic imaging sensors and the acoustic openings; and a fluid channel interposed between the ultrasonic imaging sensors and the acoustically transparent member.

[0008] In Example 2, the probe according to Example 1, wherein each ultrasonic imaging sensor is configured to transmit ultrasonic waves through the fluid channel, the acoustically transparent member, and a corresponding one of the acoustic openings.

[0009] In Example 3, the probe according to any of Examples 1 or 2, wherein the ablation electrode tip comprises a tubular-shaped metal shell.

[0010] In Example 4, the probe according to any of Examples 1-3, wherein the acoustic openings are located circumferentially about the ablation electrode tip.

[0011] In Example 5, the probe according to any of Examples 1-4, wherein the ablation electrode tip further includes a plurality of irrigation ports.

[0012] In Example 6, the probe according to Example 5, wherein the irrigation ports are located circumferentially about the ablation electrode tip.

[0013] In Example 7, the probe according to any of Examples 5-6, wherein the irrigation ports are located distally and/or proximally of the acoustic openings.

[0014] In Example 8, the probe according to any of Examples 5-7, wherein the ultrasonic imaging sensors are located within the interior lumen of the ablation electrode tip at a location proximal to the irrigation ports.

[0015] In Example 9, the probe according to any of Examples 1-8, wherein the ultrasonic imaging sensors are each configured for transmitting laterally-directed ultrasonic waves from a side of the ablation electrode tip.

[0016] In Example 10, the probe of according to any of Examples 1-9, further comprising at least one additional ultrasonic imaging sensor disposed within the ablation electrode tip, the at least one additional ultrasonic imaging sensor configured for transmitting ultrasonic waves in a distal direction away from a distal end of the ablation electrode tip.

[0017] In Example 11, the probe according to Example 10, wherein the acoustically transparent member is further disposed between the at least one additional ultrasonic imaging sensor and a distal-facing acoustic opening disposed through the ablation electrode tip, and wherein the fluid channel is further interposed between the at least one additional ultrasonic imaging sensor and the distal-facing acoustic opening.

[0018] In Example 12, the probe according to any of Examples 1-10, wherein the acoustically transparent member comprises a tubular-shaped shell.

[0019] In Example 13, the probe according to any of Examples 1-12, wherein fluid within the fluid channel acoustically couples the ultrasonic imaging sensors to the body tissue.

[0020] In Example 14, the probe according to any of Examples 1-13, further comprising an insert configured for supporting the ultrasonic imaging sensors within the interior lumen of the ablation electrode tip.

[0021] In Example 15, the probe according to Example 14, wherein the insert comprises a cylindrically-shaped insert body including a plurality of recesses each configured for receiving an ultrasonic transducer therein.

[0022] In Example 16, the probe according to any of Examples 14-15, wherein a transmitting face of each ultrasonic imaging sensor is substantially flush with an outer surface of the insert body.

[0023] In Example 17, the probe according to any of Examples 14-16, wherein the interior lumen of the ablation electrode tip includes a proximal fluid chamber and a distal fluid chamber, wherein the proximal and distal fluid chambers are separated by the insert.

[0024] In Example 18, an ablation probe for treating and imaging body tissue comprises: an elongate probe body having a proximal section and a distal section; an ablation electrode tip coupled to the distal section of the elongate probe body, the ablation electrode tip configured for delivering ablation energy to body tissue; a plurality of acoustic openings disposed through a side of the ablation electrode tip; an insert disposed within an interior lumen of the ablation electrode tip; a plurality of lateral-facing ultrasonic imaging sensors coupled to the insert, the lateral-facing ultrasonic imaging sensors configured for transmitting ultrasonic waves from a side of the ablation electrode tip; an acoustically transparent member disposed between the lateral-facing ultrasonic imaging sensors and the acoustic openings; a fluid channel interposed between the lateral-facing ultrasonic imaging sensors and the acoustically transparent member; and at least one distal-facing ultrasonic imaging sensor disposed within the interior lumen of the ablation electrode, the distal-facing ultrasonic imaging sensor configured for transmitting ultrasonic waves in a distal direction away from a distal end of the ablation electrode tip.

[0025] In Example 19, an ablation and ultrasound imaging system comprises: an ablation probe including an ablation electrode tip configured for delivering ablation energy to body tissue, the ablation electrode tip comprising a plurality of acoustic openings disposed through the ablation electrode tip, a plurality of ultrasonic imaging sensors disposed within an interior lumen of the ablation electrode tip, an acoustically transparent member disposed between the ultrasonic imaging sensors and the acoustic openings, and a fluid channel interposed between the ultrasonic imaging sensors and the acoustically transparent member. The system further comprises a fluid source configured for delivering cooling fluid to the ablation electrode tip, the cooling fluid acoustically coupling the ultrasonic imaging sensors to the body tissue; an ablation therapy module configured for generating and supplying an electrical signal to the ablation electrode tip; and an ultrasound imaging module configured for processing ultrasonic imaging signals received from the ultrasonic imaging sensors.

[0026] In Example 20, the system according to Example 19, wherein the ultrasonic imaging module comprises a signal generator configured to generate control signals for controlling each ultrasonic imaging sensor; and an image processor configured for processing electrical signals received from each ultrasonic imaging sensor and generating a plurality of ultrasonic images.

[0027] While multiple embodiments are disclosed, still other embodiments of the present invention will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments of the invention. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] FIG. **1** is a schematic view of a combined ablation and imaging system in accordance with an illustrative embodiment;

[0029] FIG. **2** is a perspective view showing the distal section of the combined ablation and ultrasonic imaging probe of FIG. **1** in greater detail;

[0030] FIG. **3** is a schematic view showing an interior portion of the ablation electrode tip in accordance with an illustrative embodiment;

[0031] FIG. **4** is a perspective view of the tip insert of FIG. **3**;

[0032] FIG. **5** is a cross-sectional view of the ablation electrode tip along line **5-5** in FIG. **3**;

[0033] FIG. **6** is another schematic view of the ablation electrode tip showing the flow of cooling fluid across the surface of the ultrasonic imaging sensors; and

[0034] FIG. **7** is an enlarged view showing the transmission of ultrasonic waves from one of the ultrasonic imaging sensors through the cooling fluid, acoustically transparent shell, and acoustic opening of the ablation electrode tip.

[0035] While the invention is amenable to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and are described in detail below. The intention, however, is not to limit the invention to the particular embodiments described. On the contrary, the invention is intended to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

[0036] FIG. **1** is a schematic view of a combined ablation and imaging system **10** in accordance with an illustrative embodiment. As shown in FIG. **1**, the system **10** includes a combined ablation and ultrasonic imaging probe **12**, an RF generator **14**, a fluid reservoir and pump **16**, and an ultrasonic imaging module **18**. The probe **12** comprises an elongate probe body **20** having a proximal section **22** equipped with a handle assembly **24**, and a deflectable distal section **26** including an ablation electrode tip **28**. The probe body **20** includes an internal cooling fluid lumen **29** fluidly coupled to the fluid reservoir and pump **16**, which supplies cooling fluid, such as saline, through the probe body **20** to a number of irrigation ports **30** in the ablation electrode tip **28**. The probe body **20** may further include additional lumens or other tubular elements for supporting electrical conductors, additional fluid lumens, a thermocouple, an insertable stylet, as well as other components. In some embodiments, the probe body **20** comprises flexible plastic tubing with a braided metal mesh to increase the rotational stiffness of the body **20**.

[0037] The RF generator **14** is configured for generating RF energy for performing ablation procedures using the ablation electrode tip **28**. The RF generator **14** includes an RF energy source **32** and a controller **34** for controlling the timing and level of the RF energy delivered by the tip **28**. During an ablation procedure, the RF generator **14** is configured to deliver ablation energy to the tip **28** in a controlled manner to ablate any sites identified or targeted for ablation. Other types of ablation sources in addition to or in lieu of the RF generator **14** can also be used for ablating target sites. Examples of other types of ablation sources can include, but are not limited to, microwave generators, acoustic generators, cryoablation generators, and laser/optical generators.

[0038] The ultrasonic imaging module **18** is configured for generating high resolution ultrasonic images (e.g., A, M, or B-mode images) of anatomical structures within the body based on signals received from several ultrasonic imaging sensors **36** located within the probe tip **28**. In the embodiment of FIG. **1**, the ultrasonic imaging module **18** includes an ultrasonic signal generator **40** and an image processor **42**. The ultrasonic signal generator **40** is configured to provide electrical signals for controlling each of the ultrasonic imaging sensors **36**. The imaging signals received back from the ultrasonic imaging sensors **36**, in turn, are fed to the image processor **42**, which processes the signals and generates images that can be displayed on a graphical user interface (GUI) **44**. In certain embodiments, for example, the ultrasonic images displayed on the GUI **44** can be used to assist the physician with advancing the probe **12** through the body and to perform an ablation procedure. In cardiac ablation procedures, for example, the ultrasonic images generated from the ultrasound signals can be used to confirm tissue contact of the probe **12** within the heart or surrounding anatomy, to determine the orientation of the probe **12** within the body, to determine the tissue depth of the tissue at a target ablation site, and/or to visualize the progression of a lesion being formed in the tissue.

[0039] Various characteristics associated with the ultrasonic imaging sensors **36** as well as the circuitry within the ultrasonic imaging module **18** can be controlled to permit the sensors **36** to accurately detect tissue boundaries (e.g., blood or other bodily fluids), lesion formation and progression, as well as other characteristics of the tissue before, during, and/or after the ablation procedure. Example tissue characteristics that can be visualized using the probe **12** include, but are not limited to, the presence of fluid vaporization inside the tissue, the existence of a prior scar, the size and shape of a lesion being formed, as well as structures adjacent to heart tissue (e.g., lungs, esophagus). The depth at which the ultrasonic imaging sensors **36** can visualize anatomical structures within the body is dependent on the mechanical characteristics of the sensors **36**, the electrical characteristics of the sensor circuitry including the drive frequency of the signal generator **40**, the boundary conditions and degree of attenuation between the sensors **36** and the surrounding anatomy, as well as other factors.

[0040] In some embodiments, the probe **12** further includes a steering mechanism to permit the operator to deflect and steer the probe **12** within the body. In one embodiment, for example, a steering member such as a steering knob **46** rotatably coupled to the handle **24** can be used to deflect the ablation electrode tip **28** in one or multiple directions relative to a longitudinal axis of the probe body **20**. Rotational movement of the steering knob **46** in a first direction relative to the handle **24** causes a steering wire within the probe body **20** to move proximally relative to the probe body **20**, which, in turn, bends the distal section **26** of the probe body **20** into a particular shape such as an arced shape. Rotational movement of the steering knob **46** in the opposite direction, in turn, causes the distal section **26** of the probe body **20** to return to its original shape, as shown. To assist in the deflection, and in some embodiments, the probe body **20** includes one or more regions made of a lower durometer material than the other portions of the probe body **20**.

[0041] Although the system **10** is described in the context of a medical system for use in intracardiac electrophysiology procedures for diagnosing and treating the heart, in other embodiments the system **10** may be used for treating, diagnosing, or otherwise visualizing other anatomical structures such as the prostate, brain, gall bladder, uterus, esophagus, and/or other regions in the body. Moreover, many of the elements in FIG. **1** are functional in nature, and are not meant to limit the structure that performs these functions in any manner. For example, several of the functional blocks can be embodied in a single device or one or more of the functional blocks can be embodied in multiple devices.

[0042] FIG. **2** is a perspective view showing the distal section **26** of the probe **12** of FIG. **1** in greater detail. As can be further seen in FIG. **2**, the ablation electrode tip **28** includes an RF ablation electrode **48** configured for delivering ablation energy to body tissue surrounding the tip **28**. In the embodiment of FIG. **2**, the RF ablation electrode **48** comprises a tubular-shaped metal shell that extends from a distal end **50** of the probe body **20** to a distal end **52** of the tip **28**. A number of exposed openings **54***a*, **54***b*, **54***c*, **54***d* disposed through the ablation electrode tip **28** form acoustic openings that permit ultrasonic waves transmitted by the ultrasonic imaging sensors **36***a*, **36***b*, **36***c*, **36***d* to pass through the tip **28** and into the surrounding tissue. The reflected ultrasonic waves received back from the tissue pass through the acoustic openings **54***a*, **54***b*, **54***c*, **54***d* and are sensed by the ultrasonic imaging sensors **36***a*, **36***b*, **36***c*, **36***d* operating in a receive mode. In some embodiments, the acoustic openings **54***a*, **54***b*, **54***c*, **54***d* comprise exposed openings or apertures formed through the wall of the ablation electrode tip **28**.

[0043] In addition to serving as an ablation electrode, the RF ablation electrode **48** also functions as a housing that contains the ultrasonic imaging sensors **36***a*, **36***b*, **36***c*, **36***d*, the electrical conductors coupling the RF ablation electrode **48** to the RF generator **14**, the electrical conductors coupling the ultrasonic imaging sensors **36***a*, **36***b*, **36***c*, **36***d* to the ultrasonic imaging module **18**, one or more steering wires of the steering mechanism, as well as other components. In certain embodiments, the RF ablation electrode **48** comprises an electrically conductive alloy such as platinum-iridium, which in addition to serving as an electrode for providing ablation therapy, is also used as a fluoroscopic marker to determine the location of the ablation electrode tip **28** within the body using fluoroscopy.

[0044] In the embodiment of FIG. **2**, the probe **12** includes a distal-facing ultrasonic imaging sensor **36***a* located at or near the distal end **52** of the ablation electrode tip **28**. The ultrasonic sensor **36***a* is configured to transmit ultrasonic waves primarily in a forward or distal direction away from the distal end **52** of the ablation electrode tip **28**. A second set of ultrasonic imaging sensors **36***b*, **36***c*, **36***d* disposed within the tip **28** at a location proximal to the distal-facing ultrasonic imaging sensor **36***a* are configured to transmit ultrasonic waves primarily in a lateral or side-facing direction away from the side of the ablation electrode tip **28**. The reflected waves received back from the ultrasonic imaging sensors **36***a*, **36***b*, **36***c*, **36***d* produces signals that can be used by the ultrasonic imaging module **18** to generate images of the surrounding body tissue.

[0045] In some embodiments, the ultrasonic imaging sensors **36***a*, **36***b*, **36***c*, **36***d* each comprise piezoelectric transducers formed of a piezoceramic material such as lead zirconate titanate (PZT) or a piezoelectric polymer such as polyvinylidene fluoride (PVDF). In some embodiments, the ablation electrode tip **28** includes three laterally-facing ultrasonic imaging sensors **36***b*, **36***c*, **36***d* each oriented circumferentially at 120° intervals apart from each other about the tip **28** for use in imaging tissue located adjacent to the sides of the tip **28**. In other embodiments, a greater or lesser number of laterally-facing ultrasonic imaging sensors are employed for imaging tissue adjacent to the sides of the probe tip **28**.

[0046] In the embodiment of FIG. **2**, the ablation electrode tip **28** has an open irrigated configuration including a number of irrigation ports **30** used to deliver cooling fluid to cool the tip **28** and the surrounding tissue. In other embodiments, the ablation electrode tip **28** has a closed irrigation configuration in which the cooling fluid is recirculated through the tip **28** without being ejected into the surrounding tissue. In some embodiments, the ablation electrode tip **28** comprises six irrigation ports **30** each disposed circumferentially at 60° intervals apart from each other about the tip **28** and at a location proximal to the distal-facing ultrasonic sensor **36***a* and distal to the location of the laterally-facing ultrasonic sensors **36***b*, **36***c*, **36***d*. In other embodiments, a greater or lesser number of fluid irrigation ports **30** are employed. In some embodiments, the fluid irrigation ports **30** are circular in shape, and have a diameter in the range of approximately 0.01 inches to 0.02 inches. The size, number, and/or positioning of the irrigation ports **30** can vary, however.

[0047] During ablation therapy, cooling fluid is used to control the temperature and reduce coagulum formation on the ablation electrode tip **28**, thus preventing an impedance rise of the tissue in contact with the tip **28** and increasing the transfer of RF ablation energy delivered into the tissue. In certain embodiments, and as discussed further herein, the cooling fluid also serves as an impedance matching layer to acoustically couple the ultrasonic sensors **36***a*, **36***b*, **36***c*, **36***d* to the surrounding body tissue, thus decreasing reflections that can occur at the interface between the tissue and the sensors **36***a*, **36***b*, **36***c*, **36***d*.

[0048] FIG. **3** is a schematic view showing an interior portion of the ablation electrode tip **28** in accordance with an illustrative embodiment. As shown in FIG. **3**, the ablation electrode tip **28** includes a distal tip insert **58** configured to divide the interior of the probe tip **28** into a proximal fluid chamber **60** and a distal fluid chamber **62**. As can be further seen in conjunction with FIG. **4**, the distal insert **58** comprises a cylindrically-shaped body **64** having an outer extent **66** with a number of recesses **68** each configured to receive a corresponding one of the lateral-facing ultrasonic imaging sensors **36***b*, **36***c*, **36***c* therein. In certain embodiments, for example, the distal insert **58** comprises a stainless steel body having recesses **68** sized and shaped to frictionally receive the ultrasonic imaging sensors **36***b*, **36***c*, **36***d* by press-fitting the sensors **36***b*, **36***c*, **36***d* into the recesses **68**. In some embodiments, the depth of the recesses **68** are configured such that the transmitting face of the ultrasonic sensors **36***b*, **36***c*, **36***d* lie substantially flush with the outer extent **66** of the insert body **64**. In use, the insert body **64** separates the proximal fluid chamber **60** from the distal fluid chamber **62**, creating a back pressure as fluid enters the proximal fluid chamber **60**. This back pressure causes the fluid to circulate before being forced into the distal fluid chamber **62**.

[0049] An internal bore **70** extending through the insert body **64** is configured to receive electrical conductors used for electrically coupling the ultrasonic sensors **36***a*, **36***b*, **36***c*, **36***d* to the ultrasonic imaging module **18**. As can be further seen in FIG. **3**, for example, the interior lumen **70** of the insert body **64** is connected at both ends to tubular members **72**, **74** that contain electrical conductors **76**, **78** for the ultrasonic sensors **36***a*, **36***b*, **36***c*, **36***d*.

[0050] FIG. **5** is a cross-sectional view of the ablation electrode tip **28** along line **5-5** of FIG. **3**. As can be further seen in conjunction with FIGS. **4** and **5**, a tubular-shaped shell **80** disposed radially about the tip insert body **64** defines an annular-shaped fluid channel **82** connecting the proximal fluid chamber **60** with the distal fluid chamber **62**. In other embodiments, the shape of the fluid channel **82** is different from that shown. In some embodiments, the shell **80** comprises an acoustically transparent material such as clear acrylic, which has a relatively low acoustic impedance. The shell **80** also serves to fluidly seal the acoustic openings **54***b*, **54***c*, **54***d* from the surrounding body tissue and, in some embodiments, provides a desired acoustic coupling effect between the cooling fluid within the fluid channel **82** and the body tissue.

[0051] As can be further seen in FIG. **5**, and in some embodiments, the ablation electrode tip **28** includes three laterally-facing ultrasonic imaging sensors **36***b*, **36***c*, **36***d* at equidistant angles α of 120° about the circumference of the tip **28**. Although three laterally-facing ultrasonic imaging sensors **36***b*, **36***c*, **36***d* are shown, a greater or lesser number of sensors may be employed in other embodiments. By way of example and not limitation, four ultrasonic imaging sensors may be disposed at equidistant angles α of 90° about the circumference of the ablation electrode tip **28**. In some embodiments, the laterally-facing ultrasonic imaging sensors **36***b*, **36***c*, **36***d* are configured to transmit ultrasonic waves in a direction perpendicular to the side of the ablation electrode tip **28**. In other embodiments, the laterally-facing ultrasonic imaging sensors **36***b*, **36***c*, **36***d* are configured to transmit ultrasonic waves from the side of the ablation electrode tip **28** at a slight forward angle.

[0052] During imaging, the use of multiple ultrasonic imaging sensors **36***b*, **36***c*, **36***d* spaced about the circumference of the ablation electrode tip **28** ensures that at least one of the laterally-facing sensors **36***b*, **36***b*, **36***d* is in view of target tissue located to the side of the tip **28** irrespective of the tip orientation. Such configuration also permits the physician to easily visualize the target tissue without having to rotate the probe **12** once the probe **12** is in contact with the tissue.

[0053] FIG. **6** is another schematic view of the ablation electrode tip **28** showing the flow of cooling fluid **84** across the surface of the ultrasonic imaging sensors **36***b*, **36***c*, **36***d*. During an ablation procedure, cooling fluid **84** delivered through the probe body **20** enters into the proximal fluid chamber **60**. The cooling fluid **84** then enters into the fluid channel **82** and passes across the ultrasonic imaging sensors **36***b*, **36***c*, **36***d*, providing an acoustic coupling effect between the sensors **36***b*, **36***c*, **36***d* and the shell **80**. The cooling fluid

84 then enters into the distal fluid chamber **62** and exits into the surrounding body tissue through the irrigation ports **30** shown in FIGS. **1-2**.

[0054] FIG. **7** is an enlarged view showing the transmission of ultrasonic waves **86** from one of the ultrasonic imaging sensors **36***c* through the cooling fluid **84**, shell **80**, and acoustic opening **54***c* of the ablation probe tip **28**. As shown in FIG. **7**, the cooling fluid **84** within the fluid channel **82** comes into contact with the transmitting/receiving surface **88** of the ultrasonic imaging sensor **30***c* and the interior surface **90** of the shell **80**. The cooling fluid **84** is selected so as to have an acoustic impedance similar to that of the body tissue, which serves to facilitate transmission of the ultrasonic waves **86** into the shell **80**, through the acoustic opening **54***c*, and into the tissue within minimal boundary reflection losses at each interface. A similar effect occurs for the fluid passing across the transmitting face or surface for other ultrasonic imaging sensors **36***b*, **36***c*.

[0055] Various modifications and additions can be made to the exemplary embodiments discussed without departing from the scope of the present invention. For example, while the embodiments described above refer to particular features, the scope of this invention also includes embodiments having different combinations of features and embodiments that do not include all of the described features. Accordingly, the scope of the present invention is intended to embrace all such alternatives, modifications, and variations as fall within the scope of the claims, together with all equivalents thereof.

What is claimed is:

1. An ablation system for treating and imaging body tissue, the system comprising:
- a probe comprising:
  - an elongate probe body having a proximal section and a distal section;
  - an ablation electrode coupled to the distal section of the elongate probe body, the ablation electrode comprising a conductive shell having an interior, the ablation electrode configured for delivering ablation energy to body tissue;
  - a plurality of openings disposed through the ablation electrode;
  - a plurality of ultrasonic imaging sensors disposed within the interior of the conductive shell;
  - an acoustically transparent tubular member disposed between the ultrasonic imaging sensors and the openings; and
  - a fluid channel interposed between the ultrasonic imaging sensors and the acoustically transparent member within the interior of the conductive shell;
- a fluid source configured for delivering cooling fluid through the fluid channel of the probe, the cooling fluid configured to acoustically couple the ultrasonic imaging sensors to the body tissue;
- an ablation therapy module configured for generating and supplying an electrical ablation signal to the ablation electrode of the probe configured to ablate tissue; and
- an ultrasound imaging module configured for processing ultrasonic imaging signals received from the ultrasonic imaging sensors of the probe.

2. The system of claim **1**, wherein each ultrasonic imaging sensor is configured to transmit ultrasonic waves through the fluid channel, the acoustically transparent member, and a corresponding one of the openings.

3. The system of claim **1**, wherein the conductive shell of the ablation electrode is a tubular metal shell.

4. The system of claim **1**, wherein the openings are located circumferentially about the ablation electrode.

5. The system of claim **1**, wherein the ablation electrode further includes a plurality of irrigation ports.

6. The system of claim **5**, wherein the irrigation ports are in fluid communication with the fluid channel.

7. The system of claim **5**, wherein the irrigation ports are located circumferentially about the ablation electrode.

8. The system of claim **5**, wherein the irrigation ports are located distally and proximally of the openings.

9. The system of claim **5**, wherein the ultrasonic imaging sensors are located within the interior of the conductive shell at a location proximal to the irrigation ports.

10. The system of claim **1**, wherein the ultrasonic imaging sensors are each configured for transmitting laterally-directed ultrasonic waves from a side of the ablation electrode.

11. The system of claim **10**, further comprising at least one additional ultrasonic imaging sensor disposed within the interior of the conductive shell, the at least one additional ultrasonic imaging sensor configured for transmitting ultrasonic waves in a distal direction away from a distal end of the ablation electrode.

12. The system of claim **11**, wherein the acoustically transparent member is further disposed between the at least one additional ultrasonic imaging sensor and a distal-facing opening disposed through the ablation electrode, and wherein the fluid channel is further interposed between the at least one additional ultrasonic imaging sensor and the distal-facing opening.

13. The system of claim **1**, wherein the acoustically transparent tubular member circumferentially surrounds the plurality of ultrasonic imaging sensors.

14. The system of claim **1**, further comprising a graphical user interface, wherein the ultrasound imaging module is configured to generate images on the graphical user interface based on the ultrasonic imaging signals and indicative of body tissue sensed by the ultrasonic imaging sensors.

15. The system of claim **1**, further comprising an insert configured for supporting the ultrasonic imaging sensors within the ablation electrode.

16. The system of claim **15**, wherein the insert comprises a cylindrically-shaped insert body including a plurality of recesses each configured for receiving an ultrasonic transducer.

17. The system of claim **15**, wherein a transmitting face of each ultrasonic imaging sensor is substantially flush with an outer surface of the insert body.

18. The system of claim **15**, wherein the ablation electrode includes a proximal fluid chamber and a distal fluid chamber, wherein the proximal and distal fluid chambers are separated by the insert.

19. An ablation system for treating and imaging body tissue, the system comprising:
- a probe comprising:
  - an elongate probe body having a proximal section and a distal section;
  - an ablation electrode coupled to the distal section of the elongate probe body, the ablation electrode configured for delivering ablation energy to body tissue;
  - a plurality of openings disposed through the ablation electrode;

a plurality of ultrasonic imaging sensors disposed within an interior lumen of the ablation electrode, the plurality of ultrasonic imaging sensors facing a plurality of different lateral directions with respect to a longitudinal axis of the ablation electrode, the plurality of ultrasonic imaging sensors respectively aligned with the plurality of openings to send and receive ultrasonic imaging signals through the plurality of openings;

an acoustically transparent member disposed between the ultrasonic imaging sensors and the openings; and

a fluid channel interposed between the ultrasonic imaging sensors and the acoustically transparent member;

a fluid source configured for delivering cooling fluid to the interior lumen of the ablation electrode, the cooling fluid configured to acoustically couple the ultrasonic imaging sensors to the body tissue;

an ablation therapy module configured for generating and supplying an electrical ablation signal to the ablation electrode; and

an ultrasound imaging module configured for processing ultrasonic imaging signals received from the plurality of ultrasonic imaging sensors.

20. An ablation system for treating and imaging body tissue, the system comprising:

a probe comprising:

an elongate probe body having a proximal section and a distal section;

an ablation electrode coupled to the distal section of the elongate probe body, the ablation electrode configured for delivering ablation energy to body tissue;

a plurality of openings disposed through the ablation electrode;

a plurality of ultrasonic imaging sensors disposed within an interior lumen of the ablation electrode;

an acoustically transparent member disposed between the ultrasonic imaging sensors and the openings;

an insert within the interior lumen of the ablation electrode, the insert attached to the plurality of ultrasonic imaging sensors; and

a fluid channel interposed between the ultrasonic imaging sensors and the acoustically transparent member,

wherein the interior lumen of the ablation electrode includes a proximal fluid chamber and a distal fluid chamber, wherein the proximal and distal fluid chambers are separated by the insert and the fluid channel fluidly connects the proximal fluid chamber to the distal fluid chamber;

a fluid source configured for delivering cooling fluid to the fluid channel of the probe;

an ablation therapy module configured for generating and supplying an electrical signal to the ablation electrode of the probe; and

an ultrasound imaging module configured for processing ultrasonic imaging signals received from the ultrasonic imaging sensors of the probe.

* * * * *

patsnap

专利名称(译)	用于超声组织成像的基于流体的声学耦合的消融探针		
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申请(专利权)人(译)	皇家飞利浦N.V. BOSTON SCIENTIFIC SCIMED INC.		
当前申请(专利权)人(译)	皇家飞利浦N.V. BOSTON SCIENTIFIC SCIMED INC.		
[标]发明人	RANKIN DARRELL L KOBLISH JOSEF V DELADI SZABOLCS		
发明人	RANKIN, DARRELL L. KOBLISH, JOSEF V. DELADI, SZABOLCS		
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摘要(译)

公开了用于超声成像组织和执行消融治疗的装置和系统。用于治疗和成像身体组织的消融探针包括具有多个声学开口的消融电极尖端和设置在尖端的内腔内的多个超声成像传感器。超声成像传感器通过插入件支撑在内腔内，该插入件配备有接收超声成像传感器的多个凹槽。设置在超声成像传感器和声学开口之间的声学透明壳形成传感器的声学路径中的流体通道。在消融过程期间，来自外部流体源的冷却流体通过流体通道输送，从而在超声成像传感器和周围身体组织之间提供声耦合效应。