

IMAGING PROBE HOUSING WITH FLUID FLUSHING**PRIORITY CLAIM**

[1] The present application claims the benefit of
copen ding United States Provisional Patent Application
5 Serial No. 61/008,725, filed 20 December 2007, and Patent
Application Serial No. 12/330,308, filed 8 December 2008,
which applications are incorporated herein by reference in
their entirety.

BACKGROUND

10 [2] The present invention generally relates to an
imaging probe of an imaging catheter. The present invention
more specifically relates to mechanically scanned imaging
probes for use in, for example, an intravascular ultrasound
(IVUS) or intra-cardiac echo-cardiography (ICE) catheter.
15 The present invention still further relates to such an
imaging probe wherein the imaging probe is configured to
assure efficient and complete fluid flushing from the
catheter sheath to preclude formation of air bubbles in the
vicinity of the ultrasonic transducer of the imaging probe.
20 In addition this invention relates to imaging probe
configuration to ensure the prevention of air bubbles during
rotational operation by continuously directing fluid across
the imaging probes transmission surface.

[3] IVUS catheters enable the imaging of internal
25 structures in the body. ICE catheters enable the imaging of
larger internal structures in the body. Coronary IVUS
catheters are used in the small arteries of the heart to
visualize coronary artery disease, for example. Coronary ICE
catheters are used in the cavity of the heart to visualize
30 structural heart disease, including atrial septal defects
(ASD), patent foramen ovale (PFO) and to guide various

procedures including septal punctures, percutaneous valvular replacement, and various ablations treatment strategies. To that end, an IVUS or an ICE catheter will employ at least one ultrasonic transducer that creates pressure waves to enable visualization. At least one transducer is usually housed within a surrounding sheath or catheter member and rotated to enable 360 degree visualization. Because air is not an efficient medium for the transmission of the ultrasonic waves produced by at least one transducer, a fluid interface between the transducer and the sheath in which it is disposed is usually provided. Unfortunately, current imaging probe configurations do not always prevent the formation of air bubbles in the fluid in the vicinity of the transducer resulting in compromised performance of the imaging catheter. The present invention addresses this and other issues.

SUMMARY

[4] The invention provides an imaging probe for use in a catheter for ultrasonic imaging. The catheter may include a sheath having an opening at a distal end for conducting a fluid there through. The imaging probe comprises a distal housing coupled to a drive shaft for rotation, a transducer within the distal housing for generating and sensing

25 ultrasonic waves, and

[5] a fluid flow promoter that promotes flow of the fluid within the sheath across the transducer.

[6] The imaging probe may further include a wall distal to the transducer and the fluid flow promoter may include an opening within the wall and adjacent to the transducer. The distal housing preferably has a first profile at a proximal end of the distal housing, a second profile at the wall distal to the transducer, and the fluid

flow promoter includes the second profile being greater than the first profile to promote fluid flow over the transducer and through the opening within the wall.

[7] The catheter has a center axis and the fluid flow promoter may further include a mounting for the transducer that disposes the transducer at an angle sloping toward the catheter center axis in a proximal direction.

[8] The distal housing has a proximal extent and the fluid flow promoter may include at least one aqua duct within the proximal extent of the distal housing. The at least one aqua duct is preferably formed within the proximal extent of the distal housing at an angle to the center axis. The at least one aqua duct may comprise at least two aqua ducts. The transducer includes a face surface. The at least two aqua ducts may include a first aqua duct that directs fluid directly onto the face surface of the transducer and a second aqua duct that directs fluid onto the face surface of the transducer from a side of the transducer. The at least one aqua duct has a proximal side and a distal side and may be formed so that the proximal side leads the distal side in the direction of rotation of the distal housing. The at least one aqua duct may include a radius of curvature.

BRIEF DESCRIPTION OF THE DRAWINGS

[9] The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further features and advantages thereof, may best be understood by making reference to the following description taken in conjunction with the accompanying drawings, in the several figures of which like reference numerals identify identical elements, and wherein:

FIG. 1 is a side view, partly in section, of an ultrasonic imaging catheter in accordance with a first embodiment of the invention;

FIG. 2 is a partial perspective view of the imaging probe of the catheter of **FIG.1**; and

FIG. 3 is a perspective view showing another imaging probe embodying the invention connected to a drive cable of an intravascular ultrasound (IVUS) catheter.

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DETAILED DESCRIPTION

[10] **FIG. 1** shows an imaging catheter **10** with the first embodiment of the present invention. The imaging catheter **10** is particularly adapted for use as an IVUS catheter, but those skilled in the art will appreciate that the invention may be used in many other forms of ultrasound catheters as well without departing from the present invention. The catheter **10** generally includes a sheath or catheter member **12** and an imaging probe **14**. As shown, the imaging probe **14** is disposed within the sheath **14**. The imaging probe **14** is moveable axially within the sheath **12** to enable the sheath to remain stationary as the imaging probe is moved to scan the internal body structures to be visualized. Also, as well known, the imaging probe **14** is also rotatable to enable 360 degree scanning.

25 [11] The imaging probe **14** generally includes a distal housing **16**, a flexible drive shaft **18**, and a coaxial cable **20**. The distal housing **16** is carried on the distal end of the flexible drive shaft **18** in a known manner. The drive shaft **18** may be formed, for example, by winding multiple strands of metal wire on a mandrel to create a long spring containing a repeating series of concentric rings, or windings, of the wire. Two or more springs may be wound, one

over the other, with adjacent springs being wound in opposite directions to each other. This provides a drive shaft that is both flexible and with high torsional stiffness.

5 **[12]** The distal housing **16** generally includes the ultrasound transducer **22**, a distal tip wall **24**, and a proximal cutout surface **26**. The transducer **22** is mounted on a transducer backing **28**. The backing **28** and the distal tip wall **24** are adhered together by a conductive adhesive **27**.

10 The backing **28** is dimensioned and of such a material as to absorb ultrasonic waves from the backside of the transducer **22** so that only energy from the front side of the transducer is emitted from the imaging probe **14** in the general direction indicated by reference character **30** transverse to

15 the exposed surface of the transducer **22** . The coaxial cable **20** extends down the drive shaft **18** and includes a center conductor **32** and a shield lead **34**. The center conductor **32** and shield lead **34** are coupled across the transducer **20** as shown. The coaxial cable **20** couples energy to the transducer

20 to cause the transducer **22** to generate a pressure wave into the lumen **36** of the sheath **12**. The interior of the lumen **36** is preferably filled with a fluid, such as saline. The saline flows from the proximal end of the catheter **10** to the distal end of the catheter **10** and serves to efficiently

25 couple the ultrasonic energy into the sheath and then to the body. To support the fluid flow, the sheath includes a point of egress (not shown) for the fluid at its distal end. As previously mentioned, it is important to prevent air bubbles from being formed or residing in the vicinity of the

30 transducer **22**.

[13] To assure that air bubble formation in the vicinity of the transducer **22** is prevented, and with additional reference to **FIG. 2**, the distal extent of the

distal housing **16** includes a distal tip wall **24** distal and adjacent to the transducer **22**. The distal tip wall **24** has an opening **38** therein adjacent to the transducer **22**. Proximal to the transducer **22**, the distal housing **16** has a proximal cutout forming a tapered surface **26** leading toward the transducer **22**. Fluid flow within the sheath from proximal to the transducer **22** to distal of the transducer **22** is conducted down the tapered cutout surface **26**, over the transducer **22**, and out the distal tip wall opening **38** in a continuous manner, without turbulence, to prevent air bubble formation in the vicinity of the transducer.

[14] The distal housing **16** at the proximal extent of the tapered cutout surface **26** has or defines a first profile substantially transverse to the catheter center axis **40** and the fluid flow. The distal tip wall **24** defines a second profile also substantially transverse to the catheter center axis **40** and the fluid flow. The second profile is greater in dimension than the first profile. Hence, this serves to promote fluid flow through the distal tip opening **38** and hence over the transducer **22**.

[15] To further promote fluid flow over the transducer **22**, the transducer has a surface **22a** over which the fluid flows that is disposed at an angle sloping toward the catheter center axis in the proximal direction. This presents a greater surface resistance against the fluid flow to assure fluid contact therewith.

[16] **FIG. 3** shows another imaging catheter **110** according to a further embodiment of the present invention. The catheter **110** is similar to the catheter **10** of **FIGS. 1 and 2** and hence, reference characters for like elements are repeated in **FIG. 3**. To further assure that air bubble formation in the vicinity of the transducer **22** is prevented during rotational operation, and with additional reference

to **FIG. 3**, the proximal extent of the distal housing **26** is constructed with aqua ducts **41** and **42**. As shown in **Fig. 3**, one aqua duct directs fluid onto the transducer face **22** from the top of the proximal portion of the distal housing **26**,
5 while the other aqua duct **41** directs fluid onto the transducer face **22** from the side. Further, the aqua ducts are built into the proximal portion **26** of the distal housing **16** at an angle with respect to a line extending along the catheter drive shaft **43**. This is shown in **FIG. 3** with the
10 angle theta being formed with the intersection of a line **43** extending parallel to the catheter drive shaft **13** and a line **44** extending through the center of one of the aqua ducts **41**. Both aqua ducts **41** and **42** are constructed at such an angle such that the proximal side of each duct leads the distal
15 side in the direction of rotation. This is shown in **FIG. 3** with the clockwise direction of rotation (from the view looking distally along the catheter drive shaft **13**) indicated by **45**. Further, each side of each aqua duct is constructed with a small radius of curvature shown by **46** in
20 **FIG. 3**. One way to achieve the duct side curvatures is to construct the ducts in a helical spiral with a small pitch, as, for example, on the order of 0.1 inch. The duct angle and curvature, coupled with rotation of the distal housing **16** and the fluid flow promoting structure shown in **FIG. 1**,
25 act to continuously draw fluid residing within the catheter sheath **12**, proximal to the distal housing **16**, onto the face of the transducer **22**. Fluid flow within the sheath from proximal to the transducer **22** to distal of the transducer **22** is conducted down the tapered cutout surface **26**, over the
30 transducer **22**, and out the distal tip wall opening **38** in a continuous manner, without turbulence, to prevent air bubble formation in the vicinity of the transducer.

[17] While particular embodiments of the present invention have been shown and described, modifications may

be made, and it is therefore intended in the appended claims to cover all such changes and modifications which fall within the true spirit and scope of the invention as defined by those claims.

What is claimed is:

1. An imaging probe for use in a catheter for ultrasonic imaging, the catheter including a sheath having an opening at a distal end for conducting a fluid there through, the imaging probe comprising:
 - a distal housing coupled to a drive shaft for rotation;
 - a transducer within the distal housing for generating and sensing ultrasonic waves; and
 - 10 a fluid flow promoter that promotes flow of the fluid within the sheath across the transducer.
2. The imaging probe of claim 1, further including a wall distal to the transducer, and wherein the fluid flow promoter includes an opening within the wall and adjacent to the transducer.
3. The imaging probe of claim 2, wherein the distal housing has a first profile at a proximal end of the distal housing, a second profile at the wall distal to the transducer, and wherein the fluid flow promoter includes the second profile being greater than the first profile to promote fluid flow over the transducer and through the opening within the wall.
- 25 4. The imaging probe of claim 1, wherein the catheter has a center axis and wherein the fluid flow promoter further includes a mounting for the transducer that disposes the transducer at an angle sloping toward the catheter center axis in a proximal direction.
- 30 5. The imaging probe of claim 1, wherein the distal housing has a proximal extent and wherein the fluid flow

promoter includes at least one aqua duct within the proximal extent of the distal housing.

5 6. The imaging probe of claim 5, wherein the catheter has a center axis and wherein the at least one aqua duct is formed within the proximal extent of the distal housing at an angle to the center axis.

10 7. The imaging probe of claim 5, wherein the at least one aqua duct comprises at least two aqua ducts.

15 8. The imaging probe of claim 7, wherein the transducer includes a face surface, wherein the at least two aqua ducts include a first aqua duct that directs fluid directly onto the face surface of the transducer, and wherein the at least two aqua ducts include a second aqua duct that directs fluid onto the face surface of the transducer from a side of the transducer.

20 9. The imaging probe of claim 5, where the at least one aqua duct has a proximal side and a distal side and wherein the at least one aqua duct is formed so that the proximal side leads the distal side in the direction of rotation of the distal housing.

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10. The imaging probe of claim 5, where the at least one aqua duct includes a radius of curvature.