US009039624B2

(12) **United States Patent**
Scheirer et al.

(10) **Patent No.:** **US 9,039,624 B2**
(45) **Date of Patent:** **May 26, 2015**

(54) ULTRASONIC HIFU TRANSDUCER WITH NON-MAGNETIC CONDUCTIVE VIAS

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 446 days.

(21) Appl. No.: **13/508,646**

(22) PCT Filed: **Nov. 3, 2010**

(86) PCT No.: **PCT/IB2010/054986**
§ 371 (c)(1),
(2), (4) Date: **Sep. 4, 2012**

(87) PCT Pub. No.: **WO2011/055317**
PCT Pub. Date: **May 12, 2011**

(65) **Prior Publication Data**

US 2012/0323147 A1 Dec. 20, 2012

Related U.S. Application Data

(60) Provisional application No. 61/259,309, filed on Nov. 9, 2009.

(51) **Int. Cl.**

A61B 8/00	(2006.01)
B06B 1/06	(2006.01)
A61N 7/02	(2006.01)
G10K 11/00	(2006.01)
A61N 7/00	(2006.01)

(52) **U.S. Cl.**
CPC ***B06B 1/0637*** (2013.01); ***A61N 7/02*** (2013.01); *A61N 2007/0065* (2013.01); *A61N 2007/0078* (2013.01); *A61N 2007/0095* (2013.01); ***G10K 11/004*** (2013.01)

(58) **Field of Classification Search**
USPC 600/407, 437, 439, 459
See application file for complete search history.

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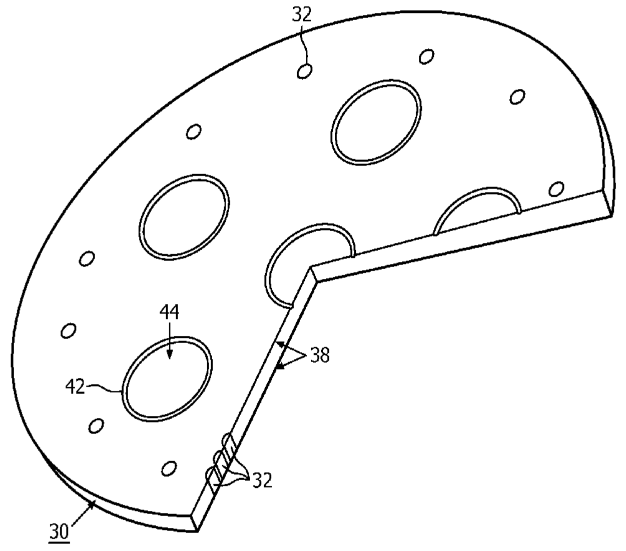
Primary Examiner — Peter Luong

(57) **ABSTRACT**

A high intensity focused ultrasound (HIFU) transducer comprising a piezoelectric array with a layer of piezoelectric material having a patient-facing front surface and a back surface, the front surface comprising a transmitting surface, and a plurality of electrodes located on the front and back surfaces of the piezoelectric material for applying electrical signals to the piezoelectric array. Electrical connections between an electrode on the back surface to an electrode on the front surface of the piezoelectric array are made through non-magnetic conductive vias extending through the layer of piezoelectric material.

18 Claims, 8 Drawing Sheets



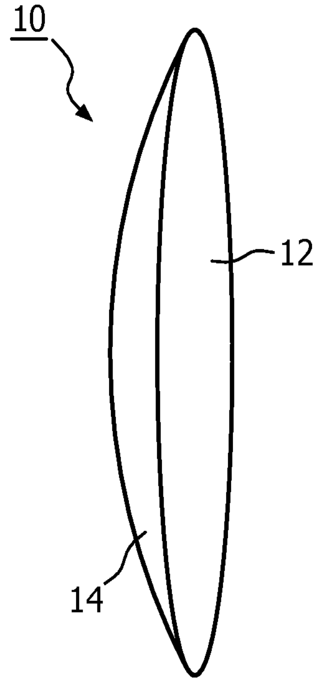


FIG. 1

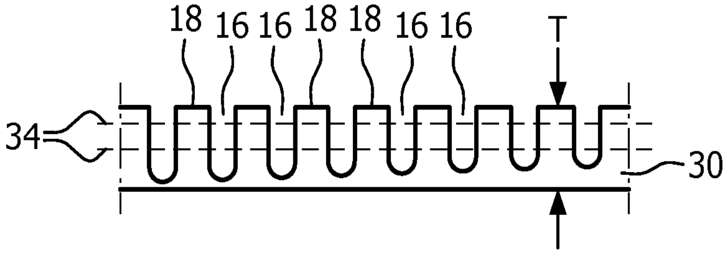


FIG. 2a

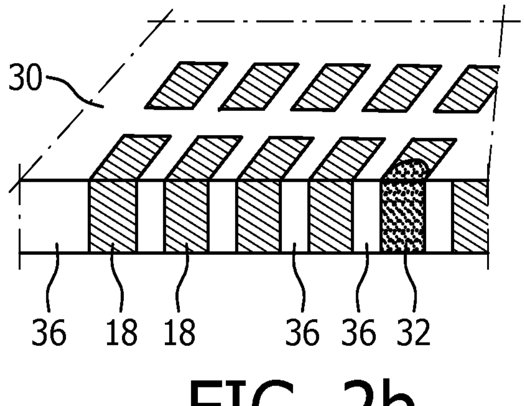


FIG. 2b

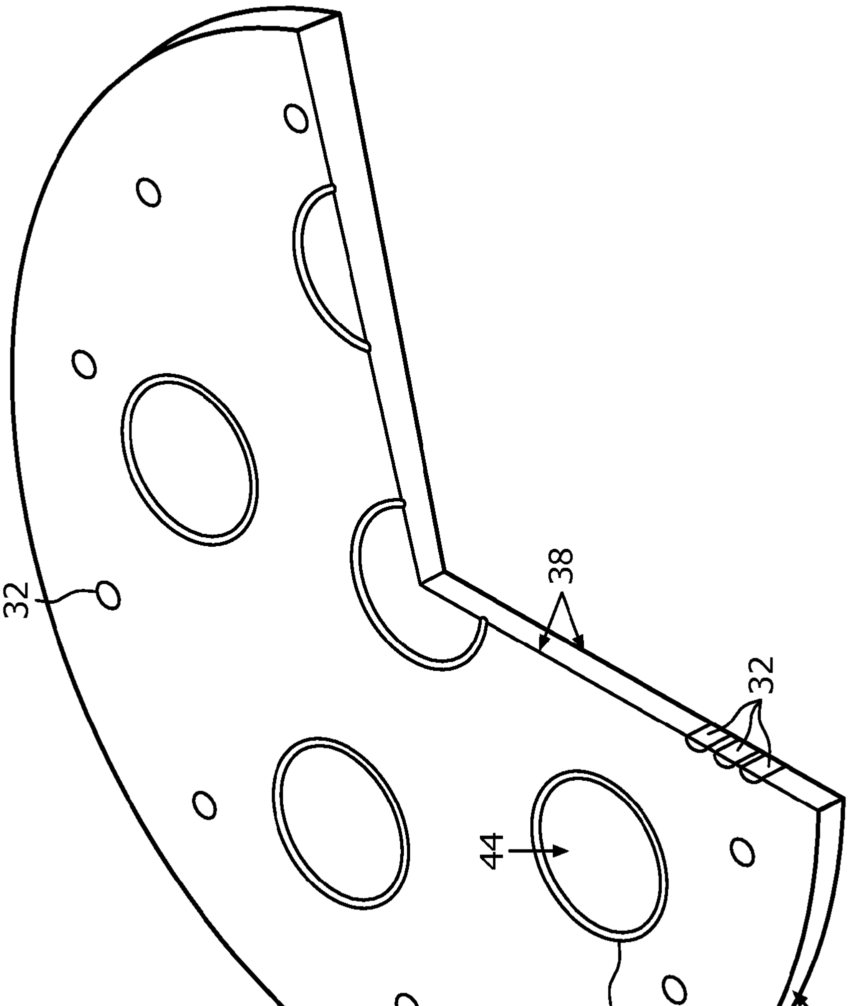


FIG. 3

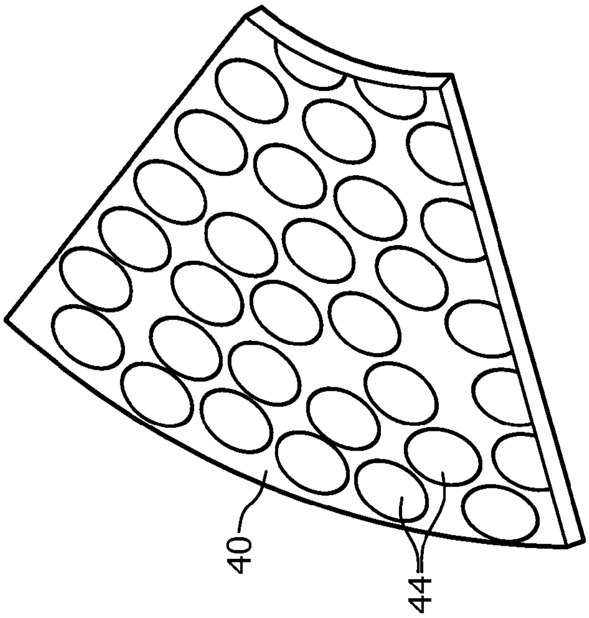


FIG. 4

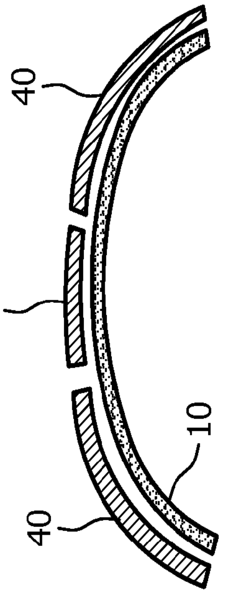


FIG. 5

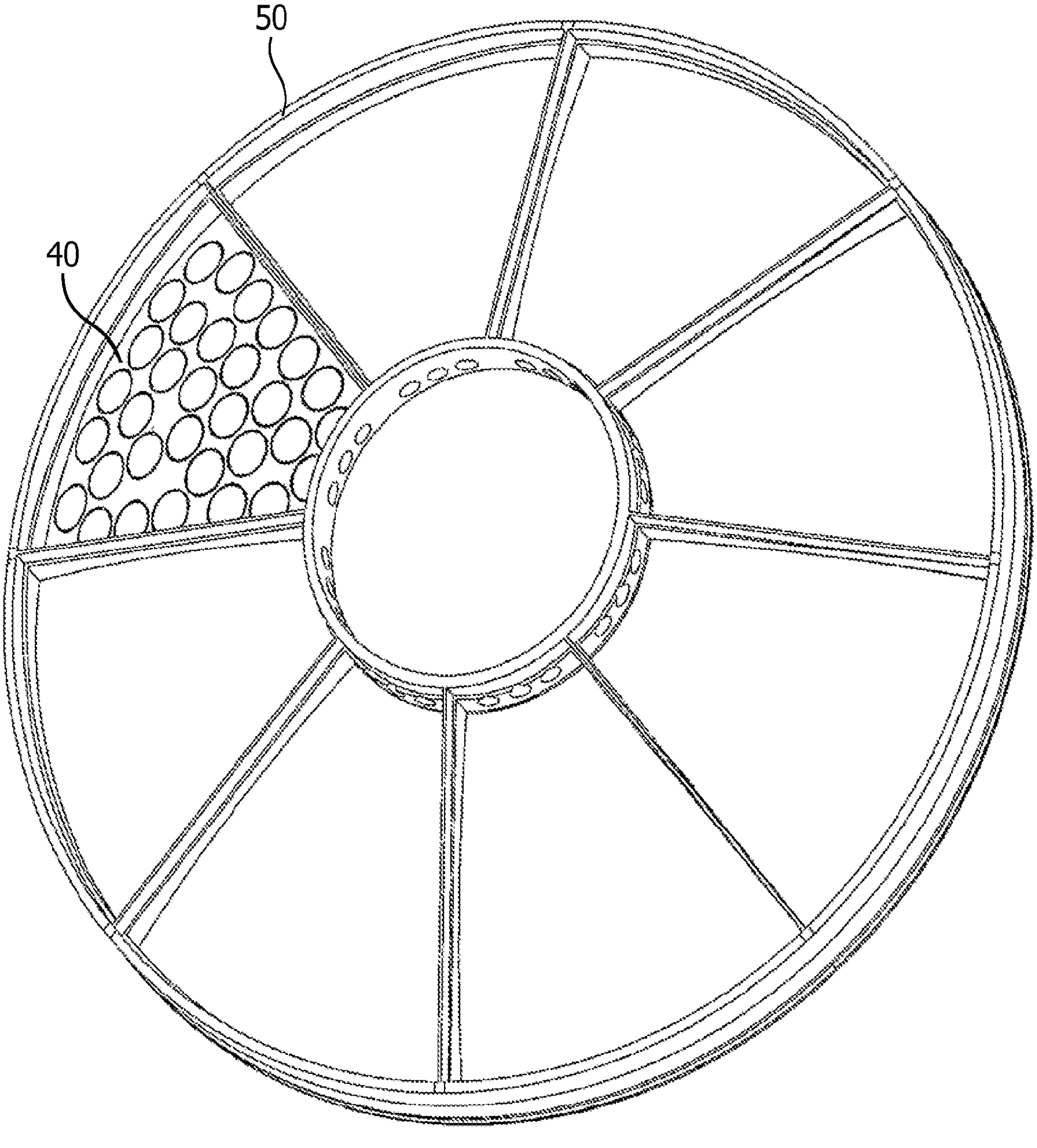


FIG. 6

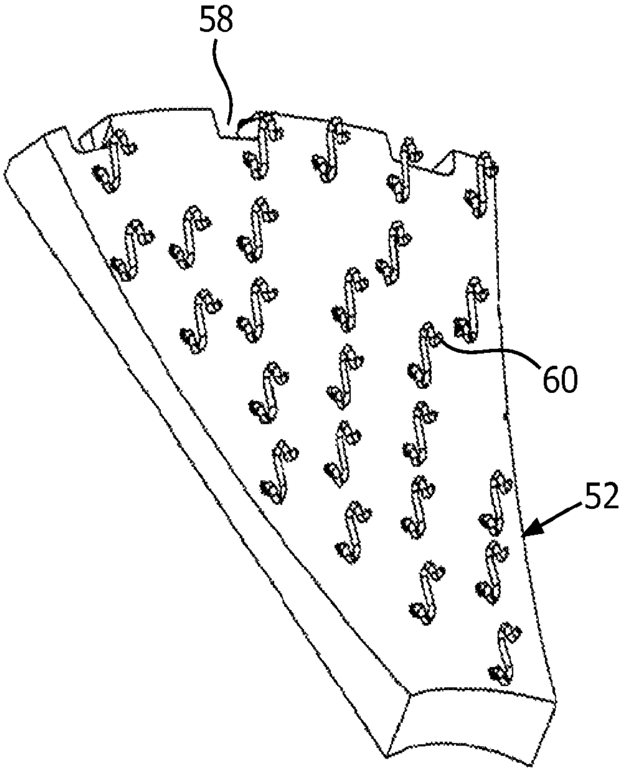


FIG. 7a

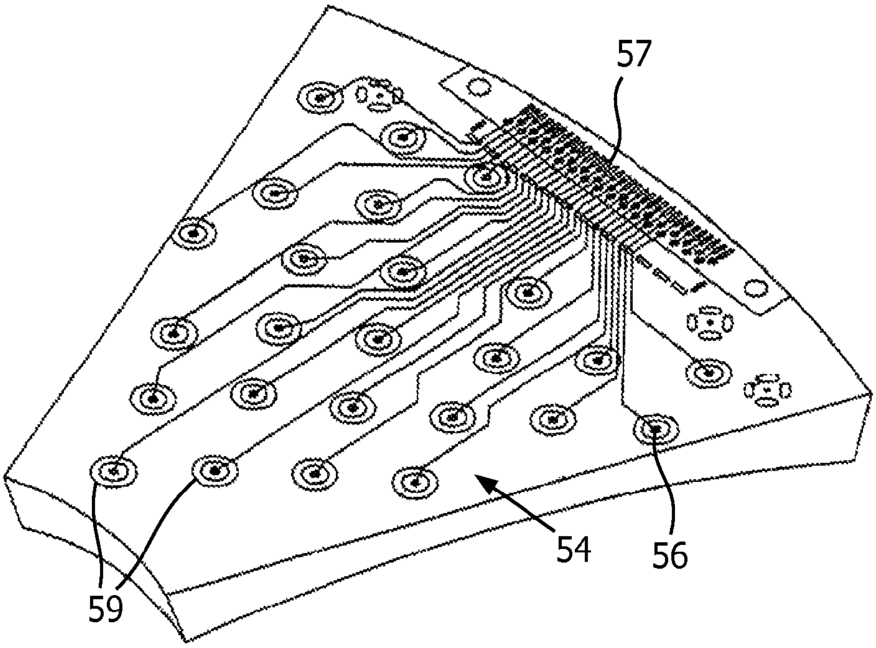


FIG. 7b

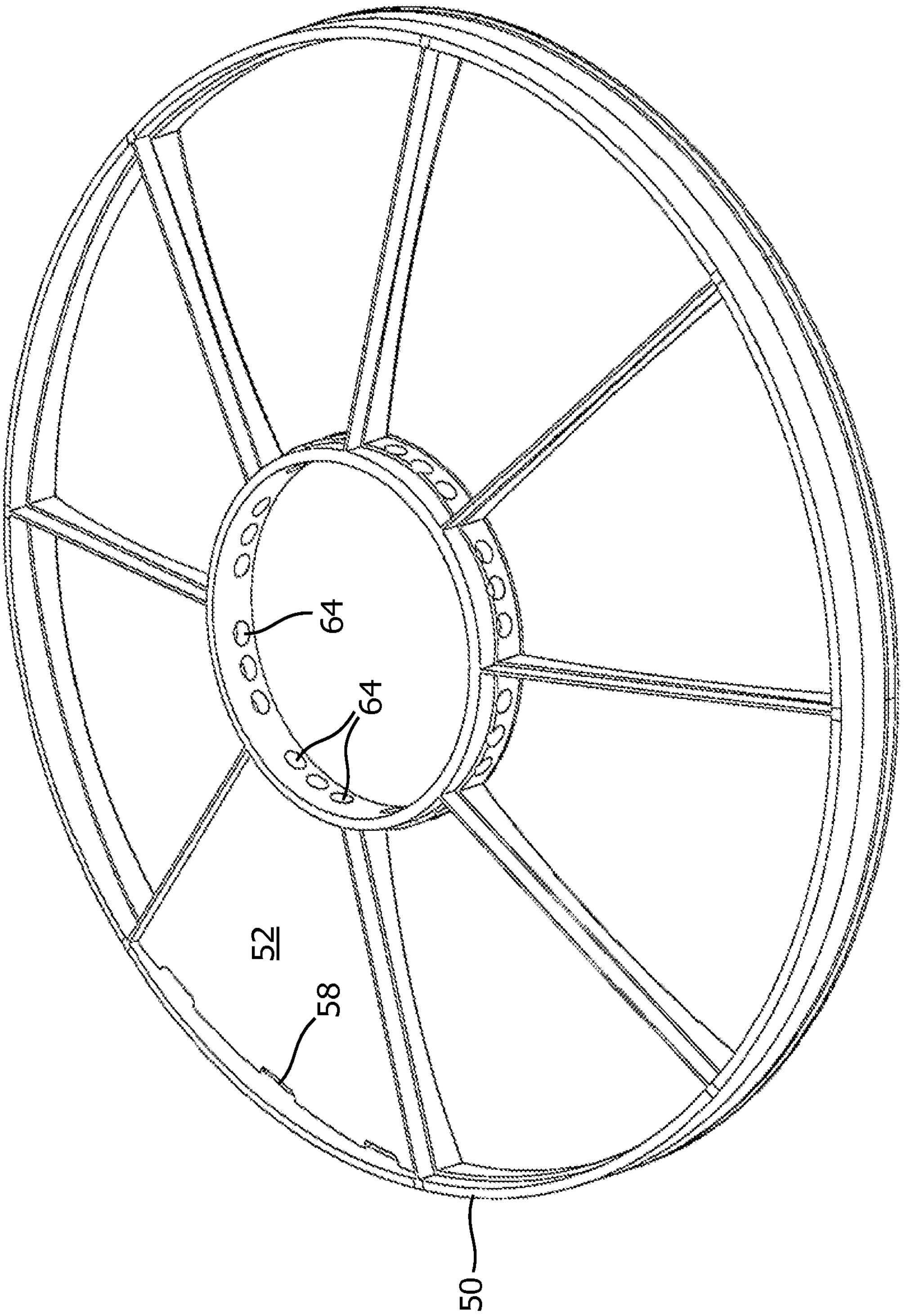


FIG. 8

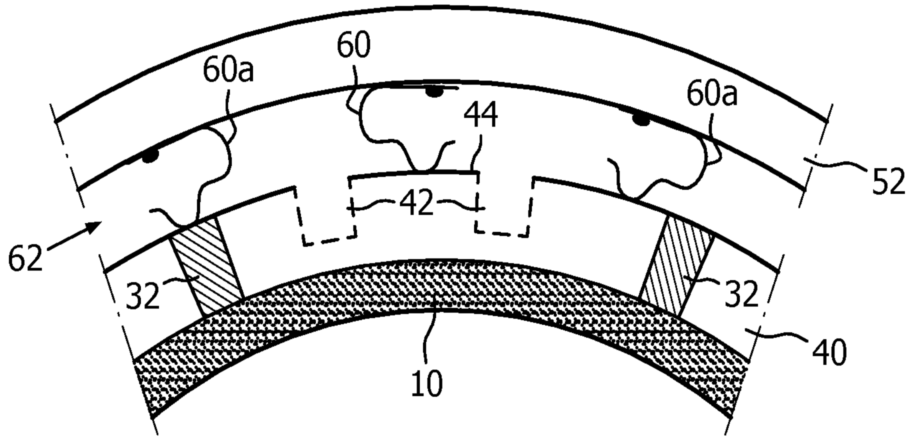

60
60a
60a
44
52
42
62
32
32
40
10

FIG. 9

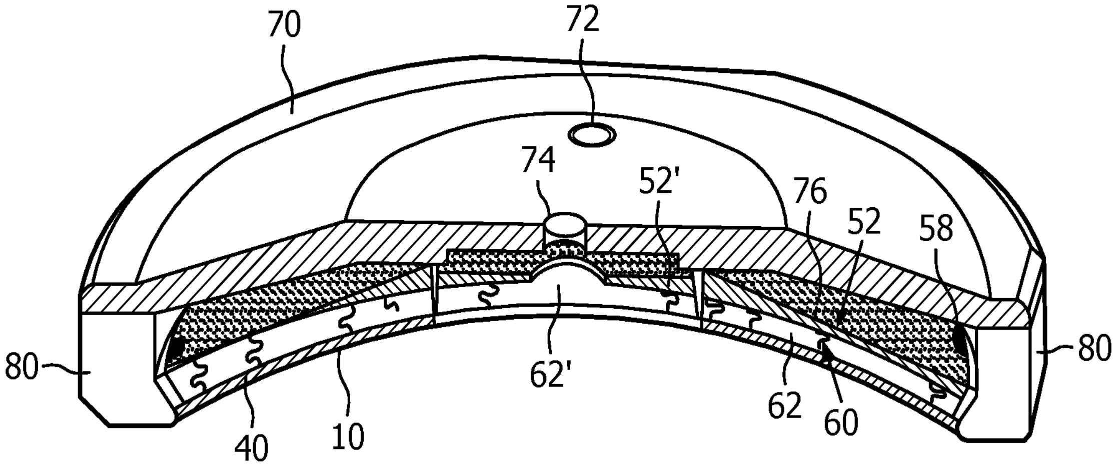

70
72
74
52'
76
52
58
80
80
62'
62
60
40
10

FIG. 10

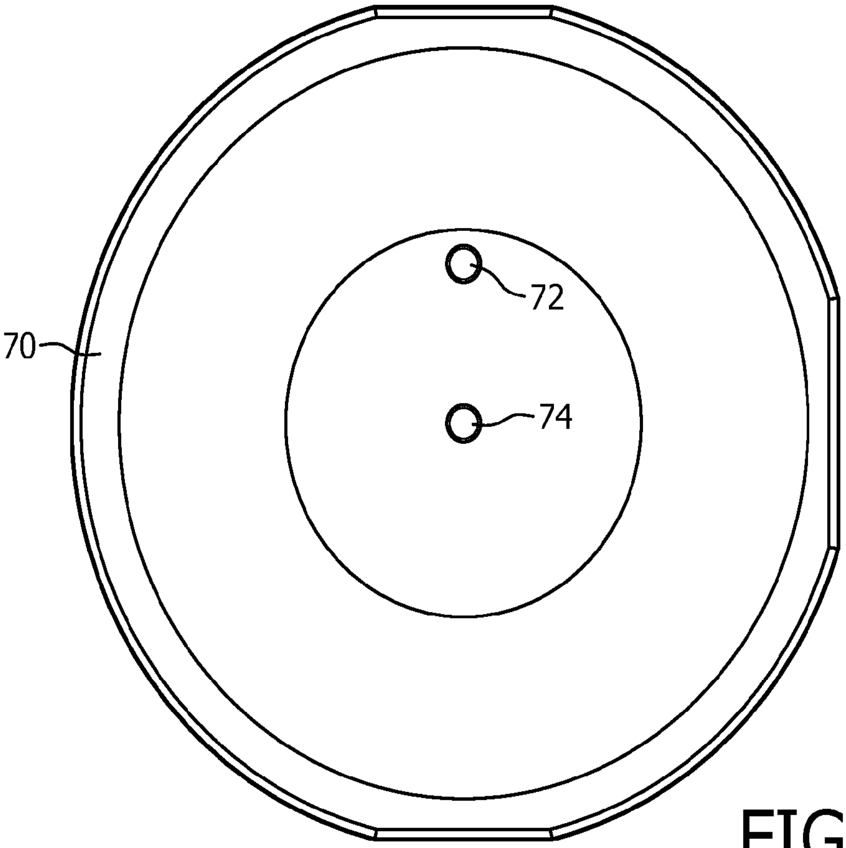


FIG. 11

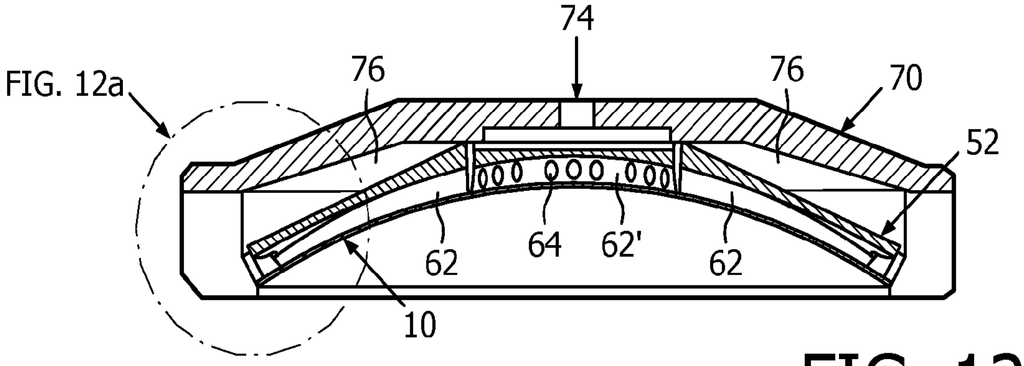


FIG. 12

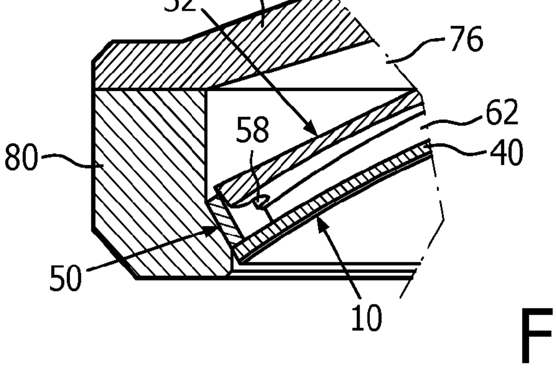


FIG. 12a

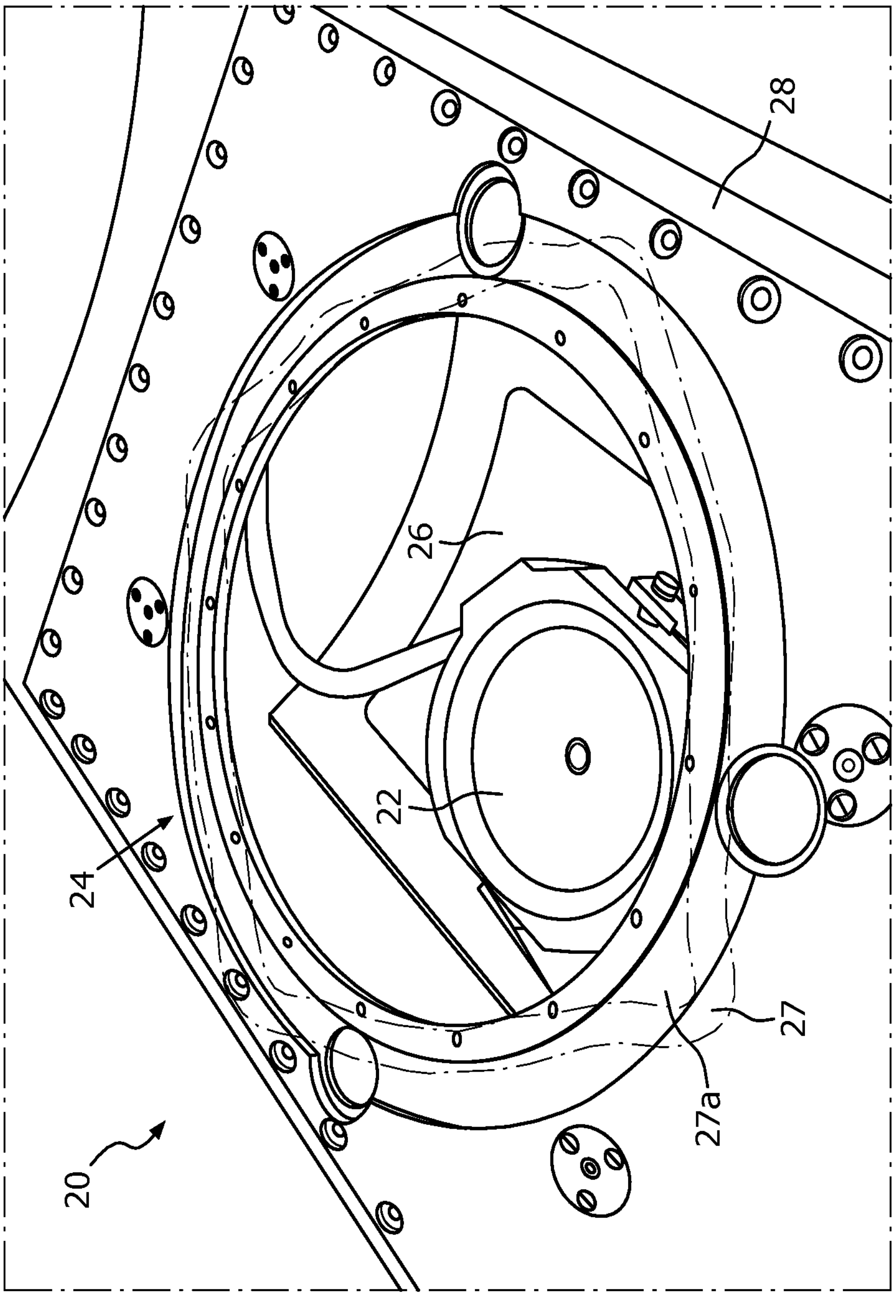


FIG. 13

ULTRASONIC HIFU TRANSDUCER WITH NON-MAGNETIC CONDUCTIVE VIAS

This invention relates to medical diagnostic ultrasound systems and, in particular, to ultrasonic transducers which are used for controlled heating of body tissues by high intensity focused ultrasound, known as HIFU.

Ultrasonically delivered elevated temperature treatments are used for a variety of therapeutic purposes In HIFU treatment, ultrasonic energy is focused to a small spot within the body so as to heat the tissues to a temperature sufficient to create a desired therapeutic effect. The technique is similar to lithotripsy, where focused energy is high enough to break up kidney stones, but with considerably less energy that is delivered over an extended time rather than a sudden pulse. The HIFU technique can be used to selectively destroy unwanted tissue within the body. For example, tumors or other pathological tissues can be destroyed by applying focused ultrasonic energy so as to heat the cells to a temperature sufficient to kill the tissue, generally about 60 to about 80 degrees C., without destroying adjacent normal tissues. Other elevated-temperature treatments include selectively heating tissues so as to selectively activate a drug or to promote some other physiological change in a selected portion of the subject's body.

HIFU transducers are often formed as spherical or parabolic dishes with a radius of curvature that gives the transducer a geometric focal point. See, for example, the HIFU transducer described in international patent application publication number WO 98/52465 (Acker et al.) As shown in the Acker et al. publication, the guidance of HIFU therapy is often performed by magnetic resonance imaging which follows the progress of the thermal treatment within the body. Thus the HIFU transducer must frequently be operable in the high magnetic field of an MRI system.

HIFU transducers are energized by electrodes formed on opposite sides of piezoelectric material as shown by Acker et al. and also by US patent application publication no. US 2009/0230822 (Kushculey et al.) Electrical connections must be made to both electrodes, which is particularly problematic for electrodes on the front (patient-facing side) of the transducer. Both of these patent publications only schematically indicate these connections which provide little guidance on how these connections are made physically. Accordingly it is desirable to provide a simple and effective way of coupling signals to electrodes on both sides of a HIFU transducer.

In accordance with the principles of the present invention, a spherical HIFU transducer is described which is formed by a plurality of composite ceramic piezoelectric tiles. The tiles are curved in two dimensions so that they will fit together to form the desired spherical transmitting surface of a desired geometric focus. The transducer has electrodes on both the front (patient-facing) and back surfaces of the piezoelectric layer. Electrical connections are made to electrodes on the front surface by non-magnetic conductive vias formed through the piezoelectric layer, enabling electrical connection to the front surface of the transducer from the rear by a means which is immune to the effects of a magnetic field.

In the drawings:

FIG. **1** illustrates in perspective a spherical transducer matching layer separately formed for a HIFU transducer of the present invention.

FIG. **2***a* illustrates an end view of a sheet of ceramic piezoelectric material which has been diced to form a composite transducer array for a HIFU transducer of the present invention.

FIG. **2***b* illustrates a composite transducer array with a nonmagnetic via constructed in accordance with the principles of the present invention.

FIG. **3** illustrates a composite transducer array with emitting elements and nonmagnetic vias constructed in accordance with the principles of the present invention.

FIG. **4** illustrates a composite piezoelectric tile prior to spherical shaping for a HIFU transducer of the present invention.

FIG. **5** illustrates in cross-section the placement of composite piezoelectric tiles on the matching layer for a HIFU transducer of the present invention.

FIG. **6** illustrates in perspective the back of a nine-tile HIFU transducer of the present invention.

FIGS. **7***a* and **7***b* illustrate the front and back surfaces of a curved printed circuit board with extended compliant contacts for a HIFU transducer of the present invention.

FIG. **8** illustrates in perspective the back of a HIFU transducer of the present invention with a support frame attached for the printed circuit boards of FIGS. **7***a* and **7***b*.

FIG. **9** is a detailed illustration of the connection of the extended compliant contacts of a printed circuit board to transducer areas of a HIFU transducer of the present invention.

FIG. **10** is a partial cross-sectional and perspective view of a HIFU transducer of the present invention with a peripheral frame and back duct cover.

FIG. **11** is a plan view of the back duct cover of FIG. **10**.

FIG. **12** is a cross-sectional view of the HIFU transducer of FIG. **10**.

FIG. **12***a* is an enlarged view of the periphery of the HIFU transducer of FIG. **12**.

FIG. **13** is a perspective view of a HIFU transducer of the present invention when mounted in a patient support table.

Construction of a HIFU transducer of the present invention may begin with fabrication of a spherical or dish-shaped matching layer. The matching layer(s) of a transducer provide at least a partial matching of the acoustic properties of the piezoelectric transducer to the acoustic properties of the patient's body or the medium between the transducer and the patient. The properties matched may include acoustic impedance, velocity of sound, and material density. In the conventional construction of an ultrasound transducer the matching layer is generally formed on the transducer stack and is formed over the reference electrodes on the emitting surface of the piezoelectric material. For the HIFU transducer described in this disclosure a spherical matching layer is formed by itself, separate from the rest of the transducer. There are several ways to form the spherical matching layer, including casting, molding, thermoforming, or machining. The spherical matching layer of the HIFU transducer described herein is made of a loaded epoxy which is loaded with particles which provide the matching layer with its desired acoustic properties as is known in the art. Preferably the particles are non-magnetic. In casting or molding the spherical matching layer, the loaded epoxy is poured into a concave fixture of the desired spherical shape. A convex fixture is closed over the concave fixture, forcing the liquid epoxy to fill the spherical space between the two fixtures. The epoxy is cured and removed from the fixtures, then peripherally machined to its final form. In a thermoform process a planar sheet of the desired thickness is formed of the loaded epoxy, then partially cured. The sheet is then placed over a heated convex or concave fixture of the desired curvature which warms the sheet so that it becomes pliant and conforms to the curvature of the fixture. When the sheet has attained its desired spherical shape it is cured and finished. In a machining process a disk of loaded epoxy is cast or molded and cured. The disk is then machined on one side to form a convex surface. The disk is then put on a concave fixture and the other side of the disk is machined to form the concave side of the spherical matching layer. In a constructed embodiment the finished spherical matching layer from any of these processes is 0.5 mm thick, has a diameter of 140 mm, and a spherical radius of 140 mm, the size and shape of the finished HIFU transducer. FIG. **1** illustrates such a spherical matching layer **10**. The concave surface **12** is the emitting surface of the finished transducer which faces the patient and the convex surface **14** is sputtered to produce a redundant signal return electrode, then covered with composite piezoelectric tiles. The rigid matching layer thus provides a form of the desired curvature for assembly of the piezoelectric tile layer. Since the matching layer **10** in front of the tiles is a continuously formed surface, it provides the desired electrical and environmental isolation of the rest of the HIFU transducer from the patient and the external surroundings in front of the HIFU transducer.

Construction of the composite piezoelectric transducer array begins with a sheet **30** of ceramic piezoelectric material as shown in FIGS. **2***a* and **2***b*. In a constructed transducer the sheet **30** is 1.2 mm thick (T). First, a number of holes are drilled through the sheet **30** where it is desired to have electrical connections from the back to the front (emitting side) of the transducer. The holes are then filled with silver-filled epoxy to form vias **32** through the sheet. The silver filling provides electrical conductivity and is non-magnetic for operation in a magnetic field of an MRI system. Other non-magnetic conductive material may be used for the conductive filling. The silver epoxy is cured. The sheet is then diced part-way through the thickness with parallel cuts **16** in one direction as shown in the view of the edge of the sheet **30** in FIG. **2***a*. Then the sheet is diced part-way through with parallel cuts in the orthogonal direction, leaving a plurality of upward projecting piezoelectric posts **18** and vias **32**. The dicing cuts are then filled with non-conducting epoxy and cured. The top and bottom surfaces of the sheet are then machined flat to the depths indicated by dashed lines **34** in FIG. **2***a*. This will result in a finished sheet of a matrix of piezoelectric posts **18** and conductive vias **32** in epoxy **36** as shown in FIG. **2***b*. The finished sheet comprises a 1:3 matrix of piezoelectric posts, each of which has its dominant vibrational mode in its longitudinal direction through the thickness of the sheet, and which transmits ultrasound predominately in a direction toward the front (patient facing) side of the transducer. This predominant vibrational mode of the composite material reduces unwanted lateral transmission across the array to other active areas of the array.

The flat composite piezoelectric sheet **30** is machined to a trapezoidal shape as shown by the peripheral shape of the composite piezoelectric tile **40** of FIG. **4**. In a constructed HIFU transducer the tiles have the trapezoidal shape of FIG. **4** to allow for a circular spherical center tile as described below. Alternatively, each tile may be machined in the shape of a slice of pie, so that the tiles will cover the matching layer without need for a center tile. The tiles could also take on other geometric shapes arranged to cover the spherical surface including but not limited to pentagons mixed with hexagons as demonstrated by the panels of a soccer ball. The flat trapezoidal tile of FIG. **4** is then given its desired spherical curvature. Since the composite transducer is formed of a matrix in epoxy, the tile can be heated to soften the epoxy so that the tile can be conformed to the desired curvature. This can be done by placing the tile **40** on a heated concave or convex fixture, then pressing the tile into conformance with the convex or concave shape. While the tile is held in the desired curvature, the fixture is cooled and the epoxy is allowed to fully cure. The result is a spherical-shaped composite piezoelectric tile for a spherical HIFU transducer.

After the tile has been curved the top and bottom surfaces **38** are metallized by sputtering a conductive material onto the surfaces of the sheet as shown for the sheet **30** of FIG. **3**. Preferably the conductive material is non-magnetic such as gold or titanium/gold. The metallized surfaces are electrically connected by the conductive vias **32**, providing electrical connection from the back surface of the composite sheet to the front. Active (transmitting and receiving) areas of the composite piezoelectric sheet are then isolated by diamond core drilling, laser drilling, or ultrasonic machining around desired active areas from the back (convex) surface of the tile. Several such defined active areas **44** are shown in FIGS. **3** and **4**. The cuts **42** which define the active areas cut through the metallization of the surface of the sheet to electrically isolate the areas and preferably extend over half-way through the composite sheet so as to acoustically isolate the active area from the surrounding areas of the sheet and other active areas. Alternatively, the active areas can be electrically and acoustically isolated after the tiles are bonded to the matching layer.

In a constructed tile the active areas **44** are not symmetrically arranged in rows or columns or circles or other regular patterns but are irregularly or randomly arranged as shown in FIG. **4**. The random pattern prevents any significant additive combining of the acoustic sidelobes of the active areas which would diminish the effective energy delivered by the HIFU transducer.

Eight of the spherical trapezoidal tiles **40** are then thin bonded adjacent to each other around the convex surface **14** of the matching layer **10**, which thereby provides a form for assembly of the tiles. If the spherical tiles **40** are pie-shaped as described above, the tiles will completely cover the convex side of the matching layer **10**. When the spherical tiles are trapezoidal as shown in FIG. **4**, they will cover the convex side of the matching layer except for the center of the matching layer. This circular spherical space can be left open. Alternatively it can be covered with a circular spherical thermal conductor such as aluminum for cooling. Returning acoustic energy will tend to be focused in the center of the HIFU transducer by virtue of its spherical geometric shape. Locating a thermal conductor here can aid in cooling the HIFU transducer. Alternatively, a circular spherical composite piezoelectric tile **48** can fill this space. For example, the circular sheet of FIG. **3**, with its own active areas, can be formed into a spherical shape and located here, providing full composite piezoelectric coverage of the matching layer **10** as shown by the cross-sectional view of the trapezoidal and circular tiles on the matching layer **10** in FIG. **5**. In a constructed transducer of this full coverage design, the nine tiles provide the HIFU transducer with 265 active areas, 256 for transmit and nine for receive.

It is seen in FIG. **3** that the vias **32** are located so as to connect the metallized area around the active areas on the back surface to the metallized surface on the front (patient-facing) side of the tile. In a constructed HIFU transducer the metallized area around the active areas **44** is electrically coupled to a reference potential. The vias **32** couple this reference potential to the metallized surface on the other side of the tile, the side not visible in FIG. **3**. The vias are thus used to apply a reference potential to the patient-facing side of the composite piezoelectric tiles, and also to the metallization on the patient-facing side of the active areas **44**. Since the patient-facing side of the tiles **40** are bonded to the matching layer **10** and are thus inaccessible for electrical connections, the vias provide the needed electrical connection through the piezoelectric sheet to the front side of the tile.

Next, a plastic support frame **50** is attached to the back of the assembled tiles by bonding, snap fit, or fasteners as shown in FIG. **6**. In a constructed transducer each of the nine tiles **40**,**48** is accessible between the ribs of the support frame. The support frame is used to mount eight trapezoidal and one circular printed circuit boards **52** in a spaced relation above the back surfaces of the composite piezoelectric tiles **40**. FIGS. **7***a* and **7***b* illustrate the front and back (**54**) surfaces of the trapezoidal printed circuit boards **52**. Located on the back surface **54** are printed circuit connections **56** from a connector **57** which are connected by plated through-holes **59** through the board to active areas of the HIFU transducer. On the front surface of the printed circuit boards are compliant metallic contacts **60** which span the space between a printed circuit board and its tile and electrically connect the printed circuit connections to the active areas **44** and vias **32** of the opposing composite piezoelectric tile **40**. Located at one edge of the printed circuit board **52** which is at the periphery of the HIFU transducer are cooling notches **58**.

A printed circuit board **52** is bonded to the support frame **50** above each tile such as tile **40** shown in FIG. **6**. When a printed circuit board is assembled in this manner it appears as shown by printed circuit board **52** in FIG. **8**. Before this assembly, the extended ends of the compliant metallic contacts **60** are coated with conductive epoxy. When the printed circuit board is assembled on the frame, the ends of the contacts **60** will contact metallized areas of the opposing tile and become bonded in electrical connection with the metallized areas when the conductive epoxy cures. The contacts **60** thus provide electrical communication between the printed circuit boards and active and reference potential areas of the piezoelectric tiles.

While the printed circuit boards can be fabricated as conventional planar printed circuit boards, the printed circuit board **52** of FIGS. **7***a* and **7***b* preferably have a spherical curvature, matching that of the opposing composite piezoelectric tiles **40** to which they are connected by the contacts **60**. The printed circuit boards can be curved on just the side facing the tile as shown in FIG. **7***a*, or on both sides. The printed circuit boards can be formed as curved boards in several ways. One is to start with a thick planar sheet of glass epoxy board material and machine or grind the surface of the board to the desired curvature. The other technique is to use thermoforming to heat the board material and soften the epoxy, then form the curvature by compressing the sheet against a fixture of the desired curvature. The circuit boards can be double-clad with photo-imaged and chemically-etched conductive lines on the top and bottom surfaces interconnected by plated through-holes formed in the boards. The circuit boards can also be multilayer boards with three or more layers of conductive lines formed on the surfaces and within layers of the board for more complex, higher density circuit configurations. The rigid boards **52** are also capable of securely mounting other electrical components such as the connector **57**.

The compliant metallic contacts **60** may be formed as springs, such as leaf springs, curled springs, or helical springs. The springs provide numerous benefits. First, they provide electrical connection from the printed circuit boards to provide drive signals and reference potential to areas of the piezoelectric of the HIFU transducer. When a flat, planar printed circuit board is used in opposition to a spherically shaped composite piezoelectric tile, the compliance of the contacts **60** will allow the contacts to span the uneven distance **62** between the board **52** and the piezoelectric tile, being relatively uncompressed when the spanned distance is greater and relatively more compressed when the distance is less. Second, they allow a space **62** to remain between the piezoelectric tiles which is used for cooling the piezoelectric tiles. Third, they provide compliant electrical connections which allow for the spacing between the printed circuit boards and the tiles to change with heating and cooling of the HIFU transducer. Fourth, since the metallic contacts are thermally conductive and span the air flow passageway between the piezoelectric material and the printed circuit board, they will conduct heat from the piezoelectric material which will be dissipated as air flows past the contacts in the passageway. These benefits can be appreciated from the enlarged view of these connections of FIG. **9**. In this drawing the contacts **60** are formed as spring clips which span the cooling space **62** between the printed circuit board **52** and the tile **40**. The center contact **60** is seen to be providing electrical connection to an active area **44** of the tile **40**. This active transducer area **44** is isolated from the surrounding area of the tile by cuts **42** through the surface metallization and into the composite piezoelectric tile **40**. On either side of the center contact **60** are spring clip contacts **60***a* which are connected to the metallization above vias **32**. These electrical connections thereby connect the front metallized surface of the tile, that which is bonded to the matching layer **10** and is therefore inaccessible for direct electrical connection, to a desired electrical potential such as a reference potential.

FIG. **10** illustrates further assembly of a HIFU transducer of the present invention in which the assembled matching layer **10**, composite piezoelectric tiles **40**, support frame **50** and printed circuit boards **52** are fit into a circular peripheral frame **80** which is capped with a back plate **70**. The back plate **70** thereby encloses an air passageway **76** between the back surfaces of the printed circuit boards **52** and the plate. The back plate includes two air ports **72** and **74**, one accessing the cooling space **62'** between the center printed circuit board **52'** and the center piezoelectric tile through a hole in the board **52'**, and the other accessing the air passageway **76** between the boards **52** and the plate **70**. The back plate **70** is shown in a plan view in FIG. **11**. In the example of FIG. **10** the plate **70** contacts the circular central rib of the support frame **50** to separate the cooling space **62'** from the peripheral air passageway **76**. Air for cooling is forced into one of these ports and out the other to cool the composite piezoelectric tiles **40**. It is seen that, unlike a conventional transducer stack, the composite piezoelectric tiles have no backing material attached to their back (non-emitting) surfaces. Instead, they are backed by the cooling space **62**. This means that there is no attached backing material to be heated by the composite piezoelectric during use. Instead, the back surface of the composite piezoelectric is cooled by the flow of air in the cooling space **62** between the composite piezoelectric and the printed circuit boards **52**. When air is forced into the port **74**, for instance, the air will flow through the central cooling space **62'**, through apertures **64** in the support frame **50** (see FIG. **8**), through the cooling spaces **62** between the trapezoidal tiles **40** and the trapezoidal printed circuit boards **52**, through the peripheral notches **58** of the printed circuit boards into the air passageway **76**, and out through the port **72**. Thus, the back surface of the composite piezoelectric tiles can be continuously directly air-cooled during use of the HIFU transducer.

FIG. **12** is a cross-sectional view through the center of the HIFU transducer assembly of FIG. **10** which further illustrates the elements of the air cooling system of the assembly. FIG. **12***a* is an enlarged view of the periphery of the assembly, showing a piezoelectric tile **40**, support frame **50** and printed circuit board **52** in abutment with the peripheral frame **80** and capped with the back plate **70**.

FIG. **13** illustrates a HIFU transducer **22** of the present invention employed in the patient support table **28** of an ultrasonic HIFU system **20**. FIG. **13** presents a top view of the patient support table. The patient support table **28** has a first reservoir **24** filled with a suitable transmission liquid, for example, water. For reasons of clarity, the transparent membrane sealing the top of the first reservoir **24** is not shown. The HIFU transducer **22** is located in the first reservoir **24** and is arranged to emit high intensity focused ultrasonic energy upward toward a patient reclined on the table **28**. The water of the reservoir **24** provides an acoustic coupling medium between the HIFU transducer **22** and the patient, and also provides cooling of the front of the HIFU transducer. In order to complete the coupling of the ultrasonic energy emanating from the first reservoir to the patient, a second reservoir **27** comprising a low reflective medium is positioned above the first reservoir **24**. Preferably, a suitable gel pad is used for the second reservoir. The second reservoir **27** comprises a contact surface **27***a* onto which a patient to be treated is positioned. The apparatus **20** further comprises an aperture **26** arranged to enable an inspection, for example, a visual inspection, of the contact surface **27***a* between the second reservoir **27** and the patient. The aperture **26** is preferably arranged as a substantially transparent window through which medical personnel directly, or using a mirror or a suitably arranged camera, can inspect for the presence of air bubbles between the contact surface **27***a* and the patient. In the case when an air bubble is detected, the patient is repositioned until no air bubbles are present. After that, the patient is suitably immobilized and a treatment may be commenced. The HIFU system **20** of FIG. **13** is further described in international patent application publication number WO 2008/102293 (Bruggers).

What is claimed is:

1. A high intensity focused ultrasound (HIFU) transducer comprising:

a piezoelectric array comprising a layer of piezoelectric material having a patient-facing front surface and a back surface, the front surface comprising a transmitting surface;

a plurality of electrodes located on the front and back surfaces of the piezoelectric material for applying electrical signals to the piezoelectric array; and

a nonmagnetic conductive via, extending through the layer of piezoelectric material and electrically connecting an electrode on the back surface to an electrode on the front surface of the piezoelectric array,

wherein the electrode on the front surface of the piezoelectric array comprises a reference potential electrode.

2. The HIFU transducer of claim **1**, wherein the nonmagnetic conductive via further comprises a hole through the layer of piezoelectric material which is filled with conductive epoxy.

3. The HIFU transducer of claim **2**, wherein the conductive epoxy further comprises silver epoxy.

4. The HIFU transducer of claim **1**, wherein the reference potential electrode covers substantially the entire patient-facing front surface of the array.

5. The HIFU transducer of claim **1**, wherein a plurality of electrodes comprising transmission electrodes are located on the back surface of the array,

wherein the transmission electrodes are each surrounded by a reference potential electrode.

6. The HIFU transducer of claim **5**, further comprising a plurality of conductive vias electrically coupling reference potential electrodes on the back surface with the reference potential electrode on the front surface.

7. The HIFU transducer of claim **1**, further comprising a printed circuit board coupled to provide a reference potential to a reference potential electrode on the back surface of the array.

8. The HIFU transducer of claim **7**, wherein the printed circuit board is further coupled to provide transmit signals to transmission electrodes on the back surface of the array.

9. The HIFU transducer of claim **1**, wherein the layer of piezoelectric material further comprises a composite of ceramic elements embedded in a nonconductive matrix, wherein the via extends through one or more ceramic elements.

10. The HIFU transducer of claim **1**, wherein the conductive via further comprises the only electrical connection to the electrode on the front surface.

11. The HIFU transducer of claim **10**, wherein the conductive via further comprises a plurality of conductive vias electrically coupling electrode areas on the back surface with the electrode on the front surface.

12. The HIFU transducer of claim **1**, wherein the piezoelectric array further comprises a plurality of piezoelectric tiles, each having at least one via electrically coupling an electrode area on the back surface of the tile with an electrode area on the front surface of the tile.

13. The HIFU transducer of claim **12**, further comprising a matching layer having a metallic coating bonded to the front surfaces of the tiles and electrically connecting the electrode areas on the front surfaces of the tiles.

14. The HIFU transducer of claim **1**, comprising a plurality of nonmagnetic conductive vias.

15. A high intensity focused ultrasound (HIFU) transducer comprising:

a piezoelectric array comprising a layer of piezoelectric material having a patient-facing front surface and a back surface, the front surface comprising a transmitting surface;

a plurality of electrodes located on the front and back surfaces of the piezoelectric material for applying electrical signals to the piezoelectric array; and

a nonmagnetic conductive via, extending through the layer of piezoelectric material and electrically connecting an electrode on the back surface to an electrode on the front surface of the piezoelectric array, and

a printed circuit board coupled to provide a reference potential to a reference potential electrode on the back surface of the array.

16. The HIFU transducer of claim **15**, wherein the printed circuit board is further coupled to provide transmit signals to transmission electrodes on the back surface of the array.

17. The HIFU transducer of claim **15**, wherein the conductive via further comprises the only electrical connection to the electrode on the front surface.

18. The HIFU transducer of claim **17**, comprising a plurality of conductive vias electrically coupling electrode areas on the back surface with the electrode on the front surface.

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专利名称(译)	超声波HIFU换能器，带有非磁性导电通孔		
公开(公告)号	US9039624	公开(公告)日	2015-05-26
申请号	US13/508646	申请日	2010-11-03
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IPC分类号	A61B8/00 A61N7/00 A61N7/02 B06B1/06 G10K11/00		
CPC分类号	B06B1/0637 A61N7/02 G10K11/004 A61N2007/0065 A61N2007/0078 A61N2007/0095		
审查员(译)	LUONG，PETER		
优先权	61/259309 2009-11-09 US		
其他公开文献	US20120323147A1		
外部链接	Espacenet USPTO		

摘要(译)

一种高强度聚焦超声（HIFU）换能器，包括具有压电材料层的压电阵列，所述压电材料层具有面向患者的前表面和后表面，所述前表面包括透射表面，以及位于正面和背面的多个电极用于将电信号施加到压电阵列的压电材料的表面。背面上的电极与压电阵列前表面上的电极之间的电连接通过延伸穿过压电材料层的非磁性导电通孔形成。