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(54) Title: CURVED ULTRASONIC HIFU TRANSDUCER WITH COMPLIANT ELECTRICAL CONNECTIONS

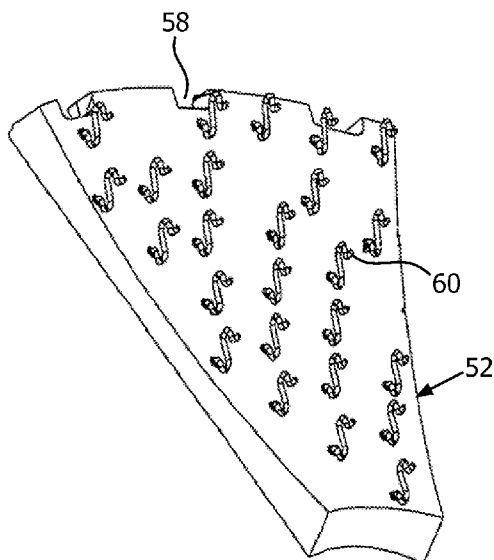


FIG. 7a

(57) Abstract: A curved high intensity focused ultrasound (HIFU) transducer comprising a curved piezoelectric array having opposite concave front and convex back surfaces, and a plurality of acoustic transmission areas, a plurality of electrodes located on the convex back surface of the curved piezoelectric array for applying electrical transmit signals to the acoustic transmission areas, and a printed circuit board spaced apart from and in opposition to the back surface of the curved piezoelectric array which couples electrical signals to the acoustic transmission areas, the printed circuit board comprising a plurality of metal contacts which are compliant in the presence of thermal expansion and contraction and which span the space between the printed circuit board and the curved piezoelectric array and are electrically coupled to electrodes of the acoustic transmission areas of the curved piezoelectric array.

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- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

## CURVED ULTRASONIC HIFU TRANSDUCER WITH COMPLIANT ELECTRICAL CONNECTIONS

5 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.

10 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  
15 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  
20 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  
25 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.

30 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  
35 WO 98/52465 (Acker et al.) and in US patent

application publication no. US 2009/0230822

(Kushculey et al.) HIFU transducers are driven with considerably more energy than diagnostic imaging transducers and can produce a substantial amount of heat. This heat can cause expansion and contraction of the HIFU transducer and components attached to the transducer such as mounting frames and electrical components. Consequently some means is usually provided to cool the transducer such as the coolant passageway in the mount for the Acker et al. transducer. It would further be desirable to fabricate the transducer assembly so that connections to other components are resistant to the forces caused by repeated heating and cooling of the transducer assembly.

In accordance with the principles of the present invention, a spherical HIFU transducer is described which is electrically energized by the application of drive signals to electrodes on the rear convex surface of the transducer. The drive signals are coupled to the electrodes by compliant contacts between the electrodes and printed circuit boards. The compliant contacts can flex and bend in response to expansion and contraction of the assembly caused by heating and cooling of the transducer. The compliant contact further allow the printed circuit boards to be spaced apart from the transducer, forming an air gap backing of the transducer which provides a cooling passageway.

In the drawings:

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

FIGURE 2a 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.

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

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

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

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

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

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

FIGURE 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 FIGURES 7a and 7b.

FIGURE 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.

FIGURE 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.

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

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

5           FIGURE 12a is an enlarged view of the periphery of the HIFU transducer of FIGURE 12.

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

10           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  
15           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  
20           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  
25           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  
30           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  
35           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 0.5mm thick, has a diameter of 140mm, and a spherical radius of 140mm, the size and shape of the finished HIFU transducer. FIGURE 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 moisture-impervious 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 FIGURES 2a and 2b. In a constructed transducer the sheet 30 is 1.2mm 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 FIGURE 2a. 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 FIGURE 2a. This will result in a finished sheet of a matrix of piezoelectric posts 18 and conductive vias 32 in epoxy 36 as shown in FIGURE 2b. 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.

5           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 FIGURE 4. In a constructed HIFU transducer the tiles have the trapezoidal shape of FIGURE 4 to allow  
10 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  
15 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 FIGURE 4 is then given its desired spherical curvature. Since the  
20 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  
25 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.

30           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 FIGURE 3. Preferably the conductive material is non-magnetic such as gold or  
35 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 FIGURES 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 FIGURE 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 FIGURE 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  
5 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  
10 piezoelectric tile 48 can fill this space. For example, the circular sheet of FIGURE 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  
15 shown by the cross-sectional view of the trapezoidal and circular tiles on the matching layer 10 in FIGURE 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  
20 receive.

It is seen in FIGURE 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  
25 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  
30 side not visible in FIGURE 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  
35 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.

5           Next, a plastic support frame 50 is attached to the back of the assembled tiles by bonding, snap fit, or fasteners as shown in FIGURE 6. In a constructed transducer each of the nine tiles 40,48 is accessible between the ribs of the support frame. The support  
10 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. FIGURES 7a and 7b illustrate the front and back (54) surfaces of the trapezoidal  
15 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  
20 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  
25 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  
30 shown in FIGURE 6. When a printed circuit board is assembled in this manner it appears as shown by printed circuit board 52 in FIGURE 8. Before this assembly, the extended ends of the compliant metallic contacts 60 are coated with conductive epoxy. When  
35 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  
5 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  
10 boards, the printed circuit board 52 of FIGURES 7a and 7b 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  
15 the side facing the tile as shown in FIGURE 7a, 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  
20 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-  
25 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  
30 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.

35 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 FIGURE 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 60a which are connected to the metallization above vias 32. These electrical connections thereby connect the front metallized surface of the tile, that which is  
5 bonded to the matching layer 10 and is therefore inaccessible for direct electrical connection, to a desired electrical potential such as a reference potential.

FIGURE 10 illustrates further assembly of a HIFU  
10 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  
15 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  
20 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 FIGURE 11. In the example of FIGURE 10 the plate 70 contacts the circular central  
25 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  
30 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  
35 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 FIGURE 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.

FIGURE 12 is a cross-sectional view through the center of the HIFU transducer assembly of FIGURE 10 which further illustrates the elements of the air cooling system of the assembly. FIGURE 12a 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.

FIGURE 13 illustrates a HIFU transducer 22 of the present invention employed in the patient support table 28 of an ultrasonic HIFU system 20. FIGURE 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

5 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

10 reservoir 27 comprises a contact surface 27a 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 27a between

15 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

20 between the contact surface 27a 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

25 FIGURE 13 is further described in international patent application publication number WO 2008/102293 (Bruggers).

WHAT IS CLAIMED IS:

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

5 a curved piezoelectric array having opposite concave front and convex back surfaces, and a plurality of acoustic transmission areas;

10 a plurality of electrodes located on the convex back surface of the curved piezoelectric array for applying electrical transmit signals to the acoustic transmission areas; and

15 a printed circuit board spaced apart from and in opposition to the back surface of the curved piezoelectric array which couples electrical signals to the acoustic transmission areas, the printed circuit board comprising a plurality of metal contacts which are compliant in the presence of thermal expansion and contraction and which span the space between the printed circuit board and the curved piezoelectric array and are electrically coupled to electrodes of the acoustic transmission areas of the curved piezoelectric array.

25 2. The curved HIFU transducer of Claim 1, wherein the metal contacts are electrically coupled to electrodes of the acoustic transmission areas by conductive epoxy.

30 3. The curved HIFU transducer of Claim 1, wherein the metal contacts further comprise springs.

4. The curved HIFU transducer of Claim 3, wherein the springs further comprise leaf springs.

35 5. The curved HIFU transducer of Claim 3,

wherein the springs further comprise curled springs.

6. The curved HIFU transducer of Claim 3,  
wherein the springs further comprise helical springs.

5

7. The curved HIFU transducer of Claim 1,  
wherein the metal contacts further comprise spring  
clips.

10

8. The curved HIFU transducer of Claim 1,  
wherein the space between the printed circuit board  
and the curved piezoelectric array comprises a  
different distance for different ones of the metal  
contacts.

15

9. The curved HIFU transducer of Claim 1,  
further comprising a frame on which the printed  
circuit board is mounted in spaced relation to the  
curved piezoelectric array.

20

10. The curved HIFU transducer of Claim 9,  
further comprising a plurality of printed circuit  
boards mounted on the frame in spaced relation to  
different areas of the curved piezoelectric array.

25

11. The curved HIFU transducer of Claim 10,  
wherein the printed circuit boards further comprise  
planar printed circuit boards.

30

12. The curved HIFU transducer of Claim 10,  
wherein the printed circuit boards further comprise  
curved printed circuit boards.

35

13. The curved HIFU transducer of Claim 1,  
further comprising a reference potential electrode

located on the convex back surface of the piezoelectric array;

5 wherein a plurality of the metal contacts couple transmit signals to electrodes of the acoustic transmission areas and at least one further metal contact couples a reference potential to the reference potential electrode.

10 14. The curved HIFU transducer of Claim 1, wherein the space between the printed circuit board and the piezoelectric array changes in distance with thermal expansion and contraction of the transducer,

15 wherein the compliant metal contacts bend to accommodate the distance change of the space.

20 15. The curved HIFU transducer of Claim 14, wherein the lateral relationship of the printed circuit board and the piezoelectric array changes with thermal expansion and contraction of the transducer,

wherein the compliant metal contacts bend to accommodate the change in lateral relationship.

1/8

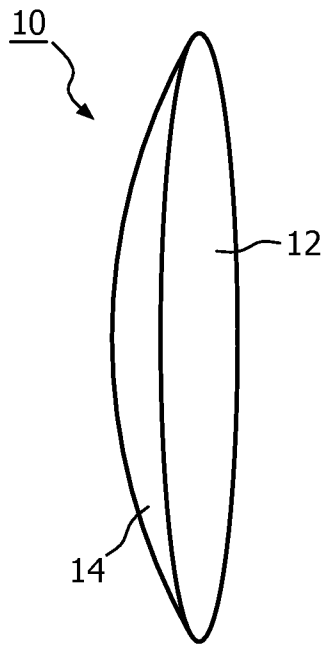


FIG. 1

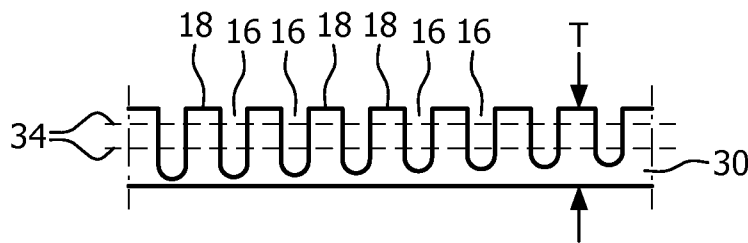


FIG. 2a

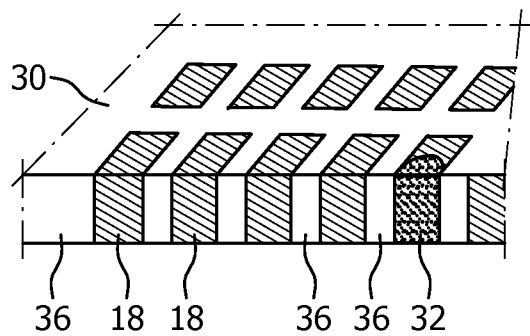


FIG. 2b

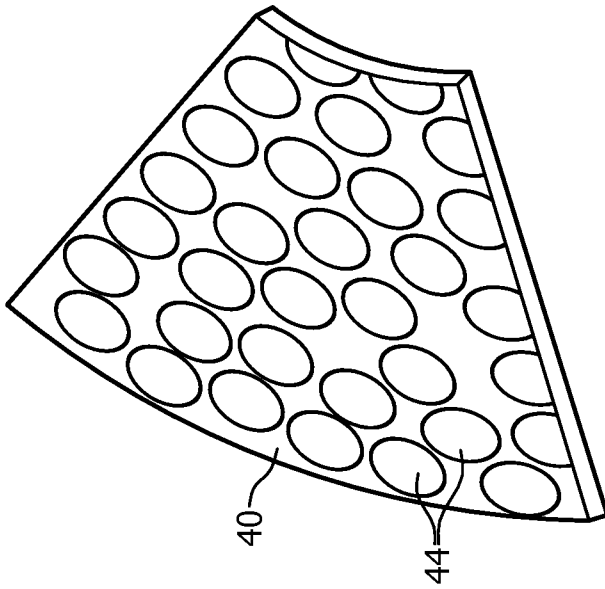


FIG. 4

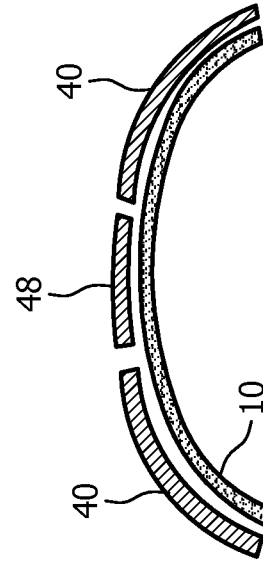


FIG. 5

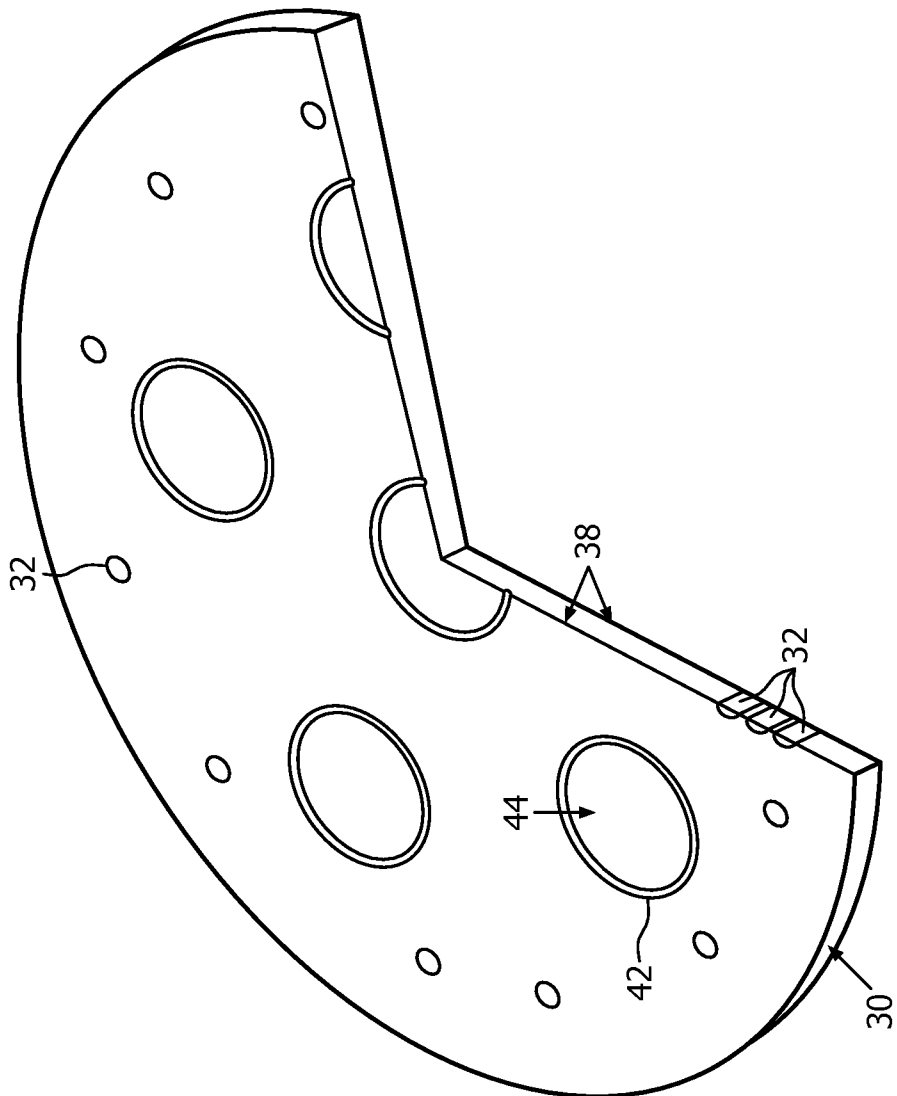


FIG. 3

3/8

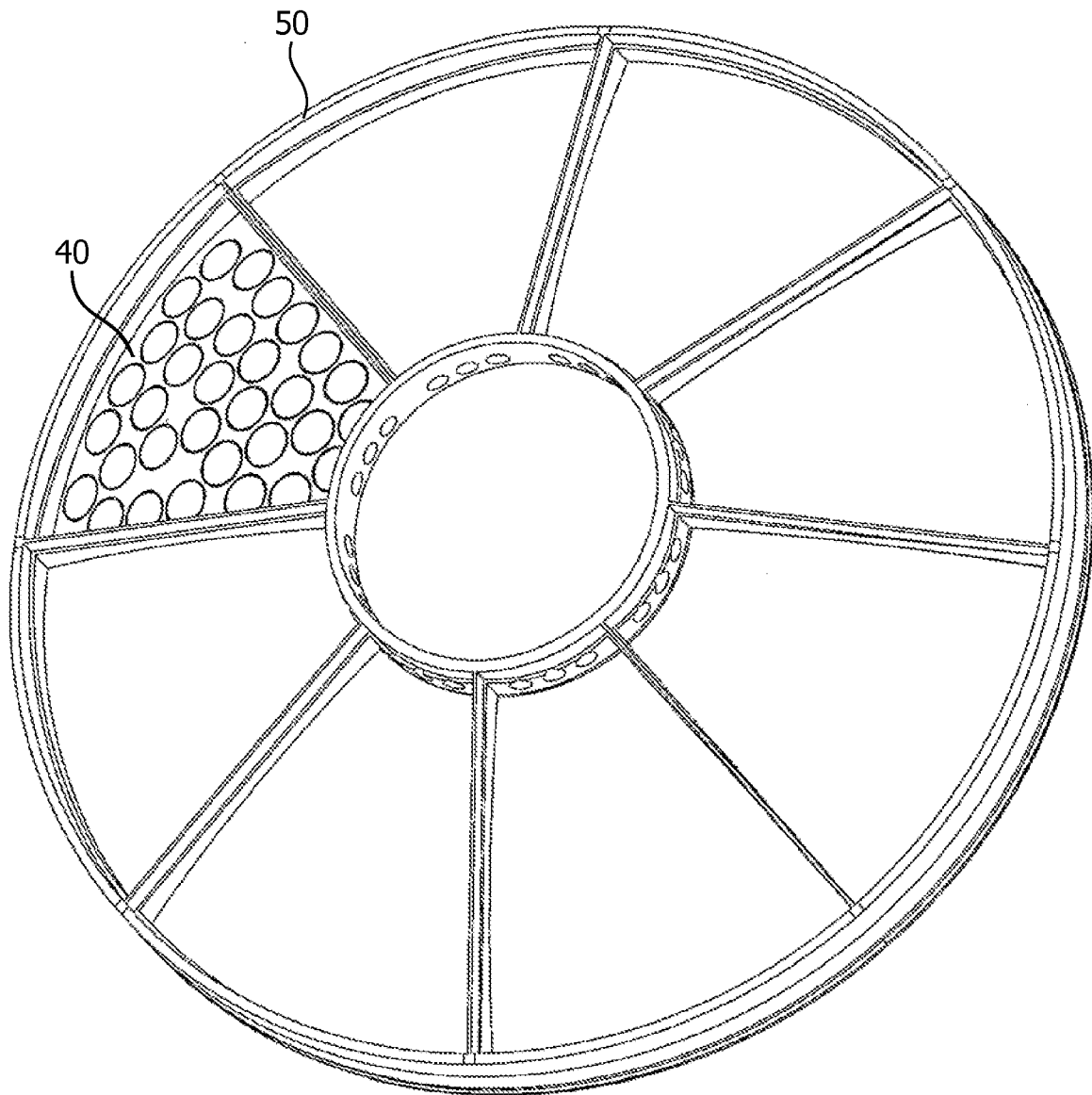


FIG. 6

4/8

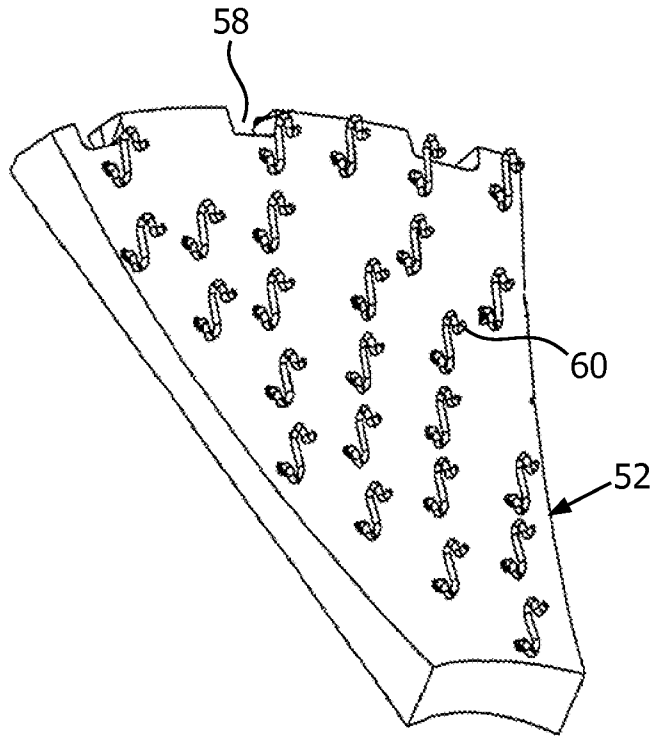


FIG. 7a

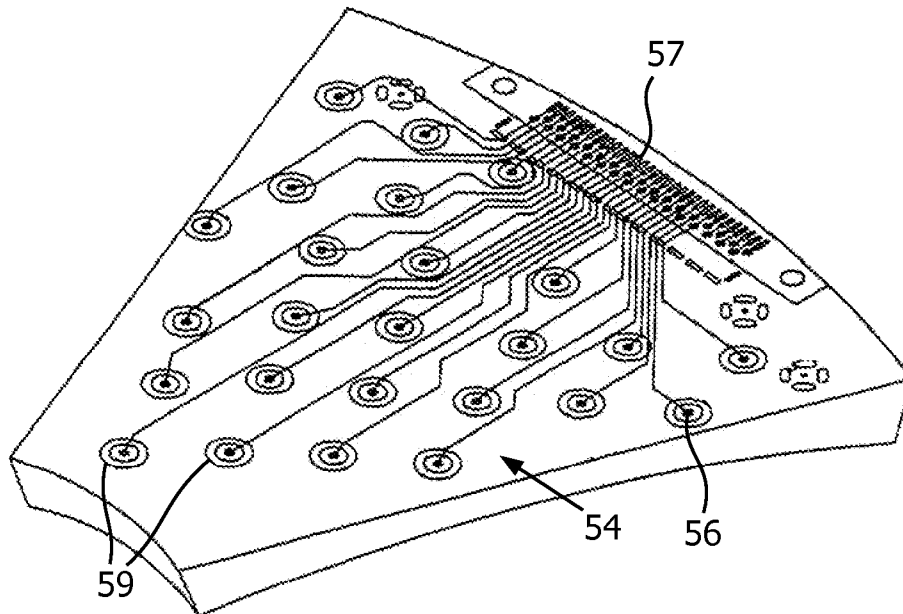


FIG. 7b



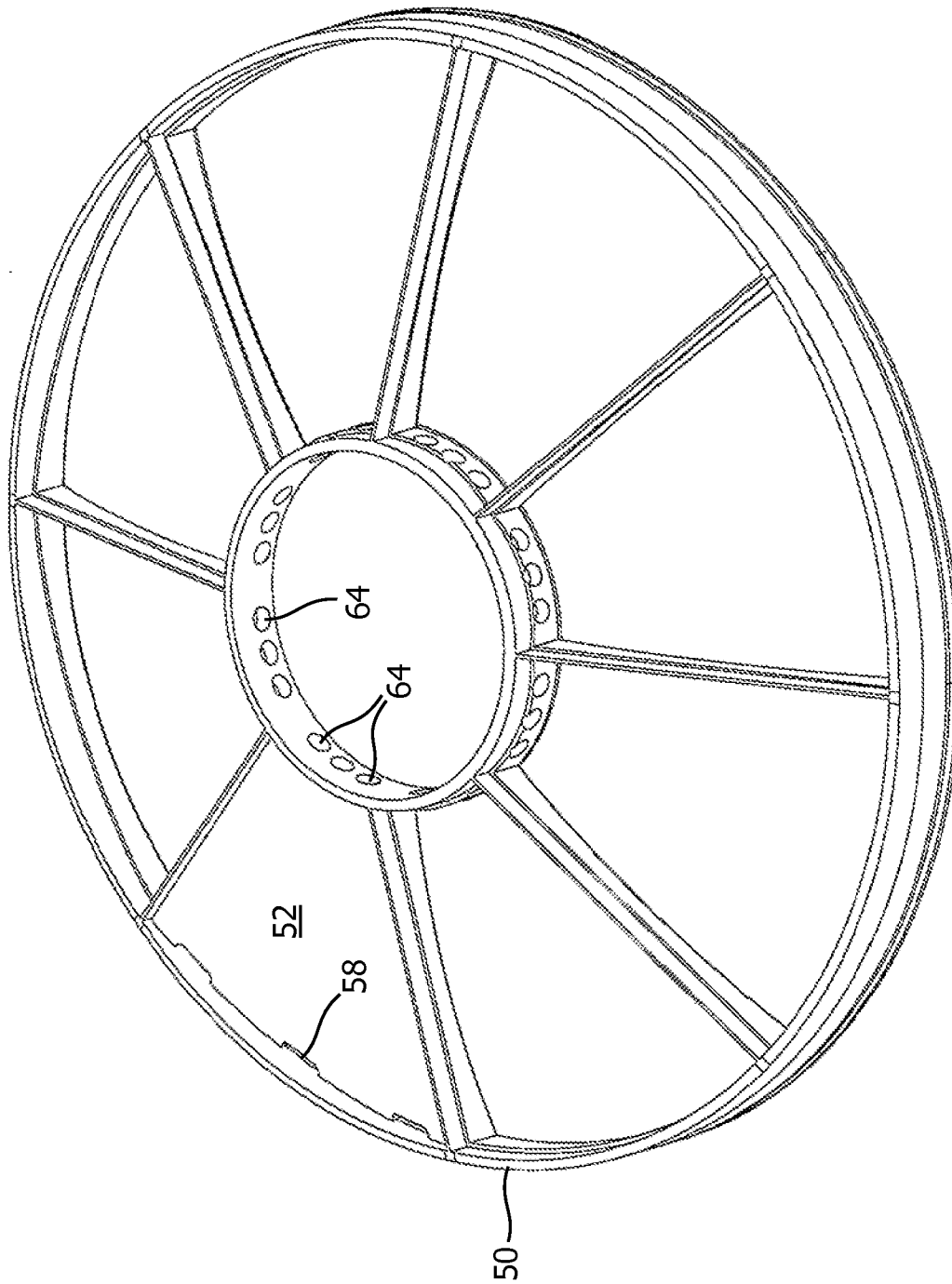


FIG. 8

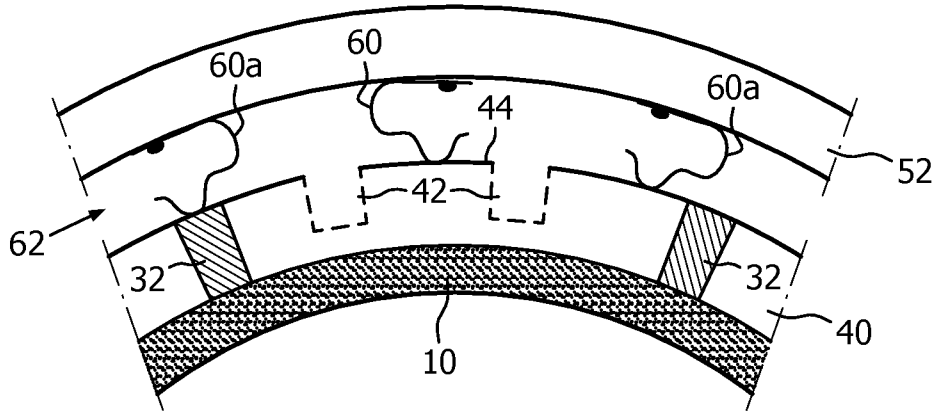


FIG. 9

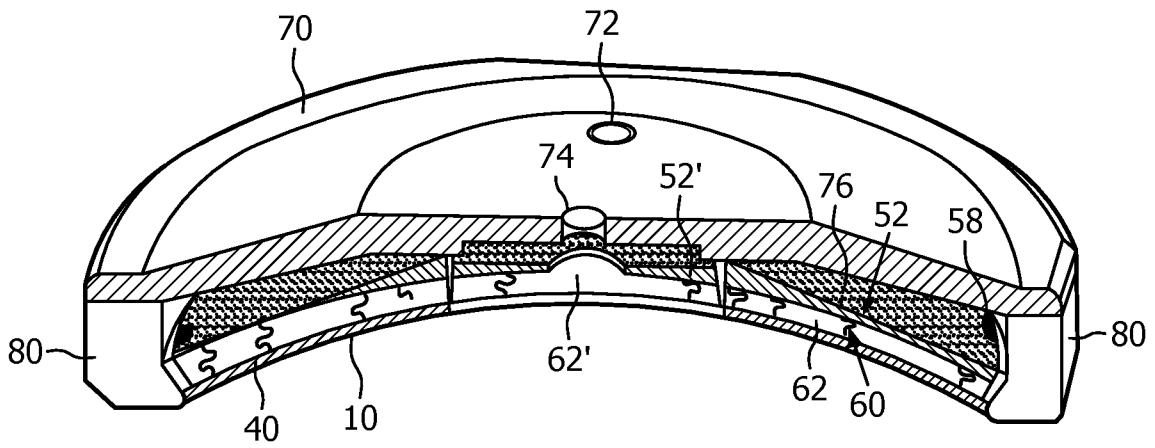
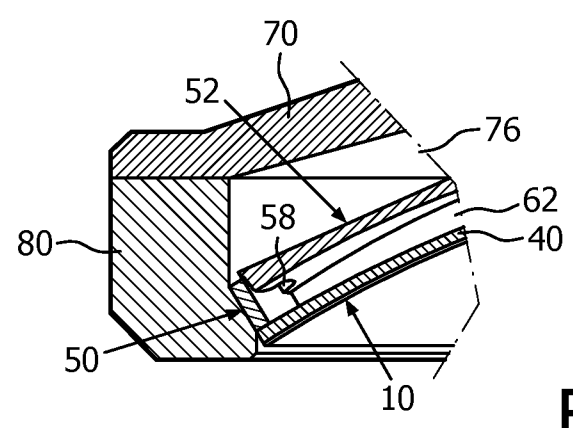
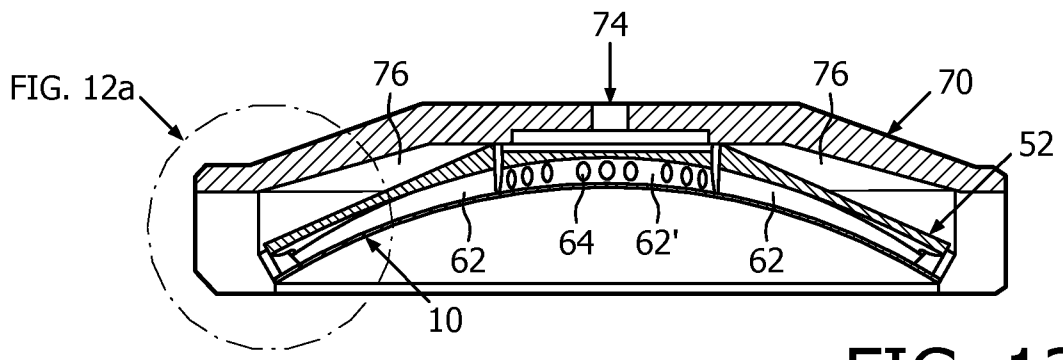
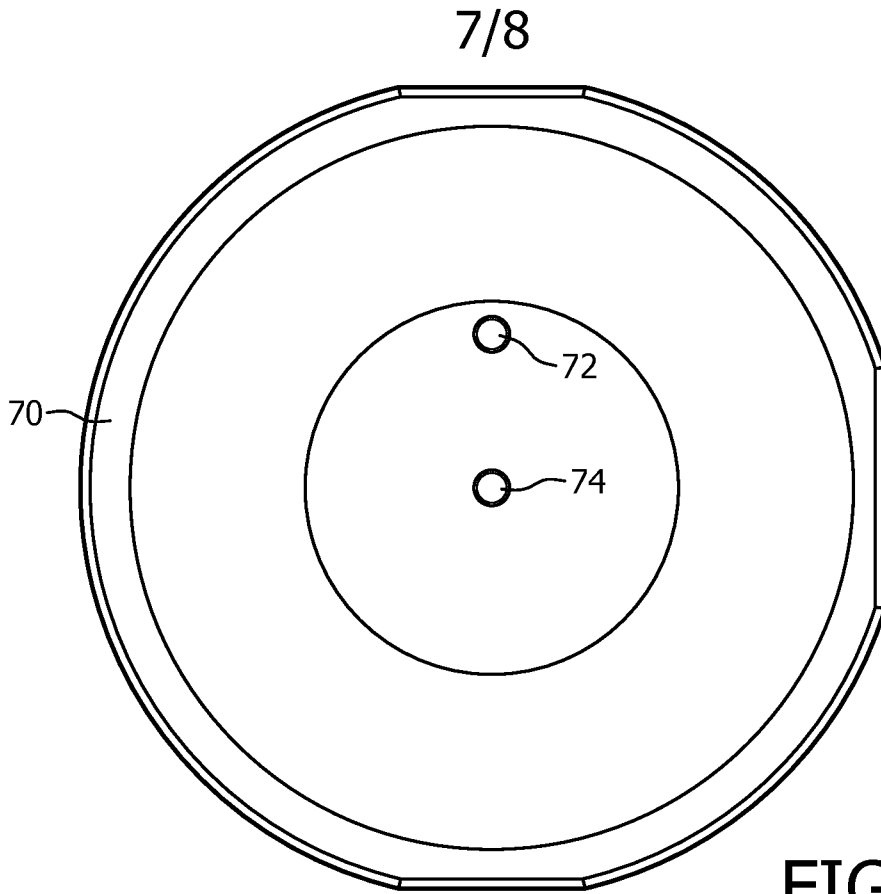


FIG. 10



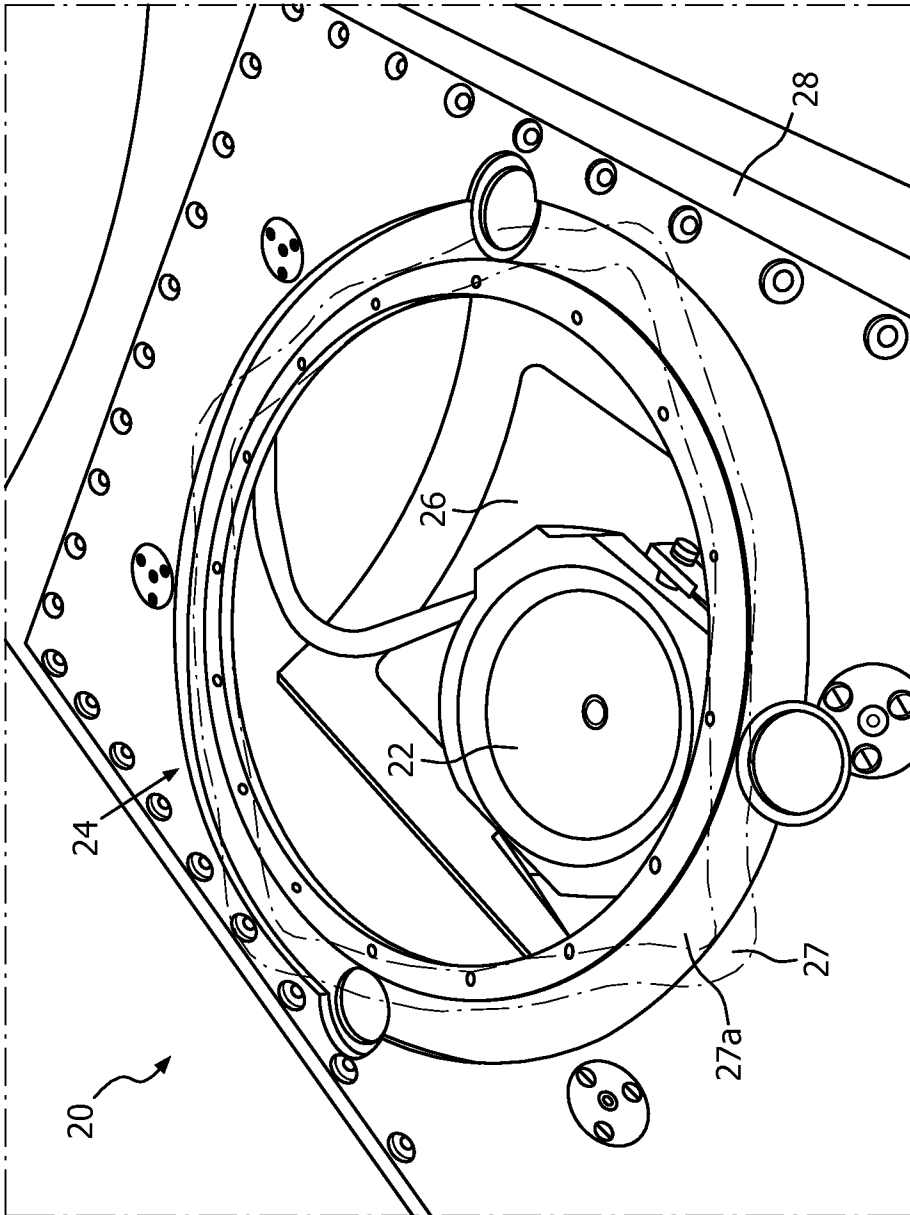


FIG. 13

# INTERNATIONAL SEARCH REPORT

International application No PCT/IB2010/054983
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<b>A. CLASSIFICATION OF SUBJECT MATTER</b>				
INV. H01L41/22 H05K3/32 A61N7/02 B06B1/06 G10K11/00				
H01L41/047 H01L41/053				
ADD.				
According to International Patent Classification (IPC) or to both national classification and IPC				
<b>B. FIELDS SEARCHED</b>				
Minimum documentation searched (classification system followed by classification symbols) H01L H05K A61N B06B G10K				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data				
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
Y	US 2009/230822 A1 (KUSHCULEY LEONID [IL] ET AL) 17 September 2009 (2009-09-17) cited in the application paragraph [0115] figures 2A-2C,3A	1-15		
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<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <span style="margin-left: 200px;"><input checked="" type="checkbox"/> See patent family annex.</span>				
* Special categories of cited documents : <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;">               "A" document defining the general state of the art which is not considered to be of particular relevance                "E" earlier document but published on or after the international filing date                "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)                "O" document referring to an oral disclosure, use, exhibition or other means                "P" document published prior to the international filing date but later than the priority date claimed             </td> <td style="width: 50%; border: none; vertical-align: top;">               "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention                "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone                "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.                "&amp;" document member of the same patent family             </td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family			
Date of the actual completion of the international search	Date of mailing of the international search report			
3 February 2011	09/02/2011			
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Willig, Hendrik			

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