US 20150119717A1

(19) United States

(12) Patent Application Publication

YOSHIDA et al.

(10) Pub. No.: US 2015/0119717 A1

(43) Pub. Date: Apr. 30, 2015

(54) ULTRASONIC DEVICE, ULTRASONIC PROBE HEAD, ULTRASONIC PROBE, ELECTRONIC APPARATUS, AND ULTRASONIC IMAGING APPARATUS

(71) Applicant: **SEIKO EPSON CORPORATION**, Tokyo (JP)

(72) Inventors: **Kazuki YOSHIDA**, Fujimi-machi (JP); **Yasunori ONISHI**, Shiojiri (JP); **Hironori SUZUKI**, Chino (JP)

(21) Appl. No.: **14/515,012**

(22) Filed: **Oct. 15, 2014**

(30) **Foreign Application Priority Data**

Oct. 28, 2013 (JP) 2013-223009

Publication Classification

(51) **Int. Cl.**

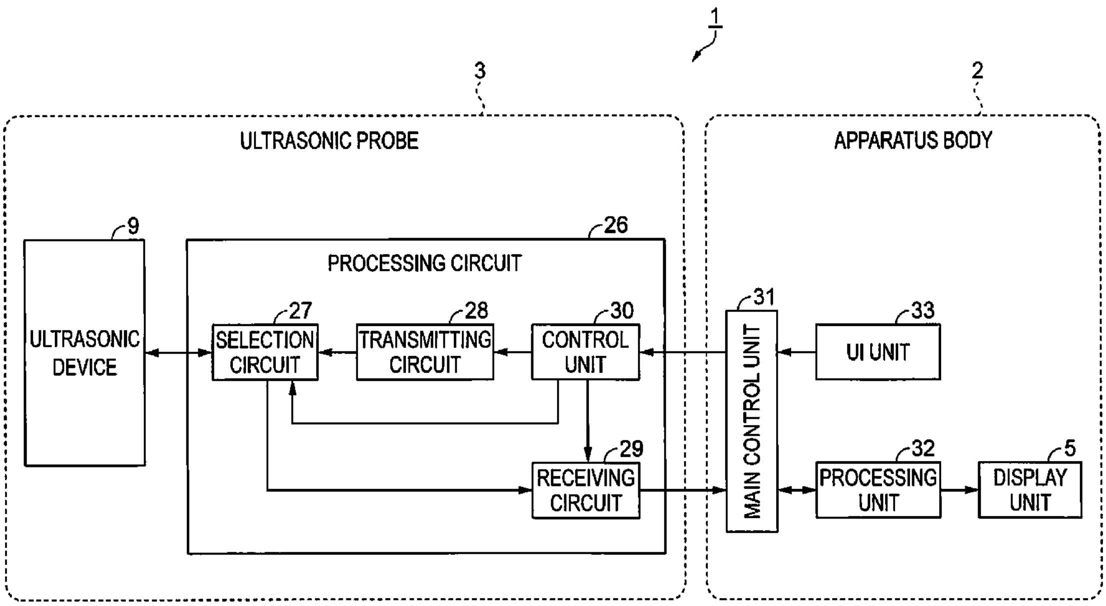
A61B 8/00	(2006.01)
A61B 8/14	(2006.01)
A61B 8/08	(2006.01)
G10K 11/30	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 8/4444*** (2013.01); ***G10K 11/30*** (2013.01); ***A61B 8/145*** (2013.01); ***A61B 8/4494*** (2013.01); ***A61B 8/5207*** (2013.01); ***A61B 8/461*** (2013.01); ***A61B 8/4272*** (2013.01); ***A61B 8/4427*** (2013.01); ***A61B 8/4405*** (2013.01)

(57) **ABSTRACT**

Provided is an ultrasonic device including: an ultrasonic element array substrate having a plurality of ultrasonic elements configured to perform at least one of transmission and reception of ultrasound; an acoustic lens configured to focus the ultrasound; an acoustic matching unit formed using resin, the acoustic matching unit being arranged between the ultrasonic element array substrate and the acoustic lens; and a plurality of columnar spacing members arranged between the ultrasonic element array substrate and the acoustic lens so as to be in contact with the ultrasonic element array substrate and the acoustic lens.



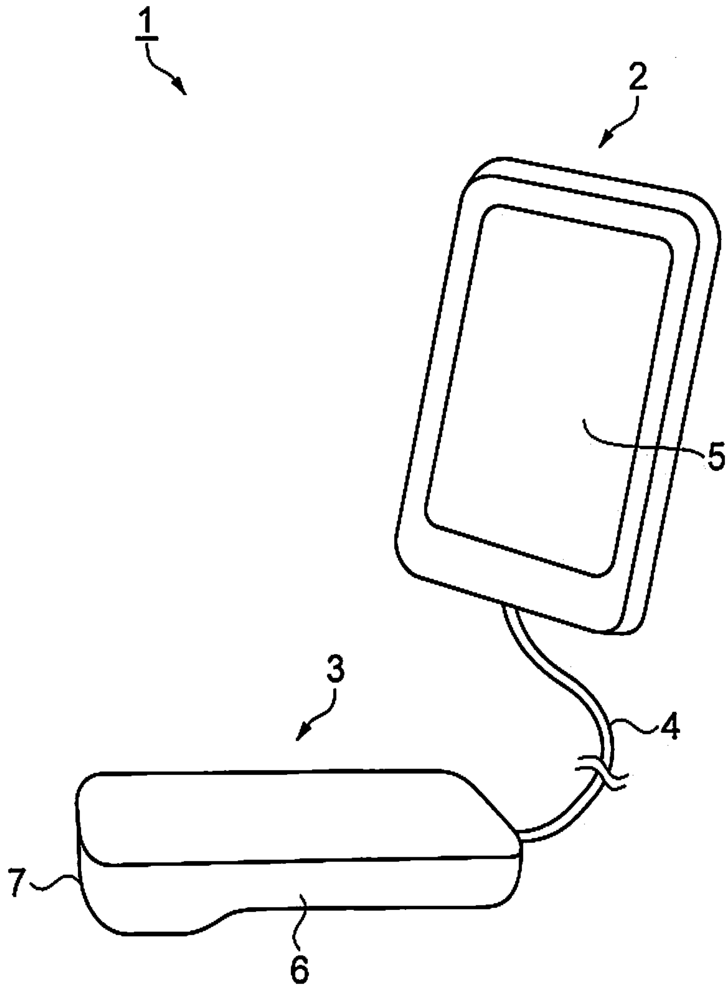


FIG. 1

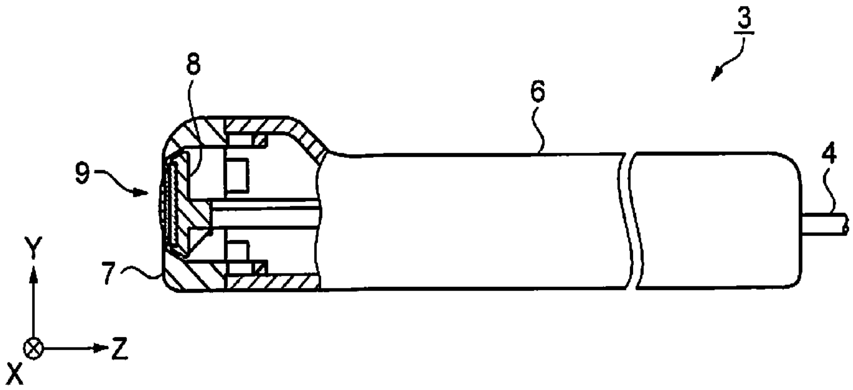

3
8
6
9
4
Y
7
X
Z

FIG. 2

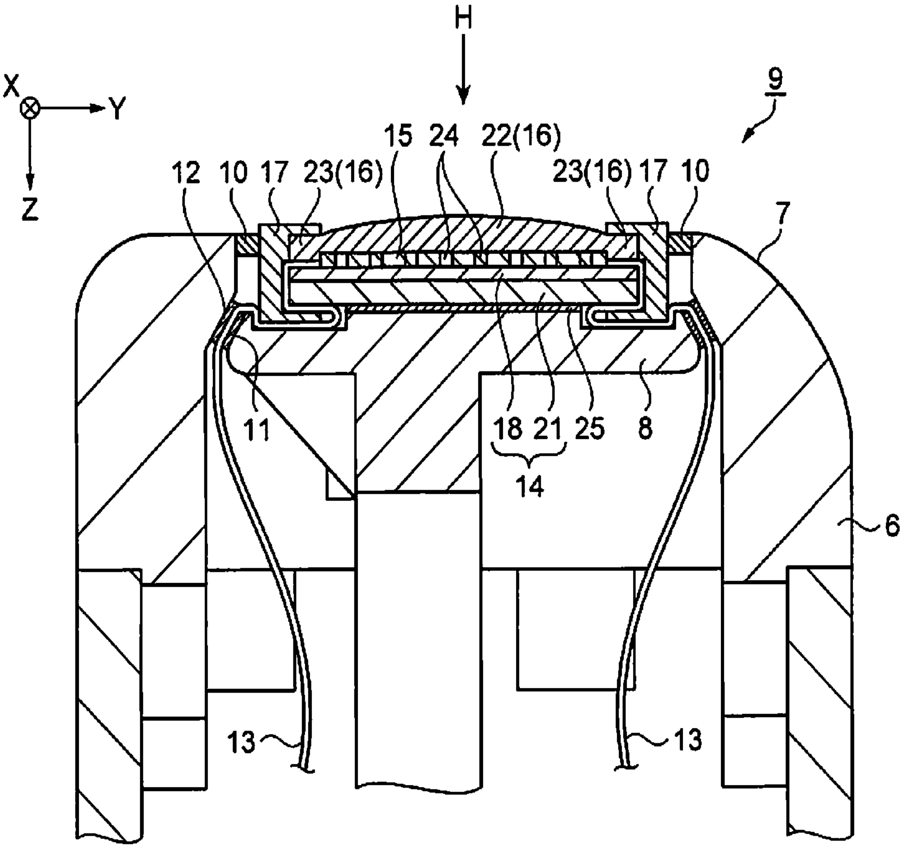

H
X
Y
9
Z
15
24
22(16)
12
10
17
23(16)
23(16)
17
10
7
11
18
21
25
8
14
6
13
13

FIG. 3

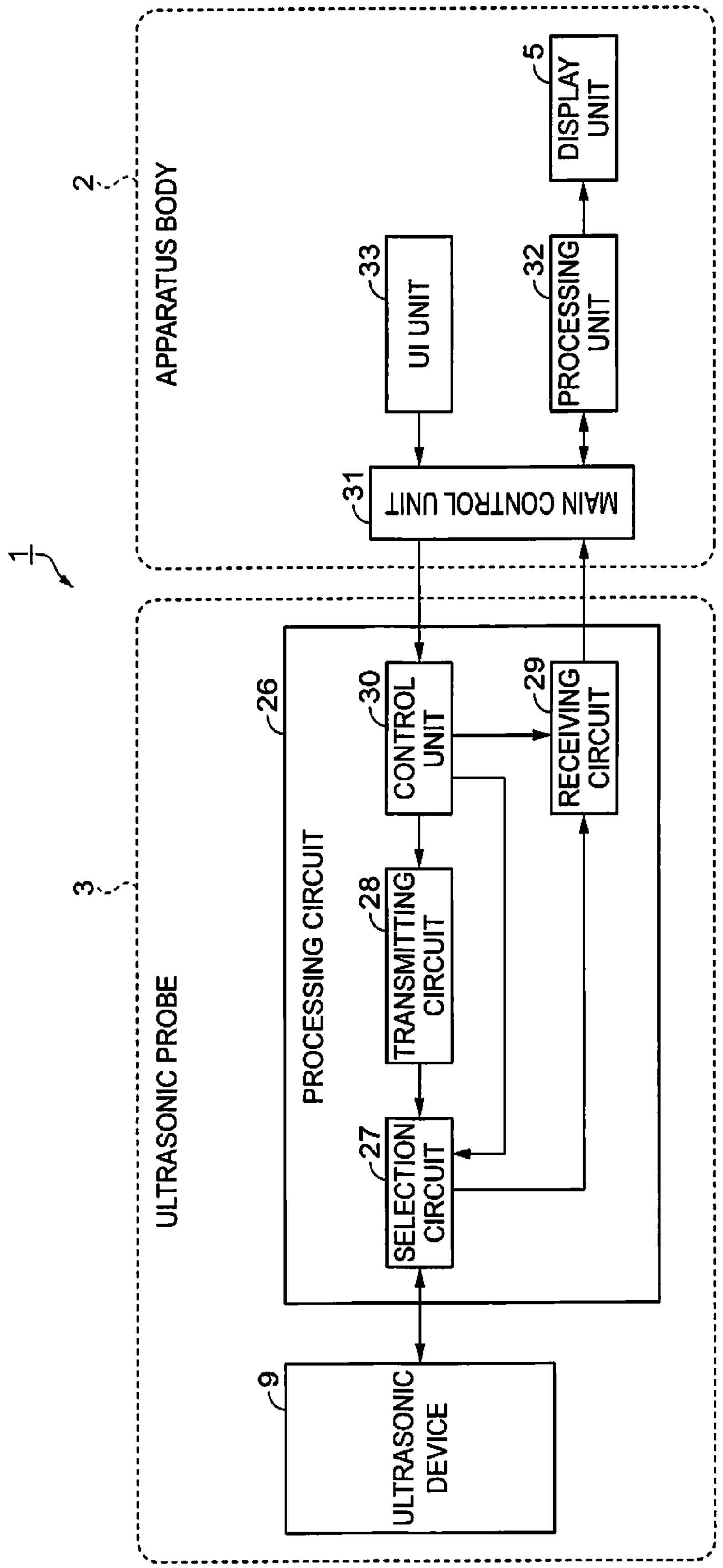

1
2
APPARATUS BODY
UI UNIT
33
MAIN CONTROL UNIT
31
PROCESSING UNIT
32
DISPLAY UNIT
5
3
ULTRASONIC PROBE
26
PROCESSING CIRCUIT
CONTROL UNIT
30
RECEIVING CIRCUIT
29
TRANSMITTING CIRCUIT
28
SELECTION CIRCUIT
27
ULTRASONIC DEVICE
9

FIG. 4

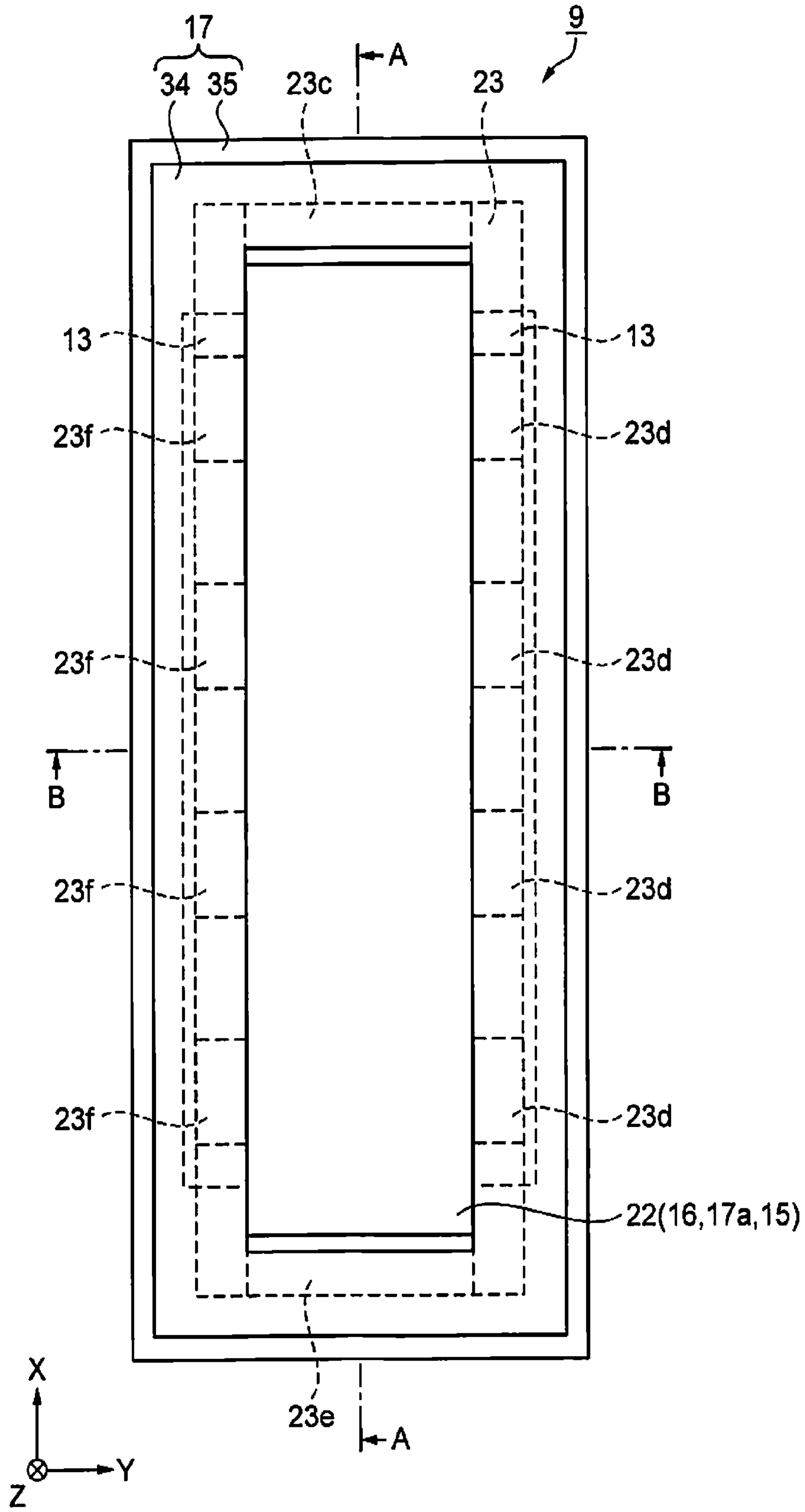

17
34
35
23c
A
23
9
13
13
23f
23d
23f
23d
B
B
23f
23d
23f
23d
22(16,17a,15)
X
23e
A
Y
Z

FIG. 5

FIG. 6A

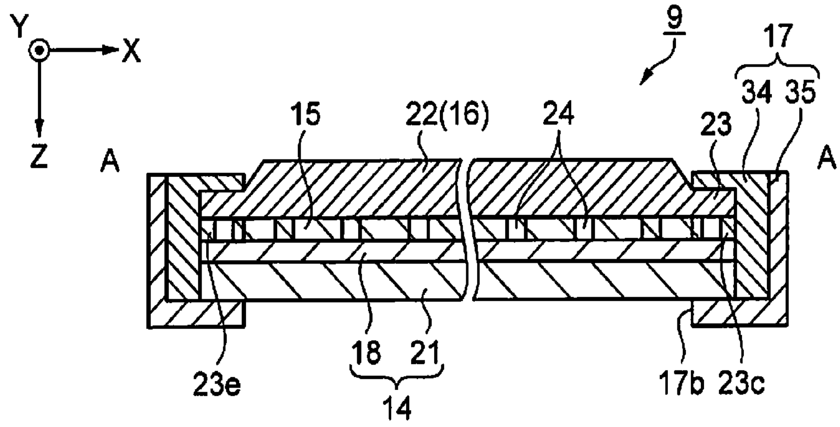


FIG. 6B

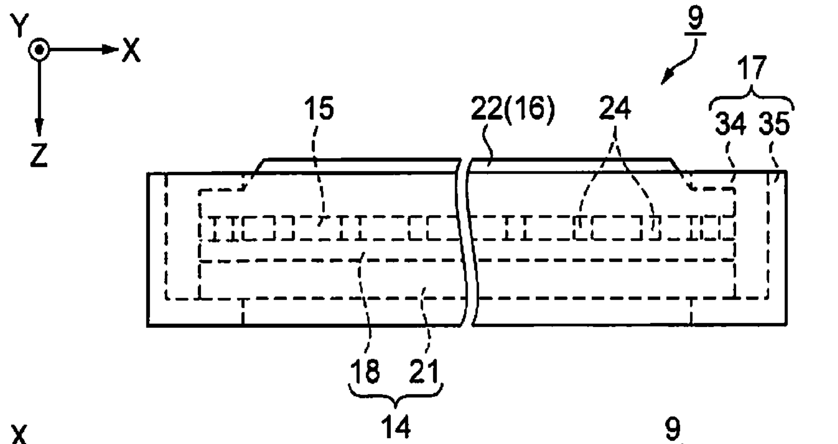


FIG. 6C

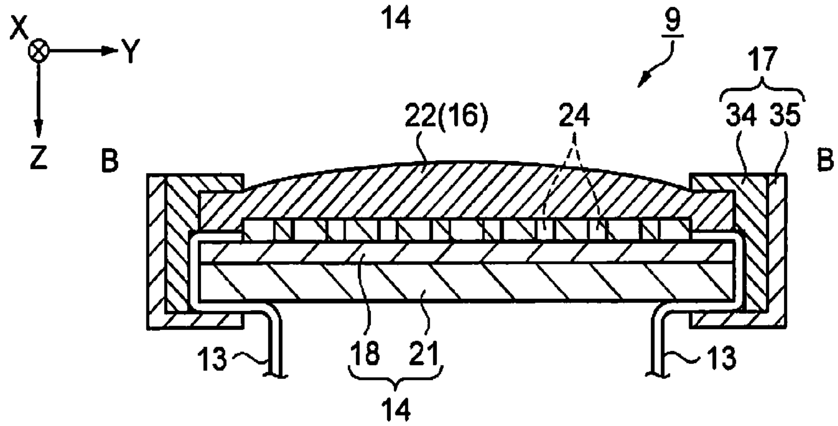
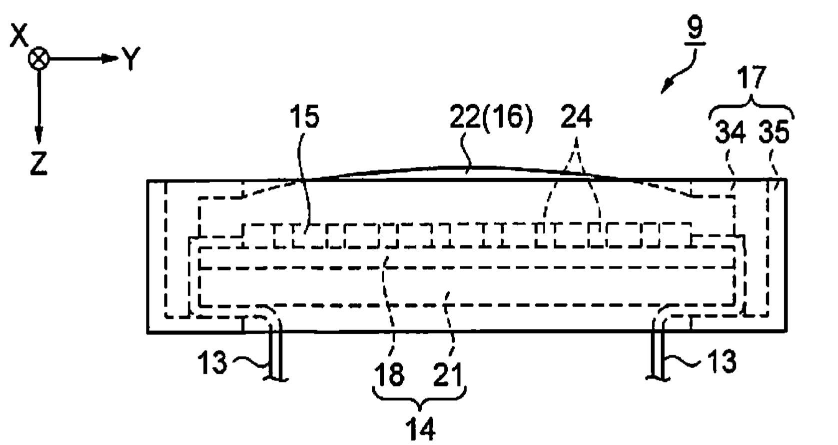
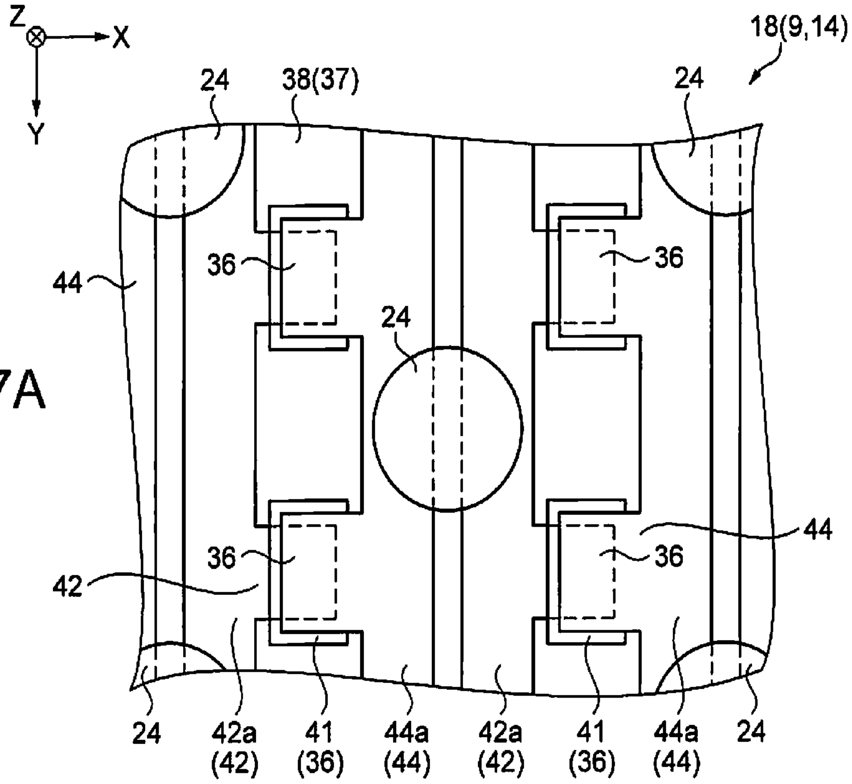


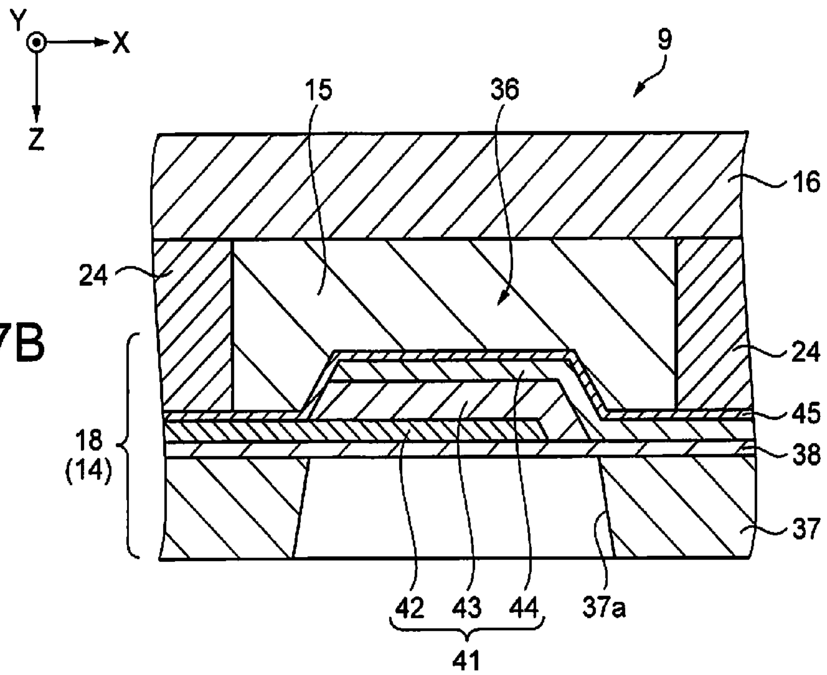
FIG. 6D





Z
X
Y
18(9,14)
24
38(37)
24
36
36
44
24
36
36
44
42
24
42a (42)
41 (36)
44a (44)
42a (42)
41 (36)
44a (44)
24

FIG. 7A



Y
X
Z
9
15
36
16
24
24
45
38
18 (14)
37
42
43
44
37a
41

FIG. 7B

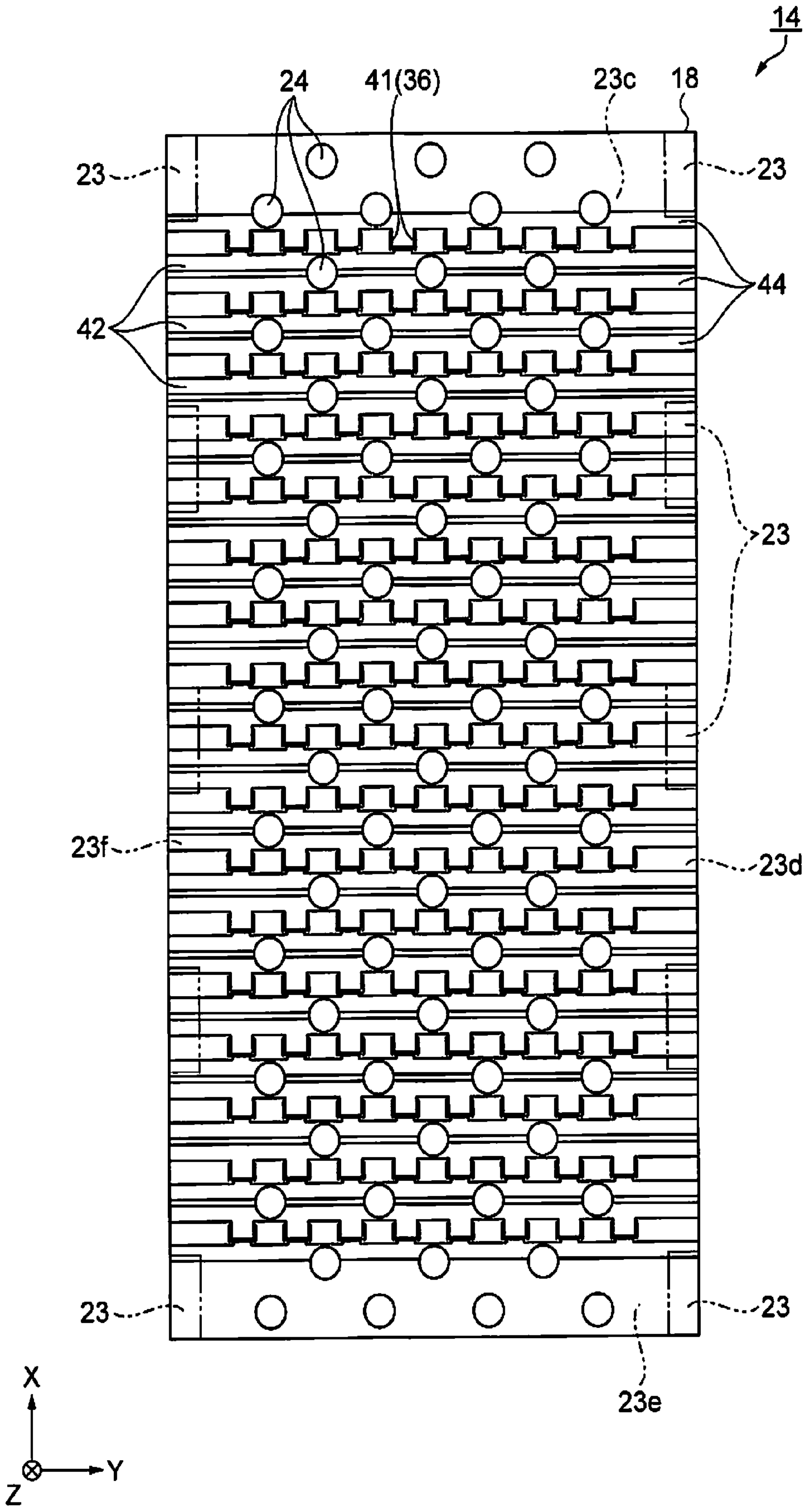


FIG. 8

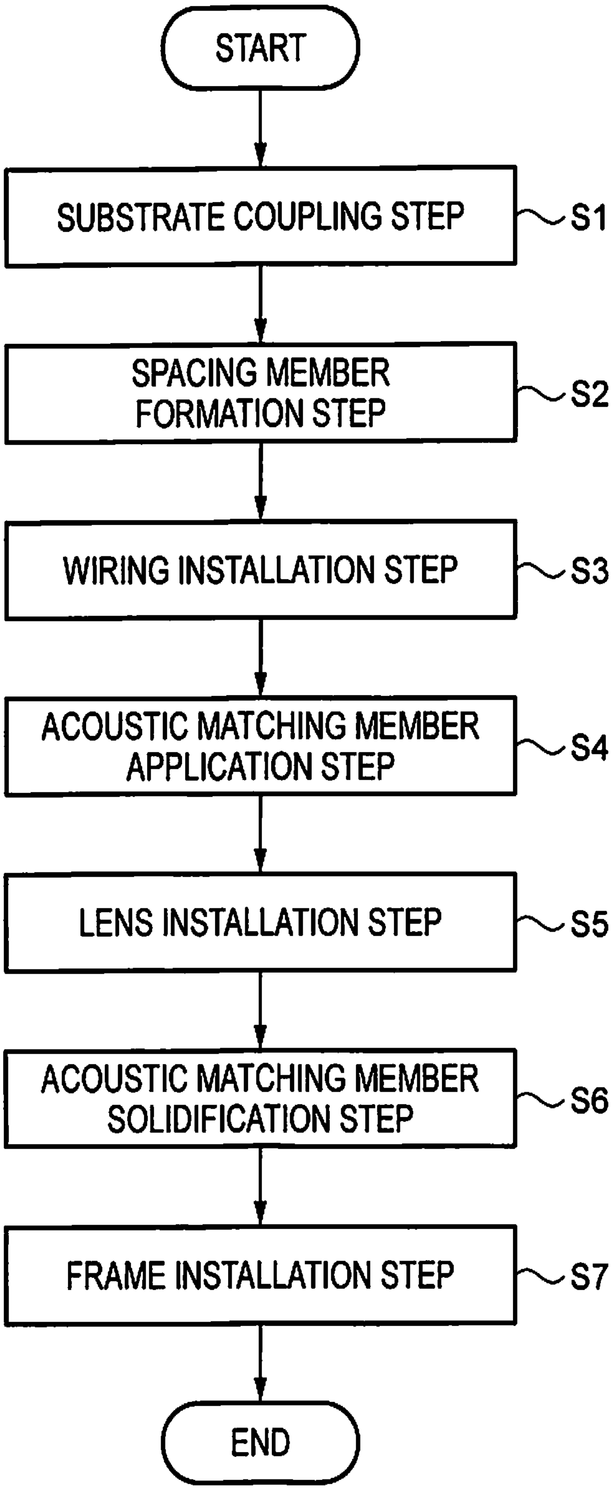

START
SUBSTRATE COUPLING STEP
S1
SPACING MEMBER FORMATION STEP
S2
WIRING INSTALLATION STEP
S3
ACOUSTIC MATCHING MEMBER APPLICATION STEP
S4
LENS INSTALLATION STEP
S5
ACOUSTIC MATCHING MEMBER SOLIDIFICATION STEP
S6
FRAME INSTALLATION STEP
S7
END

FIG. 9

FIG.10A

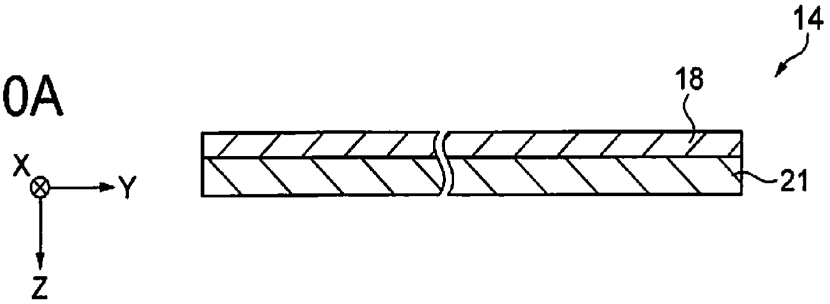


FIG.10B

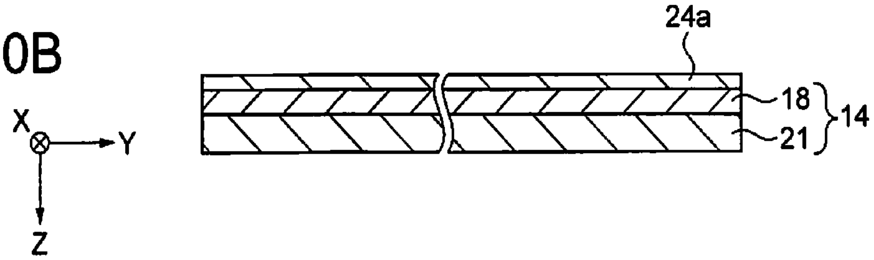


FIG.10C

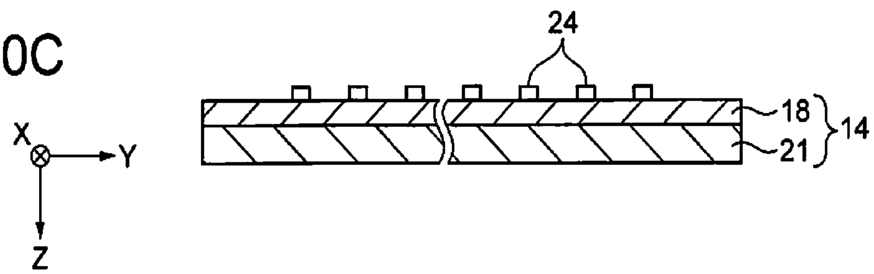


FIG.10D

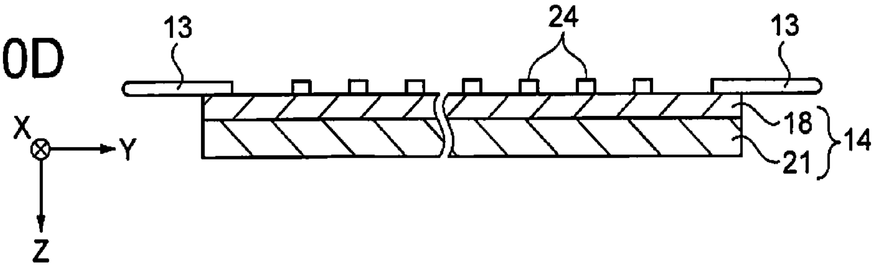


FIG.10E

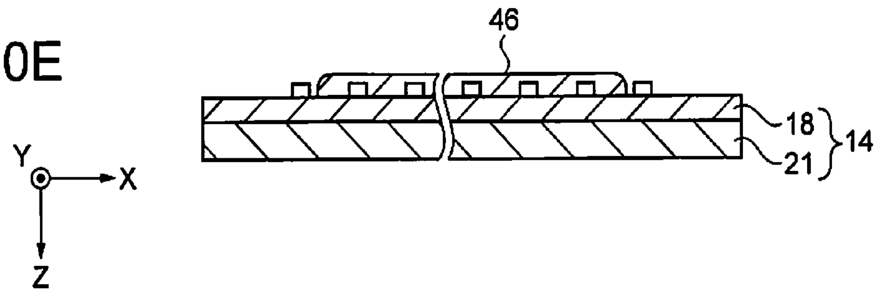


FIG.11A

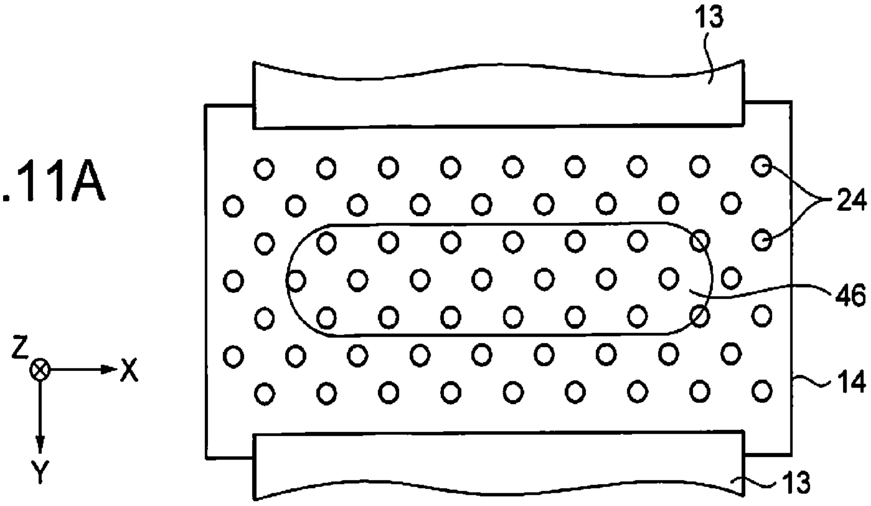


FIG.11B

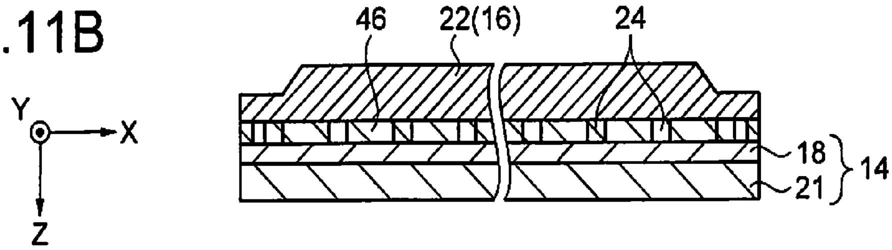


FIG.11C

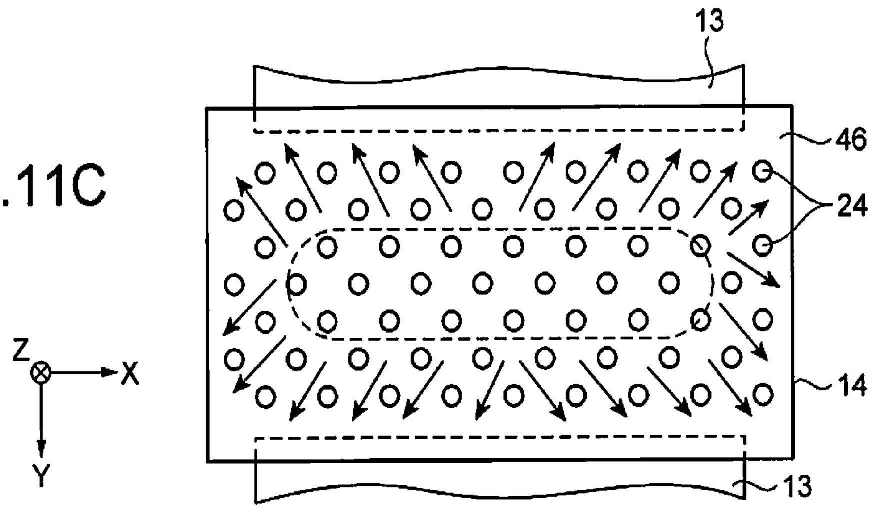
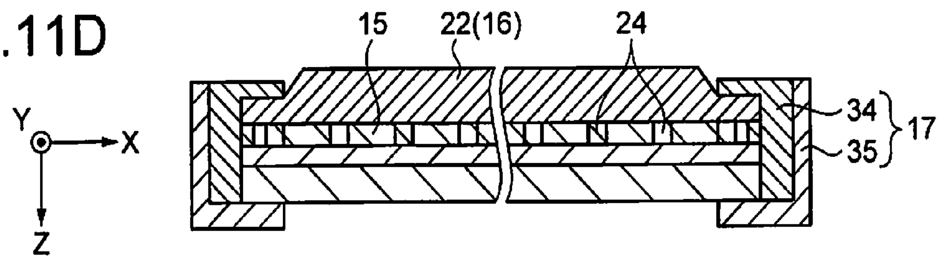


FIG.11D



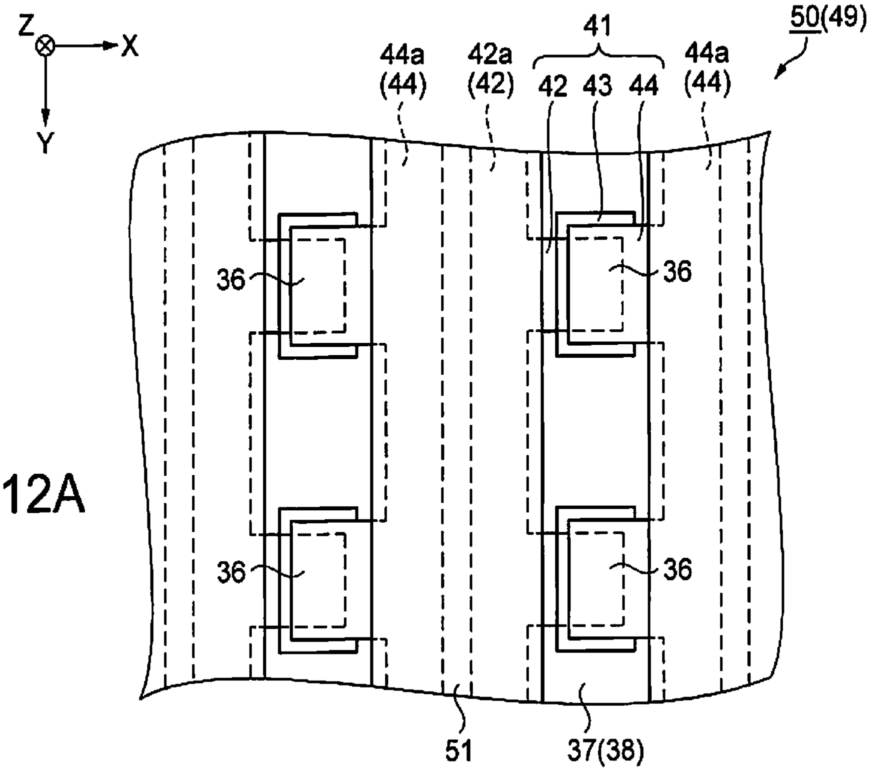


FIG.12A

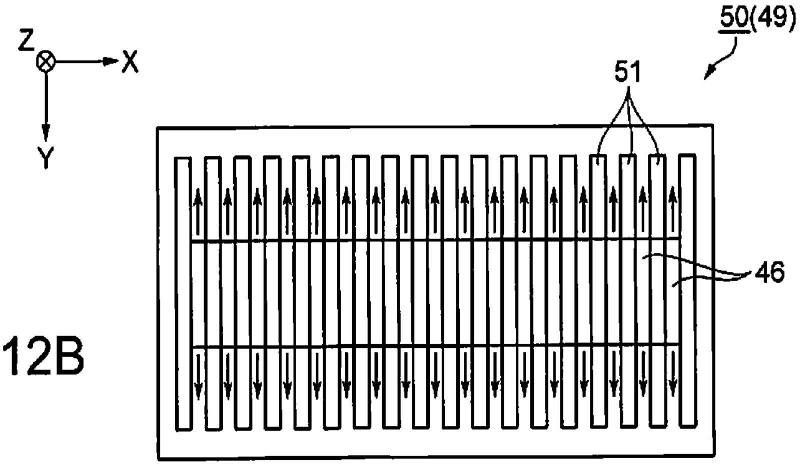


FIG.12B

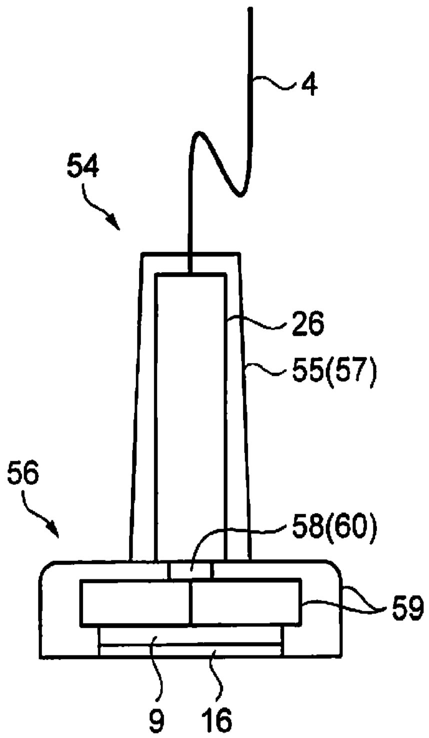


FIG.13A

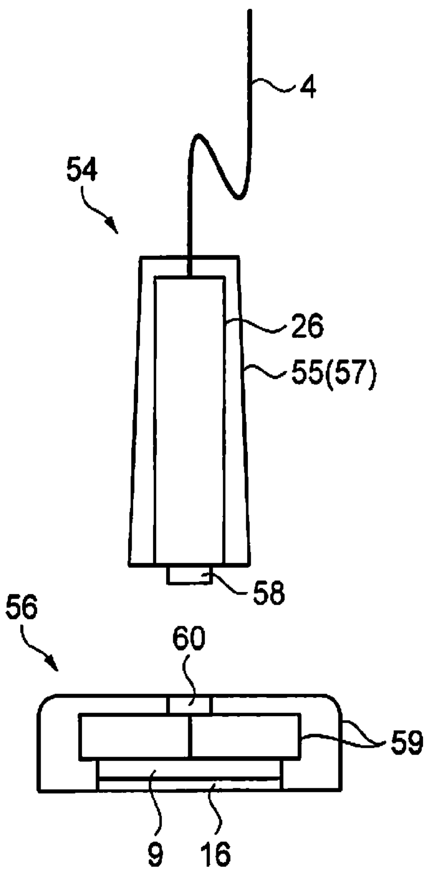


FIG.13B

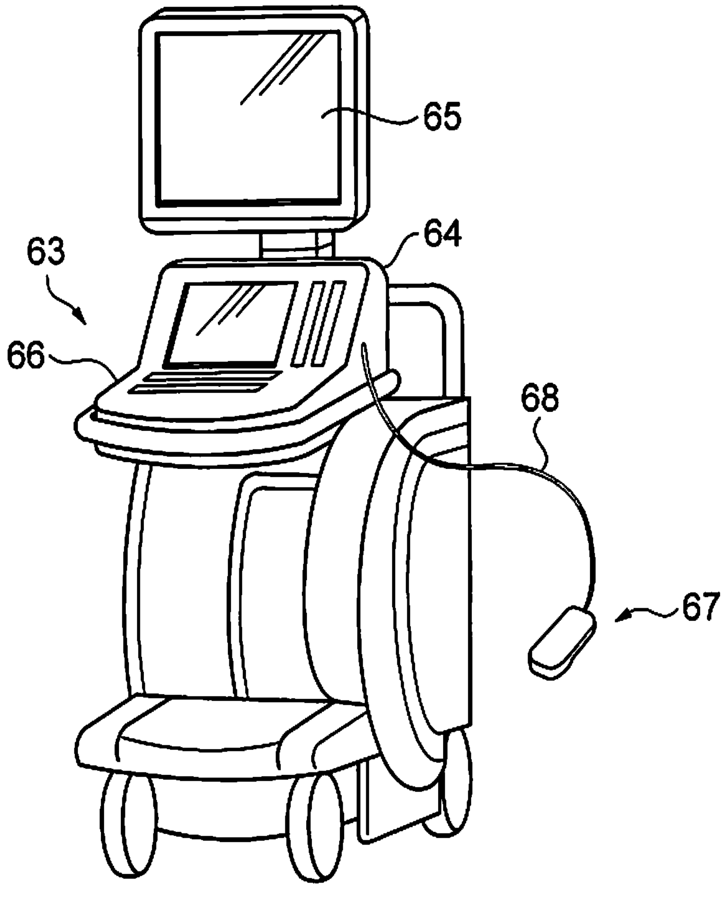


FIG.14

ULTRASONIC DEVICE, ULTRASONIC PROBE HEAD, ULTRASONIC PROBE, ELECTRONIC APPARATUS, AND ULTRASONIC IMAGING APPARATUS

BACKGROUND

[0001] 1. Technical Field

[0002] The present invention relates to an ultrasonic device, an ultrasonic probe head, an ultrasonic probe, an electronic apparatus, and an ultrasonic imaging apparatus.

[0003] 2. Related Art

[0004] Ultrasonic devices using ultrasonic elements that transmit and receive ultrasound have been used in various applications. JP-A-2011-35916, which is an example of related art, discloses an ultrasonic endoscope provided with ultrasonic elements. This ultrasonic endoscope is provided with ultrasonic elements of the electrostatic capacitance type that transmit and receive ultrasound, and an acoustic lens that focuses the ultrasound.

[0005] The ultrasonic elements apply an AC voltage to a substrate on which a lower electrode is installed and a membrane on which an upper electrode is installed. This causes an electrostatic force to act on the substrate and the membrane, so that the membrane vibrates so that ultrasound is transmitted. The ultrasound passes through the acoustic lens, thereby being emitted so as to be focused on a predetermined point. The acoustic lens is formed using silicone resin, which is a material that easily transfers ultrasound to a material being examined and that is easily deformed due to a stress being applied.

[0006] An acoustic lens transmits ultrasound more easily when it is in contact with the material being examined. Further, since the position of the acoustic lens is controlled by an operator, the acoustic lens may be pressed by the material being examined in some cases. In JP-A-2011-35916, the periphery of the acoustic lens is supported by a metal package. Accordingly, when stress is applied to the acoustic lens by the material being examined, the center of the acoustic lens is easily deformed because it is held by its outer circumference. When the acoustic lens is deformed, the point on which the ultrasound is focused is shifted, and the sound pressure at the point on which the ultrasound was to be focused is reduced. Therefore, an ultrasonic device capable of transmitting and receiving ultrasound efficiently by suppressing the deformation of the acoustic lens has been desired.

SUMMARY

[0007] The invention has been devised to solve the aforementioned problems and can be practiced as embodiments or application examples described below.

APPLICATION EXAMPLE 1

[0008] An ultrasonic device according to this application example includes: an ultrasonic element array substrate having a plurality of ultrasonic elements configured to perform at least one of transmission and reception of ultrasound; an acoustic lens configured to focus the ultrasound; an acoustic matching unit formed using resin, the acoustic matching unit being arranged between the ultrasonic element array substrate and the acoustic lens; and a plurality of columnar spacing members arranged between the ultrasonic element array substrate and the acoustic lens so as to be in contact with the ultrasonic element array substrate and the acoustic lens.

[0009] According to this application example, a plurality of ultrasonic elements are installed on the ultrasonic element array substrate. An ultrasonic element transmits or receives ultrasound. Alternatively, the ultrasonic element transmits and receives ultrasound. The ultrasound transmitted by the ultrasonic element passes through the acoustic matching unit and the acoustic lens to a material being examined. The acoustic matching unit adjusts the acoustic impedance between the acoustic lens and the ultrasonic element. This makes it difficult for ultrasound to be reflected by the interface between the acoustic lens and the ultrasonic element, and makes it difficult for ultrasound to be reflected by the interface between the acoustic matching unit and the acoustic lens. Accordingly, ultrasound is emitted efficiently to the material being examined.

[0010] The acoustic lens is used while in contact with the material being examined. At this time, the acoustic lens is pressed by the material being examined, and stress occurs inside the acoustic lens. The resin of the acoustic matching unit is susceptible to deformation, and therefore is deformed due to the stress of the acoustic lens. On the other hand, the columnar spacing members are in contact with the acoustic lens and the ultrasonic element array substrate, and transfer the stress of the acoustic lens to the ultrasonic element array substrate. Further, the thickness of the acoustic matching unit is kept constant, thereby suppressing the deformation of the acoustic lens so that ultrasound can be focused accurately. Further, ultrasound reflected by the material being examined also can be focused accurately on the ultrasonic element since the deformation of the acoustic lens is suppressed. As a result, the ultrasonic device can transmit and receive ultrasound efficiently.

APPLICATION EXAMPLE 2

[0011] In the ultrasonic device according to the aforementioned application example, the spacing members are arranged in locations that do not overlap with the ultrasonic elements in plan view, as viewed in a thickness direction of the ultrasonic element array substrate.

[0012] According to this application example, the spacing members are arranged at locations that do not overlap with the ultrasonic elements. The ultrasonic elements are overlapped by the ultrasonic matching unit formed of resin. Accordingly, the ultrasonic device can emit ultrasound whose acoustic impedance has been adjusted by the acoustic matching unit. Further, in the ultrasonic device, the acoustic matching unit can adjust the acoustic impedance of the received ultrasound and emit it to the ultrasound element.

APPLICATION EXAMPLE 3

[0013] In the ultrasonic device according to the aforementioned application example, the spacing members are arranged between the ultrasonic elements so as to extend in the form of a wall and hardly allow ultrasound to pass therethrough in an in-plane direction of the ultrasonic element array substrate.

[0014] According to the present example, the spacing members are arranged between the ultrasonic elements so as to extend in the form of a wall. The spacing members make it difficult for ultrasound to pass therethrough in the in-plane direction of the ultrasonic element array substrate and regulate the direction in which the ultrasound propagates. Note that the in-plane direction of the ultrasonic element array substrate is a direction parallel to the surface of ultrasonic element array substrate. Accordingly, it is possible to suppress a case in which ultrasonic elements located with a spacing member interposed therebetween influence each other when receiving and transmitting ultrasound.

APPLICATION EXAMPLE 4

[0015] In the ultrasonic device according to the aforementioned application example, the spacing members have lower water permeability than the acoustic matching unit and are arranged so as to cover wiring for transmitting an electrical signal to the ultrasonic elements.

[0016] According to this application example, the spacing members are arranged so as to cover the wiring. The spacing members are sites that have low water permeability and hardly allow moisture to pass therethrough. Accordingly, the spacing members suppress a case in which moisture attaches to the wiring, and therefore it is possible to prevent galvanic corrosion of the wiring.

APPLICATION EXAMPLE 5

[0017] In the ultrasonic device according to the aforementioned application example, a flow path through which material for the acoustic matching unit flows is formed between two of the spacing members.

[0018] According to this application example, the spacing members extend in the form of a wall. When the acoustic matching unit is to be formed, a flow path through which the material for the acoustic matching unit flows is formed between two spacing members. The material for the acoustic matching unit flows along the spacing members, and therefore the spaces between the spacing members can be filled tightly with the material for the acoustic matching unit.

APPLICATION EXAMPLE 6

[0019] In the ultrasonic device according to the aforementioned application example, the shape of the spacing members is circular or elliptical in plan view.

[0020] According to this application example, the shape of the spacing members is circular or elliptical. A circle or an ellipse has no corners, thereby allowing a fluid to flow along its outer circumference with little resistance. Accordingly, when the material for the acoustic matching unit is allowed to flow in the location where the spacing members are present, the material for the acoustic matching unit moves along the spacing members. At this time, the material for the acoustic matching unit pushes out the air located in the space for the acoustic matching unit, and therefore the intervals between the spacing members can be filled tightly with the material for the acoustic matching unit.

APPLICATION EXAMPLE 7

[0021] An ultrasonic probe head according to this application example includes: the ultrasonic device according to one of the aforementioned examples; and a housing configured to support the ultrasonic device.

[0022] According to this application example, the ultrasonic probe head includes the aforementioned ultrasonic device and the housing configured to support the ultrasonic device. The ultrasonic probe head of this application example includes the ultrasonic device that appropriately maintains the thickness of the acoustic matching unit, and that transmits and receives ultrasound efficiently. Accordingly, it is possible to provide the ultrasonic probe head that transmits and receives ultrasound efficiently.

APPLICATION EXAMPLE 8

[0023] An ultrasonic probe according to this application example includes: the ultrasonic device according to one of the aforementioned examples; and a driving circuit configured to drive the ultrasonic device.

[0024] According to this application example, the ultrasonic probe includes the aforementioned ultrasonic device and the driving circuit configured to drive the ultrasonic device. The ultrasonic probe of this application example includes the ultrasonic device that appropriately maintains the thickness of the acoustic matching unit, and that transmits and receives ultrasound efficiently. Accordingly, it is possible to provide the ultrasonic probe that transmits and receives ultrasound efficiently.

APPLICATION EXAMPLE 9

[0025] An electronic apparatus according to this application example includes: the ultrasonic device according to one of the aforementioned examples; and a processing unit connected to the ultrasonic device, the processing unit being configured to generate an image using an output of the ultrasonic device.

[0026] According to this application example, the electronic apparatus includes the aforementioned ultrasonic device and the processing unit. The processing unit generates image data using the output of the ultrasonic device. The electronic apparatus of this application example includes the ultrasonic device that appropriately maintains the thickness of the acoustic matching unit, and that transmits and receives ultrasound efficiently. Accordingly, it is possible to provide the electronic apparatus that transmits and receives ultrasound efficiently.

APPLICATION EXAMPLE 10

[0027] An ultrasonic imaging apparatus according to this application example includes: the ultrasonic device according to one of the aforementioned examples; and a processing unit connected to the ultrasonic device, the processing unit being configured to perform processing to generate an image using an output of the ultrasonic device; and a display unit configured to display the image.

[0028] According to this application example, the ultrasonic imaging apparatus includes the aforementioned ultrasonic device, the processing unit, and the display unit. The processing unit generates image data using the output of the ultrasonic device. The display unit displays images generated by the processing unit. The ultrasonic imaging apparatus of this application example includes the ultrasonic device that appropriately maintains the thickness of the acoustic matching unit, and that transmits and receives ultrasound efficiently. Accordingly, it is possible to provide the ultrasonic imaging apparatus that transmits and receives ultrasound efficiently.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The invention will be described with reference to the accompanying drawings, wherein like numbers reference like elements.

[0030] FIG. **1** is a schematic perspective view showing a configuration of an ultrasonic imaging apparatus.

[0031] FIG. **2** is a schematic side cross-sectional view showing a part of a structure of an ultrasonic probe.

[0032] FIG. **3** is a schematic cross-sectional view showing a main part of the structure of the ultrasonic probe.

[0033] FIG. **4** is a block diagram illustrating the control of the ultrasonic imaging apparatus.

[0034] FIG. **5** is a schematic plan view showing a structure of an ultrasonic device.

[0035] FIGS. **6**A and **6**C are schematic side cross-sectional views showing the structure of the ultrasonic device, FIGS. **6**B and **6**D are schematic side views showing the structure of the ultrasonic device.

[0036] FIG. **7**A is a schematic plan view showing a configuration of an ultrasonic element, and FIG. **7**B is a schematic side cross-sectional view showing the configuration of the ultrasonic element.

[0037] FIG. **8** is a schematic plan view showing a configuration of an ultrasonic element array substrate.

[0038] FIG. **9** is a flow chart of a method for manufacturing an ultrasonic device.

[0039] FIGS. **10**A to **10**E are schematic diagrams for describing the method for manufacturing an ultrasonic device.

[0040] FIGS. **11**A to **11**D are schematic diagrams for describing the method for manufacturing an ultrasonic device.

[0041] FIG. **12**A is a schematic plan view showing a main part of a configuration of an ultrasonic element, and FIG. **12**B is a schematic plan view showing a configuration of an ultrasonic element array substrate.

[0042] FIGS. **13**A and **13**B are schematic side views showing a configuration of an ultrasonic probe.

[0043] FIG. **14** is a schematic perspective view showing a configuration of an ultrasonic imaging apparatus.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0044] In this embodiment, characteristic examples of an an ultrasonic device and an ultrasonic probe and an ultrasonic imaging apparatus provided with the ultrasonic device will be described with reference to the drawings. It should be noted that the sizes of the members in the drawings are scaled differently in each figure so as to be perceptible.

First Embodiment

[0045] In this embodiment, an ultrasonic imaging apparatus for examining an interior portion of a human body will be described as an example of an electronic apparatus with reference to FIG. **1** to FIG. **11**D. FIG. **1** is a schematic perspective view showing a configuration of the ultrasonic imaging apparatus. FIG. **2** is a schematic side cross-sectional view showing a part of a structure of an ultrasonic probe. FIG. **3** is a schematic cross-sectional view showing a main part of the structure of the ultrasonic probe.

[0046] As shown in FIG. **1**, an ultrasonic imaging apparatus **1** serving as an electronic apparatus includes an apparatus body **2** and an ultrasonic probe **3**. The apparatus body **2** and the ultrasonic probe **3** are connected to each other by a cable **4**. The apparatus body **2** and the ultrasonic probe **3** can exchange electrical signals via the cable **4**. The apparatus body **2** incorporates a display unit **5** such as a display panel. The display unit **5** is a touch panel display, and serves also as a user interface unit with which an operator inputs information into the apparatus body **2**. Hereinafter, the user interface unit will be referred to as "UI unit".

[0047] In the apparatus body **2**, an image is generated on the basis of ultrasound detected by the ultrasonic probe **3**, and the detection results that are output as an image are displayed on the screen of the display unit **5**. The ultrasonic probe **3** includes a rectangular parallelepiped housing **6**. The cable **4** is connected to one end in the longitudinal direction of the housing **6**. On the opposite side, a head portion **7** that transmits and receives ultrasound is provided. It should be noted that a configuration of the ultrasonic imaging apparatus **1** is used in which the apparatus body **2** and the ultrasonic probe **3** are connected by the cable **4**. A configuration is also possible in which the apparatus body **2** and the ultrasonic probe **3** wirelessly exchange signals without using the cable **4**.

[0048] As shown in FIG. **2**, the ultrasonic probe **3** includes an ultrasonic device **9** that is fixed to a support member **8** and that is accommodated within the housing **6**. The ultrasonic device **9** is exposed from the head portion **7** of the housing **6** so that ultrasound is output from the ultrasonic device **9** to a target object. Further, the ultrasonic device **9** receives reflected waves of the ultrasound from the object. Such reflected waves are referred to also as echo waves. The housing **6** has a cylindrical shape, which is easy for the operator to grip. The ultrasonic device **9** is installed at one end of the housing **6**, and the cable **4** is installed at the other end thereof. A direction extending from the ultrasonic device **9** toward the cable **4** is referred to as Z direction. The two directions orthogonal to the Z direction are referred to as the X direction and the Y direction. The ultrasonic device **9** is approximately plate-shaped and extends in the X direction and the Y direction. The ultrasonic device **9** is longer in the X direction than in the Y direction.

[0049] As shown in FIG. **3**, there is a gap between the ultrasonic device **9** and the head portion **7** of the housing **6**. A sealing portion **10** filled with a silicone-based sealing material is provided in the gap. This sealing portion **10** prevents moisture, etc., from entering the ultrasonic device **9** in the housing **6** of the ultrasonic probe **3**. The support member **8** is located on the Z direction side of the ultrasonic device **9**. A sealing structure is installed between the support member **8** and the head portion **7**. This sealing structure includes an adhesive member **11** and an adhesive member **12**. The adhesive member **11** is a member, such as a double-sided adhesive tape having elasticity, which is attached to the outer circumferential portion of the support member **8**. The adhesive member **12** is a member, such as a double-sided adhesive tape having elasticity, which is attached to the housing **6**.

[0050] An FPC **13** (Flexible Printed Circuit) that connects the ultrasonic device **9** to a processing circuit is interposed between the adhesive member **11** and the adhesive member **12**. The FPC **13** is fixed by being sandwiched by the adhesive member **11** and the adhesive member **12**. The FPC **13** is referred to also as flexible printed circuit board. As the adhesive member **11** and the adhesive member **12**, a double-sided adhesive tape formed by applying an acrylic-based adhesive material to a closed cell foam material such as polyethylene or urethane can be used, for example. In this way, a double sealing structure is employed for the ultrasonic probe **3**, in which the sealing portion **10**, the adhesive member **11**, and the adhesive member **12** prevent moisture, dust, and the like from entering the inside of the housing **6**.

[0051] The ultrasonic device **9** includes an ultrasonic element array substrate **14**, an acoustic matching unit **15**, an acoustic lens **16**, the FPC **13**, and a frame **17** as a fixing frame. The ultrasonic element array substrate **14** has an element substrate **18** and a back plate **21**. The element substrate **18** is a substrate on which a plurality of ultrasonic elements are arranged in an array on a surface on the −Z direction side, and has a rectangular shape elongated in the X direction, in plan view as viewed from the Z direction. The element substrate **18** is formed using a silicon substrate and has a thickness of about 150 μm to 200 μm. The back plate **21** having the same flat plate shape as the element substrate **18** is adhered to the opposite surface of the element-formed surface of the element substrate **18** oriented in the −Z direction. The back plate **21** serves to suppress excess vibration of the element substrate **18** and absorb ultrasound. A silicon substrate with a thickness of 500 μm to 600 μm is used for the back plate **21**. For the back plate **21**, a metal plate may be used, rather than such a silicon substrate. In the case where the influence of ultrasound that travels in the Z direction from the element substrate **18** is small, the ultrasonic device **9** may be formed without using the back plate **21**.

[0052] On the surface of the element substrate **18** on which the ultrasonic elements are formed, a plurality of terminals connected to the plurality of ultrasonic elements are installed along the long edge extending in the X direction, in plan view. These terminals are connected to the terminals of the FPC **13** and are thus connected electrically as well.

[0053] On the surface of the element substrate **18** on which the ultrasonic elements are formed, the acoustic lens **16** is arranged. The planar shape of the acoustic lens **16** as viewed from the −Z direction is the same as the shape of the ultrasonic element array substrate **14**. On the acoustic lens **16**, a lens portion **22** is provided. The lens portion **22** has a surface facing the −Z direction that protrudes in the thickness direction with a predetermined curvature. On the surface facing the Z direction, a wall **23** that projects in the thickness direction and that is formed on the outer edge portion of the acoustic lens **16** is provided. The acoustic lens **16** is formed using a resin such as silicone resin. It is possible to adjust the acoustic impedance of the silicone resin by adding silica, or the like, to the silicone resin to change the specific gravity of the silicone resin.

[0054] The acoustic matching unit **15** is formed between the ultrasonic element array substrate **14** and the acoustic lens **16**. For the acoustic matching unit **15**, a silicone-based adhesive material is used. Curing of the adhesive material causes the ultrasonic element array substrate **14** and the acoustic lens **16** to be secured (adhered) to each other. The thus cured adhesive material (resin) functions as the acoustic matching unit **15**. A plurality of columnar spacing members **24** are installed in parallel with the acoustic matching unit **15**. The spacing members **24** keep the thickness of the acoustic matching unit **15** constant. When the acoustic lens **16** is pressed by a target object, the spacing members **24** transfer the force applied onto the acoustic lens **16** to the ultrasonic element array substrate **14**. The spacing members **24** suppress the deformation of the acoustic lens **16** due to a reaction force received from the ultrasonic element array substrate **14**.

[0055] The acoustic lens **16** serves to focus ultrasound transmitted from the ultrasonic elements of the element substrate **18** and guide them efficiently to a target object. The acoustic lens **16** also serves to guide echo waves reflected back from the object efficiently to the ultrasonic elements. The acoustic matching unit **15** serves to relax the acoustic impedance mismatch between the acoustic lens **16** and the ultrasonic elements. The back plate **21** of the ultrasonic device **9** is fixed to the support member **8** by an adhesive material **25**.

[0056] FIG. **4** is a block diagram illustrating the control of the ultrasonic imaging apparatus. As shown in FIG. **4**, the ultrasonic imaging apparatus includes the apparatus body **2** and the ultrasonic probe **3**. The ultrasonic probe **3** includes the ultrasonic device **9** and a processing circuit **26** as a driving circuit. The processing circuit **26** has a selection circuit **27**, a transmitting circuit **28**, a receiving circuit **29**, and a control unit **30**. This processing circuit **26** performs transmission processing and reception processing for the ultrasonic device **9**.

[0057] The transmitting circuit **28** outputs transmission signals VT to the ultrasonic device **9** via the selection circuit **27** in a transmission period. Specifically, the transmitting circuit **28** generates the transmission signals VT, on the basis of control by the control unit **30**, and outputs them to the selection circuit **27**. Then, the selection circuit **27** outputs the transmission signals VT from the transmitting circuit **28**, on the basis of control by the control unit **30**. The frequency and amplitude voltage of the transmission signals VT are set by the control unit **30**.

[0058] The receiving circuit **29** performs reception processing to receive reception signals VR from the ultrasonic device **9**. Specifically, the receiving circuit **29** receives the reception signals VR from the ultrasonic device **9** via the selection circuit **27** in a reception period. The receiving circuit **29** performs reception processing such as amplification of the reception signals, gain setting, frequency setting, and A/D conversion (analog/digital conversion). The receiving circuit **29** outputs the results of the reception processing to the apparatus body **2** as detected data (detected information). The receiving circuit **29**, for example, can be composed of a low-noise amplifier, a voltage-controlled attenuator, a programmable gain amplifier, a low-pass filter, an A/D converter, and the like.

[0059] The control unit **30** controls the transmitting circuit **28** and the receiving circuit **29**. Specifically, the control unit **30** controls the transmitting circuit **28** for generation of the transmission signals VT and output processing, and controls the receiving circuit **29** for frequency setting of the reception signals VR, gain, or the like. The selection circuit **27** outputs the selected transmission signals VT to the ultrasonic device **9**, on the basis of control by the control unit **30**.

[0060] The apparatus body **2** includes the display unit **5**, a main control unit **31**, a processing unit **32**, and a UI unit **33** (user interface unit). The main control unit **31** controls the ultrasonic probe **3** for transmission and reception of ultrasound, and controls the processing unit **32** for image processing of detected data, for example. The processing unit **32** receives detected data from the receiving circuit **29**, and performs image processing to remove noises, generation of image data to be displayed, or the like. The UI unit **33** includes a function of receiving input of a user instruction, and the UI unit **33** outputs necessary instruction (command) to the main control unit **31** on the basis of operation (such as touch panel operation) by the user. The display unit **5**, for example, is a liquid crystal display, and receives input of the image data to be displayed from the processing unit **32** and displays it. It should be noted that part of control by the main control unit **31** may be performed by the control unit **30** of the processing circuit **26**, or part of control by the control unit **30** may be performed by the main control unit **31**.

[0061] FIG. **5** is a schematic plan view showing a structure of the ultrasonic device of the ultrasonic probe **3**, as viewed in the direction of the arrow H in FIG. **3**. FIG. **6**A is a schematic side cross-sectional view showing the structure of the ultrasonic device, which is taken along line A-A in FIG. **5**. FIG. **6**B is a schematic side view showing the structure of the ultrasonic device, as viewed from the Y direction. FIG. **6**C is a schematic side cross-sectional view showing the structure of the ultrasonic device, which is taken along line B-B in FIG. **5**. FIG. **6**D is a schematic side view showing the structure of the ultrasonic device, as viewed from the −X direction.

[0062] As shown in FIG. **5** and FIGS. **6**A to **6**D, the ultrasonic device **9** has a rectangular parallelepiped shape elongated in the X direction. When the ultrasonic device **9** is viewed from the −Z direction, the frame **17** has a rectangular first hole **17***a* formed at its center, and the lens portion **22** is exposed through the first hole **17***a*. When the ultrasonic device **9** is viewed from the Z direction, the frame **17** has a rectangular second hole **17***b* formed at its center, and the back plate **21** is exposed through the second hole **17***b*.

[0063] The frame **17** is composed of an inner frame **34** located on the inner side and an outer frame **35** located on the outer side. The inner frame **34** presses the acoustic lens **16** from the −Z direction side. The outer frame **35** presses the ultrasonic element array substrate **14** from the Z direction side. The inner frame **34** and the outer frame **35** are adhered to each other so as to be secured. Accordingly, the frame **17** fixes the ultrasonic element array substrate **14**, the acoustic matching unit **15**, and the acoustic lens **16** by sandwiching them in the Z direction.

[0064] The spacing members **24** are installed in parallel with the acoustic matching unit **15**. The spacing members **24** are arranged between the ultrasonic element array substrate **14** and the acoustic lens **16** that are sandwiched by the frame **17**. The frame **17** reliably fixes the ultrasonic element array substrate **14** and the acoustic lens **16** by sandwiching them with the spacing members **24** interposed therebetween. Accordingly, the spacing members **24** can keep the thickness of the acoustic matching unit **15** constant.

[0065] A first recessed portion **23***c* is formed in the X direction of the wall **23**, and a third recessed portion **23***e* is formed in the −X direction thereof. The first recessed portion **23***c* and the third recessed portion **23***e* are continuous with the acoustic matching unit **15** in a location opposing the lens unit **22**. The acoustic matching unit **15** is located also inside the first recessed portion **23***c* and the third recessed portion **23***e*.

[0066] Second recessed portions **23***d* are formed in the Y direction of the wall **23**, and fourth recessed portions **23***f* are formed on the −Y direction thereof. The second recessed portions **23***d* and the fourth recessed portions **23***f* are continuous with the acoustic matching unit **15** at a location opposing the lens **22**. The acoustic matching unit **15** is located also inside the second recessed portions **23***d* and the fourth recessed portions **23***f*.

[0067] The spacing members **24** are located in the first recessed portion **23***c* and the third recessed portion **23***e*. The spacing members **24** are arranged between the ultrasonic element array substrate **14** and the acoustic lens **16** in a portion sandwiched by the frame **17** in plan view, as viewed from the −Z direction. The frame **17** sandwiches the ultrasonic element array substrate **14** and the acoustic lens **16** with the spacing members **24** interposed therebetween, and therefore the spacing members **24** can reliably keep the thickness of the acoustic matching unit **15** constant.

[0068] The FPC **13** is sandwiched by the ultrasonic element array substrate **14** and the wall **23** on the Y direction side and the −Y direction side of the acoustic lens **16**. The frame **17** holds the ultrasonic element array substrate **14** and the wall **23** by sandwiching them, thereby preventing the FPC **13** from lifting in a portion where the ultrasonic element array substrate **14** and the FPC **13** are connected to each other. Thus, the FPC **13** is reliably fixed.

[0069] Letting X be the wavelength of the ultrasound to be used, the thickness of the acoustic matching unit **15** is set to an odd multiple of ¼λ. The thickness of the spacing members **24** in the Z direction is set equal to the thickness of the acoustic matching unit **15**.

[0070] FIG. **7**A is a schematic plan view showing a configuration of an ultrasonic element, with the acoustic lens **16** and the acoustic matching unit **15** omitted and with the spacing members **24** installed. FIG. **7**B is a schematic side cross-sectional view showing the configuration of the ultrasonic element, with the acoustic lens **16** and the acoustic matching unit **15** installed. As shown in FIGS. **7**A and **7**B, a plurality of ultrasonic elements **36** are installed in the element substrate **18**. An ultrasonic element **36** has a base substrate **37** as a substrate, a vibrating membrane **38** (membrane) formed on the base substrate **37**, and a piezoelectric body **41** provided on the vibrating membrane **38**. The piezoelectric body **41** has a first electrode **42** serving as a lower electrode, a piezoelectric layer **43**, and a second electrode **44** serving as an upper electrode.

[0071] An opening **37***a* is formed in the base substrate **37** made of a silicon substrate, or the like, and the ultrasonic element **36** includes the vibrating membrane **38** that covers the opening **37***a* so as to close it. The vibrating membrane **38** is composed of a double layer structure, for example, of a SiO_2 layer and a ZrO_2 layer. In the case where the base substrate **37** is a silicon substrate, the SiO_2 layer can be formed by subjecting the surface of the substrate to a thermal oxidation treatment. Further, the ZrO_2 layer can be formed on the SiO_2 layer, for example, by a technique such as sputtering. For example, in the case of using PZT (lead zirconate titanate) as the piezoelectric layer **43**, the ZrO_2 layer is a layer for preventing Pb that constitutes the PZT from diffusing into the SiO_2 layer. Further, the ZrO_2 layer also has an effect of improving the warpage efficiency corresponding to distortion of the piezoelectric layer, etc.

[0072] The first electrode **42** is formed on the vibrating membrane **38**. The piezoelectric layer **43** is formed on the first electrode **42**. The second electrode **44** is formed further on the piezoelectric layer **43**. That is, the piezoelectric body **41** has a structure in which the piezoelectric layer **43** is sandwiched between the first electrode **42** and the second electrode **44**.

[0073] The first electrode **42** is formed of a thin metal film, and extends in the Y direction. A portion thereof protrudes in the X direction at the ultrasonic element **36**. The first electrode **42** is arranged over a plurality of piezoelectric bodies **41**, and functions also as wiring. The portion of the first electrode **42** that functions as wiring will be referred to as "first line **42***a*". The piezoelectric layer **43** is formed, for example, of a thin PZT (lead zirconate titanate) film, and is provided to cover part of the first electrode **42**. It should be noted that the material of the piezoelectric layer **43** is not limited to PZT. For example, lead titanate ($PbTiO_3$), lead zirconate ($PbZrO_3$), lead lanthanum titanate ((Pb, La) TiO_3), or the like, may be used. The second electrode **44** is formed of a thin metal film, and is provided to cover the piezoelectric layer **43**. The second electrode **44** extends in the Y direction, and a portion thereof protrudes in the −X direction at the ultrasonic element **36**. The second electrode **44** is arranged over the plurality of piezoelectric bodies **41**, and functions also as wiring. The portion of the second electrode **44***a* that functions as wiring will be referred to as "second line **44***a*".

[0074] When the element substrate **18** is viewed from the −Z direction, the first electrode **42** and the second electrode **44** overlap each other at the ultrasonic element **36**. The first line **42***a* and the second line **44***a* are portions at which the first electrode **42** and the second electrode **44** do not overlap. The spacing members **24** are arranged in locations where the first line **42***a* and the second line **44***a* are installed. The spacing members **24** are installed in locations that do not overlap with the ultrasonic elements **36**. The acoustic matching unit **15** is installed so as to overlap the ultrasonic elements **36**. The spacing members **24** do not need to be arranged in all locations that do not overlap with the ultrasonic elements **36**, and it is sufficient to provide the spacing members **24** in some locations. The spacing members **24** may be provided in an amount such that the thickness of the acoustic matching unit **15** can be kept constant.

[0075] An insulation film **45** that prevents moisture permeation from the outside and insulates the acoustic matching unit **15** from the first electrode **42** and the second electrode **44** is provided to cover the ultrasonic element **36**. The insulation film **45** is formed of a material such as alumina, and is provided entirely or partially on the surface of the ultrasonic element **36**. Further, the insulation film **45** is arranged to cover the first electrode **42** and the second electrode **44**.

[0076] The piezoelectric layer **43** expands and contracts in the in-plane direction due to a voltage applied between the first electrode **42** and the second electrode **44**. Accordingly, when a voltage is applied to the piezoelectric layer **43**, convex warpage occurs on the opening **37***a* side, so that the vibrating membrane **38** is deflected. Application of an AC voltage to the piezoelectric layer **43** causes the vibrating membrane **38** to vibrate in the membrane thickness direction, and the vibration of the vibrating membrane **38** causes ultrasound to be emitted from the opening **37***a*. The voltage (drive voltage) to be applied to the piezoelectric layer **43**, for example, is 10 to 30 V from peak to peak, and the frequency thereof, for example, is 1 to 10 MHz.

[0077] The ultrasonic element **36** acts also as a receiving element to receive ultrasonic echo of the emitted ultrasound that is reflected by the target object and returns back. The ultrasonic echo vibrates the vibrating membrane **38**, and stress is applied to the piezoelectric layer **43** due to this vibration, thereby generating a voltage between the first electrode **42** and the second electrode **44**. This voltage can be output as a reception signal.

[0078] FIG. **8** is a schematic plan view showing a configuration of the ultrasonic element array substrate. As shown in FIG. **8**, a plurality of ultrasonic elements **36** arranged in a matrix, the first electrode **42**, and the second electrode **44** are installed in the ultrasonic element array substrate **14**. For ease of viewing the figure, the ultrasonic elements **36** are arranged in 17 rows and 8 columns. However, there is no specific limitation on the number of rows and the number of columns.

[0079] During the transmission period in which ultrasound is emitted, the transmission signals VT output by the processing circuit **26** are supplied to the respective ultrasonic elements **36** via the second electrode **44**. Meanwhile, during the reception period in which ultrasonic echo signals are received, the reception signals VR from the ultrasonic elements **36** are output to the processing circuit **26** via the second electrode **44**. The first electrode **42** is supplied with a common voltage VCOM. It is sufficient that this common voltage is a constant voltage, and it need not be 0 V, or in other words, a ground potential. In the transmission period, a voltage that is the difference between the transmission signal voltage and the common voltage is applied to each of the ultrasonic elements **36**, and ultrasound is emitted at a predetermined frequency.

[0080] The spacing members **24** are installed in the location where the first recessed portion **23***c* of the acoustic lens **16** is located, along an edge of the element substrate **18** on the X direction side. Similarly, the spacing members **24** are installed also in the location where the third recessed portion **23***e* of the acoustic lens **16** is located, along an edge of the element substrate **18** on the—X direction side. When the frame **17** sandwiches the acoustic lens **16** and the ultrasonic element array substrate **14**, the spacing members **24** receive the load in a portion close to the frame **17**, which enables the thickness of the acoustic matching unit **15** to be kept constant.

[0081] Next, a method for manufacturing the aforementioned ultrasonic device **9** will be described with reference to FIGS. **9** to **11**. FIG. **9** is a flowchart of the method for manufacturing the ultrasonic device. FIGS. **10**A to **10**E and FIGS. **11**A to **11**D are schematic diagrams for describing the method for manufacturing the ultrasonic device. In the flowchart of FIG. **9**, step S1 corresponds to a substrate coupling step. In this step, the element substrate **18** and the back plate **21** are coupled to each other so that the ultrasonic element array substrate **14** is formed. Next, the process proceeds to step S2. Step S2 corresponds to a spacing member formation step. In this step, the spacing members **24** are installed in the ultrasonic array substrate **14**. Step S3 corresponds to a wiring installation step. In this step, the FPC **13** is coupled to the ultrasonic element array substrate **14**. Next, the process proceeds to step S4. Step S4 corresponds to an acoustic matching unit application step. In this step, the material for the acoustic matching unit is applied and the acoustic matching unit is installed in the ultrasonic element array substrate **14**. Next, the process proceeds to step S5.

[0082] Step S5 corresponds to a lens installation step. In this step, the acoustic lens **16** is installed so as to overlap the ultrasonic element array substrate **14**. Next, the process proceeds to step S6. Step S6 corresponds to an acoustic matching unit solidification step. In this step, the acoustic matching unit is solidified. Next, the process proceeds to step S7. Step S7 corresponds to a frame installation step. In this step, the frame **17** is installed so as to sandwich the ultrasonic element array substrate **14** and the acoustic lens **16**. By performing the aforementioned steps, the ultrasonic device **9** is achieved.

[0083] Next, with reference to FIGS. **10**A to **10**E and FIGS. **11**A to **11**D, the manufacturing method will be described in detail in correspondence with the steps shown in FIG. **9**. FIG. **10**A is a view corresponding to the substrate coupling step of step S1. As shown in FIG. **10**A, the element substrate **18** and the back plate **21** are prepared in step S1. In the element substrate **18**, the piezoelectric body **41** is formed. Since the method for manufacturing the piezoelectric body **41** is known to the public, the description thereof is omitted. An adhesive material is applied to the element substrate **18** or the back plate **21**, and the element substrate **18** and the back plate **21**

are laminated together. Next, the adhesive material is solidified by heating and drying, and the ultrasonic element array substrate **14** is complete.

[0084] FIG. **10**B and FIG. **10**C are views corresponding to the spacing member forming step of step S**2**. As shown in FIG. **10**B, a spacing member film **24***a* is installed on the element substrate **18** in step S**2**. For the spacing member film **24***a*, a photosensitive resin film can be used. Then, an adhesive material is applied to the ultrasonic element array substrate **14**, and the spacing member film **24***a* is adhered to the ultrasonic element array substrate **14**. Next, the spacing member film **24***a* is masked by a predetermined pattern and is exposed to light. Subsequently, the spacing member film **24***a* is etched. As a result, the spacing members **24** are installed on the ultrasonic element array substrate **14**, as shown in FIG. **10**C. It is also possible to use a method different from the method with which the spacing member film **24***a* is adhered on the ultrasonic element array substrate **14**. For example, the material of the spacing member film **24***a* may be applied using a method such as spin coating and dipping, followed by drying. For the material of the spacing member film **24***a*, epoxy resin can be used.

[0085] FIG. **10**D is a view corresponding to the wiring installation step of step S**3**. As shown in FIG. **10**D, the FPC **13** is prepared in step S**3**. Solder plating is applied to the ends of the wiring of the FPC **13**. The first electrode **42** and the second electrode **44** extend to the ends on the Y direction side and on the −Y direction side of the element substrate **18**. The ends of the first electrode **42** and the second electrode **44** serve as terminals that are coupled to the FPC **13**. The wiring of the FPC **13** and the terminals of the element substrate **18** are fitted and heated, thereby allowing the FPC **13** to be mounted on the ultrasonic element array substrate **14**. Other than that, the FPC **13** may be mounted on the ultrasonic element array substrate **14** with an anisotropic conductive film interposed therebetween, or with a resin core bump interposed therebetween.

[0086] FIG. **10**E and FIG. **11**A are views corresponding to the acoustic matching member application step of step S**4**. As shown in FIG. **10**E, an acoustic matching member **46** is applied to the surface of the element substrate **18** on the −Y direction side. As shown in FIG. **11**A, the acoustic matching member **46** is applied to the center of the ultrasonic element array substrate **14** in plan view. The shape in which it is applied is elongated in the X direction.

[0087] FIG. **11**B and FIG. **11**C are views corresponding to the lens installation step of step S**5**. As shown in FIG. **11**B, the acoustic lens **16** is installed so as to overlap the ultrasonic element array substrate **14** in step S**5**. Thus, the lower parts of the spacing members **24** are adhered to the ultrasonic element array substrate **14**, and the upper parts thereof are in contact with the acoustic lens **16**. In other words, the spacing members **24** are installed in contact with the ultrasonic element array substrate **14** and the acoustic lens **16**. The ultrasonic element array substrate **14** and the acoustic lens **16** have the same outer shape as viewed from the Z direction. Accordingly, the ultrasonic element array substrate **14** and the acoustic lens **16** can be positioned by fitting their outer shapes.

[0088] FIG. **11**C is a view with the acoustic lens **16** omitted. As shown in FIG. **11**C, when the acoustic matching member **46** is sandwiched by the ultrasonic element array substrate **14** and the acoustic lens **16**, the acoustic matching member **46** flows toward the outer circumference. The portion surrounded by the dashed line in the figure is where the acoustic matching member **46** is applied. The arrows indicate the directions in which the acoustic matching member **46** flows. The spacing members **24** are installed at intervals. The spacing members **24** constitute a flow path through which the acoustic matching member **46** flows. Accordingly, the acoustic matching member **46** can flow from the center of the ultrasonic element array substrate **14** toward the outer circumference.

[0089] The shape of the spacing members **24** is circular or elliptical in plan view as viewed from the −Z direction. Such a circular or elliptical shape has no corners, thereby allowing a fluid to flow with a low resistance along its outer circumference. Accordingly, when the acoustic matching member **46** is allowed to flow in the location where the spacing members **24** are present, the acoustic matching member **46** moves along the spacing members **24**. At this time, the acoustic matching member **46** pushes out the air located in the space between the ultrasonic element array substrate **14** and the acoustic lens **16**, and therefore the intervals of the spacing members **24** can be filled tightly with the acoustic matching member **46**.

[0090] The acoustic matching member **46** overflowing from the space between the ultrasonic element array substrate **14** and the acoustic lens **16** may be removed with a spatula or the like. It is also possible to adjust the amount of the acoustic matching member **46** to be applied so that the acoustic matching member **46** does not overflow from the space between the ultrasonic element array substrate **14** and the acoustic lens **16**.

[0091] FIG. **11**D is a view corresponding to the acoustic matching member solidification step of step S**6** and the frame installation step of step S**7**. As shown in FIG. **11**D, the acoustic matching member **46** is heated and dried so as to serve as the acoustic matching unit **15** in step S**6**. A material that solidifies by reaction with light or a material that solidifies by reaction with moisture may be used for the acoustic matching member **46**.

[0092] An adhesive material is applied to the outer side surface of the inner frame **34** in step S**7**. Next, the inner frame **34** is inserted from the −Z direction side so as to fit the ultrasonic element array substrate **14** and the acoustic lens **16**. Next, the outer frame **35** is inserted from the Z direction side to fit the inner frame **34**. Next, the adhesive material between the inner frame **34** and the outer frame **35** is solidified so that the inner frame **34** and the outer frame **35** are adhered to each other. At this time, it is preferable that a load is applied in a manner such that the inner frame **34** and the outer frame **35** sandwich the ultrasonic element array substrate **14** and the acoustic lens **16**. This allows the ultrasonic element array substrate **14** and the acoustic lens **16** to be fixed with an accurate spacing therebetween. By performing the aforementioned steps, the ultrasonic device **9** is achieved.

[0093] As described above, this embodiment has the following effects.

[0094] (1) According to this embodiment, the acoustic lens **16** is used in contact with the material being examined. At this time, the acoustic lens **16** is pressed by the material being examined. Stress occurs inside the acoustic lens **16**. The acoustic matching unit **15** made of resin, which is susceptible to deformation, deforms due to the stress of the acoustic lens **16**. On the other hand, the columnar spacing members **24** are in contact with the acoustic lens **16** and the ultrasonic element array substrate **14** so as to transfer the stress of the acoustic lens **16** to the ultrasonic element array substrate **14**. Thus, the thickness of the acoustic matching unit **15** is kept constant, thereby suppressing the deformation of the acoustic lens **16**, so that ultrasound can be accurately focused. Further, ultrasound reflected by the material being examined also can be accurately focused on the ultrasonic element **36** since the deformation of the acoustic lens **16** is suppressed. As a result, the ultrasonic device **9** can transmit and receive ultrasound efficiently.

[0095] (2) According to this embodiment, the spacing members **24** are installed in locations that do not overlap with the ultrasonic elements **36**. Accordingly, the ultrasonic elements **36** are overlapped by the ultrasonic matching unit **15** formed of resin. Accordingly, the ultrasonic device **9** can emit ultrasound with an acoustic impedance adjusted by the acoustic matching unit **15**. Further, in the ultrasonic device **9**, the acoustic matching unit **15** can adjust the acoustic impedance of the received ultrasound and emit it to the ultrasound element **36**.

[0096] (3) According to this embodiment, the shape of the spacing members is circular or elliptical. A circle or an ellipse has no corners, thereby allowing a fluid to flow along its outer circumference with little resistance. Accordingly, when the acoustic matching member **46** is allowed to flow in the location where the spacing members **24** are present, the acoustic matching member **46** moves along the arrangement of the spacing members **24**. At this time, the acoustic matching member **46** pushes out the air located in the space between the ultrasonic element array substrate **14** and the acoustic lens **16**, and therefore the intervals between the spacing members **24** can be filled tightly with the acoustic matching member **46**.

Second Embodiment

[0097] Next, an embodiment of an ultrasonic device will be described with reference to FIGS. **12**A and **12**B. FIG. **12**A is a schematic plan view showing a main part of a configuration of the ultrasonic element, with the acoustic lens **16** omitted and with the spacing members installed. FIG. **12**B is a schematic plan view showing a configuration of the ultrasonic element array substrate **14**, with the spacing members and the acoustic matching unit installed. In these figures, the FPC **13** is omitted. This embodiment is different from the first embodiment in that a shape of spacing members that is different from that of the spacing members **24** shown in FIGS. **7**A and **7**B is employed. It should be noted that descriptions for the same parts as the first embodiment are omitted.

[0098] In this embodiment, the ultrasonic device **49** includes an element substrate **50**, as shown in FIGS. **12**A and **12**B. The element substrate **50** includes the base substrate **37** on which the vibrating membrane **38** is installed. On the vibrating membrane **38**, the first electrode **42** and the second electrode **44** are installed. On the upper side of the first line **42***a* and the second line **44***a*, a spacing member **51** is installed so as to cover the first line **42***a* and the second line **44***a*. The spacing member **51** has the same function as in the first embodiment, and the spacing member **51** maintains the thickness of the acoustic matching unit **15** constant.

[0099] The spacing member **51** hardly allows ultrasound to pass therethrough, and is arranged between ultrasonic elements that are adjacent to each other in the X direction, so as to extend in the form of a wall. It is difficult for ultrasound to pass through the spacing member **51**, and the spacing member **51** regulates the direction in which ultrasound propagates. Accordingly, it is possible to suppress a case in which the ultrasonic elements **36** located in the X direction with the spacing member **51** interposed therebetween influence each other via ultrasound.

[0100] The spacing member **51** is formed using a material that has low water permeability and hardly allows moisture to pass therethrough. For example, epoxy resin can be used as a material of the spacing member **51**. The spacing member **51** is arranged so as to cover the first line **42***a* and the second line **44***a*. Accordingly, the spacing member **51** suppresses a case in which moisture attaches to the first line **42***a* and the second line **44***a*, and thus can prevent the galvanic corrosion of the first line **42***a* and the second line **44***a*.

[0101] As shown in FIG. **12**B, spacing members **51** are installed on the element substrate **50** in the spacing member forming step of step S**2**. In the acoustic matching member application step of step S**4**, the acoustic matching member **46** is applied. In the lens installation step of step S**5**, the acoustic matching member **46** is sandwiched by the element substrate **50** and the acoustic lens **16**. At this time, the acoustic matching member **46** is pressed by the element substrate **50** and the acoustic lens **16**, so as to flow toward the outer circumferential side.

[0102] The spacing members **51** constitute flow paths through which the acoustic matching member **46** flows. The acoustic matching member **46** moves along the spacing members **51**, and therefore pushes out air bubbles, thereby allowing the intervals of the spacing members **51** to be filled tightly with the acoustic matching member **46**.

[0103] As described above, this embodiment has the following effects.

[0104] (1) According to this embodiment, the spacing member **51** is arranged between the ultrasonic elements **36**, so as to extend in the form of a wall. It is difficult for ultrasound to pass through the spacing member **51**, and the spacing member **51** regulates the direction in which ultrasound propagates. Accordingly, it is possible to suppress a case in which the ultrasonic elements **36** located with the spacing member **51** interposed therebetween influence each other via ultrasound.

[0105] (2) According to this embodiment, the spacing member **51** is arranged so as to cover the first line **42***a* and the second line **44***a*. The spacing member **51** has a structure that hardly allows moisture to pass therethrough. Accordingly, the spacing member **51** suppresses a case in which moisture attaches to the first line **42***a* and the second line **44***a*, and thus can prevent the galvanic corrosion of the first line **42***a* and the second line **44**a.

[0106] (3) According to this embodiment, the spacing members **51** form flow paths through which the acoustic matching member **46** flows. The acoustic matching member **46** moves along the spacing members **51**, and thus the air between the spacing members **51** is pushed out by the acoustic matching member **46**. As a result, the intervals of the spacing members **51** can be filled tightly with the acoustic matching member **46**.

Third Embodiment

[0107] Next, an embodiment of an ultrasonic probe will be described with reference to FIG. **13**A and FIG. **13**B, which are schematic side views showing a configuration of the ultrasonic probe. This embodiment is different from the first embodiment in that the ultrasonic probe is separable into a body and an ultrasonic probe head. It should be noted that descriptions for the same parts as in the first embodiment are omitted.

[0108] As shown in FIG. **13**A, an ultrasonic probe **54** includes a probe body **55** and a probe head **56**. The probe body **55** includes a body housing **57**, and the processing circuit **26** is installed inside the body housing **57**. The processing circuit **26** is connected to the apparatus body **2** via the cable **4**. A first connector **58** is installed in the body housing **57**, and the first connector **58** is connected to the processing circuit **26**.

[0109] The probe head **56** includes a head housing **59** as a housing, and the ultrasonic device **9** is incorporated in the head housing **59**. The acoustic lens **16** of the ultrasonic device **9** is exposed from the head housing **59**. A second connector **60** connected to the first connector **58** is installed in the head housing **59**, and the processing circuit **26** and the ultrasonic device **9** are electrically connected to each other via the first connector **58** and the second connector **60**.

[0110] As shown in FIG. **13**B, the probe body **55** and the probe head **56** are separable from each other. The first connector **58** and the second connector **60** allow disconnection and connection. A plurality of probe heads **56** are prepared for different frequencies of ultrasound to be transmitted and received by the ultrasonic device **9**. Depending on the properties of the material being examined or the depth of the portion of the material being examined, an appropriate probe head **56** can be connected to the probe body **55**.

[0111] As described above, this embodiment has the following effects.

[0112] (1) According to this embodiment, the probe head **56** includes the ultrasonic device **9** and the head housing **59** supporting the ultrasonic device **9**. The ultrasonic probe **54** includes the ultrasonic device **9** that appropriately maintains the thickness of the acoustic matching unit **15**, and that transmits and receives ultrasound efficiently. Accordingly, it is possible to provide the ultrasonic probe **54** that transmits and receives ultrasound efficiently.

[0113] (2) According to this embodiment, the probe head **54** of the ultrasonic probe **56** can be exchanged. Accordingly, it is possible to exchange it with an ultrasonic device **9** that is suitable for the acoustic impedance or the portion of the material being examined.

Fourth Embodiment

[0114] Next, an embodiment of an ultrasonic imaging apparatus will be described with reference to FIG. **14**, which is a schematic perspective view showing a configuration of the ultrasonic imaging apparatus. In the ultrasonic imaging apparatus of this embodiment, the ultrasonic probe of the first embodiment is installed. It should be noted that descriptions for the same parts as in the first embodiment are omitted.

[0115] As shown in FIG. **14**, an ultrasonic imaging apparatus **63** is a mobile ultrasonic imaging apparatus. The ultrasonic imaging apparatus **63** has an apparatus body **64** (electronic apparatus body), a display unit **65** that displays image data to be displayed, a UI unit **66** (user interface unit), an ultrasonic probe **67**, and a cable **68**. The ultrasonic imaging apparatus **63** can be used for the in-vivo measurement of fat thickness, muscle thickness, bloodstream, bone density, or the like. The ultrasonic device **9** provided in the ultrasonic imaging apparatus **63** appropriately maintains the thickness of the acoustic matching unit **15** and transmits and receives ultrasound efficiently. Accordingly, it can be said that the ultrasonic imaging apparatus **63** is an apparatus provided with the ultrasonic device **9** that transmits and receives ultrasound efficiently.

[0116] The invention is not limited to the foregoing embodiments. The specific arrangements and procedures in practicing the invention may be altered by another arrangement or the like as necessary as long as the objects of the invention can be achieved. Many modifications can be made by a person of ordinary skill in the art without departing from the technical scope of the invention. Examples of the modifications will be described below.

[0117] Modification 1

[0118] In the first embodiment, the spacing members **24** are circular or elliptical. However, there is no limitation on the shape of the spacing members **24**. They may be in various forms such as a cone, elliptic cone, cube, rectangular parallelepiped, triangular prism, and polyhedral prism. The shape of the spacing members **24** can be selected so as to facilitate the manufacture thereof.

[0119] Modification 2

[0120] In the first embodiment, the ultrasonic element **36** performs both the transmission and reception of ultrasound. It is also possible to separate an element that performs the transmission of ultrasound from an element that performs the reception of ultrasound. Further, it is also possible to provide an element that performs the transmission of ultrasound, an element that performs the reception of ultrasound, and an element that performs the transmission and reception of ultrasound. They may be combined depending on the accuracy requirements in the transmission and reception of ultrasound.

[0121] In the first embodiment, the piezoelectric layer **43** is a thin film formed using a photolithographic technique. The piezoelectric layer **43** may be of a thick bulk type. Also in this case, the spacing members **24** keep the thickness of the acoustic matching unit **15** constant, which can make the deformation of the acoustic lens **16** difficult, even if the acoustic lens **16** is pressed.

[0122] Modification 3

[0123] In the second embodiment, the spacing member **51** is in the form of a continuous rectangular parallelepiped that extends in the Y direction so as to cover the first line **42***a* and the second line **44***a*. The spacing member **51** may be divided into multiple parts in the Y direction. The acoustic matching member **46** can be allowed to flow so as to fill the spaces between the spacing members **51**.

[0124] The entire disclosure of Japanese Patent Application No. 2013-223009, filed Oct. 28, 2013 is expressly incorporated by reference herein.

1. An ultrasonic device comprising:

an ultrasonic element array substrate having a plurality of ultrasonic elements configured to perform at least one of transmission and reception of ultrasound;

an acoustic lens configured to focus the ultrasound;

an acoustic matching unit formed using resin, the acoustic matching unit being arranged between the ultrasonic element array substrate and the acoustic lens; and

a plurality of columnar spacing members arranged between the ultrasonic element array substrate and the acoustic lens so as to be in contact with the ultrasonic element array substrate and the acoustic lens.

2. The ultrasonic device according to claim **1**, wherein

the spacing members are installed in locations that do not overlap with the ultrasonic elements in plan view, as viewed in a thickness direction of the ultrasonic element array substrate.

3. The ultrasonic device according to claim **1**, wherein

the spacing members are arranged between the ultrasonic elements so as to extend in the form of a wall, and hardly allow ultrasound to pass therethrough in an in-plane direction of the ultrasonic array substrate.

4. The ultrasonic device according to claim **3**, wherein

the spacing members have lower water permeability than the acoustic matching unit and are arranged so as to cover wiring for transmitting an electrical signal to an ultrasonic element.

5. The ultrasonic device according to claim **3**, wherein

a flow path through which material for an acoustic matching unit flows is formed between two of the spacing members.

6. The ultrasonic device according to claim **1**, wherein

the shape of the spacing members is circular or elliptical in the plan view.

7. An ultrasonic probe head comprising:

the ultrasonic device according to claim **1**; and

a housing configured to support the ultrasonic device.

8. An ultrasonic probe comprising:

the ultrasonic device according to claim **1**; and

a driving circuit configured to drive the ultrasonic device.

9. An electronic apparatus comprising:

the ultrasonic device according to claim **1**; and

a processing unit connected to the ultrasonic device, the processing unit being configured to generate an image using an output of the ultrasonic device.

10. An ultrasonic imaging apparatus comprising:

the ultrasonic device according to claim **1**;

a processing unit connected to the ultrasonic device, the processing unit being configured to perform processing to generate an image using an output of the ultrasonic device; and

a display unit configured to display the image.

* * * * *

patsnap

专利名称(译)	超声波装置，超声波探头，超声波探头，电子设备和超声波成像装置

公开(公告)号	US20150119717A1	公开(公告)日	2015-04-30
申请号	US14/515012	申请日	2014-10-15

[标]申请(专利权)人(译)	精工爱普生株式会社
申请(专利权)人(译)	SEIKO EPSON CORPORATION
当前申请(专利权)人(译)	SEIKO EPSON CORPORATION
[标]发明人	YOSHIDA KAZUKI ONISHI YASUNORI SUZUKI HIRONORI
发明人	YOSHIDA, KAZUKI ONISHI, YASUNORI SUZUKI, HIRONORI
IPC分类号	A61B8/00 A61B8/14 A61B8/08 G10K11/30
CPC分类号	A61B8/4444 G10K11/30 A61B8/145 A61B8/4494 A61B8/4405 A61B8/461 A61B8/4272 A61B8/4427 A61B8/5207 A61B8/4281 A61B8/4411 A61B8/4483 A61B8/4488 B06B1/0622 B06B1/067 G10K11/02
优先权	2013223009 2013-10-28 JP
外部链接	Espacenet USPTO

摘要(译)

提供一种超声波装置，包括：超声波元件阵列基板，具有多个超声波元件，被配置为执行超声波的发送和接收中的至少一个;声透镜，被配置为聚焦超声波;使用树脂形成的声匹配单元，声匹配单元设置在超声元件阵列基板和声透镜之间;多个柱状间隔件设置在超声波元件阵列基板和声透镜之间，以与超声波元件阵列基板和声透镜接触。