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(54) **ULTRASONIC TRANSDUCER DEVICE, PROBE HEAD, ULTRASONIC PROBE, ELECTRONIC MACHINE AND ULTRASONIC DIAGNOSTIC APPARATUS**

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

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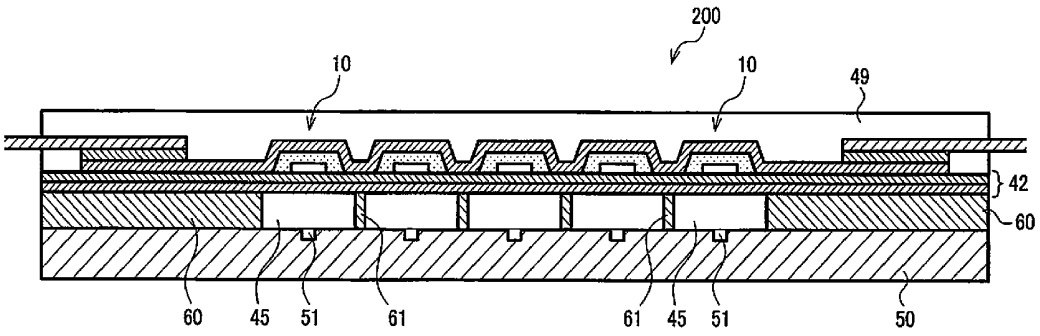
(57) **ABSTRACT**

An ultrasonic transducer device includes a substrate on which a plurality of openings are arranged; a plurality of ultrasonic transducer elements, each of the ultrasonic transducer elements being provided to each of the openings of the plurality of openings, on a first surface of the substrate; and a member fixed to a second surface of the substrate, which is a surface on the opposite side of the first surface of the substrate. Provided to the member are a plurality of first groove sections, and a second groove section for bundling together the plurality of the first groove sections.



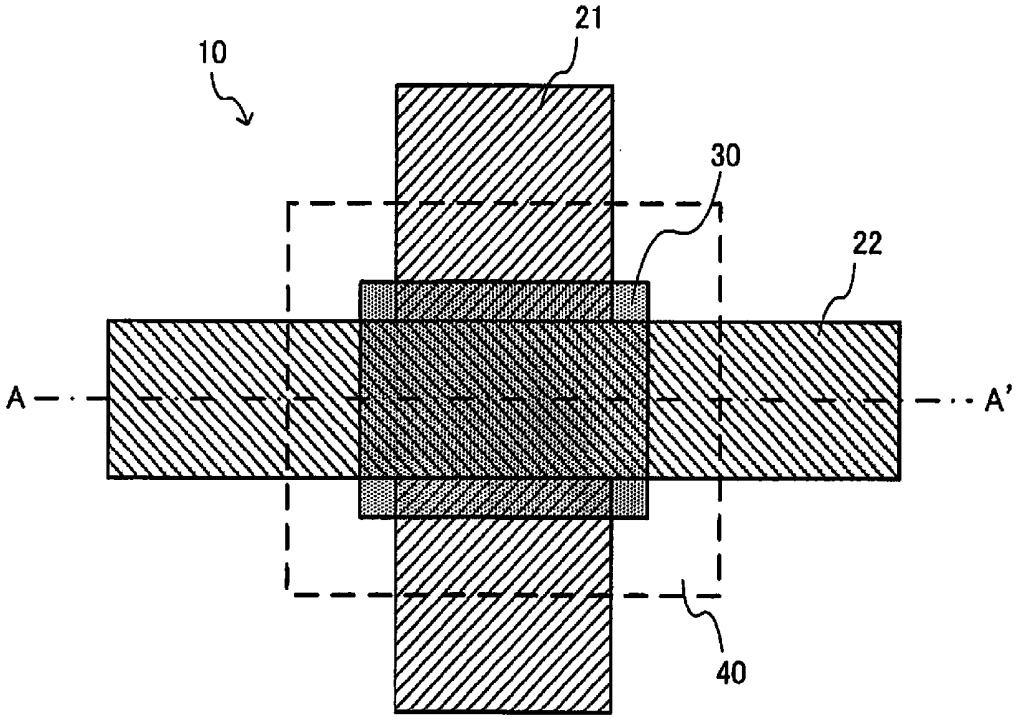


Fig. 1A

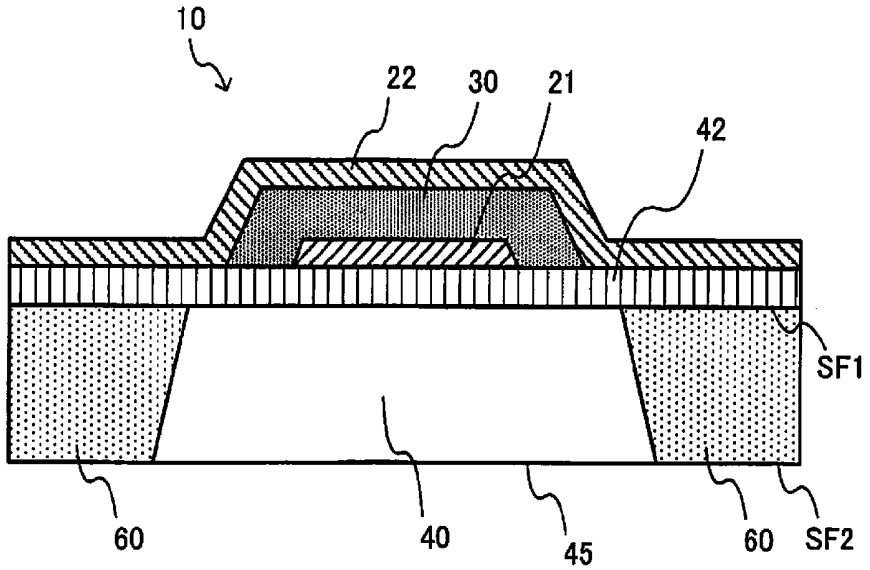


Fig. 1B

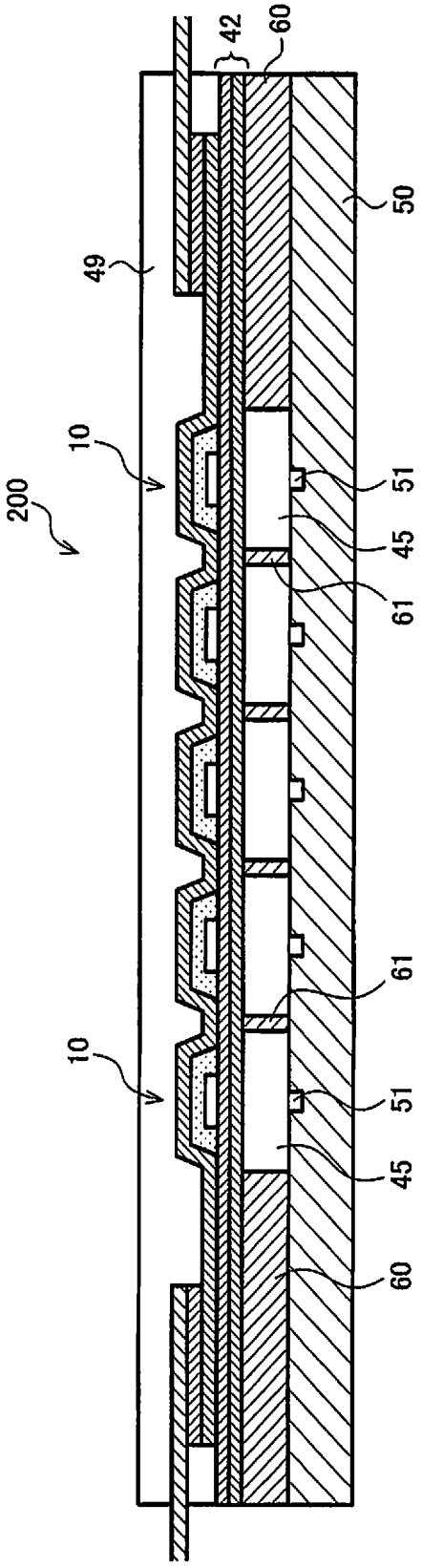


Fig. 2

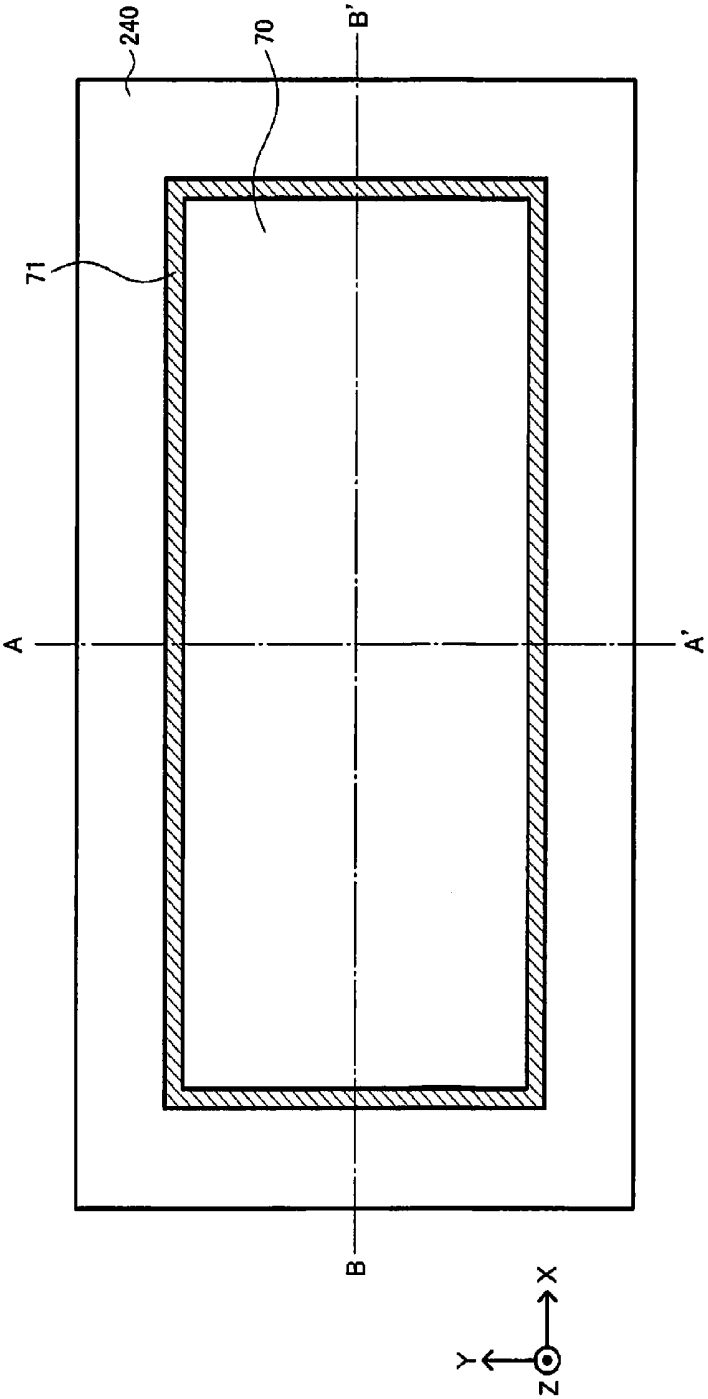

240
70
B'
71
A
A'
B
X
Y
Z

Fig. 3A

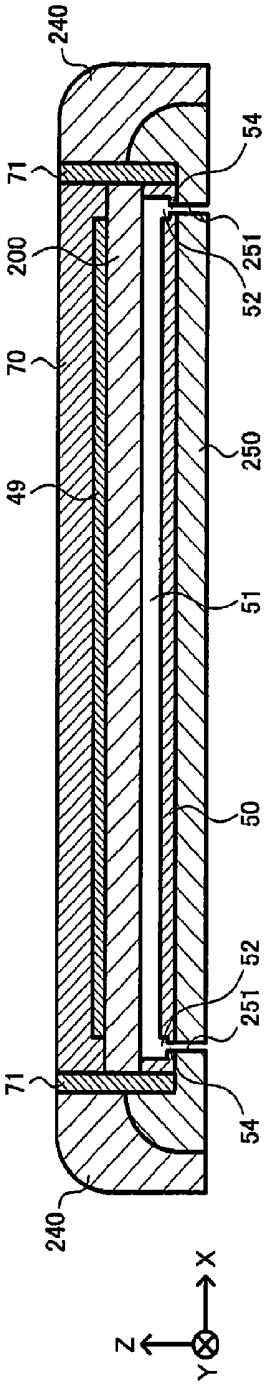

240
54
71
200
251
52
70
250
49
51
50
52
251
71
54
240
X
Z
Y

Fig. 3B

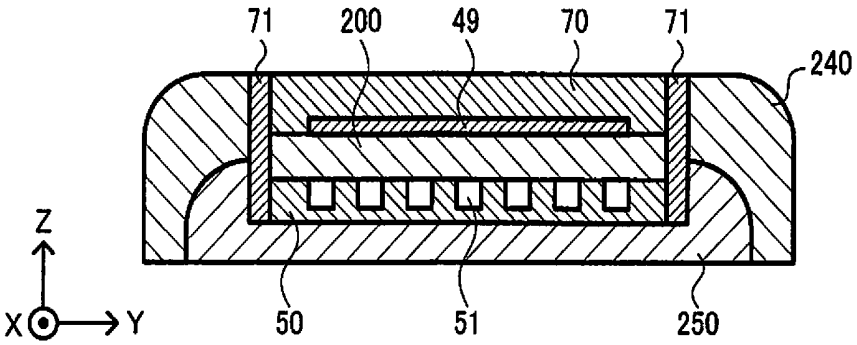


Fig. 4

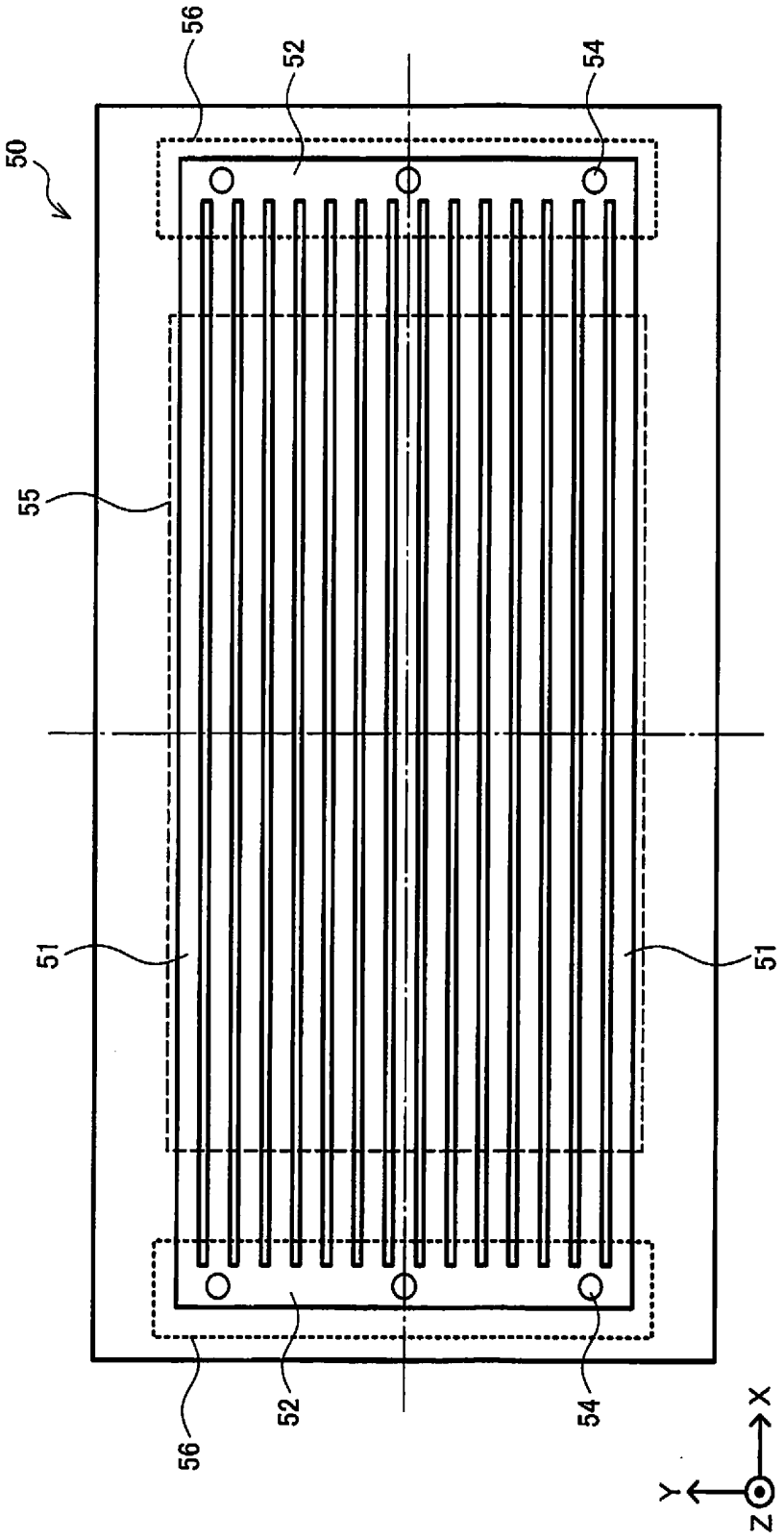


Fig. 5

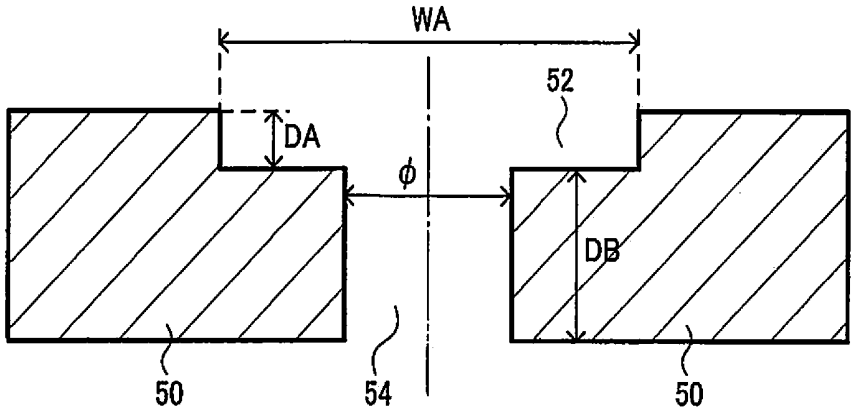


Fig. 6

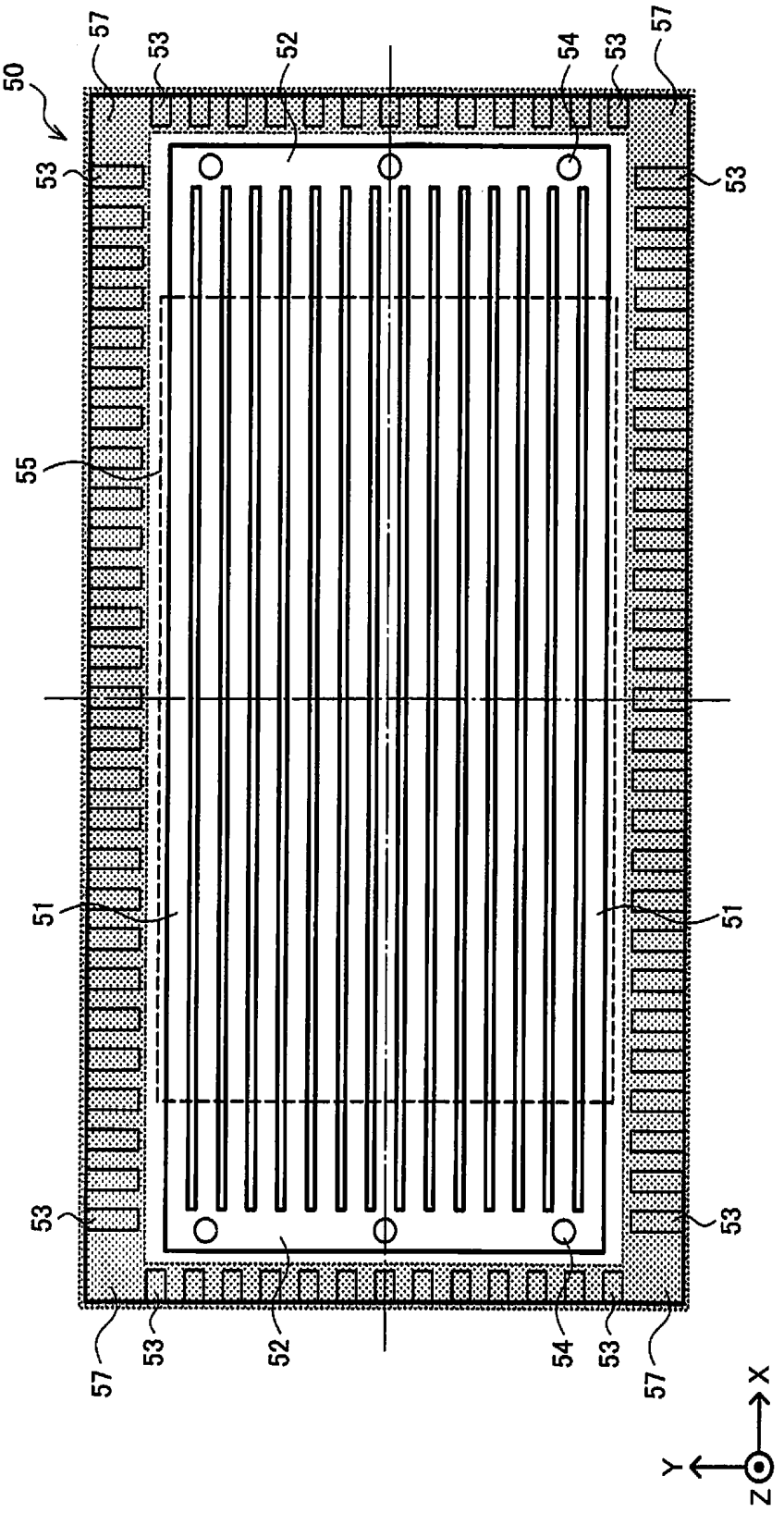


Fig. 7

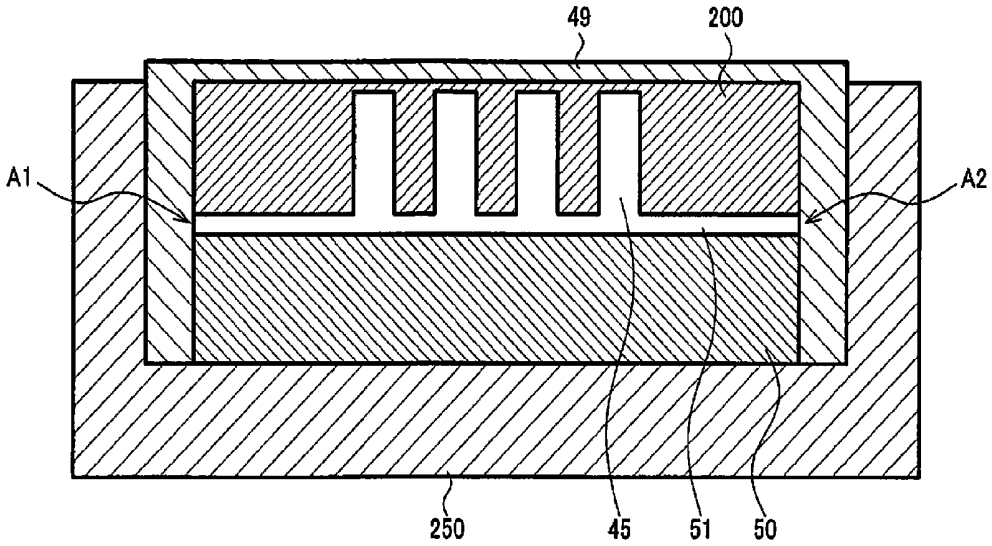


Fig. 8A

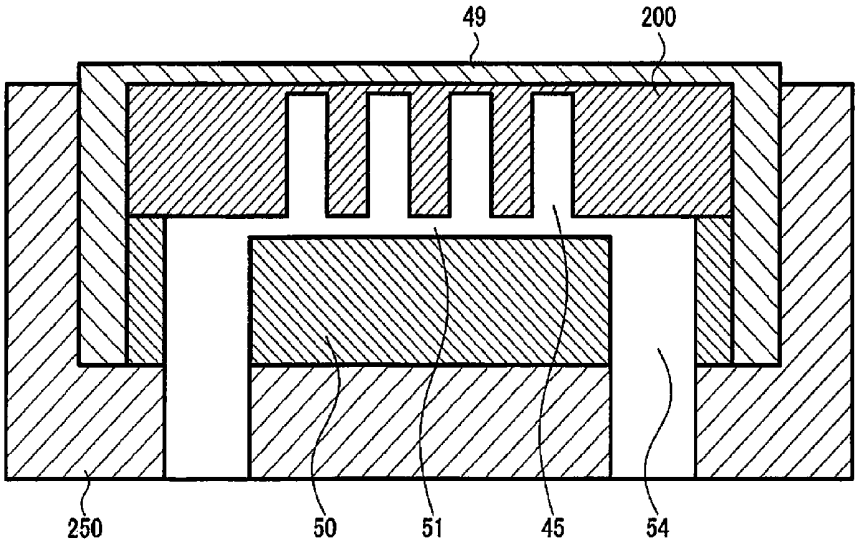


Fig. 8B

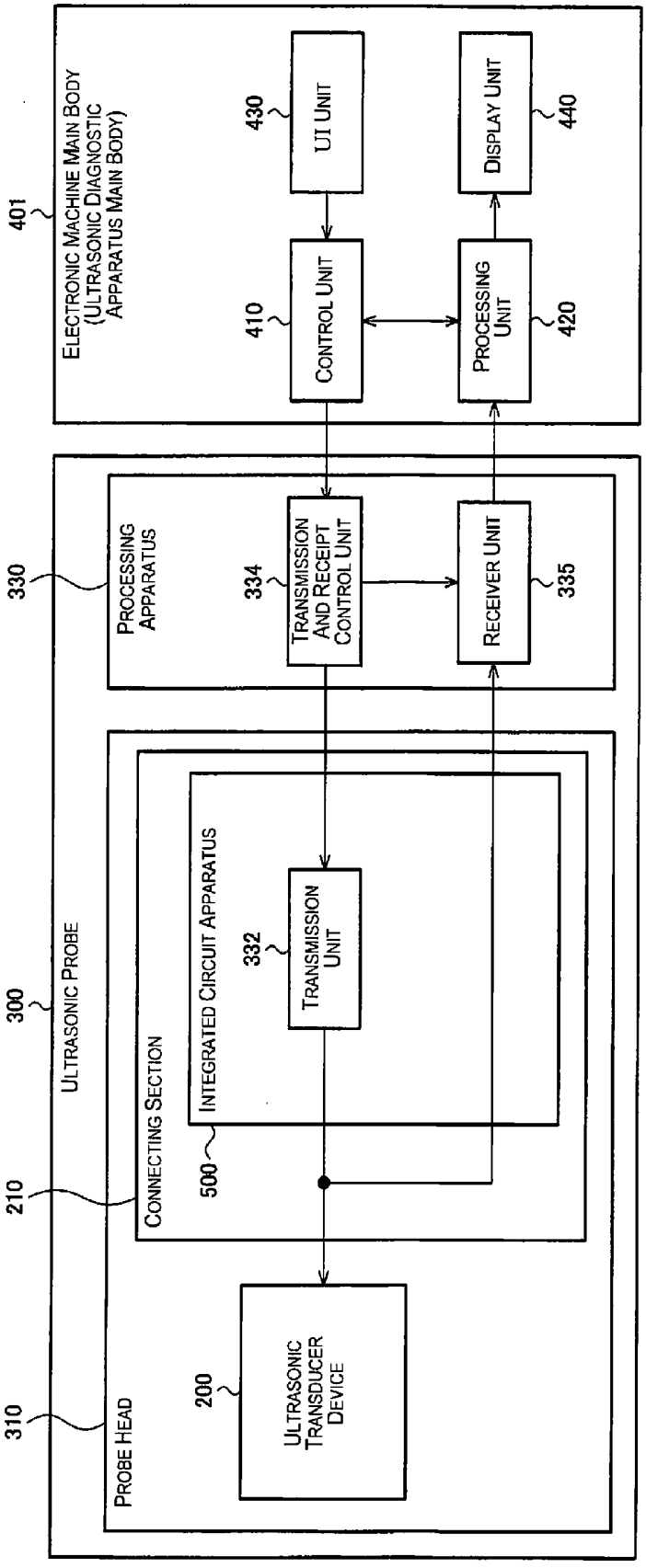

401
ELECTRONIC MACHINE MAIN BODY (ULTRASONIC DIAGNOSTIC APPARATUS MAIN BODY)
410
CONTROL UNIT
420
PROCESSING UNIT
430
UI UNIT
440
DISPLAY UNIT
300
ULTRASONIC PROBE
330
PROCESSING APPARATUS
334
TRANSMISSION AND RECEIPT CONTROL UNIT
335
RECEIVER UNIT
210
CONNECTING SECTION
500
INTEGRATED CIRCUIT APPARATUS
332
TRANSMISSION UNIT
310
PROBE HEAD
200
ULTRASONIC TRANSDUCER DEVICE

Fig. 9

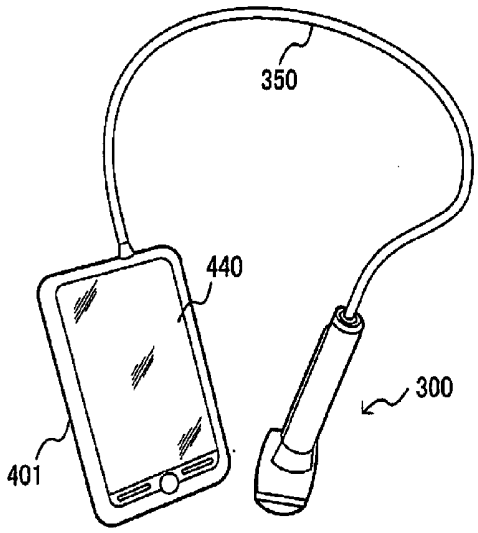


Fig. 10A

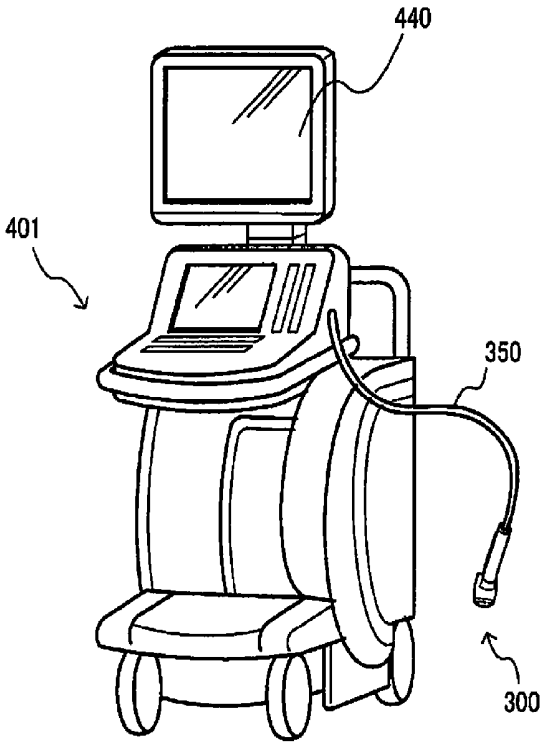


Fig. 10B

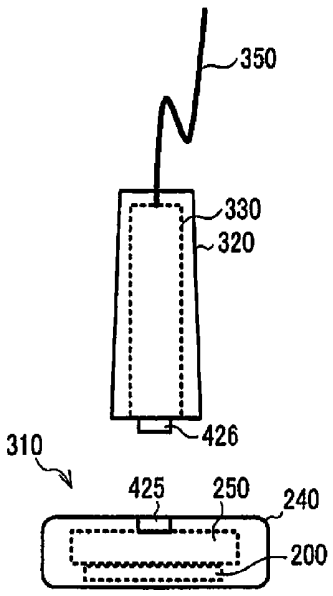


Fig. 10C

ULTRASONIC TRANSDUCER DEVICE, PROBE HEAD, ULTRASONIC PROBE, ELECTRONIC MACHINE AND ULTRASONIC DIAGNOSTIC APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation application of U.S. patent application Ser. No. 14/051,563 filed on Oct. 11, 2013. This application claims priority to Japanese Patent Application No. 2012-226671 filed on Oct. 12, 2012. The entire disclosures of U.S. patent application Ser. No. 14/051,563 and Japanese Patent Application No. 2012-226671 are hereby incorporated herein by reference.

BACKGROUND

[0002] 1. Technical Field

[0003] The present invention relates to an ultrasonic transducer device, a probe head, an ultrasonic probe, an electronic machine, an ultrasonic diagnostic apparatus, and the like.

[0004] 2. Related Art

[0005] One known example of an apparatus for insonifying a subject with ultrasonic waves and receiving reflected waves coming from an interfacial surface at which the acoustic impedance is different within the interior of the subject is an ultrasonic diagnostic apparatus for inspecting the interior of a human body. For example, Japanese Laid-open Patent Publication 2011-82624 discloses a technique in which a transducer element comprising a piezoelectric body layer and an electrode layer is formed on a substrate, as an ultrasonic transducer device to be used in an ultrasonic diagnostic apparatus.

[0006] However, in this technique, a plurality of openings are provided to the substrate, and therefore the strength of the substrate has been diminished, and the ultrasonic transducer device has been damaged by pressure from the exterior, among other problems.

SUMMARY

[0007] According to several aspects of the present invention, it is possible to provide an ultrasonic transducer device, a probe head, an ultrasonic probe, an electronic machine, an ultrasonic diagnostic apparatus, and the like by which the strength is raised and any decline in element properties can be minimized.

[0008] According to one aspect of the invention, an ultrasonic transducer device includes: a substrate on which a plurality of openings are arranged; a plurality of ultrasonic transducer elements, each of the ultrasonic transducer elements being provided to each of the openings of the plurality of openings, on a first surface of the substrate; and a reinforcement member for reinforcing the substrate, the reinforcement member being fixed to a second surface of the substrate, which is a surface on the opposite side of the first surface of the substrate, a plurality of first groove sections formed so as to oppose the plurality of openings of the substrate and second groove sections for bundling together the plurality of first groove sections being provided to the reinforcement member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Referring now to the attached drawings which form a part of this original disclosure:

[0010] FIG. **1**A is an example of a basic configuration for an ultrasonic transducer element;

[0011] FIG. **1**B are the example of the basic configuration for the ultrasonic transducer element;

[0012] FIG. **2** is a cross-sectional view of an example of a configuration for an ultrasonic transducer device;

[0013] FIG. **3**A is an example of mounting for an ultrasonic transducer device;

[0014] FIG. **3**B is the example of mounting for the ultrasonic transducer device;

[0015] FIG. **4** is an example of mounting for an ultrasonic transducer device;

[0016] FIG. **5** is an example of a first configuration for a reinforcement member;

[0017] FIG. **6** is a cross-sectional view of a through hole;

[0018] FIG. **7** is an example of second configuration for a reinforcement member;

[0019] FIG. **8**A is a drawing for describing a reason why it would be desirable for through holes to be provided to a reverse surface of a reinforcement member;

[0020] FIG. **8**B is the drawing for describing the reason why it would be desirable for the through holes to be provided to the reverse surface of the reinforcement member;

[0021] FIG. **9** is an example of a basic configuration for an electronic machine (an ultrasonic diagnostic apparatus);

[0022] FIG. **10**A is an example of a specific configuration for an ultrasonic diagnostic apparatus;

[0023] FIG. **10**B is the example of the specific configuration for the ultrasonic diagnostic apparatus; and

[0024] FIG. **10**C is an example of a specific configuration for an ultrasonic probe.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0025] The following describes in greater detail a preferred embodiment of the present invention. The present embodiment described below is not, however, meant to gratuitously limit the content of the present invention described in the claims, nor is the entire configuration described in the present embodiment necessarily essential in terms of the solution of the present invention.

1. Ultrasonic Transducer Element

[0026] FIGS. **1**A and **1**B illustrate an example of a basic configuration for an ultrasonic transducer element (a thin-film piezoelectric ultrasonic transducer element) **10** included in an ultrasonic transducer device of the present embodiment. The ultrasonic transducer element **10** of the present embodiment includes a vibrating membrane (membrane, support membrane) **42** and a piezoelectric element section. The piezoelectric element section includes a lower electrode (first electrode layer) **21**, a piezoelectric body membrane (piezoelectric body layer) **30**, and an upper electrode (second electrode layer) **22**. The ultrasonic transducer element **10** of the present embodiment is not limited to being the configuration of FIGS. **1**A and **1**B, but rather a variety of modifications can be implemented, such as omitting a part of the constituent elements thereof, replacing same with other constituent elements, or adding other constituent elements.

[0027] In the following description, the ultrasonic transducer element is also called an "ultrasonic element **10**".

[0028] FIG. **1**A is a plan view of the ultrasonic element **10**, which is formed on a substrate (silicon substrate) **60**, as seen from a direction perpendicular to the substrate on an element formation surface side. FIG. **1**B is a cross-sectional view illustrating a cross-section taken along the A-A' line in FIG. **1**A. In the substrate **60**, a surface on the side where the element is formed is understood to be a first surface SF**1**, and the surface on the opposite side of the first surface SF**1** is understood to be a second surface SF**2**.

[0029] The first layer **21** is formed of, for example, a metal thin film, on an upper layer of the vibrating membrane **42**. The first electrode layer **21** may be a wiring that extends to the outside of an element formation region, as illustrated in FIG. **1**A, and is connected to an adjacent ultrasonic element **10**.

[0030] The piezoelectric body membrane **30** is formed of, for example, a lead zirconate titanate (PZT) thin film, and is provided so as to at least partially cover the first electrode layer **21**. The material of the piezoelectric body membrane **30**, however, is not limited to being PZT, but rather, for example, lead titanate (PbTiO3), lead zirconate (PbZrO3), lanthanum lead titanate ((Pb, La)TiO3), or the like may be used.

[0031] The second electrode layer **22** is formed of, for example, a metal thin film, and is provided so as to at least partially cover the piezoelectric body membrane **30**. The second electrode layer **22** may be a wiring that extends to the outside of the element formation region, as illustrated in FIG. **1**A, and is connected to an adjacent ultrasonic element **10**.

[0032] The vibrating membrane (membrane) **42** is provided so that an opening **45** is covered by, for example, a two-layered structure of an SiO2 thin film and a ZrO2 thin film. The vibrating membrane **42** supports the piezoelectric body membrane **30** and the first and second electrode layers **21**, **22**, and is able to vibrate in conformity with the expansion and contraction of the piezoelectric body membrane **30** to generate ultrasonic waves.

[0033] The opening **45** is arranged on the substrate **60**. A cavity region **40** created by the opening **45** is formed by etching by reactive ion etching (RIE) or the like from a reverse surface of the substrate **60** (the surface on which the element is not formed).

[0034] The lower electrode of the ultrasonic element **10** is formed of the first electrode layer **21** and the upper electrode is formed of the second electrode layer **22**. More specifically, the portion of the first electrode layer **21** that is covered by the piezoelectric body membrane **30** forms the lower electrode, and the portion of the second electrode layer **22** that covers the piezoelectric body membrane **30** forms the upper electrode. That is to say, the piezoelectric body membrane **30** is provided sandwiched between the lower electrode and the upper electrode.

[0035] The piezoelectric body membrane **30** is expanded and contracted in an in-plane direction by the application of a voltage between the lower electrode and the upper electrode, i.e., between the first electrode layer **21** and the second electrode layer **22**. The ultrasonic element **10** uses a monomorph (unimorph) structure obtained by bonding together a thin piezoelectric element section and the vibrating membrane **42**, and when the piezoelectric element section undergoes in-plane expansion and contraction, warping takes place because the dimensions of the vibrating membrane **42** remain unaffected. As such, applying an alternating current voltage to the piezoelectric body membrane **30** causes the vibrating membrane **42** to vibrate with respect to the film thickness direction, and the vibration of the vibrating membrane **42** causes ultrasonic waves to be emitted. The voltage that is applied to the piezoelectric body membrane **30** is, for example, 10 to 30 V, and the frequency is, for example, 1 to 10 MHz.

[0036] In contrast to the fact that the drive voltage for bulk ultrasonic elements would be about 100 V in peak-to-peak, the drive voltage could be reduced to about 10 to 30 V in peak-to-peak in a thin-film piezoelectric ultrasonic element **10** as is illustrated in FIGS. **1**A and **1**B.

[0037] The ultrasonic element **10** also operates as a receiver element for receiving an ultrasonic echo produced when emitted ultrasonic waves are reflected by a subject and then come back. The ultrasonic echo causes the vibrating membrane **42** to vibrate, and this vibration causes a pressure to be applied to the piezoelectric body membrane **30** and causes a voltage to be generated between the lower electrode and the upper electrode. This voltage can be extracted as a received signal.

2. Ultrasonic Transducer Device

[0038] FIG. **2** is a cross-sectional view of an example of an example for an ultrasonic transducer device **200** of the present embodiment. The ultrasonic transducer device **200** includes a plurality of the ultrasonic transducer element **10**, the substrate **60**, and a reinforcement member **50**. The ultrasonic transducer device **200** of the present embodiment is not limited to being the configuration of FIG. **2**, but rather a variety of modifications can be implemented, such as omitting a part of the constituent elements thereof, replacing same with other constituent elements, or adding other constituent elements.

[0039] For the ultrasonic transducer elements **10**, the element illustrated in FIGS. **1**A and **1**B can be used.

[0040] The substrate **60** is, for example, a silicon substrate, and includes a plurality of the opening **45**, which are arranged in an arrayed shape. On the first surface SF**1** of the substrate **60**, the ultrasonic transducer elements **10** are provided so as to correspond to each of the plurality of openings **45**.

[0041] The reinforcement member **50** is fixed to the second surface SF**2** of the substrate **60**, which is the surface on the opposite side of the first surface SF**1** of the substrate **60**, and reinforces the substrate **60**. The reinforcement member **50** is formed, for example, by etching a silicon substrate. Alternatively, the reinforcement member **50** is formed by microprocessing a metal sheet. A plurality of first groove sections **51** are provided to a surface of the reinforcement member **50** that is bonded to the substrate **60** (see FIG. **5**). The first groove sections **51** are, for example, rectilinear grooves. That is to say, the plurality of openings **45**, which oppose the first groove sections **51**, are in communication with each other via the first groove sections **51**. The cross-sectional shape of the first groove sections **51** may be quadrangular, triangular, semicircular, or another shape.

[0042] The reinforcement member **50** is bonded, in at least one bonding region, to partition wall sections **61** separating each of the plurality of openings **45** arranged in an arrayed shape. The partition wall sections **61** are provided between adjacent openings **45**, and adjacent openings **45** are parti-

tioned from each other by the partition wall sections **61**. The bonding could involve the use of an adhesive. In so doing, movement of the partition wall sections **61** would be constrained by the reinforcement member **50**, and thus any vibration of the partition wall sections **61** can be minimized. As a result, cross-talk between the ultrasonic transducer elements **10** can be reduced.

[0043] Further provided to the surface of the reinforcement member **50** that is bonded to the substrate **60** are second groove sections **52**, as illustrated in FIGS. **3**B and **5**, to be described below. The second groove sections **52** bundle together the plurality of first groove sections **51**.

[0044] A protective film **49** is layered onto the surface of the ultrasonic transducer device **200**. The protective film **49** is coated to cover, for example, the full surface of the ultrasonic transducer device **200**. The protective film **49** protects the plurality of ultrasonic transducer elements **10** arranged in an arrayed shape, and also functions as an acoustic matching layer. For the protective film **49**, it would be possible to use, for example, a silicone resin film.

[0045] FIGS. **3**A, **3**B, and **4** illustrate an example of mounting of the ultrasonic transducer device **200** onto an ultrasonic probe (probe head). FIG. **3**A is a plan view; FIG. **3**B is a cross-sectional view taken along the B-B' line; and FIG. **4** is a cross-sectional view taken along the A-A' line. FIGS. **3**B and **4** do not depict the details of the structure of the ultrasonic transducer device **200**. The mounting of the ultrasonic transducer device **200** is not limited to what is illustrated in FIGS. **3**A, **3**B, and **4**, but rather a variety of methods would be feasible.

[0046] The protective film is layered onto the surface of the ultrasonic transducer device **200**, and further formed thereon is an acoustic lens **70**. The reverse surface of the ultrasonic transducer device **200** is fixed to a probe base **250**. A side surface of the ultrasonic transducer device **200** is enclosed by a probe housing **240** and by the probe base **250**, with a protective layer **71** interposed therebetween. That is to say, the ultrasonic transducer device **200** is supported by the probe housing **240** and the probe base **250**. The protective layer **71** can be formed of, for example, the same silicone resin as that of the protective film **49**.

[0047] Provided to the reinforcement member **50** of the ultrasonic transducer device **200** are the pluralities of first groove sections **51** and second groove sections **52**, and through holes **54**. The first groove sections **51** oppose the plurality of openings **45**, and the second groove sections **52** bundle together the plurality of first groove sections **51**. The through holes **54** provide communication between the second groove sections **52** and the external space. As a result, the first groove sections **51**, the second groove sections **52**, and the through holes **54** form ventilation channels that provide communication between the openings **45** of the substrate **60** and the external space.

[0048] More specifically, as illustrated in FIG. **3**B, the plurality of first groove sections **51** are provided along the X-direction. The second groove sections **52** are provided along the Y-direction, on a short edge side of the reinforcement member **50**. The plurality of openings **45**, which are arranged, for example, along the B-B' line, are in communication with each other via the first groove sections **51** that are provided along the B-B' line. One end of the first groove sections **51** is joined to one second groove section **52** and the other end of the first groove sections **51** is joined to another second groove section **52**. Communication is provided between the second groove sections **52** and the external space via the through holes **54**, and also the through holes **54** are joined to through holes **251** provided to the probe base **250**. As a result, the plurality of openings arranged along the B-B' line are in communication with the external space.

[0049] In this manner, according to the ultrasonic transducer device **200** of the present embodiment, ventilation channels that provide communication between each of the openings **45** and the external space can be formed. So doing causes the internal space of the openings **45** to not be sealed off and thus makes it possible to ensure ventilation with the external space. Were the internal space of the openings **45** to be hermetically sealed, problems would arise such as in that sound pressure would be locked in during actual operation, diminishing the transmission and reception properties, or in that temperature changes would cause the air in the internal space to swell or contract, thus changing the element properties. Depending on the case, the vibrating membrane **42** could be damaged. In the ultrasonic transducer device **200** of the present embodiment, the internal space of the openings **45** is readily able to follow pressure fluctuations in the surroundings, and thus the ultrasonic transducer element **10** is able to avoid the problems described above. Herein, the external space signifies a space that is separated from the internal space by, for example, the substrate **60**, the vibrating membrane **42**, and the reinforcement member **50**, and that is significantly larger than the internal space.

[0050] FIG. **5** illustrates a first configuration example of the reinforcement member **50**. The reinforcement member **50** of the first configuration example includes the pluralities of first groove sections **51**, second groove sections **52**, and through holes **54**. The X-, Y-, and Z-directions illustrated in FIG. **5** correspond to the X-, Y-, and Z-directions illustrated in FIGS. **3**A, **3**B, and **4**. The reinforcement member **50** of the present embodiment is not limited to being the configuration of FIG. **5**, but rather a variety of modifications can be implemented, such as omitting a part of the constituent elements thereof, replacing same with other constituent elements, or adding other constituent elements.

[0051] The plurality of first groove sections **51** are provided along the X-direction (more broadly, a first direction) to a region **55** opposing an opening region of the substrate **60**, on the surface of the reinforcement member **50** that is bonded to the substrate **60**. The opening region refers to a region where the openings **45** are arranged in an arrayed shape on the substrate **60**. The region **55** opposing the opening region refers to a region that opposes the opening region on the reinforcement member **50** in a case where the reinforcement member **50** has been fixed to the substrate **60**. So doing allows the first groove sections **51** to form the ventilation channels communicating through the plurality of openings **45** in a case where the reinforcement member **50** has been fixed to the substrate **60**.

[0052] The second groove sections **52** are provided along the Y-direction (more broadly, a second direction intersecting with the first direction) to a region **56** opposing a surrounding region of the opening region of the substrate **60**, on the surface of the reinforcement member **50** that is bonded to the substrate **60**. The surrounding region of the opening region refers to a region surrounding the region where the openings **45** are arranged in an arrayed shape on the substrate **60**. The region **56** opposing the surrounding region of the opening region refers to a region that opposes the surrounding region of the opening region on the rein-

forcement member **50** in a case where the reinforcement member **50** has been fixed to the substrate **60**. That is to say, the region **56** opposing the surrounding region of the opening region does not oppose the region in which the plurality of openings **45** are arranged in an arrayed shape on the substrate **60** in a case where the reinforcement member **50** has been fixed to the substrate **60**.

[0053] One end of each of the first groove sections of the plurality of first groove sections **51** is joined to the second groove sections **52** in the region **56** opposing the surrounding region of the opening region of the substrate **60**. That is to say, the second groove sections **52** bundle together the plurality of first groove sections **51**.

[0054] The through holes **54** provide communication between the second groove sections **52** and the external space. So doing allows for the first groove sections **51**, the second groove sections **52**, and the through holes **54** to form the ventilation channels providing communication between the openings **45** of the substrate **60** and the external space.

[0055] For example, as illustrated in FIG. **5**, the first groove sections **51** are provided along the X-direction in the region **55** opposing the opening region. The second groove sections **52** are provided along the Y-direction in the region **56** on the short edge side of the reinforcement member **50** (more broadly, in the region opposing the surrounding region of the opening region). One of two second groove sections **52** is joined to one end of the first groove sections **51**, and the other of two second groove sections **52** is joined to the other end of the first groove sections **51**. The through holes **54** are perforated through the second groove sections **52** and a reverse surface (a surface not bonded to the substrate **60**) of the reinforcement member **50**. There can be a plurality of the through holes **54** provided.

[0056] The first groove sections **51** may also be provided along the Y-direction in the region **55** opposing the opening region. In such a case, the second groove sections **52** would be provided along the X-direction in a region on a long edge side of the reinforcement member **50**.

[0057] FIG. **6** is a cross-sectional view of the through holes **54** of the first configuration example of the reinforcement member **50**. A width WA of the second groove sections **52** is greater than a diameter p of the through holes **54**. For example, WA=1 mm, ϕ=0.4 mm. The depth DA of the second groove sections **52** is, for example, 0.1 mm, and the depth DB of the through holes **54** is, for example, 0.4 mm.

[0058] FIG. **7** illustrates a second configuration example of the reinforcement member **50**. The reinforcement member **50** of the second configuration example includes the first groove sections **51**, the second groove sections **52**, third groove sections **53**, and the through holes **54**. The X-, Y-, and Z-directions illustrated in FIG. **7** correspond to the X-, Y-, and Z-directions illustrated in FIGS. **3**A, **3**B, and **4**. The first groove sections **51**, the second groove sections **52**, and the through holes **54** are the same as those of the first configuration example described above (see FIG. **5**), and thus a more detailed description thereof has been omitted.

[0059] The third groove sections **53** are provided to a region **57** opposing the surrounding region of the opening region of the substrate **60**, on the surface of the reinforcement member **50** that is bonded to the substrate **60**, and are in communication with the external space but are not in communication with any of the first groove sections **51** or second groove sections **52**. The region **57** opposing the surrounding region of the opening region refers to a region opposing the surrounding region of the opening region on the reinforcement member **50** in a case where the reinforcement member **50** has been fixed to the substrate **60**. The third groove sections **53** may also be provided to a region **57** opposing the surrounding region of the opening region running along the four edges of the reinforcement member **50**.

[0060] The third groove sections **53** are provided along the X-direction, in a region that runs along either the edges of the reinforcement member **50** on the X-direction (more broadly, first direction) side or along the edges on the opposite side to the X-direction. Alternatively, the third groove sections **53** are provided along the Y-direction, in a region that runs along the edges of the reinforcement member **50** on the Y-direction (more broadly, the second direction) side or along the edges on the opposite side to the Y-direction. One end of the third groove sections **53** is separated from both the pluralities of first groove sections **51** and second groove sections **52**, and the other end of the third groove sections **53** is bonded to the edge of the reinforcement member **50**.

[0061] More specifically, as illustrated in, for example, FIG. **7**, the plurality of third groove sections **53** are provided in the region **57** opposing the surrounding region of the opening region running along the four edges of the reinforcement member **50**. The one end of the third groove sections **53** is not joined to either the first groove sections **51** or second groove sections **52**. The other end of the third groove sections **53**, however, is bonded to the edge (end surface) of the reinforcement member **50**. The third groove sections **53** are provided to the region **57** (more broadly, the region opposing the surrounding region of the opening region) on the outside of the regions to which the pluralities of first groove sections **51** and second groove sections **52** are provided.

[0062] Providing the third groove sections **53** makes it possible for air between the reinforcement member **50** and the substrate **60** to escape to the external space when the reinforcement member **50** is being adhered to the substrate **60**, and therefore makes it possible to improve the adhesion between the reinforcement member **50** and the substrate **60**.

[0063] FIGS. **8**A and **8**B are drawings for describing a reason why it would be desirable for the through holes **54** to be provided to a reverse surface of the reinforcement member **50**. FIG. **8**A illustrates a case where the through holes **54** are provided to a side surface, by way of comparative example, and FIG. **8**B illustrates a case where the through holes **54** are provided to the reverse surface.

[0064] The ultrasonic transducer device **200** is placed onto a recess of the probe base **250**, and a resin for forming the protective film **49** is poured in from above. At this time, in the case where the through holes **54** are provided to the side surface, the through holes **54** become plugged up with the resin, as illustrated by A**1** and A**2** of FIG. **8**A. In the case where the through holes **54** are provided to the reverse surface, however, the through holes **54** are not plugged up with the resin.

[0065] This manner of providing the through holes **54** to the reverse surface of the reinforcement member **50** prevents the through holes **54** from being plugged up with the resin when the resin for forming the protective film **49** is being poured in, and thus makes it possible to ensure the ventilation channels providing communication between each of the openings **45** and the external space.

[0066] The method of mounting the ultrasonic transducer device **200** is not limited to being what is illustrated in FIGS. **8**A and **8**B, but rather may be another method of mounting. Also, in a case where there is no concern that the through holes **54** might be plugged up with the resin, then the through holes **54** may be provided to a location other than the reverse surface of the reinforcement member **50**, e.g., the side surface.

[0067] As described above, according to the ultrasonic transducer device **200** of the present embodiment, the reinforcement member **50** is fixed to the substrate **60**, and thus the strength of the ultrasonic transducer element **10** and of the substrate **60** can be increased. Also, because the openings **45** provided to the substrate **60** are not sealed off but rather ventilation with the external space can be ensured, it becomes possible to avoid problems such as, for example, any decline in element properties caused by sound pressure being locked in during actual operation, or element damage caused by the air inside the openings swelling and contracting due to temperature changes. Further, the reinforcement member **50** can minimize any vibration of the partition wall sections **61**, and thus it is possible, for example, to reduce cross-talk between adjacent ultrasonic transducer elements **10**. As a result, it becomes possible to implement an ultrasonic transducer device that has high strength and is able to minimize any decline in element properties.

3. Ultrasonic Probe, Probe Head, Electronic Machine, and Ultrasonic Diagnostic Apparatus

[0068] FIG. **9** illustrates an example of a basic configuration for an electronic machine (ultrasonic diagnostic apparatus) of the present embodiment. The ultrasonic diagnostic apparatus includes an ultrasonic probe **300** and an ultrasonic diagnostic apparatus main body **401**. The ultrasonic probe **300** has a probe head **310** and a processing apparatus **330**. The ultrasonic diagnostic apparatus main body **401** has a control unit **410**, a processing unit **420**, a user interface unit (UI unit) **430**, and a display unit **440**.

[0069] The processing apparatus **330** includes a transmission and reception control unit **334** and a receiver unit **335** (an analog front-end unit). The probe head **310** includes the ultrasonic transducer device **200**, as well as a connecting section **210** (connector section) for connecting the ultrasonic transducer device **200** to a circuit board (for example, a rigid substrate). Implemented on the circuit board are the transmission and reception control unit **334** and the receiver unit **335**. The connecting section **210** includes an integrated circuit apparatus **500**. The integrated circuit apparatus **500** includes a transmission unit **332**.

[0070] In a case where ultrasonic waves are transmitted, the transmission and reception control unit **334** issues a transmission command to the transmission unit **332**, and the transmission unit **332** receives the transmission command, amplifies the drive signal to a high voltage, and outputs a drive voltage. The receiver unit **335** includes a limiter circuit (not shown), and the limiter circuit cuts off the drive voltage. In a case where reflected waves of the ultrasonic waves are received, the receiver unit **335** receives a signal of the reflected waves detected by the ultrasonic transducer device **200**. The receiver unit **335** processes (for example, amplification processing, A/D conversion processing, or the like) the signal of the reflected waves on the basis of a reception command coming from the transmission and reception control unit **334**, and transmits the processed signal to the processing unit **420**. The processing unit **420** generates display image data on the basis of the signal, and causes the display unit **440** to produce a display.

[0071] The ultrasonic measurement apparatus of the present embodiment is not limited to being a medical ultrasonic diagnostic apparatus such as described above, but rather can be applied to a variety of electronic machines. For example, conceivable instances of electronic machines to which the ultrasonic transducer device has been applied include a diagnostic machine for nondestructively inspecting the interior of a building or the like, or a user interface machine for detecting movement of a user's finger by the reflection of ultrasonic waves.

[0072] FIGS. **10**A and **10**B illustrate examples of a specific configuration for the ultrasonic diagnostic apparatus **400** of the present embodiment. FIG. **10**A illustrates a portable ultrasonic diagnostic apparatus **400**, and FIG. **10**B illustrates a floor-standing ultrasonic diagnostic apparatus **400**.

[0073] Both the portable version and the floor-standing version of the ultrasonic diagnostic apparatus **400** include the ultrasonic probe **300**, a cable **350**, and the ultrasonic diagnostic apparatus main body **401**. The ultrasonic probe **300** is connected to the ultrasonic diagnostic apparatus main body **401** by the cable **350**. The ultrasonic diagnostic apparatus main body **401** includes the display unit **440** for displaying the display image data.

[0074] FIG. **10**C illustrates a specific configuration example for the ultrasonic probe **300** of the present embodiment. The ultrasonic probe **300** includes the probe head **310** and a probe main body **320**, and, as illustrated in FIG. **10**C, the probe head **310** can be attached or detached to/from the probe main body **320**.

[0075] The probe head **310** includes the ultrasonic transducer device **200**, the probe base **250**, the probe housing **240**, and a probe head-side connector **425**.

[0076] The probe main body **320** includes the processing apparatus **330** and a probe main body-side connector **426**. The probe main body-side connector **426** is connected to the probe head-side connector **425**. The probe main body **320** is connected to the ultrasonic diagnostic apparatus main body **401** by the cable **350**.

[0077] Though the present embodiment has been described in greater detail above, it shall be readily understood by a person skilled in the art that there are numerous possible modifications which do not substantially depart from the novel features and effects of the present invention. As such, the modification examples of such description are understood to all also be included in the scope of the present invention. For example, a phrase mentioned at least once in the specification or accompanying drawings together with a different phrase of broader or similar meaning can also be replaced with the different phrase in any portion in the specification or accompanying drawings. Also, the configurations and operations of the ultrasonic transducer device, the probe head, the ultrasonic probe, the electronic machine, and the ultrasonic diagnostic apparatus are also not limited to being what is described in the present embodiment, but rather a variety of modifications can be implemented.

[0078] According to the embodiment, the reinforcement member is fixed to the second surface of the substrate, and thus the strength of the ultrasonic transducer elements and of the substrate can be increased. Also, the plurality of openings can be in communication with each other via the first

groove sections, and the bundling together of the plurality of first groove sections by the second groove sections also makes it possible for the plurality of first groove sections to be in communication with each other.

[0079] According to the embodiment, the reinforcement member may include through holes perforating in the thickness direction of the reinforcement member, by which communication is provided between the second groove sections and an external space, and the plurality of first groove sections, the second groove sections, and the through holes may form ventilation channels by which communication is provided between the openings of the substrate and the external space.

[0080] In so doing, the openings are not sealed off but rather ventilation with the external space can be ensured, and thus it becomes possible to avoid problems such as, for example, any decline in element properties caused by sound pressure being locked in during actual operation, or element damage caused by the air inside the openings swelling and contracting due to temperature changes.

[0081] According to the embodiment, third groove sections which are in communication with the external space but are not in communication with the plurality of first groove sections nor the second groove sections may be provided to a region opposite the surrounding region of the opening region of the substrate, on a surface of the reinforcement member that is bonded to the substrate.

[0082] In so doing, providing the third groove sections makes it possible for air between the reinforcement member and the substrate to escape to the external space when the reinforcement member is being adhered to the substrate, and therefore makes it possible to improve the adhesion between the reinforcement member and the substrate.

[0083] According to the embodiment, the plurality of first groove sections may be provided along a first direction to a region opposing an opening region of the substrate on the surface of the reinforcement member that is bonded to the substrate, the second groove sections may be provided along a second direction intersecting with the first direction to a region opposing a surrounding region of the opening region of the substrate on the surface of the reinforcement member that is bonded to the substrate, and at least one end of each of the first groove sections of the plurality of first groove sections may be joined to the second groove sections in a region opposing the surrounding region of the opening region of the substrate.

[0084] In so doing, the plurality of first groove sections can be provided to the region opposing the opening region of the substrate on the surface of the reinforcement member that is bonded to the substrate, and the second groove sections can be provided to the region surrounding the region to which the plurality of first groove sections are provided. One end of each of the first groove sections of the plurality of first groove sections can then be joined to the second groove sections. So doing makes it possible for the second groove sections to bundle together the plurality of first groove sections.

[0085] According to the embodiment, third groove sections that are in communication with the external space but are not in communication with the plurality of first groove sections nor with the second groove sections may be provided to a region opposing the surrounding region of the opening region of the substrate on the surface of the reinforcement member that is bonded to the substrate, the third groove sections either being provided along the first direction on regions that run along edges of the reinforcement member on the first direction side or edges on the opposite side to the first direction, or being provided along the second direction on regions that run along edges of the reinforcement member on the second direction side or edges on the opposite side to the second direction, and one end of the third groove sections being separated from both the plurality of first groove sections and the second groove sections and the other end of the third groove sections being bonded to the edges of the reinforcement member.

[0086] In so doing, the third groove sections can be arranged along the four edges of the reinforcement member, and thus the adhesion between the reinforcement member and the substrate can be enhanced.

[0087] According to the embodiment, the reinforcement member may be bonded in at least one bonding region to partition wall sections for separating each of the openings of the plurality of openings arranged in an arrayed shape.

[0088] In so doing, constraining the movement of the partition wall sections by the reinforcement member makes it possible to minimize vibration of the partition wall sections. As a result, for example, cross-talk between adjacent ultrasonic transducer elements can be reduced.

[0089] According to the embodiment, each of the ultrasonic transducer elements of the plurality of ultrasonic transducer elements may include a vibrating membrane for covering the opening and a piezoelectric element section provided on the vibrating membrane, the piezoelectric element section including a lower electrode provided on the vibrating membrane, a piezoelectric body membrane provided so as to at least partially cover the lower electrode, and an upper electrode provided so as to at least partially cover the piezoelectric body membrane,

[0090] In so doing, changing the voltage difference between the voltage of the upper electrode and the voltage of the lower electrode causes the piezoelectric body membrane to expand and contract, and causes the vibrating membrane to vibrate, whereby the ultrasonic transducer elements can emit ultrasonic waves.

[0091] According to the embodiment, a probe head includes any of the ultrasonic transducer devices described above.

[0092] According to the embodiment, an ultrasonic probe includes the probe head described above, and a processing apparatus for processing a signal coming from the ultrasonic transducer device.

[0093] According to the embodiment, an electronic machine includes any of the ultrasonic probes described above.

[0094] According to the embodiment, an ultrasonic diagnostic apparatus includes any of the ultrasonic probes described above and a display unit configured to display display image data.

GENERAL INTERPRETATION OF TERMS

[0095] In understanding the scope of the present invention, the term "comprising" and its derivatives, as used herein, are intended to be open ended terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but do not exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The foregoing also applies to words having similar meanings such as the terms, "includ-

ing", "having" and their derivatives. Also, the terms "part," "section," "portion," "member" or "element" when used in the singular can have the dual meaning of a single part or a plurality of parts. Finally, terms of degree such as "substantially", "about" and "approximately" as used herein mean a reasonable amount of deviation of the modified term such that the end result is not significantly changed. For example, these terms can be construed as including a deviation of at least ±5% of the modified term if this deviation would not negate the meaning of the word it modifies.

[0096] While only selected embodiments have been chosen to illustrate the present invention, it will be apparent to those skilled in the art from this disclosure that various changes and modifications can be made herein without departing from the scope of the invention as defined in the appended claims. Furthermore, the foregoing descriptions of the embodiments according to the present invention are provided for illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

1. An ultrasonic transducer device comprising:
a vibrating member;
a first electrode disposed on the vibrating member;
a piezo electric member disposed on the first electrode;
a second electrode disposed on the piezo electric member such that the piezo electric member is located between the first electrode and the second electrode; and
a substrate disposed on the vibrating member, the substrate having a plurality of cavities,
at least one of the plurality of cavities communicating with a different one of the plurality of cavities.

2. The ultrasonic transducer device according to claim **1**, wherein
the plurality of cavities are connected by a first air passage way.

3. The ultrasonic transducer device according to claim **2**, wherein
a plurality of first air passages ways are connected with a second air passage way.

4. The ultrasonic transducer device according to claim **3**, wherein
the second air passage way is connected with an exterior.

5. The ultrasonic transducer device according to claim **3**, wherein
the plurality of first air passage ways and the second air passage way are a plurality of grooves.

6. The ultrasonic transducer device according to claim **3**, wherein
the plurality of first air passage ways are connected with the second air passage way at an end of each of the plurality of first air passage ways.

7. The ultrasonic transducer device according to claim **3**, wherein
both ends of the first air passage way are connected with one of a plurality of second air passage ways.

8. The ultrasonic transducer device according to claim **1**, further comprising
a reinforcement member disposed on a second surface of the substrate, wherein
the second surface of the substrate is an opposite surface of a first surface of the substrate which faces the vibrating member.

9. The ultrasonic transducer device according to claim **8**, wherein
the reinforcement member includes a plurality of first air passage ways connecting the plurality of cavities, and a second air passage way bundling the plurality of first air passage ways, and a through hole connecting the second air passage way and an exterior.

10. The ultrasonic transducer device according to claim **8**, wherein
the reinforcement member includes a third air passage way that is connected with an exterior at a peripheral region of the reinforcement member.

11. The ultrasonic transducer device according to claim **8**, wherein
a plurality of first air passage ways are disposed along a first direction,
a second air passage way is disposed along a second direction which is different from the first direction at a peripheral region of the reinforcement member.

12. The ultrasonic transducer device according to claim **11**, wherein
the reinforcement member includes a third air passage way which is connected with an exterior without being connected with the first air passage ways or the second air passage way.

13. The ultrasonic transducer device according to claim I, wherein
the plurality of cavities are arranged in an arrayed shape.

14. The ultrasonic transducer device according to claim **4**, wherein
the exterior communicates with an atmosphere.

15. A probe head comprising the ultrasonic transducer device according to claim **1**.

16. An ultrasonic probe comprising:
the probe head according to claim **15**; and
a processing apparatus configured to process a signal coming from the probe head.

17. An electronic machine, comprising the ultrasonic probe according to claim **16**.

18. An ultrasonic diagnostic apparatus comprising:
the ultrasonic probe according to claim **16**; and
a display device configured to display an image made based on the data signal coming from the probe head.

19. An ultrasonic transducer device comprising:
a vibrating member;
a first electrode and a second electrode configured to drive the vibrating member;
a plurality of cavities facing the vibrating member;
a plurality of first passage ways connecting the plurality of cavities; and
a second passage way bundling the plurality of first passage ways,
the second passage way communicating with an exterior.

20. The ultrasonic transducer device according to claim **19**, wherein
the vibrating member is driven by a piezo electric member.

21. The ultrasonic transducer device according to claim **20**, wherein
the first electrode, the second electrode and the piezo electric member are arranged at one side of the vibrating member, and the plurality of cavities are arranged at an opposite side of the vibrating member.

* * * * *

专利名称(译)	超声波换能器装置，探头，超声波探头，电子机器和超声波诊断装置		
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摘要(译)

一种超声波换能器装置，包括基板，在基板上布置有多个开口;多个超声换能器元件，每个超声换能器元件设置在基板的第一表面上的多个开口的每个开口中;固定到基板的第二表面的构件，其是基板的第一表面的相对侧上的表面。所述构件设置有多个第一凹槽部分和用于将所述多个第一凹槽部分捆扎在一起的第二凹槽部分。