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(54) ULTRASONIC PROBE AND METHOD OF PREPARING ULTRASONIC PROBE

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(57) **ABSTRACT**

Provided is an ultrasonic probe possessing signal lines for which generation of the acoustic crosstalk between piezoelectric elements to each other constituting a piezoelectric element array, and also provided is a method of preparing the ultrasonic probe. Disclosed is an ultrasonic probe comprising a first piezoelectric element array in which first piezoelectric elements each as a both-sided electrodes-providing piezoelectric element are two-dimensionally arrayed; a second piezoelectric element array layered on the first piezoelectric element array; an acoustic separation section provided between the first piezoelectric elements to each other, arrayed in the first piezoelectric element array; and a signal line possessing a conductive layer coated on an outer circumferential surface of a core material and the core material having an acoustic impedance nearly equal to another acoustic impedance of the acoustic separation section, the signal line connected to the second electrode by passing through the acoustic separation section.

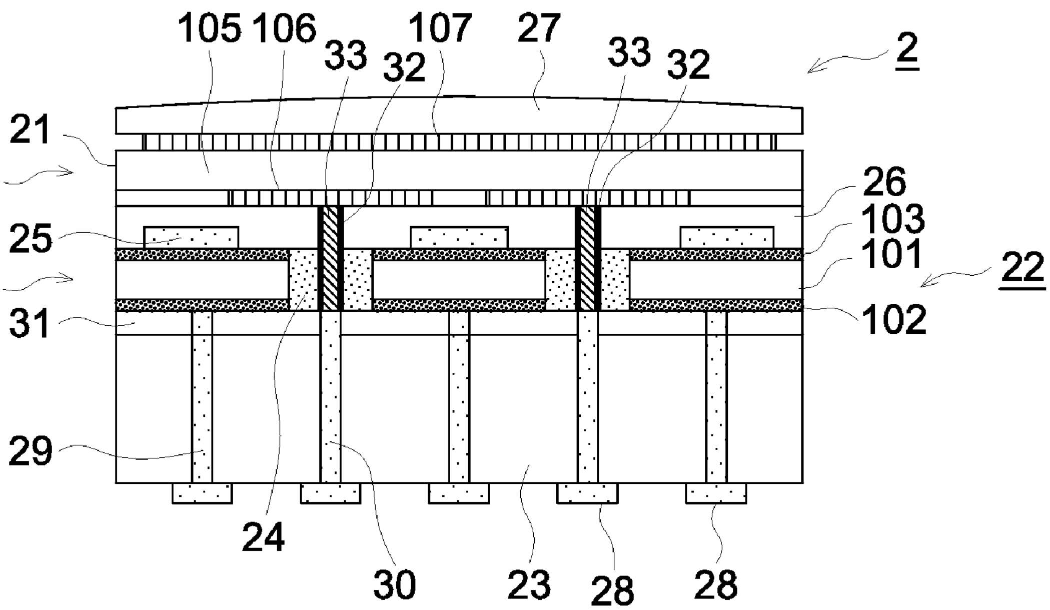


FIG. 1

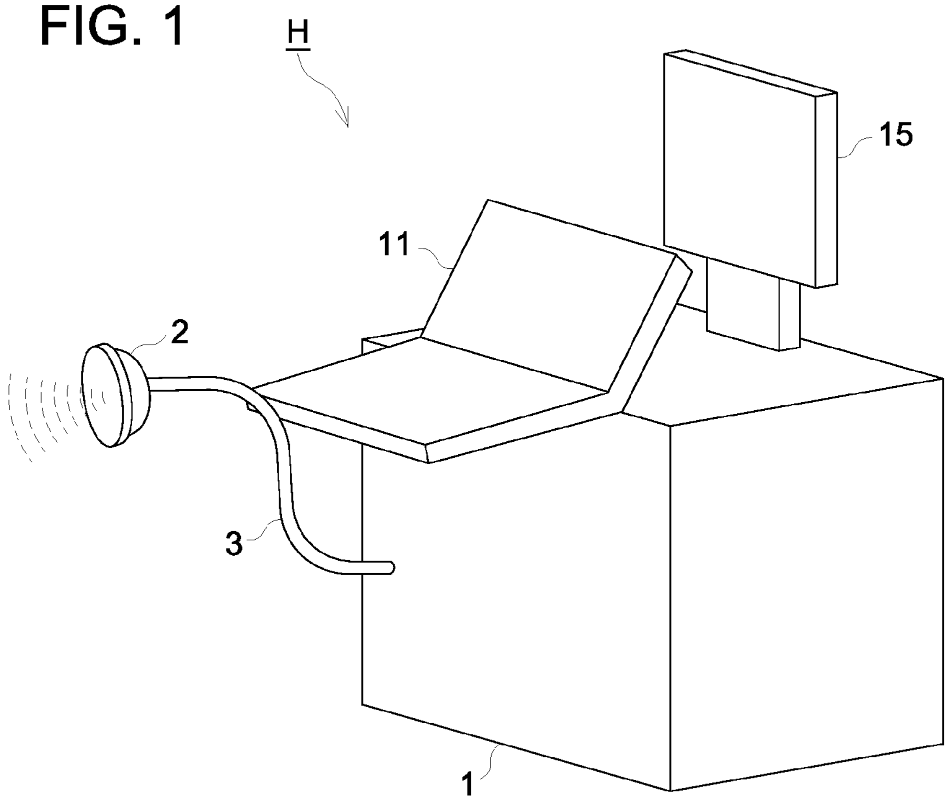

H
15
11
2
3
1

FIG. 2

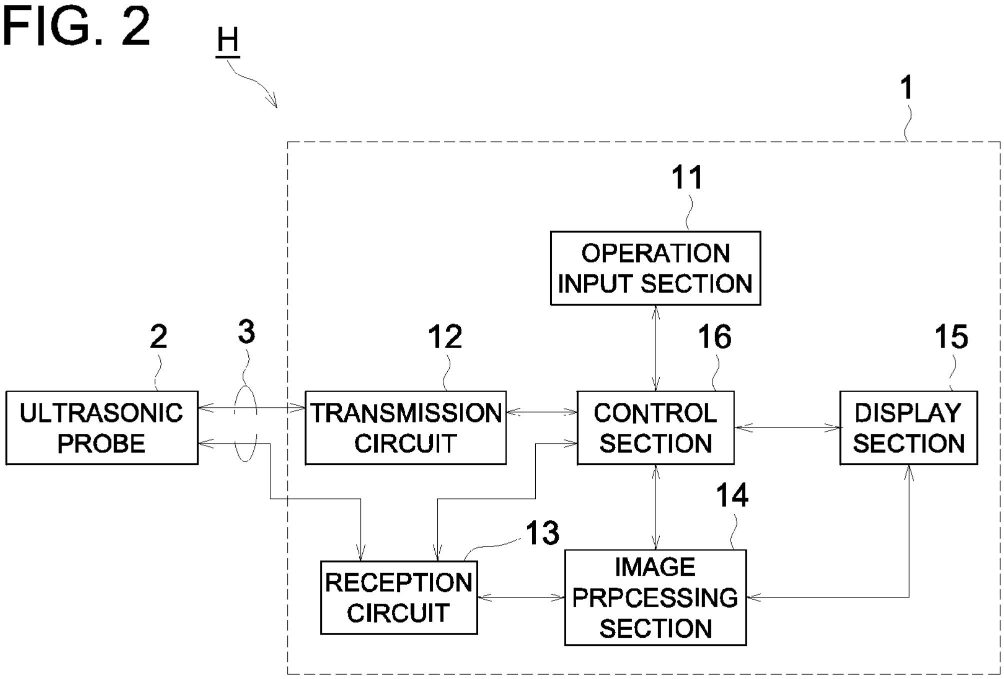

H
1
11
OPERATION INPUT SECTION
2
3
12
16
15
ULTRASONIC PROBE
TRANSMISSION CIRCUIT
CONTROL SECTION
DISPLAY SECTION
14
13
RECEPTION CIRCUIT
IMAGE PRPCESSING SECTION

FIG. 3

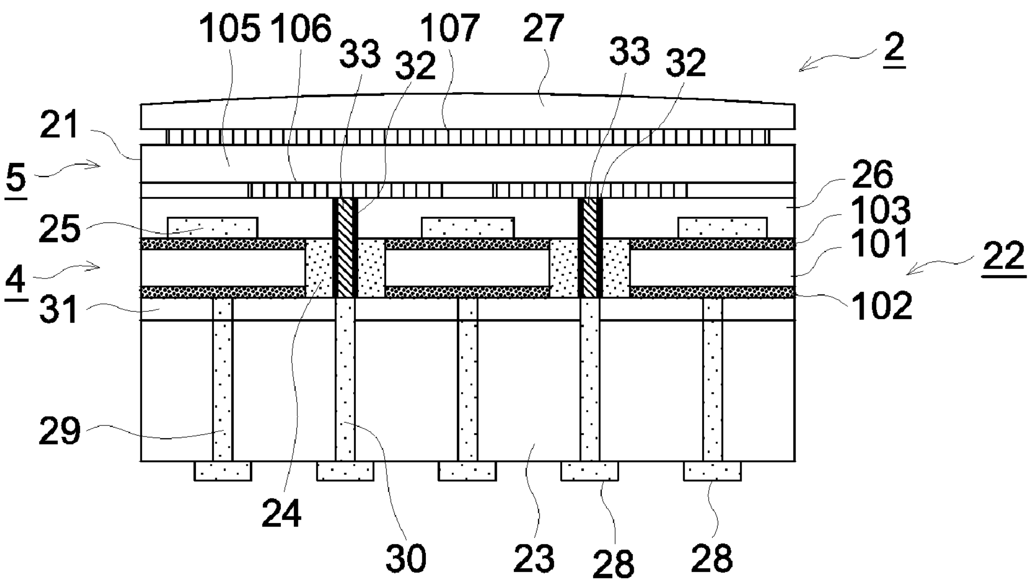

105
106
33
32
107
27
33
32
2
21
5
26
103
25
101
4
22
31
102
29
24
30
23
28
28

FIG. 4

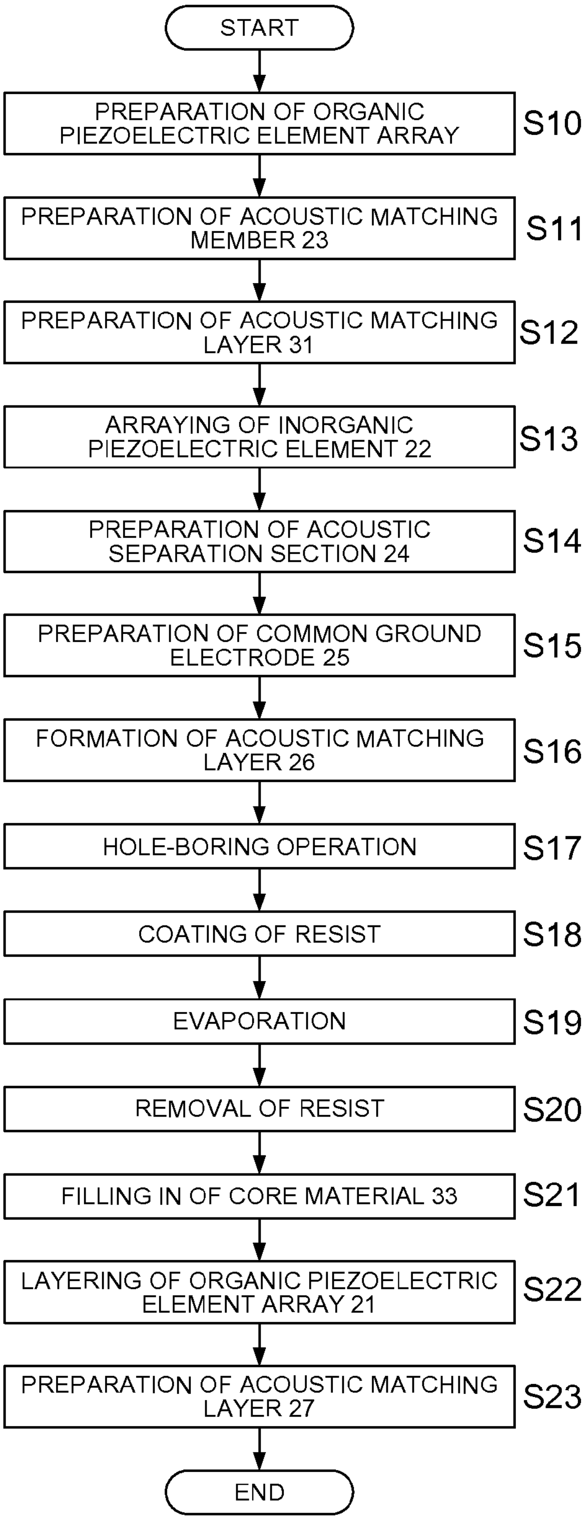

START
PREPARATION OF ORGANIC PIEZOELECTRIC ELEMENT ARRAY
S10
PREPARATION OF ACOUSTIC MATCHING MEMBER 23
S11
PREPARATION OF ACOUSTIC MATCHING LAYER 31
S12
ARRAYING OF INORGANIC PIEZOELECTRIC ELEMENT 22
S13
PREPARATION OF ACOUSTIC SEPARATION SECTION 24
S14
PREPARATION OF COMMON GROUND ELECTRODE 25
S15
FORMATION OF ACOUSTIC MATCHING LAYER 26
S16
HOLE-BORING OPERATION
S17
COATING OF RESIST
S18
EVAPORATION
S19
REMOVAL OF RESIST
S20
FILLING IN OF CORE MATERIAL 33
S21
LAYERING OF ORGANIC PIEZOELECTRIC ELEMENT ARRAY 21
S22
PREPARATION OF ACOUSTIC MATCHING LAYER 27
S23
END

FIG. 5a

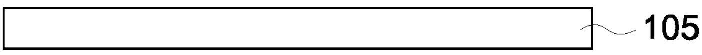


FIG. 5b

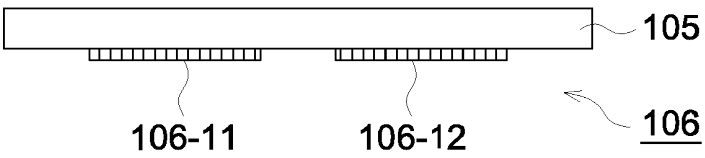


FIG. 5c

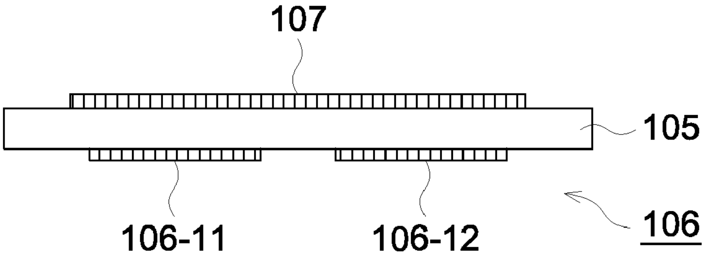


FIG. 5d

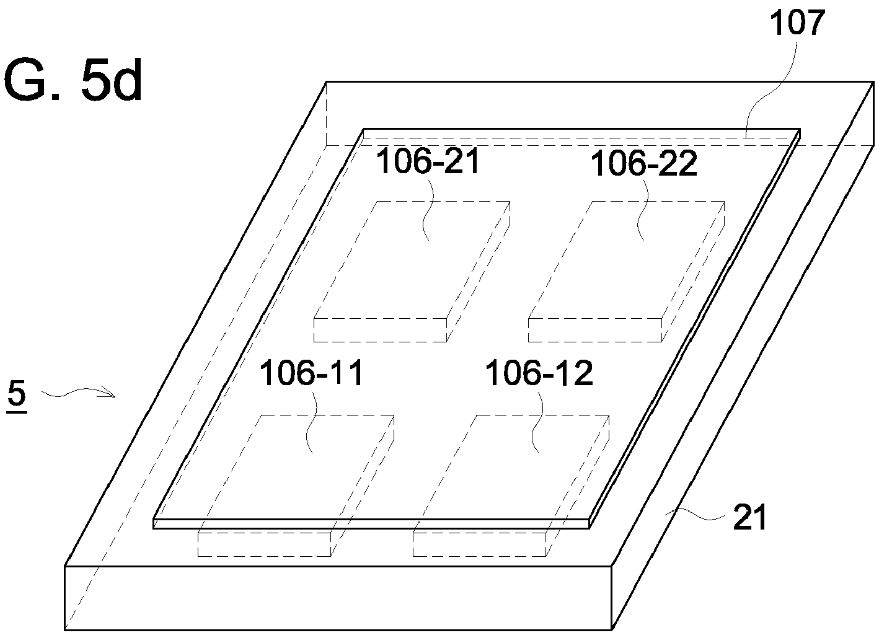


FIG. 6a

FIG. 6b

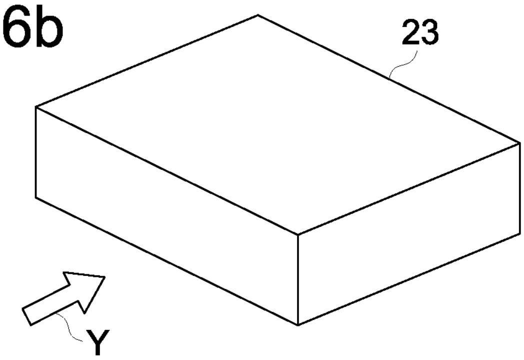


FIG. 7a

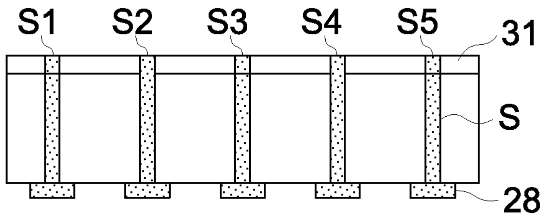


FIG. 7b

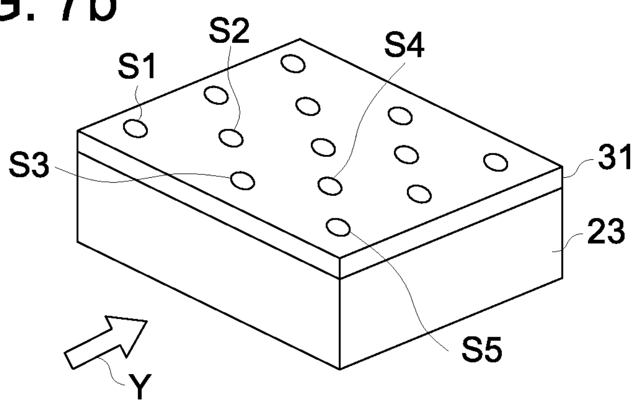


FIG. 8a

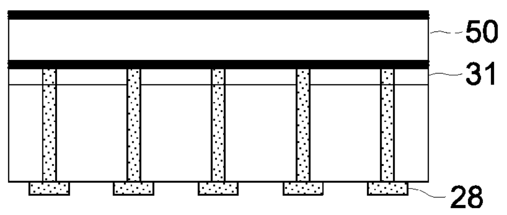


FIG. 8b

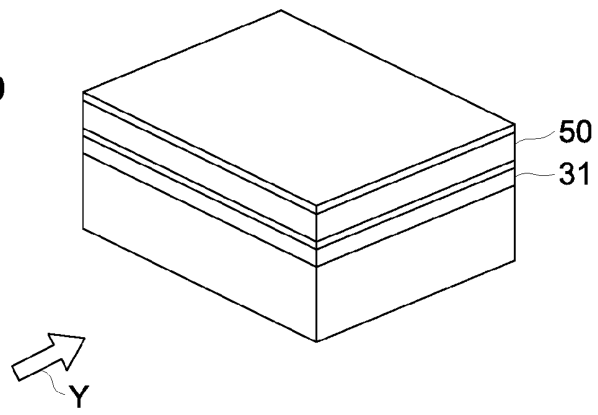


FIG. 9a

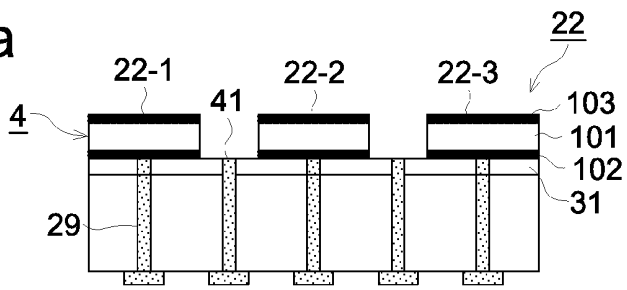


FIG. 9b

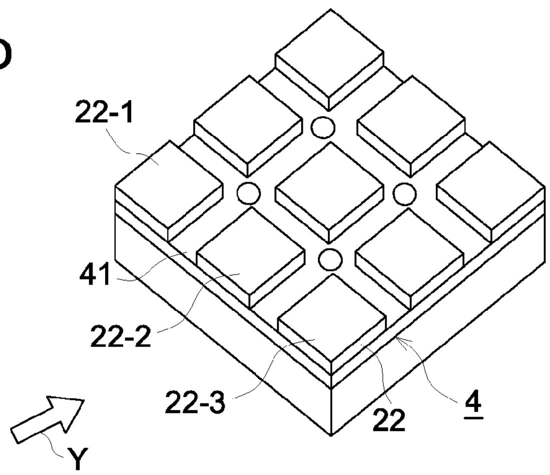


FIG. 10a

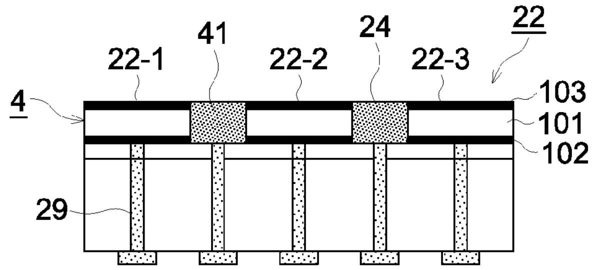


FIG. 10b

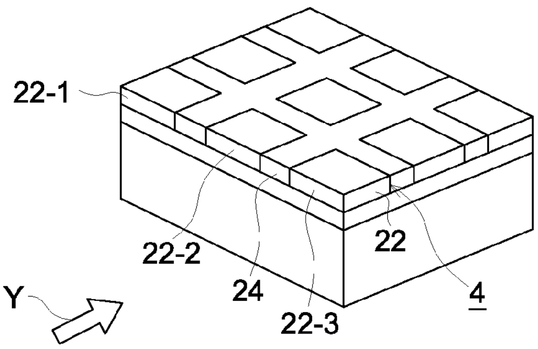


FIG. 11a

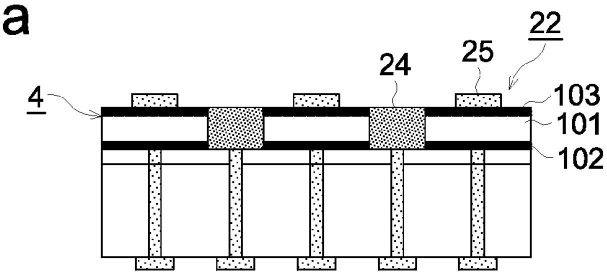


FIG. 11b

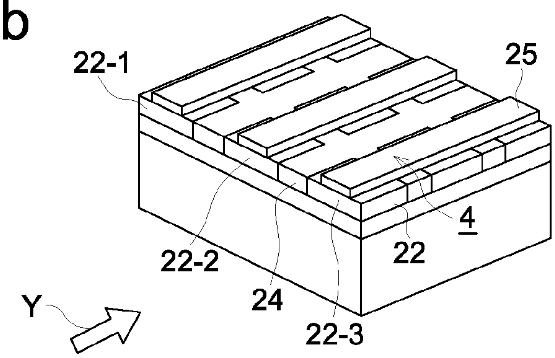


FIG. 12a

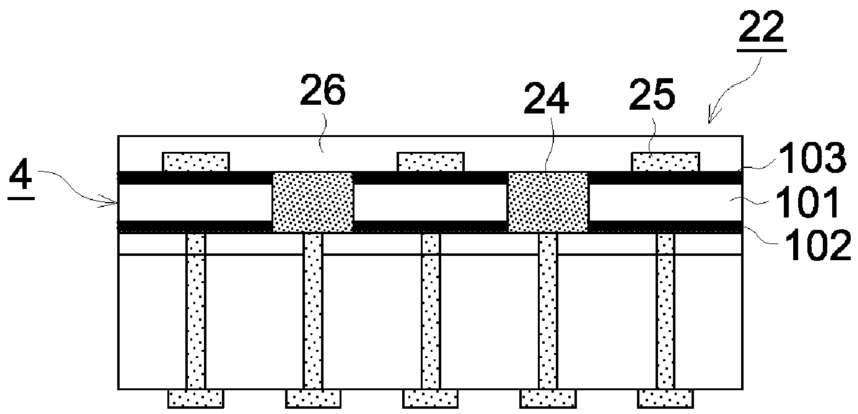


FIG. 12b

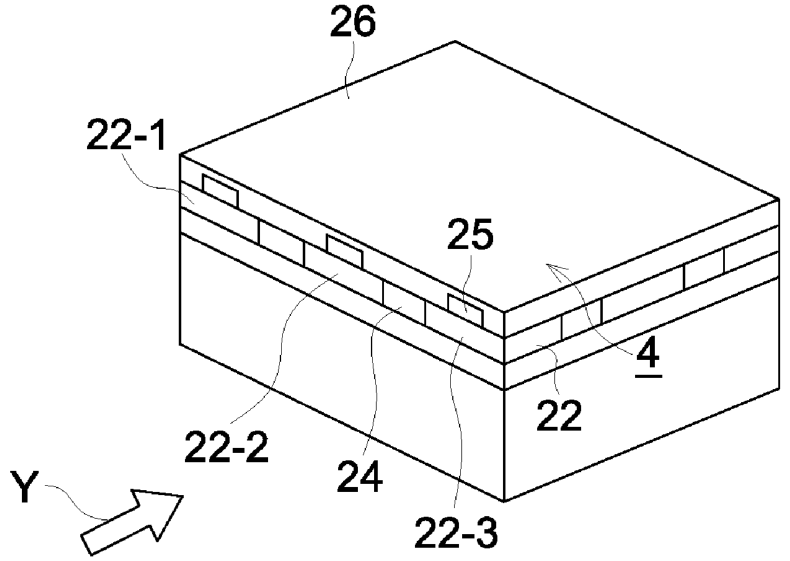


FIG. 13a

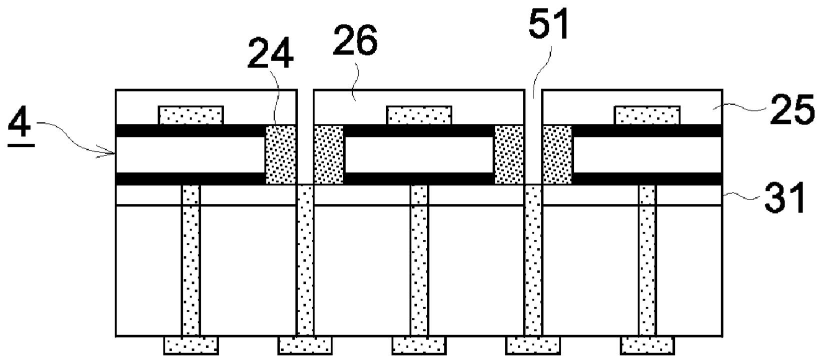


FIG. 13b

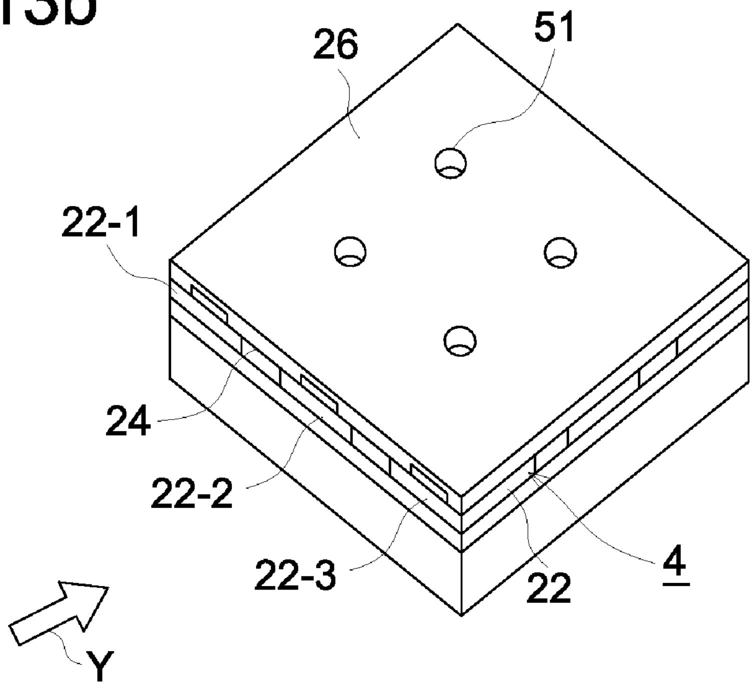


FIG. 14a

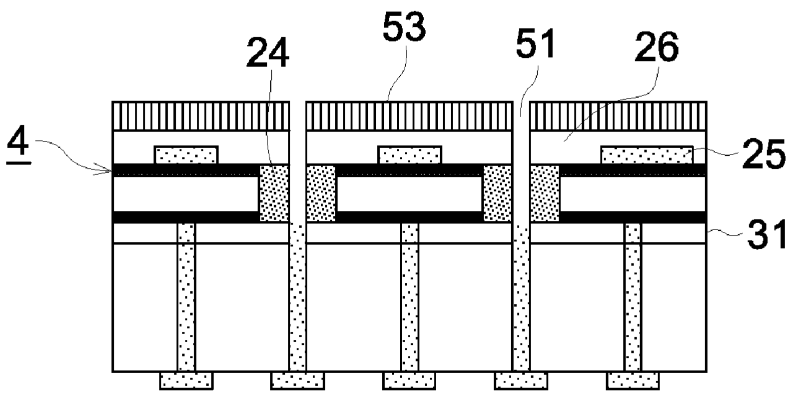


FIG. 14b

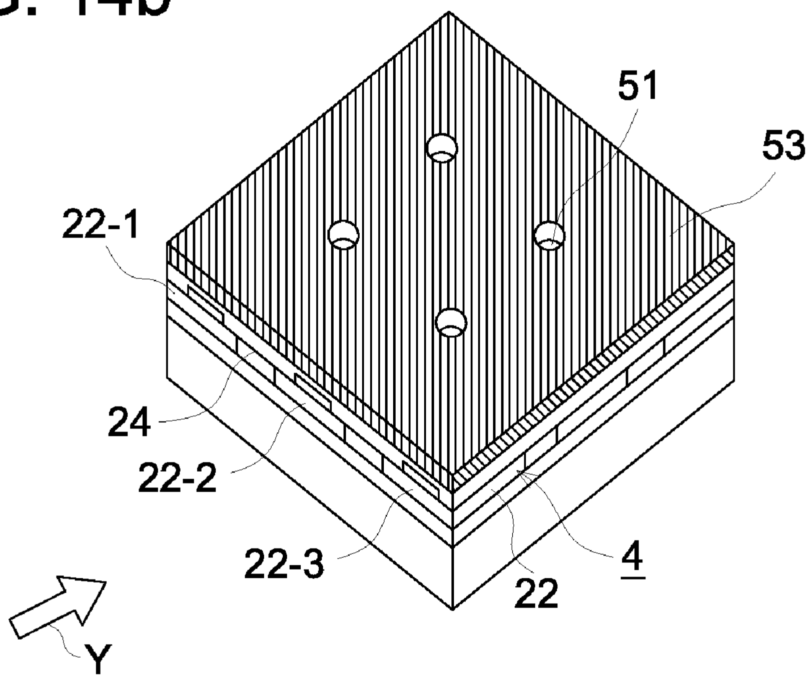


FIG. 15

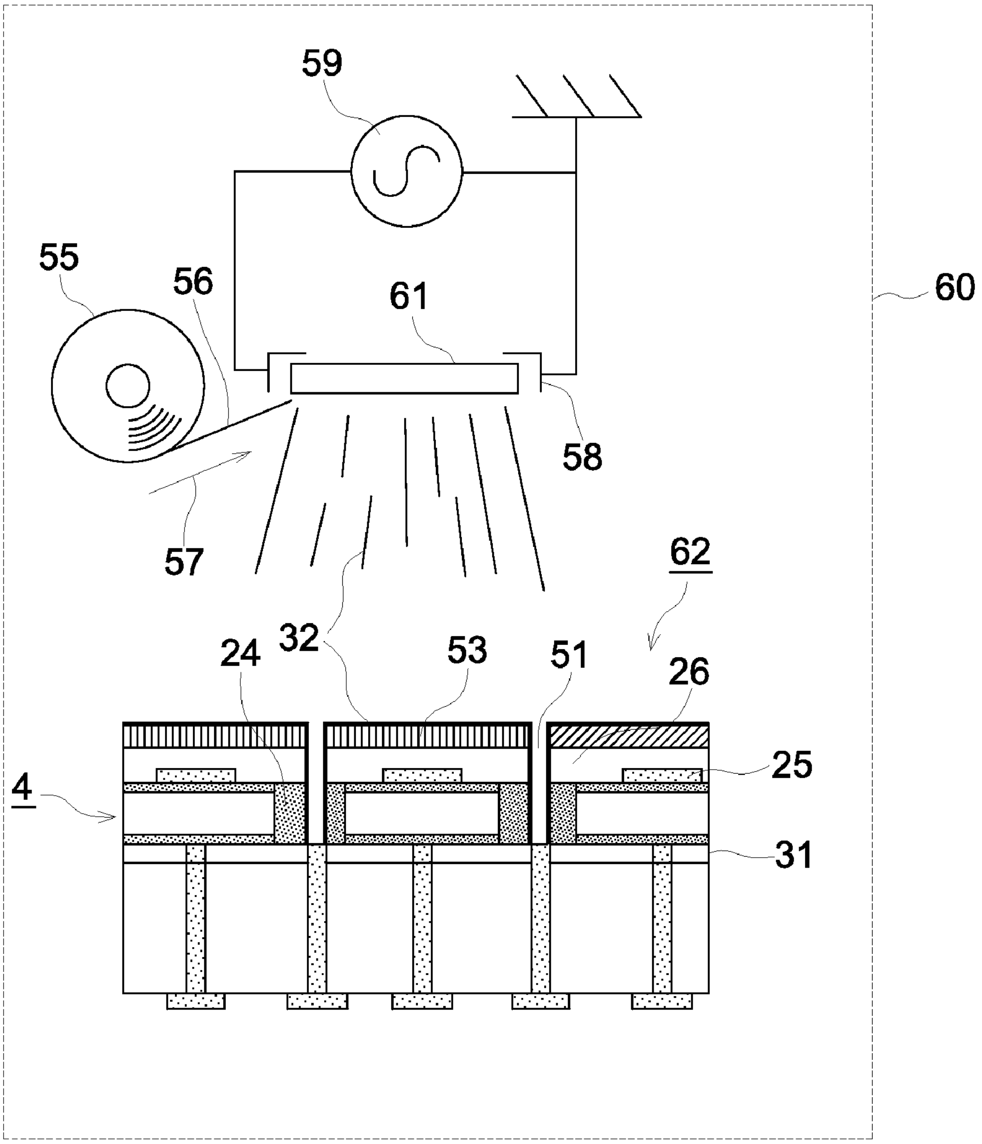


FIG. 16a

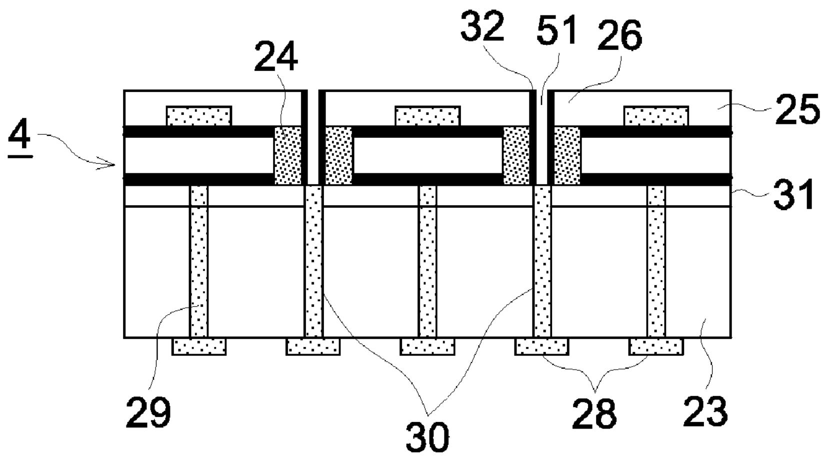


FIG. 16b

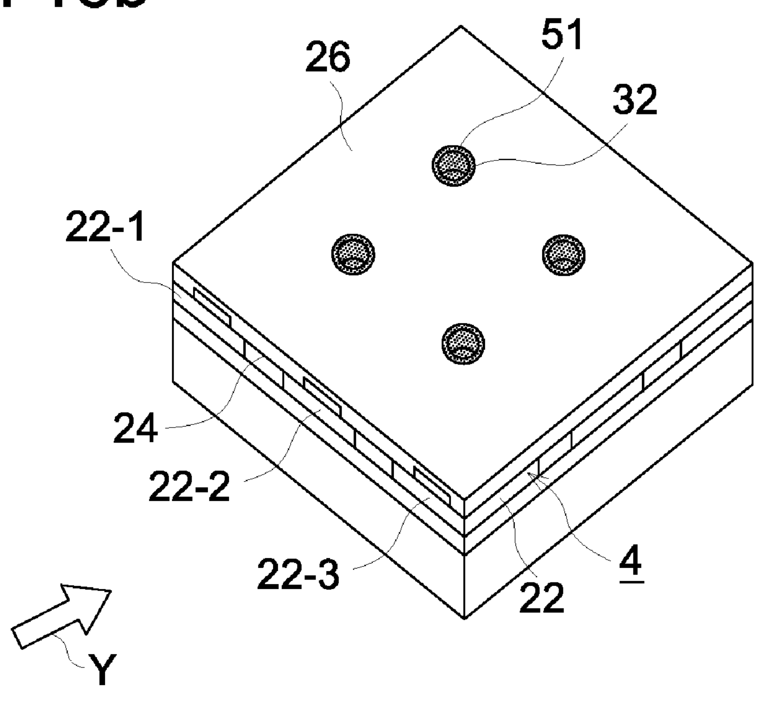


FIG. 17a

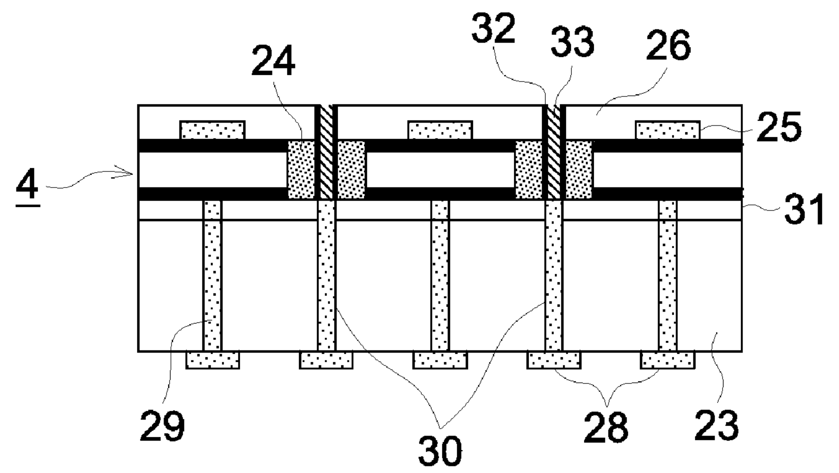


FIG. 17b

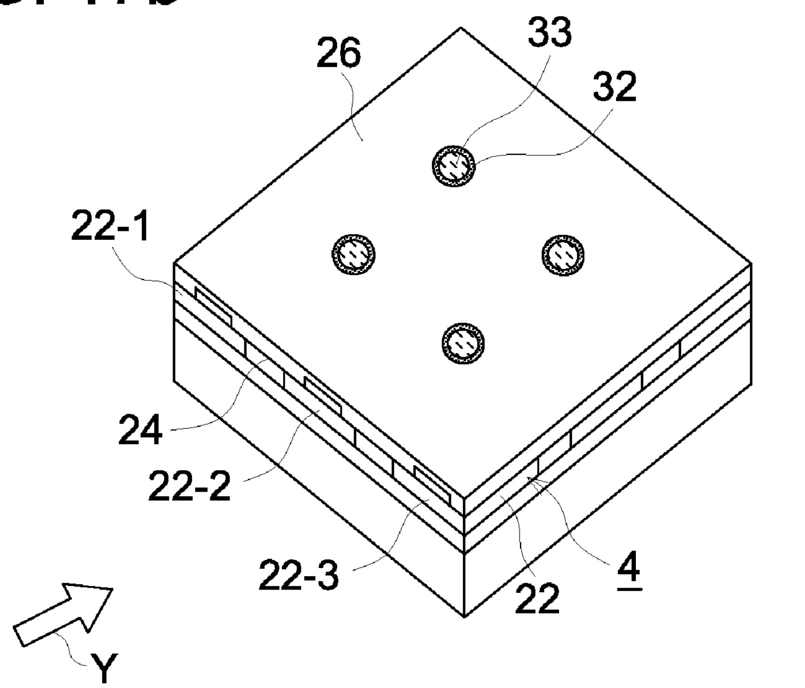


FIG. 18a

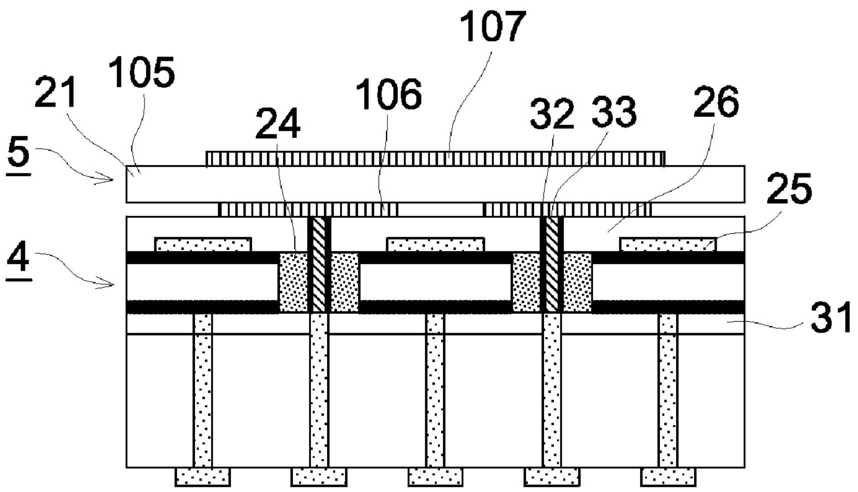


FIG. 18b

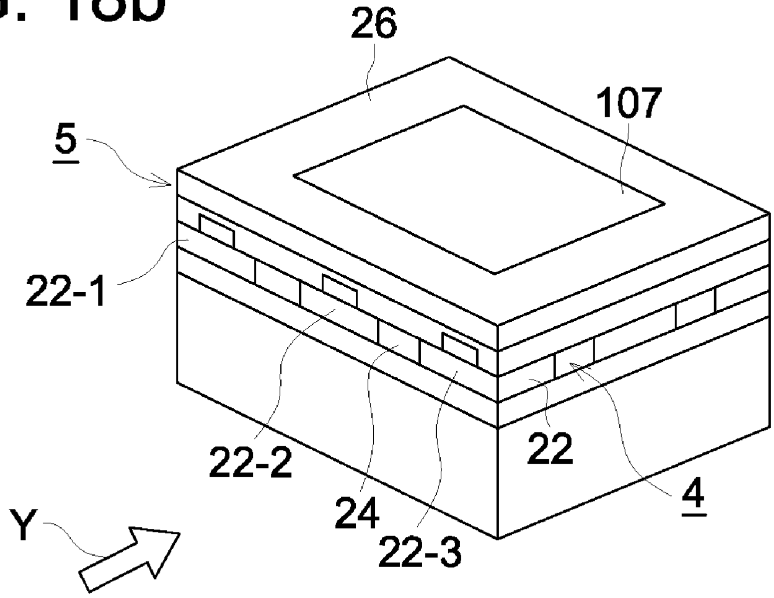


FIG. 19a

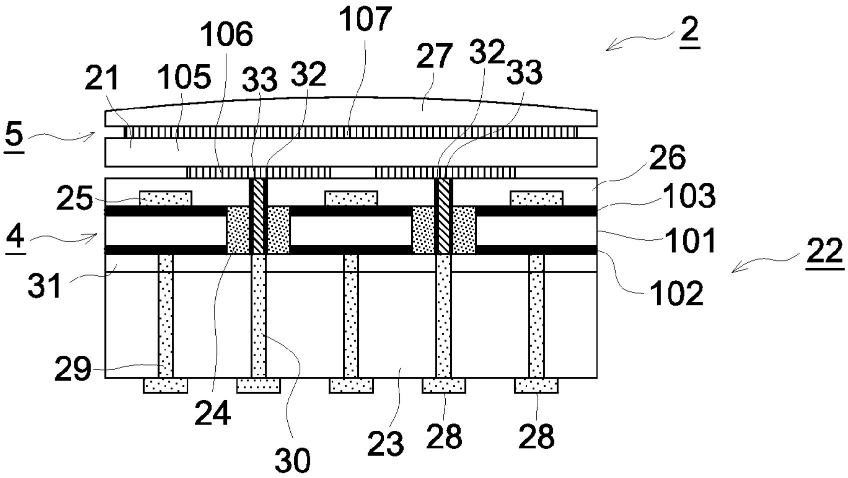


FIG. 19b

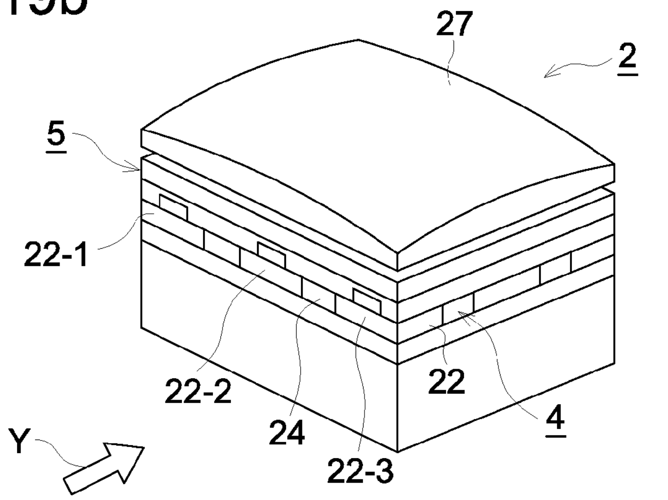


FIG. 20

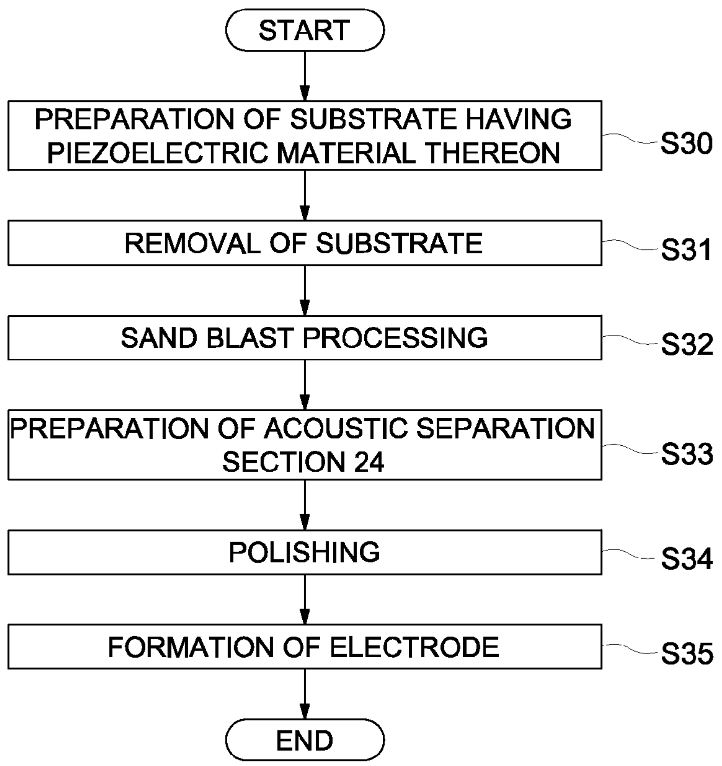


FIG. 21a

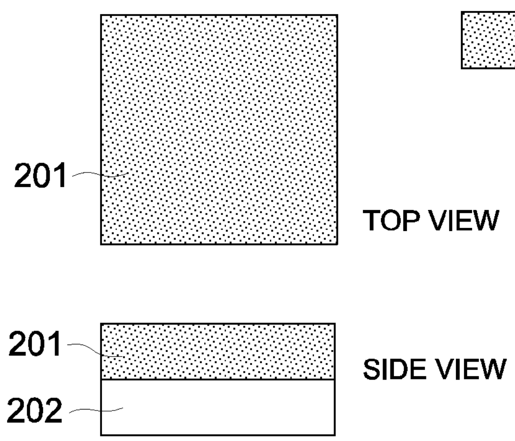


FIG. 21b

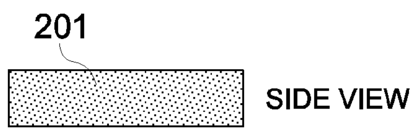


FIG. 22a

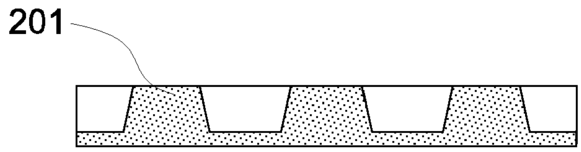


FIG. 22b

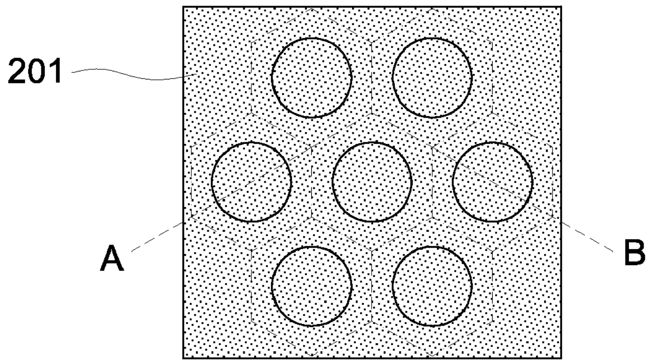


FIG. 23a

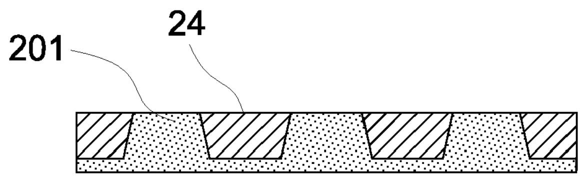


FIG. 23b

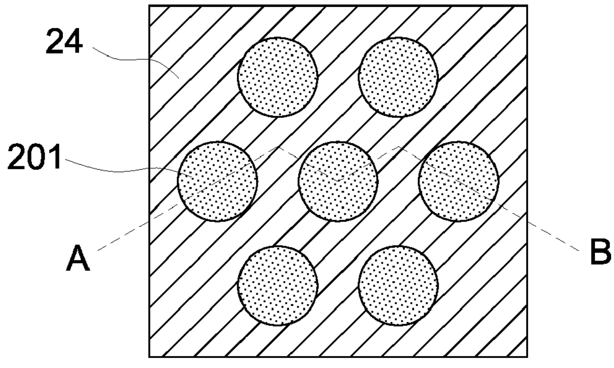


FIG. 24a

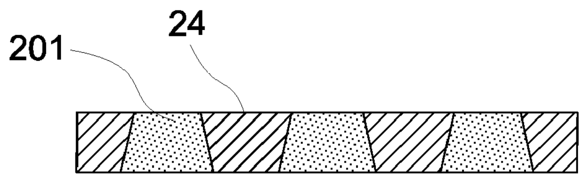


FIG. 24b

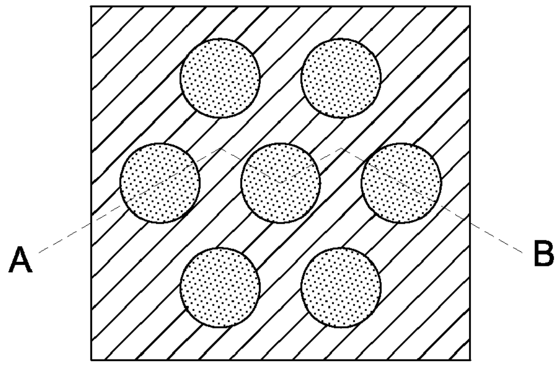


FIG. 25a

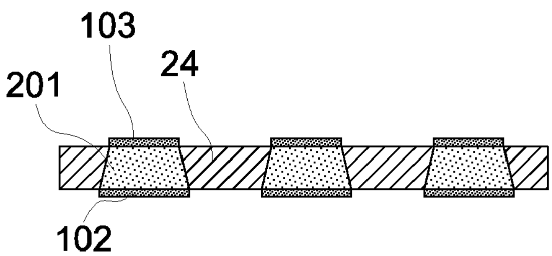
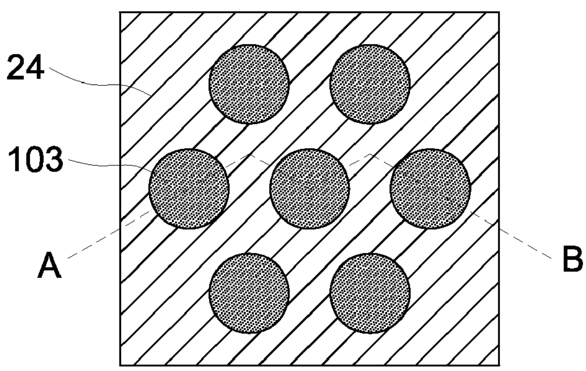


FIG. 25b



ULTRASONIC PROBE AND METHOD OF PREPARING ULTRASONIC PROBE

TECHNICAL FIELD

[0001] The present invention relates to an ultrasonic probe suitably used for ultrasonic apparatuses such as an ultrasonic diagnosis apparatus and so forth.

BACKGROUND

[0002] The ultrasonic diagnosis apparatus has been widely used for cross-sectional image-visualization of blood flow in the body and body tissues. The ultrasonic diagnosis apparatus transmits ultrasonic waves to body tissues, employing an ultrasonic probe, and receives reflection echo produced by the tissue interface impedance difference by narrowing the ultrasonic waves down to a fine beam to obtain ultrasonic wave images via image formation of tissues in the body.

[0003] The ultrasonic diagnosis apparatus conventionally places an array type probe in which piezoelectric elements are one-dimensionally arrayed, in an ultrasonic probe, and two-dimensionally scans with ultrasonic waves to form body cross-sectional images.

[0004] Appearance of a 2D array type probe equipped with a piezoelectric element army in which piezoelectric elements are two-dimensionally arrayed has recently been seen. Specifically, in order to expand the reception range, proposed is an ultrasonic probe in which the first piezoelectric element array to receive fundamental waves and the second piezoelectric element array to receive harmonic waves among waves reflected from the object (refer to Patent Document 1).

[0005] It is difficult to connect signal lines to piezoelectric elements constituting each piezoelectric element array, when two piezoelectric element arrays of the first piezoelectric element army and the second piezoelectric element array have been provided. In contrast, in order to reduce the space where signal lines are occupied, proposed is a technique by which the signal lines passing through are wired in an acoustic damping member provided on the back side of a piezoelectric element (refer to Patent Document 2).

PRIOR ART DOCUMENT

Patent Document

[0006] Patent Document 1: Japanese Patent Open to Public Inspection (O.P.I.) Publication No. 11-276478

[0007] Patent Document 2: Japanese Patent O.P.I. Publication No. 2000-166923

DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

[0008] When using the technique disclosed in Patent Document 2, since an acoustic impedance of the signal line is larger than another impedance of the acoustic damping member, ultrasonic waves are reflected in the region between the acoustic damping member and the signal line, resulting in generation of an acoustic crosstalk to a piezoelectric element.

[0009] Specifically in the technique disclosed in Patent Document 1, when signal lines from piezoelectric elements constituting the second piezoelectric element array are designed to be wired by passing through the interface between piezoelectric elements of the first piezoelectric element array to each other, a signal line of high acoustic impedance is to be present between acoustic separation materials each between piezoelectric elements constituting the first piezoelectric element array to each other, whereby crosstalk is generated to the first piezoelectric element, resulting in deterioration of performance of the ultrasonic probe.

[0010] It is an object of the present invention to provide an ultrasonic probe possessing signal lines for which generation of the acoustic crosstalk between piezoelectric elements to each other constituting a piezoelectric element array is inhibited, and a method of preparing the ultrasonic probe.

Means to Solve the Problems

[0011] The foregoing object is accomplished by the following structures.

(Structure 1) An ultrasonic probe comprising a first piezoelectric element array in which first piezoelectric elements each as a both-sided electrodes-providing piezoelectric element are two-dimensionally arrayed; a second piezoelectric element array layered on the first piezoelectric element array, in which second piezoelectric elements are two-dimensionally arrayed, a first electrode is placed on a second piezoelectric element surface on an opposite side of the first piezoelectric element array, and a second electrode is placed on another second piezoelectric element surface on a side of the first piezoelectric element array, an acoustic separation section provided between the first piezoelectric elements to each other, arrayed in the first piezoelectric element array; and a signal line comprising a conductive layer coated on an outer circumferential surface of a core material and the core material having an acoustic impedance nearly equal to another acoustic impedance of the acoustic separation section, the signal line connected to the second electrode by passing through the acoustic separation section.

[0012] (Structure 2) The ultrasonic probe of Structure 1, wherein an area of each of the first piezoelectric elements to which a voltage is applied is different from an area of each of the second piezoelectric elements to which a voltage is applied.

[0013] (Structure 3) The ultrasonic probe of Structure 1 or 2, wherein the number of the first piezoelectric elements arrayed in the first piezoelectric element array is different from the number of the second piezoelectric elements arrayed in the second piezoelectric element army.

[0014] (Structure 4) A method of preparing an ultrasonic probe, comprising the steps of forming a through-hole in an acoustic separation section provided between the first piezoelectric elements to each other in a first piezoelectric element array in which first piezoelectric elements each as a both-sided electrodes-providing piezoelectric element are two-dimensionally arrayed; forming a conductive layer on a through-hole inner circumferential surface so as to form a through-hole inner spacing; and filling a core material having an acoustic impedance nearly equal to another acoustic impedance of the acoustic separation section in the through-hole inner spacing.

Effect of the Invention

[0015] Provided can be an ultrasonic probe possessing signal lines for which generation of the acoustic crosstalk between piezoelectric elements to each other constituting a piezoelectric element array is inhibited without producing cost rises while maintaining the ultrasonic probe in size, and a method of preparing the ultrasonic probe can also be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a diagram showing the external view configuration of ultrasonic diagnosis apparatus H in an embodiment.

[0017] FIG. **2** is a block diagram showing electrical constituent parts of ultrasonic diagnosis apparatus H in an embodiment.

[0018] FIG. **3** is a cross-sectional diagram showing constituent parts of ultrasonic probe **2** installed in an ultrasonic diagnosis apparatus in an embodiment.

[0019] FIG. **4** shows a preparation flowchart in a method of preparing ultrasonic probe **2**.

[0020] FIGS. **5***a*, **5***b*, **5***c* and **5***d* each show a schematic diagram in a method of preparing organic piezoelectric element array **5**.

[0021] FIGS. **6***a* and **6***b* each show a schematic diagram of acoustic damping member **23**.

[0022] FIGS. **7***a* and **7***b* each show a schematic diagram of acoustic matching layer **31**.

[0023] FIGS. **8***a* and **8***b* each show a schematic diagram of a work body in which flat plate-shaped double-sided electrodes-providing inorganic piezoelectric element **50** provided on both surfaces of the inorganic piezoelectric element is instilled.

[0024] FIGS. **9***a* and **9***b* each show a schematic diagram of a work body in which inorganic piezoelectric element **22** is arrayed.

[0025] FIGS. **10***a* and **10***b* each show a schematic diagram of a work body in which acoustic separation section **24** is formed.

[0026] FIGS. **11***a* and **11***b* each show a schematic diagram of a work body in which common ground electrode **25** is formed.

[0027] FIGS. **12***a* and **12***b* each show a schematic diagram of a work body in which acoustic matching layer **26** is formed.

[0028] FIGS. **13***a* and **13***b* each show a schematic diagram of a bored work body.

[0029] FIGS. **14***a* and **14***b* each show a schematic diagram of a work body in which photoresist is formed.

[0030] FIG. **15** shows a schematic diagram of a process by which metal constituting conductive member **32** is evaporated on the work body.

[0031] FIGS. **16***a* and **16***b* each show a schematic diagram of a work body from which the metal constituting conductive member **32** on photoresist, together with the photoresist, is removed.

[0032] FIGS. **17***a* and **17***b* each show a schematic diagram of a work body in which core material **33** is formed in laser processing hole **51**.

[0033] FIGS. **18***a* and **18***b* each show a schematic diagram of a work body possessing a layered organic piezoelectric element array.

[0034] FIGS. **19***a* and **19***b* each show a schematic diagram of a work body in which acoustic matching layer **27** is formed.

[0035] FIG. **20** shows a preparation flowchart for a method of preparing the first piezoelectric element array **4**.

[0036] FIGS. **21***a* and **21***b* each show a schematic diagram of a substrate having a piezoelectric material thereon.

[0037] FIGS. **22***a* and **22***b* each show a schematic diagram of a work body having been subjected to sandblast processing.

[0038] FIGS. **23***a* and **23***b* each show a schematic diagram of a work body in which acoustic separation section **24** is formed.

[0039] FIGS. **24***a* and **24***b* each show a schematic diagram of a work body in which the acoustic separation section is exposed onto both surfaces of the acoustic separation section via polishing.

[0040] FIGS. **25***a* and **25***b* each show a schematic diagram of a work body in which electrodes **102** and **103** are formed on both surfaces of PZT **201**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0041] Next, an embodiment of the present invention will be described referring to figures, but the present invention is not limited thereto. In addition, constituent elements to which the same numerals are attached represent the same constituent elements as to each other, and descriptions thereof are omitted.

(Each Constituent Element and Operation of Ultrasonic Diagnosis Apparatus and Ultrasonic Probe)

[0042] FIG. **1** is a diagram showing the external view configuration of an ultrasonic diagnosis apparatus in an embodiment. FIG. **2** is a block diagram showing electrical constituent parts of the ultrasonic diagnosis apparatus in an embodiment. FIG. **3** is a cross-sectional diagram showing constituent parts of an ultrasonic probe installed in an ultrasonic diagnosis apparatus in an embodiment.

[0043] As shown in FIG. **1**, ultrasonic diagnosis apparatus H is connected to ultrasonic probe **2** not only to transmit ultrasonic waves (ultrasonic wave signal) to an object such as a body omitted in the figure or the like but also to receive reflected waves (echo, or ultrasonic wave signal) as ultrasonic waves reflected at the object, via cable **3**, and transmits ultrasonic waves to ultrasonic probe **2** with respect the object by transmitting signals as electrical signals into ultrasonic probe **2** via cable **3**. In addition, the diagnosis apparatus possesses ultrasonic diagnosis apparatus main body **1** to image-visualize the internal situation inside the object as an ultrasonic wave image, based on reception signals as electrical signals produced in ultrasonic probe **2** in response to ultrasonic waves as reflected waves from the inside of the object which are received with ultrasonic probe **2**.

[0044] As shown in FIG. **2**, for example, ultrasonic diagnosis apparatus main body **1** possesses operation input section **11** to input data such as a command to order the diagnosis-start and private information of the object; transmission circuit **12** to make ultrasonic probe **2** to generate ultrasonic waves by supplying the transmission signal as an electrical signal into ultrasonic probe **2** via cable **3**; reception circuit **13** to receive the reception signal as an electrical signal from ultrasonic Probe **2** via cable **3**; image processing section **14** to produce images (ultrasonic wave images) of the internal situation within the object, based on the reception signal received at reception circuit **13**; display section **15** to display images of the internal situation within the object which are produced at image processing section **14**; and control section **16** to totally control ultrasonic diagnosis apparatus H by controlling the foregoing operation input section **11**, transmission circuit **12**, reception circuit **13**, image processing section **14** and display section **15**, depending on each of functions thereof.

[0045] Ultrasonic probe (ultrasonic wave probe) **2** possesses an inorganic piezoelectric element and an organic piezoelectric element. The inorganic piezoelectric element is made of an inorganic piezoelectric material, and can convert signals mutually between electrical signals and ultrasonic wave signals by utilizing a piezoelectric phenomenon. The organic piezoelectric element is made of an organic piezoelectric material, and can convert signals mutually between electrical signals and ultrasonic wave signals by utilizing the piezoelectric phenomenon.

[0046] Ultrasonic probe **2** having such a structure can be exemplified, for example, as ultrasonic probe **2** having a structure as shown in FIG. **3**.

[0047] Ultrasonic probe **2** possesses flat plate-shaped acoustic damping member **23**; acoustic matching layer **31** layered on acoustic matching member **23**; inorganic piezoelectric element array (the first piezoelectric element army) **4** composed of plural inorganic piezoelectric elements (the first piezoelectric elements) **22** layered to support on one main surface of acoustic damping member **23**; acoustic separation section **24** prepared by filling in acoustic separation material in the spacing of inorganic piezoelectric element **22**-to-inorganic piezoelectric element **22**; common ground electrode **25** layered on each of plural inorganic piezoelectric elements **22**; acoustic matching layer **26** layered on common ground electrode **25**; organic piezoelectric element array (the second piezoelectric element array) **5** fitted with organic piezoelectric element **21** (the second piezoelectric element) layered on acoustic matching layer **26**; acoustic matching layer **27** layered on organic piezoelectric element **21**; the first signal line **29** with which conductive pad **28** to receive electrical signals from the outside is connected to the electrode of inorganic piezoelectric element **22**; the second signal line **30** with which conductive pad **28** to receive electrical signals from the outside is connected to the electrode of the organic piezoelectric element; and so forth.

[0048] Acoustic damping member **23** made of a material to absorb ultrasonic waves absorbs ultrasonic waves radiated in the direction of acoustic damping member **23** from plural inorganic piezoelectric elements **22**.

[0049] Acoustic matching layer **31** has a medium acoustic impedance between an acoustic impedance of acoustic damping member **23** and another acoustic impedance of each of inorganic piezoelectric elements **22**, and the acoustic impedance is matched between acoustic damping member **23** and inorganic piezoelectric elements **22**.

[0050] Each of inorganic piezoelectric elements **22** possesses electrodes **102** and **103** provided on both surfaces of piezoelectric element **101** made of an inorganic piezoelectric material, which are opposed to each other. Plural inorganic piezoelectric elements **22** are two-dimensionally arrayed to each other, spacing at the predetermined intervals in planar view, and placed on acoustic damping member **23** as the first piezoelectric element array.

[0051] Plural inorganic piezoelectric elements **22** may be arrayed so as to receive ultrasonic waves as reflected waves, but in the case of ultrasonic probe **2** and ultrasonic diagnosis apparatus H, they are arranged so as to transmit ultrasonic waves. More specifically, an electrical signal is input to plural inorganic piezoelectric elements **22** from transmission circuit **12** via cable **3**, conductive pad **28** and the first signal line **29**. This electrical signal is input between electrode **102** and electrode **103** of inorganic piezoelectric elements **22**. Plural inorganic piezoelectric elements **22** transmit ultrasonic wave signals by converting this electrical signal into the ultrasonic wave signals.

[0052] Acoustic separation section **24** is made of a low acoustic impedance resin having a largely different value of acoustic impedance from that of inorganic piezoelectric element **22** and serves as an acoustic separation material via large difference in acoustic impedance, and has a function of reducing mutual interference of plural inorganic piezoelectric elements **22**.

[0053] Common ground electrode **25** made of a conductive material is grounded by wiring in an unshown figure, and each of electrodes **103** in inorganic piezoelectric elements **22** is electrically grounded by linearly layering common ground electrode **25** on plural inorganic piezoelectric elements **22**, straddling them.

[0054] Acoustic matching layer **26** has a medium acoustic impedance between an acoustic impedance of acoustic organic piezoelectric element **21** layered in the postprocessing step and another acoustic impedance of each of inorganic piezoelectric elements **22**, and matching the acoustic impedance between organic piezoelectric element **21** and inorganic piezoelectric element **22** is made.

[0055] Organic piezoelectric element **21** is a sheet-shaped piezoelectric element possessing piezoelectric element **105** formed from organic piezoelectric material in the form of a flat plate having the predetermined thickness; plural electrodes **106** separated to each other and formed on one main surface of piezoelectric element **105**; and electrode **107** evenly formed on the mostly entire surface for the other main surface of piezoelectric element **105**.

[0056] When plural electrodes **106** are formed on one main surface of piezoelectric element **105** in this way, as to organic piezoelectric element **21**, a piezoelectric element composed of one electrode **107**, piezoelectric element **105** and electrode **106** can be two-dimensionally arrayed as the second piezoelectric element array, and each of these piezoelectric elements can be individually operated.

[0057] Plural piezoelectric elements as organic piezoelectric element **21** do not need to be separated from each other to individually function them like inorganic piezoelectric element **22**, and are possible to be formed integrally in the form of a sheet. Accordingly, in a method of preparing organic piezoelectric element **21**, there is no step of forming grooves on a plate-shaped body in the form of a sheet made of an organic piezoelectric material, resulting in further simplification of method of preparing organic piezoelectric element **21**, whereby organic piezoelectric element **21** can be formed via fewer steps. In addition, since organic piezoelectric element **21** would appear to be composed of plural piezoelectric elements, it may be composed of plural electrodes **106** and plural electrodes which should become each of the pairs in place of electrode **107**.

[0058] In an example shown in FIG. **3**, organic piezoelectric element **21** is layered indirectly on plural inorganic piezoelectric elements **22** via common ground electrode **25** and acoustic matching layer **26** entirely for plural inorganic piezoelectric elements **22**. In addition, organic piezoelectric element **21** may be layered on a part of plural inorganic piezoelectric elements **22**.

[0059] Further, the number of electrodes **106** of organic piezoelectric element **21** (the number of organic piezoelectric elements **21**) may be equal to the number of inorganic piezoelectric elements **22**, but in the present embodiment, the number of electrodes **106** of organic piezoelectric element **21** may be different from the number of inorganic piezoelectric elements **22**. That is, the number of piezoelectric elements as organic piezoelectric elements **21** is different from the number of inorganic piezoelectric elements **22**. For this reason, even though the total area of plural inorganic piezoelectric elements **22** is identical to the total area of organic piezoelectric element **21** composed of plural piezoelectric elements, the area occupied by one inorganic piezoelectric element **22** and the area occupied by one piezoelectric element in organic piezoelectric element **21** are possible to be independently designed to be set. Accordingly, inorganic piezoelectric element **22** can be designed in accordance with the specification specified for the inorganic piezoelectric element **22**, and at the same time, organic piezoelectric element **21** becomes possible to be designed in accordance with the specification specified for the organic piezoelectric element **21**.

[0060] Further, the area of electrode **106** of organic piezoelectric element **21** and the area of electrode **102** of inorganic piezoelectric element **22** in addition to the area of electrode **103** of inorganic piezoelectric element **22** can be designed in accordance with the specifications specified for the inorganic piezoelectric element **22** and the organic piezoelectric element **21** by making the area of electrode **106** of organic piezoelectric element **21** to be different from the area of electrode **102** of inorganic piezoelectric element **22** or the area of electrode **103** of inorganic piezoelectric element **22**.

[0061] The total area of grooves each between inorganic piezoelectric elements **22** is designed to be small by making the area of; for example, one inorganic piezoelectric element **22**, and similarly, transmission power of ultrasonic probe **2** can be increased by increasing the total area obtained via addition of the area of each of inorganic piezoelectric elements **22**. Further, the area of each piezoelectric element can be designed to be small by increasing the number of piezoelectric elements as organic piezoelectric element **21** to improve reception signal resolution thereof when using organic piezoelectric element **21** for the reception signal.

[0062] Organic piezoelectric element **21** may be constituted so as to transmit ultrasonic waves, but in the case of ultrasonic probe **2** and ultrasonic diagnosis apparatus H in the present embodiment, it is constituted so as to receive ultrasonic waves as reflected waves. More specifically, when ultrasonic wave signals as reflected waves are received, and the ultrasonic wave signals are converted into electrical signals, organic piezoelectric element **21** outputs the electrical signals. The electrical signals are output from electrode **106** and electrode **107** of organic piezoelectric element **21**. The electrical signals are output to reception circuit **13** via cable **3**.

[0063] The second signal line **30** is connected to conductive pad **28** receiving electrical signals from the outside, and electrode **106** of organic piezoelectric element **21**. That is, the second signal line **30** is connected to conductive pad **28**, passing through acoustic matching layer **26**, acoustic separation section **24**, acoustic matching layer **31** and acoustic damping member **23** from electrode **106** of organic piezoelectric element **21**. The portion passing through acoustic damping member **23** and acoustic matching layer **31** from conductive pad **28** has the same structure as that of the first signal line **29** to supply electrical signals into inorganic piezoelectric element **22** from the outside.

[0064] The portion passing through acoustic separation section **24** and acoustic matching layer **26** is composed of conductive member **32** and core material **33** having low acoustic impedance. Conductive member **32** has a function of conducting the portion passing through acoustic damping member **23** and acoustic matching layer **31** from conductive pad **28**, and electrode **106** of organic piezoelectric element **21**. Core material **33** has an acoustic impedance equal to that of acoustic separation **24**.

[0065] Core material **33** is formed as a cylindrical core material, and conductive member **32** is formed by thinly coating on the circumferential surface of core material **33**. Core material **33** preferably has a diameter of 50-60 μm, for example, and conductive member **32** preferably has a thickness of approximately 0.05 μm, for example. When making the thickness to be approximately 0.05 μm, minimized can be reflection of ultrasonic waves at the interface between acoustic separation section **24** and conductive member **32**, and at the interface between core material **33** and conductive member **32** by supplying sufficient electrical power to drive organic piezoelectric element **21** with ultrasonic waves, whereby generation of acoustic crosstalk between inorganic piezoelectric elements **22** can be avoided.

[0066] A material for each of acoustic separation section **24** and core material **33** is selected in such a way that an acoustic impedance of acoustic separation section **24** and another acoustic impedance of core material **33** are closely identical to each other. Reflection of ultrasonic waves between acoustic separation section **24** and core material **33** can be largely reduced by setting the acoustic impedance values for the two materials to those closely identical to each other, whereby generation of acoustic crosstalk between inorganic piezoelectric elements **22** can be inhibited.

[0067] Acoustic matching layer **27** means a member to match an acoustic impedance of organic piezoelectric element **21** with another acoustic impedance of the object. In addition, acoustic matching layer **27** is designed to be swelled in the form of a circular arc, and serves as an acoustic lens converging ultrasonic waves transmitted toward the object.

[0068] In the case of ultrasonic wave diagnosis apparatus H having such a structure, when order of diagnosis-start is input from operation input section **11**, for example, electrical signals as transmission signals are produced in transmission circuit **12** via controlling of control section **16**. The resulting electrical signals as transmission signals are supplied into ultrasonic probe **2** via cable **3**. More specifically, the electrical signals as transmission signals are supplied into each of plural inorganic piezoelectric elements **22** in ultrasonic probe **2**. The electrical signals as transmission signals are voltage pulses repeated at the predetermined periods, for example. Each of plural inorganic piezoelectric elements **22** is expanded and contracted in the thickness direction of each of them by supplying the electrical signals as transmission signals to conduct ultrasonic wave vibrations in accordance with the electrical signals as transmission signals. Plural inorganic piezoelectric elements **22** radiate ultrasonic waves by way of common ground electrode **25**, acoustic matching layer **26**, organic piezoelectric element **21** and acoustic matching layer **27** via the ultrasonic wave vibrations. In cases where ultrasonic probe **2** is brought into contact with the object, for example, ultrasonic waves are transmitted into the object from ultrasonic probe **2**.

[0069] In addition, ultrasonic probe **2** may be used by inserting it inside the object, and may be used by inserting it in the living body cavity, for example.

[0070] Ultrasonic waves transmitted into the object are reflected at one interface or plural interfaces having different acoustic impedances inside the object to become ultrasonic waves as reflected waves. The reflected waves include not only the frequency (fundamental frequency of the fundamental waves) component of transmitted ultrasonic waves but also the frequency component of higher harmonic waves in which the fundamental frequency is integrally multiplied. They include, for example, the second harmonic waves for twofold fundamental frequency, the third harmonic waves for threefold fundamental frequency, the fourth harmonic waves for fourfold fundamental frequency and so forth. The ultrasonic waves as reflected waves are received with ultrasonic probe **2**. More specifically, ultrasonic waves as reflected waves are received with organic piezoelectric element **21** via acoustic matching layer **27** to convert mechanical vibrations into electrical signals at organic piezoelectric element **21**, and taken out as reception signals. The electrical signals taken out as reception signals are received by reception circuit **13** controlled with control section **16** via cable **3**.

[0071] Herein, as to the above-described, ultrasonic waves are transmitted toward the object from each of inorganic piezoelectric elements **22** in order, and ultrasonic waves reflected at the object are received with organic piezoelectric element **21**.

[0072] Then, image processing section **14** produces images (ultrasonic wave images) of an internal situation inside the object from a duration from signal transmission to signal reception and reception intensity, based on the reception signal received at reception circuit **13** controlled by control section **16**, and display section **15** displays images of internal situation inside the object produced at image processing section **14** controlled by control section **16**. In the case of ultrasonic probe **2** and ultrasonic diagnosis apparatus H in the present embodiment, since higher harmonic waves to fundamental waves are received as described above, it becomes possible to form ultrasonic wave images via a harmonic imaging technique. For this reason, ultrasonic probe **2** and ultrasonic diagnosis apparatus H in the present embodiment become capable of providing high quality ultrasonic wave images. Further, since the second higher harmonic waves and the third higher harmonic waves exhibiting considerably large power are received, sharper ultrasonic wave images are possible to be provided.

[0073] Further, in the case of ultrasonic probe **2** and ultrasonic diagnosis apparatus H in the present embodiment, plural inorganic piezoelectric elements **22** are designed so as to transmit ultrasonic waves, ultrasonic probe **2** and ultrasonic diagnosis apparatus H can provide larger transmission power at considerably simple structure thereof. Accordingly, ultrasonic probe **2** and ultrasonic diagnosis apparatus H in the present embodiment are suitable for a harmonic imaging technique to transmit fundamental waves at considerably large power in order to obtain higher harmonic echo, and become possible to provide higher quality ultrasonic wave images.

[0074] Further, in the case of ultrasonic probe **2** and ultrasonic diagnosis apparatus H in the present embodiment, organic piezoelectric element **21** is designed so as to receive ultrasonic waves as reflected waves. In general, a piezoelectric element made of an inorganic piezoelectric material can receive only about twofold frequency of the fundamental wave frequency, but a piezoelectric element made of an organic piezoelectric material can receive, for example, about fourfold to five fold frequency of fundamental wave frequency, and is suitable for widely expanding the reception frequency range. Since ultrasonic wave signals are received with organic piezoelectric element **21** exhibiting characteristics capable of receiving such ultrasonic waves over the wide frequency range, ultrasonic probe **2** and ultrasonic diagnosis apparatus H in the present embodiment can expand the frequency range widely at considerably simple structure thereof.

[0075] In addition, in the above-described, shown is the case where inorganic piezoelectric element **22** and organic piezoelectric element **21** are two-dimensionally arrayed, but they may be one-dimensionally arrayed depending on applications.

(Method of Preparing Ultrasonic Probe **2**)

[0076] The method of preparing ultrasonic probe **2** will be described referring to FIG. **4**, FIGS. **5***a*-**5***d*, FIGS. **6***a* and **6***b*, FIGS. **7***a* and **7***b*, FIGS. **8***a* and **8***b*, FIGS. **9***a* and **9***b*, FIGS. **10***a* and **10***b*, FIGS. **11***a* and **12***b*, FIGS. **13***a* and **13***b*, FIGS. **14***a* and **14***b*, FIG. **15**, and FIGS. **16***a* and **16***b*.

[0077] FIG. **4** shows a preparation flowchart in a method of preparing ultrasonic probe **2**; FIGS. **5***a*, **5***b*, **5***c* and **5***d* each show a schematic diagram in a method of preparing organic piezoelectric element array **5**; FIGS. **6***a* and **6***b* each show a schematic diagram of acoustic damping member **23**; FIGS. **7***a* and **7***b* each show a schematic diagram of acoustic matching layer **31**; FIGS. **8***a* and **8***b* each show a schematic diagram of a work body in which flat plate-shaped double-sided electrodes-providing inorganic piezoelectric element **50** provided on both surfaces of the inorganic piezoelectric element is installed; FIGS. **9***a* and **9***b* each show a schematic diagram of a work body in which inorganic piezoelectric element **22** is arrayed; FIGS. **10***a* and **10***b* each show a schematic diagram of a work body in which acoustic separation section **24** is formed; FIGS. **11***a* and **11***b* each show a schematic diagram of a work body in which common ground electrode **25** is formed; FIGS. **12***a* and **12***b* each show a schematic diagram of a work body in which acoustic matching layer **26** is formed; and FIGS. **13***a* and **13***b* each show a schematic diagram of a bored work body.

[0078] FIGS. **14***a* and **14***b* each show a schematic diagram of a work body in which photoresist is formed; FIG. **15** shows a schematic diagram of a process by which metal constituting conductive member **32** is evaporated on the work body; FIGS. **16***a* and **16***b* each show a schematic diagram of a work body from which the metal constituting conductive member **32** on photoresist, together with the photoresist, is removed; FIGS. **17***a* and **17***h* each show a schematic diagram of a work body in which core material **33** is formed in laser processing hole **51**; FIGS. **18***a* and **18***b* each show a schematic diagram of a work body possessing a layered organic piezoelectric element array, and FIGS. **19***a* and **19***b* each show a schematic diagram of a work body in which acoustic matching layer **27** is formed.

[0079] In addition, as to FIG. **6***a* through FIG. **19***b*, FIGS. **6***a*, **7***a*, **8***a*, **9***a*, **10***a*, **11***a*, **12***a*, **13***a*, **14***a*, **16***a*, **17***a*, **18***a* and **19***a* each are a cross-sectional diagram of a work body prepared in each step, and FIGS. **6***b*, **7***b*, **8***b*, **9***b*, **10***b*, **11***b*, **12***b*, **13***b*, **14***b*, **16***b*, **17***b*, **18***b* and **19***b* each are an oblique perspective diagram. FIGS. **6***a*, **7***a*, **8***a*, **9***a*, **10***a*, **11***a*, **12***a*, **13***a*, **14***a*, **16***a*, **17***a*, **18***a* and **19***a* each are a diagram observed in the Y direction in each of FIGS. **6***b*, **7***b*, **8***b*, **9***b*, **10***b*, **11***b*, **12***b*, **13***b*, **14***b*, **16***b*, **17***h*, **18***b* and **19***b*.

[0080] Next, a method of preparing ultrasonic probe **2** will be described referring to a preparation flowchart in FIG. **4**.

[0081] First, organic piezoelectric element array (the second piezoelectric element array) **5** is prepared in Step S**10**. As shown in FIG. **5***a*, provided is piezoelectric element **105** made of an organic piezoelectric material in the form of a flat plate, which has the predetermined thickness. Thickness of piezoelectric element **105** is appropriately designed to be set depending on frequency of ultrasonic waves to be received, kinds of organic piezoelectric materials and so forth, but for example, when receiving ultrasonic waves at a center frequency of 8 MHz, piezoelectric element **105** has a thickness of about 50 μm.

[0082] As the organic piezoelectric material, a vinylidene fluoride polymer is usable, for example. A vinylidene fluoride (VDF) based copolymer is also usable as the organic piezoelectric material, for example. This vinylidene fluoride based copolymer is a copolymer of vinylidene fluoride and another monomer, and usable examples of the foregoing another monomer include trifluoroethylene, tetrafluoroethylene, perfluoroalkylvinylether (PFA), perfluoroalkoxyethylene (PAE), perfluorohexaethylene and so forth. Since a vinylidene fluoride based copolymer varies an electromechanical coupling factor (piezoelectric effect) in the thickness direction, depending on the copolymerization ratio, an appropriate copolymerization ratio is employed in accordance with the specification of an ultrasonic probe or the like. In the case of a copolymer of vinylidene fluoride and trifluoroethylene, the vinylidene fluoride preferably has a copolymerization ratio of 60-99 mol %, and in the case of a composite element in which an organic piezoelectric element is layered on an inorganic piezoelectric element, the vinylidene fluoride more preferably has a copolymerization ratio of 85-99 mol %. In the case of such a composite element, preferable examples of the foregoing another monomer include perfluoroalkylvinylether (PFA), perfluoroalkylethylene (PAE) and perfluorohexaethylene. Further, polyurea, for example, is usable for the organic piezoelectric material. In the case of this polyurea, piezoelectric element **105** is preferably prepared via an evaporation polymerization method. An H_2N—R—NH_2 structure as a formula can be provide as a monomer for polyurea, wherein R may possess an alkylene group, a phenylene group a divalent heterocyclic group, or a heterocyclic group substituted by an arbitrary substituent. The polyurea may be a copolymer of a urea derivative and another monomer. As a preferred polyurea, provided is an aromatic polyurea obtained by using 4,4'-diaminodiphenylmethane (MDA) and 4,4'-diphenylmethanediisocyanate (MDI).

[0083] Next, as shown in FIG. **5***b*, plural electrodes **106** (**106-11** and **106-12**) separated to each other are formed on one main surface of piezoelectric element **105** made of this organic piezoelectric material by screen printing, evaporation, sputtering or the like, for example. These plural electrodes **106** may be formed in the two directions which are linearly independent in planar view, for example, so as to be arrayed in the form of a two-dimensional array placed in m rows and n columns in the two directions which are at right angles to each other (each of m and n represents a positive integer). Electrode **106** is in the form of a rectangle in planar view, for example, and size thereof is appropriately designed to be provided depending on resolution and so forth, for example, but a size of about 0.1 mm×0.1 mm is designed to be provided, for example.

[0084] In addition, in the present specification, when showing collective designation, a referential symbol in which a suffix is omitted is used, and when showing individual configuration, a referential symbol in which a suffix is provided is used.

[0085] Then, as shown in FIGS. **5***c* and FIG. **5***d*, electrode **107** is formed on the other main surface of piezoelectric element **105** made of this organic piezoelectric material via screen printing, evaporation, sputtering or the like. By doing this, formed is organic piezoelectric array (the second piezoelectric element array) **5** possessing plural electrodes **106** arranged in the form of an army two-dimensionally placed in m rows and n columns, which are provided on one main surface, and electrode **107** which is provided on the other main surface.

[0086] As to organic piezoelectric element **21** having such a structure, one piezoelectric element is constituted from each electrode **106**, electrode **107** facing this each electrode, and piezoelectric element **105** made of an organic piezoelectric material present between each electrode **106** and electrode **107**, resulting in appearance of inclusion of plural piezoelectric elements.

[0087] In the case of a method of preparing ultrasonic probe **2** in the present embodiment in such a way, plural piezoelectric elements are formed by forming plural electrodes **106** separated to each other on the surface of sheet-shaped piezoelectric element **105** made of an organic piezoelectric material. For this reason, no step of forming grooves with respect to sheet-shaped piezoelectric element **105** is conducted in order to form plural piezoelectric elements. Accordingly, in the case of ultrasonic probe **2** having such a structure, since no step of forming grooves with respect to organic piezoelectric element **21** is carried out, whereby a method of preparing organic piezoelectric element **21** is largely simplified, and it becomes possible to prepare ultrasonic probe **2** with reduced man-hours.

[0088] In addition, in those described above, plural electrodes **106** are formed on one main surface of piezoelectric element **105**, and electrode **107** is subsequently formed on the other surface of piezoelectric element **105**, but electrode **106** is formed on the other main surface of piezoelectric element **105**, and plural electrodes **107** may be subsequently formed on one main surface thereof of piezoelectric element **105**.

[0089] Next, as shown in FIGS. **6***a* and **6***b*, acoustic damping member **23** suitable for size of organic piezoelectric element **21** is provided in Step **11**. Acoustic damping member **23** is equipped with a flat plate-shaped ultrasonic absorber to absorb ultrasonic waves, and absorbs ultrasonic waves radiating from the surface brought into contact with acoustic damping member **23** in inorganic piezoelectric element **22**.

[0090] Acoustic damping member **23** has acoustic impedance nearly equal to that of the after-mentioned signal line S, whereby not only reflection of ultrasonic waves at the interface between acoustic damping member **23** and signal line S is inhibited, but also generation of acoustic crosstalk with respect to inorganic piezoelectric element **22** is inhibited. Acoustic damping member **23** is formed of silicon rubber, for example.

[0091] Next, as shown in FIGS. **7***a* and **7***b*, acoustic matching layer **31** is formed on the main surface of acoustic damping member **23** in Step S**12** to form signal line S(S**1**, S**2**, S**3**, S**4**, S**5** and so forth) by passing through acoustic damping member **23** and acoustic matching layer **31**, and conductive pad **28** is formed on the surface on the opposite side of acoustic member **23** of signal line S. This signal line S is connected to electrodes of inorganic piezoelectric element **22** and organic piezoelectric element **21** to be layered in the postprocessing step.

[0092] Next, inorganic piezoelectric elements **22** are arranged and prepared in Step S**13**. First, flat plate-shaped double-sided electrodes-providing inorganic piezoelectric element **50** is layered on acoustic matching layer **31**. The double-sided electrodes-providing inorganic piezoelectric element **50** is obtained by forming an electrode on each of both surfaces of an inorganic piezoelectric plate. The same method as a method of forming an electrode for the organic piezoelectric element is utilized for a method of forming the electrode. For example, it is formed via screen printing, evaporation, sputtering or the like.

[0093] When the double-sided electrode inorganic piezoelectric element **50** is layered on acoustic matching layer **31**, signal lines S**1** through S**5** are electrically connected to an electrode formed on one main surface of the double-sided electrode inorganic piezoelectric element **50**.

[0094] Examples of materials for the inorganic piezoelectric plate include PZT quartz, lithium niobate ($LiNbO_3$), potassium tantalate niobate {K (Ta, Nb) O_3}, barium titanate ($BaTiO_3$), lithium tantalate ($LiTaO_3$), strontium titanate ($SrTiO_3$), and so forth.

[0095] Next, as shown in FIGS. **9***a* and **9***b*, grooves **41** are formed in the layering direction in the double-sided electrodes-providing inorganic piezoelectric element **50** employing a dicing saw or the like, for example to array them, until acoustic matching layer **31** appears exposed. Constituted is the first piezoelectric element array **4** possessing plural inorganic piezoelectric elements **22** (**22-1**, **22-2**, **22-3** and so forth) arranged in the form of a two-dimensional array placed in p rows and q columns in the two directions which are at right angles to each other (each of p and q represents a positive integer), and plural grooves **41** are formed in the two directions.

[0096] Electrode surfaces in the double-sided electrodes-providing inorganic piezoelectric element are divided to each other by forming grooves **41**. The upper electrode surface is divided into electrodes **103**, and the lower electrode surface is divided into electrodes **102**. Size thereof is appropriately designed to be provided depending on resolution and so forth, for example, but a size of about 0.4 mm×0.4 mm is designed to be provided, for example. Each electrode **102** is connected to each of signal lines S**1**, S**3** and S**5** to supply electrical signals from the outside via conductive pad **28**.

[0097] Next, as shown in FIGS. **10***a* and **10***b*, in order to avoid acoustic crosstalk and resonance of each inorganic piezoelectric element **22**, a member having different acoustic impedance from that of each inorganic piezoelectric element **22**, for example, an acoustic separation material made of a low acoustic impedance resin or the like is filled in grooves **41** to form acoustic separation section **24** in Step S**14**. For example, thermosetting resins such as a polyimide resin, an epoxy resin and so forth are usable as such a resin.

[0098] Next, as shown in FIGS. **11***a* and **11***b*, commonly grounding electrode **25** to be commonly grounded is formed in the form of a layer on the upper surface of the first piezoelectric element array **4** via screen printing, evaporation, sputtering or the like, for example, in Step S**15**. This commonly grounding electrode **25** is grounded via unshown wiring.

[0099] Next, as shown in FIGS. **12***a* and **12***b*, acoustic matching layer **26** is formed from the upper portion of commonly grounding electrode **25** in Step S**16**.

[0100] Next, as shown in FIGS. **13***a* and **13***b*, conducted is a hole-boring operation to form the second signal line **30** connected to organic piezoelectric element **21** before placing organic piezoelectric element **21** prepared as described above on acoustic matching layer **26** in Step S**17**. As previously described, the second signal line **30** is formed on the upper surface of acoustic matching layer **31**, and the cross-section of the second signal line **30** appears exposed. A part of acoustic matching layer **26** with acoustic separation section **24** up to signal line S from the upper surface of acoustic matching layer **26** is removed and bored to form through-holes.

[0101] For the hole-boring operation to form through-holes by removing a part of acoustic matching layer **26** and acoustic separation section **24**, laser or a drill is used, for example. When using laser, if UV laser such as excimer laser or the like is employed, acoustic matching layer **26** and acoustic separation section **24** are clearly removed via ablation processing, and laser-processing hole **51** can be obtained. Since depth of laser-processing hole **51** can be controlled by laser exposure duration, laser-processing hole **51** having appropriate depth can be formed. In addition, acoustic matching layer **26** and acoustic separation section **24** are sublimated and can be also removed via thermal processing with high-power laser such as carbon dioxide laser or the like.

[0102] Laser-processing hole **51** is designed to set a diameter of the second signal line **30**. The diameter of the second signal line is desired to be a diameter which does not shield ultrasonic waves in consideration of processing simplicity, and is, for example, preferably 50-60 μm.

[0103] Further, when using a drill, hole-boring is carried out while monitoring whether or not the drill goes through signal line S. Since it can be detected that a tip of the drill reaches signal line S, extra hole-boring can be avoided.

[0104] Next, as shown in FIGS. **14***a* and **14***b*, photoresist film **53** is formed in Step S**18**. A coater such as a spinner or the like is employed for coating the photoresist. Coating should be carefully conducted in such a way that the photoresist is not penetrated into laser-processing hole **51**.

[0105] Next, conductive member **32** is formed on the laser-processing hole **51** inner circumferential surface in Step S**19**. FIG. **15** is a schematic diagram showing film-formation of a conductive member employing an evaporator. Board **61**, electrode **58** fitted with board **61**, high-frequency power supply **59** as a thermal source for board **61**, and metal roll **55** in the form of a roll obtained by rolling metal plate **56** are placed in the upper part of evaporation chamber **60**. Metal plate **56** is transferred onto board **61** from metal roll **55** in the direction of arrow **57**. Metal constituting metal plate **56** is, for example, aluminum, gold or the like.

[0106] Work body **62** after preparation steps up to Step S**18** is grounded to the lower direction of board **61** to conduct evaporation. Not only conductive member **32** as a conductive layer made of metal is formed on the laser-processing hole **51** inner circumferential surface, but also a metal layer is formed on photoresist film **53**.

[0107] As previously described, conductive member **32** preferably has a thickness of about 0.05 μm.

[0108] Next, in Step S**20**, removal of the photoresist film is made employing a solution or the like. FIG. **16** is a schematic diagram showing a work body in which the metal film on a photoresist is removed via removal of the photoresist.

[0109] Next, a low acoustic impedance member as a material for core material **33** is filled in the laser-processing hole **51** inner spacing and solidified. Conductive member **32** appears to be thinly coated on the outer circumferential surface of core material **33**. FIGS. **17***a* and **17***b* each is a diagram showing a work body in which a low acoustic impedance member is filled in laser-processing hole **51**, and solidified to form core material **33**. Formed is a part of the signal line to reach signal line S after passing through acoustic matching layer **26** and acoustic separation section **24**. A low acoustic impedance conductive member having the same acoustic impedance as that of acoustic separation section **24** is employed for core material **33** to avoid acoustic crosstalk.

[0110] Specifically, each material is selected in such a way that acoustic impedance of acoustic separation section **24** and acoustic impedance of core material **33** satisfy the following formula (1);

$$|Z1-Z2| \leqq 0.5 \cdot 10^6 \text{ kg/m}^2 \cdot s \quad (1),$$

wherein Z1 represents the acoustic impedance of acoustic separation section **24**, and Z2 represents the acoustic impedance of core material **33**. Reflection of ultrasonic waves at the portion between acoustic separation section **24** and core material **33** can be largely reduced by selecting material satisfying Formula (1).

[0111] PZT is conventionally used as an inorganic piezoelectric material, and PZT has an acoustic impedance of $29 \cdot 10^6$ kg/m^2·s to about $38 \cdot 10^6$ kg/m^2·s. Material having an acoustic impedance value largely different from that of PZT, for example, silicon rubber is utilized for acoustic separation section **24** provided between inorganic piezoelectric elements **22** to each other so as not to transmit ultrasonic waves at the interface with PZT. The silicon rubber roughly has an acoustic impedance of $0.99 \cdot 10^6$ kg/m^2·s to $1.46 \cdot 10^6$ kg/m^2·s, which is largely different from that of PZT. Accordingly, ultrasonic waves generated inside PZT are mostly reflected at the interface between PZT and the silicon rubber.

[0112] Material having an acoustic impedance nearly equal to another impedance of acoustic separation section **24** is selected as core material **33**.

[0113] Usable examples of the specific material include aluminum, aluminum alloys (for example, Al—Mg alloy), magnesium alloys, Macor glass, glass, fused quartz, copper graphite, polyethylene (PE) or polypropylene (PP), polycarbonate (PC), ABC resin, polyphenylene ether (PPE), ABS resin, AAS resin, AES resin, nylon (PA6 or PA6-6), PPO (polyphenyleneoxide), PPS (polyphenylenesulfide: those containing glass fibers are also allowed), PPE (polyphenylene ether), PEEK (polyetherether ketone), PAI (polyamide imide), PETP (polyethylene terephthalate), PC (polycarbonate), epoxy resin, urethane resin, silicone resin and so forth.

[0114] Preferably usable are those molded by containing zinc oxide, titanium oxide, silica or aluminum, colcothar, ferrite, tungsten oxide, ytterbium oxide, barium sulfate, tungsten, molybdenum, other metal oxides, or the like as a filler in epoxy resin, urethane resin or silicone resin.

[0115] For example, when core material **33** is composed of metal oxide and silicone resin, the silicone resin possesses plural silicone bonds as Si—O bonds.

[0116] Those having dimethyl polysiloxane as a main component are preferable as silicone resins, and usable are those preferably having a polymerization degree of 3000-10000.

[0117] Preferably usable are those further containing a silicone compound represented by the following Formula (1).

$$R^1(R^1{}_2SiO)_X(R^1R^2SiO)_YSiR^1{}_3 \quad \text{Formula (1)},$$

where R^1 represents a monovalent hydrocarbon group or hydrogen atom; R^2 represents an alkyl group or polyether group; X is an integer of at least 0; and Y is an integer of at least 1.

[0118] These are commercially available, and usable examples thereof include those produced by Shin-Etsu Chemical Co., Ltd., for example, KE742U, KE752U, KE931U, KE941U, KE951U, KE961U, KE850U, KE555U, KE575U and so forth; those produced by Momentive Performance Materials Inc., for example, TSE221-3U, TSE221-4U, TSE2233U, XE20-523-4U, TSE27-4U, TSE260-3U and TSE-260-4U; and those produced by Dow Corning Toray Co., Ltd., for example, SH35U, SH55UA, SH831U, SE6749U, SE1120U, SE4704U and so forth.

[0119] The silicone resin preferably has a content of 40% by weight or more, and more preferably has a content of 40-80% by weight or more, based on the weight occupied by core material **33**, in view of acoustic characteristics and durability.

[0120] Examples of metal oxide particles usable in the present invention include TiO_2, SnO_2, ZnO, Bi_2O_3, WO_3, ZrO_2, Fe_2O_3, MnO_2, Y_2O_3, MgO, BaO and Yb_2O_3. Of these, ZnO, TiO_2 and Yb_2O_3 are preferably utilized in view of acoustic characteristics.

[0121] Metal oxide particles preferably have an average particle diameter of 1-200 nm, and more preferably have an average particle diameter of 5-20 nm. Each of 100 particle diameters was measured to determine an average particle diameter, and the average particle diameter is a value obtained by determining a number average of these values. The particle diameter is a mean value obtained from the maximum diameter and the minimum diameter of particles, which are measured from an image observed by an electron microscope.

[0122] Metal oxide particles preferably have a content of 10-60% by weight, and more preferably have a content of 15-50% by weight in view of acoustic characteristics.

[0123] Metal oxide particles are commercially available. Examples of ZnO include grade 1 zinc oxide, fine zinc oxide, FINEX-30, FINEX-30SLP2, FINEX-30WLP2, FINEX-50, FINEX-50SLP2, FINEX-50WLP2, NANOFINE-50, NANOFINE-50A and NANOFINE-50SD produced by Sakai Chemical Industry Co., Ltd.; Zinc oxide for pharmaceutical use, ZINCOX, Super F-1, Super F-2 and Super F-3, produced by Hakusuitech Ltd.; MAXLIGHT ZS-64 (silica-coating zinc oxide) produced by SHOWA DENKO K.K., and so forth. Examples of TiO_2 include R-45M, R32, R-11P, R-21, D-918, STR-60C-LP, STR-100C-LP and STR-100A-LP produced by Sakai Chemical Industry Co., Ltd.; R-820, R-830 and R-670, produced by Ishihara Sangyo Ltd.; MAXLIGHT TS-043 (silica-coating titanium oxide) produced by SHOWA DENKO K.K.; and so forth. As Yb_2O_3, high purity Yb_2O_3 particles produced by Shin-Etsu Chemical Co., Ltd. are usable.

[0124] Core material **33** may be those obtained by mixing and kneading a silicone resin and silica-coating oxide particles, and by adding a vulcanizing agent into the kneaded to conduct vulcanization-molding.

[0125] Further, secondary vulcanization can be carried out, if desired. Usable examples of vulcanizing agents include peroxide based vulcanizing agents such as 2,5-dimethyl-2,5-

ditert-butylperoxyhexane, p-methylbenzoylperoxide, ditert-butylperoxide, and so forth. An amount of the peroxide based vulcanizing agent is preferably 0.3-2% by weight, based on silicone rubber in the acoustic lens composition. Further, vulcanizing agents other than the peroxide based vulcanizing agents may be used.

[0126] When mixing a silicone resin and silica-coating oxide particles, water content is preferably removed from metal oxide particles. Temperature of the vulcanization-molding is preferably 100-200° C.

[0127] Further, the following additives may be contained in an amount of approximately 5% by weight. Examples thereof include titanium oxide, alumina, cerium oxide, iron oxide, barium sulfate, organic fillers, coloring pigments, and so forth.

[0128] As described above, reflection of ultrasonic waves between acoustic separation section **24** and core material **33** can be reduced by matching an impedance of core material **33** and another impedance of acoustic separation section **24**

[0129] In order to fill core material **33** in laser-processing hole **51**, a needle of a dispenser filled in by a core material is approached to a bored hole, and the core material is pressed and filled in by an air pressure.

[0130] Next, as shown in FIGS. **18***a* and **18***b*, sheet-shaped organic piezoelectric element array (the second piezoelectric element array) **5** prepared in another step as described above is layered on acoustic matching layer **26** in Step S22. Organic piezoelectric element array **5** is fixed on inorganic piezoelectric element **22** via adhesion. Electrode **106** fitted with organic piezoelectric element **21** is layered so as to correspond to the second signal line **30**. Electrode **107** fitted with organic piezoelectric element **21** is a common electrode, and grounded through unshown wiring.

[0131] Next, as shown in FIGS. **19***a* and **19***b*, acoustic matching layer **27** is formed on organic piezoelectric element **21** in Step S23. Acoustic matching layer **27** is composed of a single layer or plural layers, if desired. In order to widely expand the reception frequency range, acoustic matching layer **27** is preferably composed of plural layers.

[0132] With that, ultrasonic probe **2** having a structure as shown in FIG. **3** is prepared, and a preparation flow of ultrasonic probe **2** is terminated.

[0133] In the present embodiment, inorganic piezoelectric element **22** possesses a single layer as piezoelectric element **101** fitted with electrode **102** and electrode **103**, respectively, provided on the both surfaces of piezoelectric element **101**, but may possess plural layers layered as piezoelectric element **101** fitted with electrode **102** and electrode **103**, respectively, provided on the both surfaces of piezoelectric element **101**.

[0134] Further, in the present embodiment, organic piezoelectric element **21** possesses a single layer as piezoelectric element **105** fitted with electrode **106** and electrode **107**, respectively, provided on the both surfaces of piezoelectric element **105**, but may possess plural layers formed as piezoelectric element **105** fitted with electrode **106** and electrode **107**, respectively, provided on the both surfaces of piezoelectric element **105**. When transmitting ultrasonic waves, power thereof is possible to be increased, and when receiving ultrasonic waves, reception sensitivity thereof is possible to be improved by forming the plural layers.

[0135] Further, as described in FIGS. **8***a* and **8***b*, there is a method of preparing the first piezoelectric element array **4** provided after layering flat plate-shaped both-sided electrodes-providing inorganic piezoelectric element **50** on acoustic matching layer **31**. In addition, there is another method of layering it on acoustic matching layer **31** after preparing the first piezoelectric element array **4** in advance. High-volume production of the first piezoelectric element array **4** is improved by separately preparing the first piezoelectric element array **4**. The method of preparing the first piezoelectric element array **4** in advance will be described referring to FIG. **20**, FIGS. **21***a* and **21***b*, FIGS. **22***a* and **22***b*, FIGS. **23***a* and **23***b*, and FIGS. **24***a* and **24***b*.

[0136] FIG. **20** shows a preparation flowchart for a method of preparing the first piezoelectric element array **4**. FIGS. **21***a* and **21***b* each show a schematic diagram of a substrate having a piezoelectric material thereon. FIGS. **22***a* and **22***b* each show a schematic diagram of a work body having been subjected to sandblast processing. FIGS. **23***a* and **23***b* each show a schematic diagram of a work body in which acoustic separation section **24** is formed. FIGS. **24***a* and **24***b* each show a schematic diagram of a work body in which the acoustic separation section is exposed onto both surfaces of the acoustic separation section via polishing. FIGS. **25***a* and **25***b* each show a schematic diagram of a work body in which electrodes **102** and **103** are formed on both surfaces of PZT **201**.

[0137] Next, a method of preparing the first piezoelectric element array **4** is described based on a preparation flowchart of FIG. **20**. First, a substrate fitted with a piezoelectric material as shown in FIG. **21***a* is prepared in Step S**30**. PZT or the like is used as an inorganic piezoelectric material as described before. PZT is coated on substrate **202**, and then calcined to obtain PZT **201** calcined on substrate **202**.

[0138] Next, substrate **202** is removed via polishing in Step S**31** to obtain a substrate of calcined PZT **201** as shown in FIG. **21***b*.

[0139] Next, sandblast processing is carried out to emboss the shape of each inorganic piezoelectric element **22** constituting the first piezoelectric element array **4** in Step S**32**. FIGS. **22***a* and **22***b* show a schematic diagram of a work body having been subjected to the sandblast processing. FIG. **22***b* shows a top view, and FIG. **22***a* shows a cross-sectional view along a zig-zag dashed line AB, based on FIG. **22***b* (hereinafter, the same manner up to FIGS. **25***a* and **25***b* from FIGS. **23***a* and **23***b*). An array of inorganic piezoelectric elements **22** may be in the form of a grid pattern as shown in FIG. **9**, but may be composed of a honey comb structure as shown in FIG. **22***b*. A feature of sandblast processing makes etching portions to be slightly in the form of an earthenware mortar, but there appears no problem in view of fulfillment of a function of an ultrasonic probe,

[0140] Next, acoustic separation section **24** is prepared in Step S**33**. Specifically, a material having an impedance nearly equal to that of the material used as core material **33** described above is selected to embed it in etching portions of a PZT **201** substrate as shown in FIG. **23**. In cases where silicon rubber is employed as core material **33**, silicon rubber having the same composition as that of the core material may be used for acoustic separation section **24**, and silicon rubber having a different composition from that of the core material may be selected in consideration of preparation-related matters. Further, an epoxy resin may be employed as described above.

[0141] Next, as to a work body prepared in Step S**33**, one surface of a work body is subjected to polishing in order to separate the first piezoelectric element army **4** into each of the resulting inorganic piezoelectric elements **22** by exposing acoustic separation section **24** on the front surface and back surface of the work body in Step S**34**. FIGS. **24***a* and **24***b* show an outline of the work body after polishing.

[0142] Finally, electrodes **102** and **103** are formed on the surfaces on which PZT **201** is exposed as shown in FIGS. **25***a* and **25***b* to complete the first piezoelectric element array **4** in Step S**35**.

[0143] As described above, in the present embodiment, generation of acoustic crosstalk between plural inorganic piezoelectric elements **22** can be avoided by forming an acoustic separation section provided between the first piezoelectric elements to each other, arrayed in the first piezoelectric element array, and by utilizing a core material having an acoustic impedance nearly equal to another acoustic impedance of the acoustic separation section, the core material connected to the second electrode by passing through the acoustic separation section, and a signal line possessing a conductive layer coated on an outer circumferential surface of the core material.

[0144] Further, the number of electrodes **106** of organic piezoelectric element **21** and the number of inorganic piezoelectric elements **22** are possible to be designed in accordance with the specification desired for inorganic piezoelectric elements **22** and organic piezoelectric element **21** by making the number of electrodes **106** of organic piezoelectric element **21** (the number of organic piezoelectric elements **21**) to be different from the number of inorganic piezoelectric elements **22**. For example, it is possible to reduce the area of each piezoelectric element when the number of piezoelectric elements possessed by organic piezoelectric element **21** is increased, whereby in cases where organic piezoelectric element **21** is used for receiving signals, reception resolution thereof can be improved.

[0145] Further, the area of electrode **106** of organic piezoelectric element **21** and the area of electrode **102** of inorganic piezoelectric element **22** in addition to the area of electrode **103** of inorganic piezoelectric element **22** can be designed in accordance with the specifications specified for the inorganic piezoelectric element **22** and the organic piezoelectric element **21** by making the area of electrode **106** of organic piezoelectric element **21** to be different from the area of electrode **102** of inorganic piezoelectric element **22** or the area of electrode **103** of inorganic piezoelectric element **22**. The total area of grooves each between inorganic piezoelectric elements **22** is designed to be small by making the area of, for example, one inorganic piezoelectric element **22**, and similarly, transmission power of ultrasonic probe **2** can be increased by increasing the total area obtained via addition of the area of each of inorganic piezoelectric elements **22**.

[0146] Further, generation of acoustic crosstalk between the first piezoelectric elements arrayed in the first piezoelectric element array can be avoided by utilizing a method of preparing an ultrasonic probe comprising the steps of forming an acoustic separation section between the first piezoelectric elements to each other arrayed in the first piezoelectric element array; and filling a core material having an acoustic impedance nearly equal to another acoustic impedance of the acoustic separation section in a through-hole inner spacing for solidification after forming a through-hole in the acoustic separation section to form a conductive layer on the circumferential surface of the through-hole.

EXPLANATION OF NUMERALS

[0147] **1** Ultrasonic diagnosis apparatus
[0148] **2** Ultrasonic probe
[0149] **3** Cable
[0150] **4** The first piezoelectric element array
[0151] **5** Organic piezoelectric element array
[0152] **11** Operation input section
[0153] **12** Transmission circuit
[0154] **13** Reception circuit
[0155] **14** Image processing section
[0156] **15** Display section
[0157] **16** Control section
[0158] **21** Organic piezoelectric element
[0159] **22** inorganic piezoelectric element
[0160] **23** Acoustic damping member
[0161] **24** Acoustic separation section
[0162] **25** Common ground electrode
[0163] **26**, **27**, and **31** Acoustic matching layer
[0164] **28** Conductive pad
[0165] **29** The first signal line
[0166] **30** The second signal line
[0167] **32** Conductive member
[0168] **33** Core material
[0169] **41** Groove
[0170] **50** Double-sided electrodes-providing inorganic piezoelectric element
[0171] **51** Laser-processing hole
[0172] **53** Photoresist film
[0173] **55** Metal roll
[0174] **56** Metal plate
[0175] **58** Electride
[0176] **59** High-frequency power supply
[0177] **60** Evaporation chamber
[0178] **61** Board
[0179] **62** Work body
[0180] **102**, **103**, **106**, and **107** Electrode
[0181] **202** Substrate

1. An ultrasonic probe comprising:

a first piezoelectric element array in which first piezoelectric elements each as a both-sided electrodes-providing piezoelectric element are two-dimensionally arrayed;

a second piezoelectric element array layered on the first piezoelectric element array, in which second piezoelectric elements are two-dimensionally arrayed, a first electrode is placed on a second piezoelectric element surface on an opposite side of the first piezoelectric element array, and a second electrode is placed on another second piezoelectric element surface on a side of the first piezoelectric element array,

an acoustic separation section provided between the first piezoelectric elements to each other, arrayed in the first piezoelectric element array, and

a signal line comprising a conductive layer coated on an outer circumferential surface of a core material and the core material having an acoustic impedance nearly equal to another acoustic impedance of the acoustic separation section, the signal line connected to the second electrode by passing through the acoustic separation section.

2. The ultrasonic probe of claim **1**,

wherein an area of each of the first piezoelectric elements to which a voltage is applied is different from an area of each of the second piezoelectric elements to which a voltage is applied.

3. The ultrasonic probe of claim **1** or **2**,

wherein the number of the first piezoelectric elements arrayed in the first piezoelectric element array is different from the number of the second piezoelectric elements arrayed in the second piezoelectric element array.

4. A method of preparing an ultrasonic probe, comprising the steps of:

forming a through-hole in an acoustic separation section provided between the first piezoelectric elements to each other in a first piezoelectric element array in which first piezoelectric elements each as a both-sided electrodes-providing piezoelectric element are two-dimensionally arrayed;

forming a conductive layer on a through-hole inner circumferential surface so as to form a through-hole inner spacing; and

filling a core material having an acoustic impedance nearly equal to another acoustic impedance of the acoustic separation section in the through-hole inner spacing.

* * * * *

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摘要(译)

本发明提供一种超声波探头，其具有信号线，在该信号线上，压电元件彼此之间产生声学串扰构成压电元件阵列，并且还提供了一种制备超声波探头的方法。本发明公开了一种超声波探头，包括第一压电元件阵列，其中每个作为双侧电极的压电元件的第一压电元件是二维排列的;第二压电元件阵列，层叠在第一压电元件阵列上;声学分离部分，设置在第一压电元件之间，排列在第一压电元件阵列中;具有涂覆在芯材料的外圆周表面上的导电层的信号线和具有几乎等于声学分离部分的另一声阻抗的芯材料，该信号线通过穿过所述第二电极的第二电极连接到所述第二电极。声学分离部分。