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(54) **ULTRASONIC PROBE AND METHOD OF MANUFACTURING THE SAME**

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(51) **Int. Cl.**
H01L 41/047 (2006.01)
H01L 41/083 (2006.01)

(52) **U.S. Cl.** **310/334**; 310/366

(58) **Field of Classification Search** 310/334, 310/366

See application file for complete search history.

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(74) *Attorney, Agent, or Firm*—Sughrue Mion, PLLC

(57) **ABSTRACT**

In an ultrasonic probe in which individual wires led out from multilayered piezoelectric elements are arranged in a staggered manner, short-circuit is prevented. Each of the elements includes: a multilayered structure in which piezoelectric material layers and at least one internal electrode are stacked; first and second flat electrodes; first and second side electrodes; an insulating film formed at a second side surface side of the multilayered structure; a wiring member bonded to the first flat electrode on the one end of the multilayered structure by using a conducting adhesive material; and the wiring member is provided at the second side surface side of the multilayered structure and the insulating film electrically separates the second side electrode and the conducting adhesive material in a first element, and the wiring member is provided at a first side surface side of the multilayered structure in a second element.

6 Claims, 9 Drawing Sheets

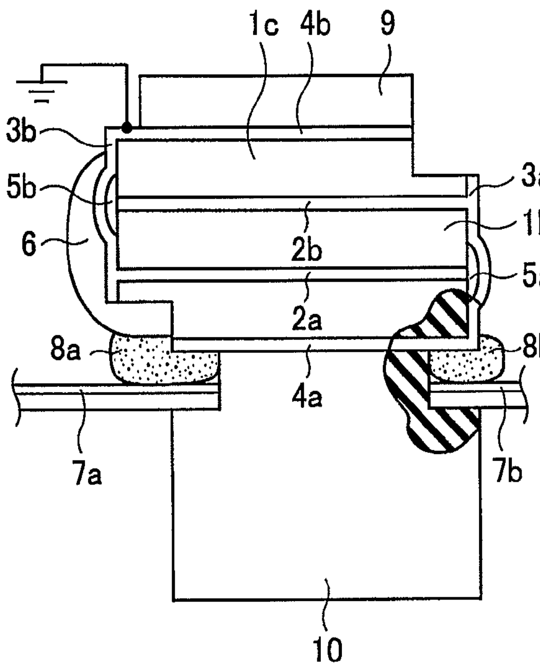
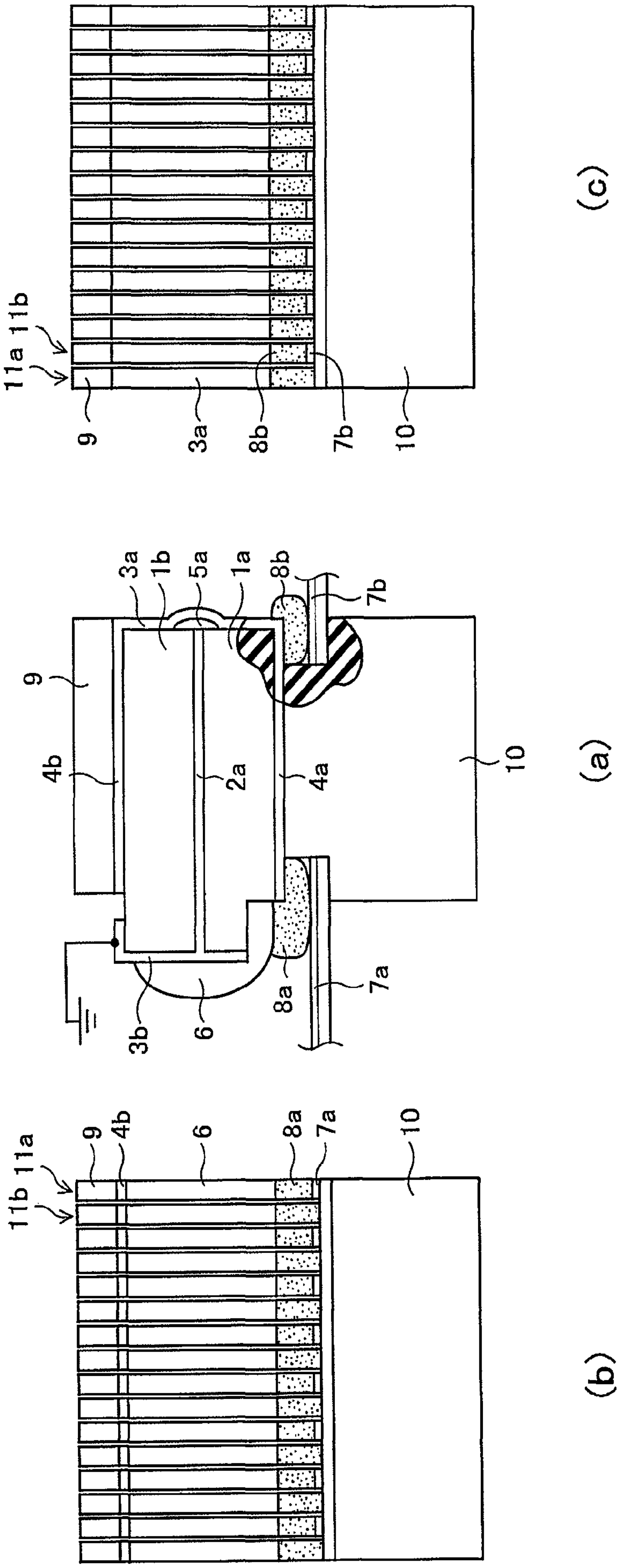


FIG.1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11b
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7b
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4a
10
3b
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7a
(a)
11b
11a
9
4b
6
8a
7a
10
(b)

FIG.2A

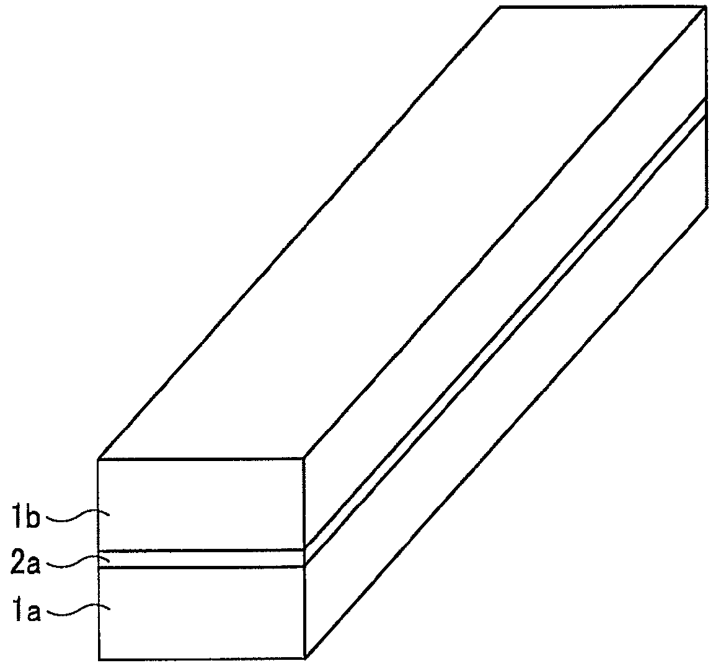


FIG.2B

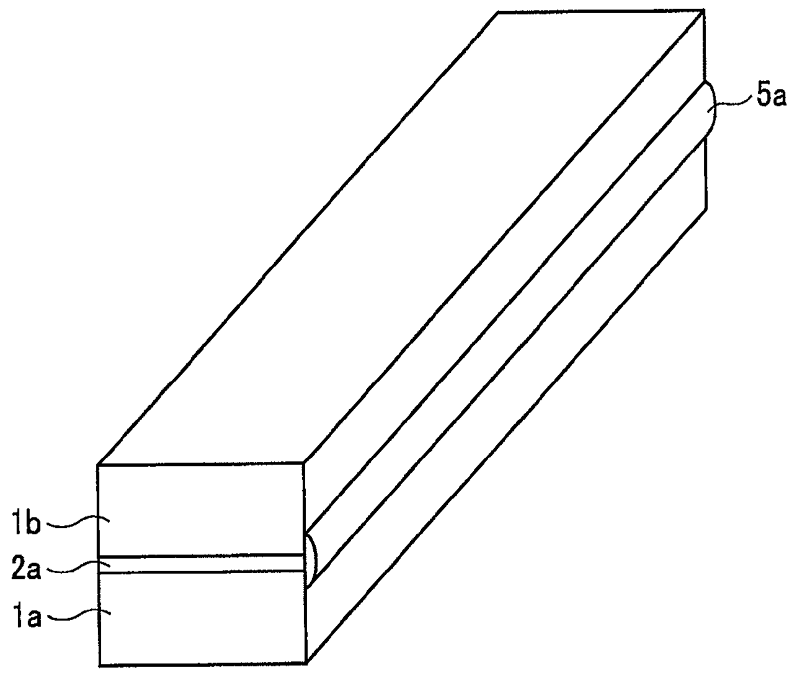


FIG.2C

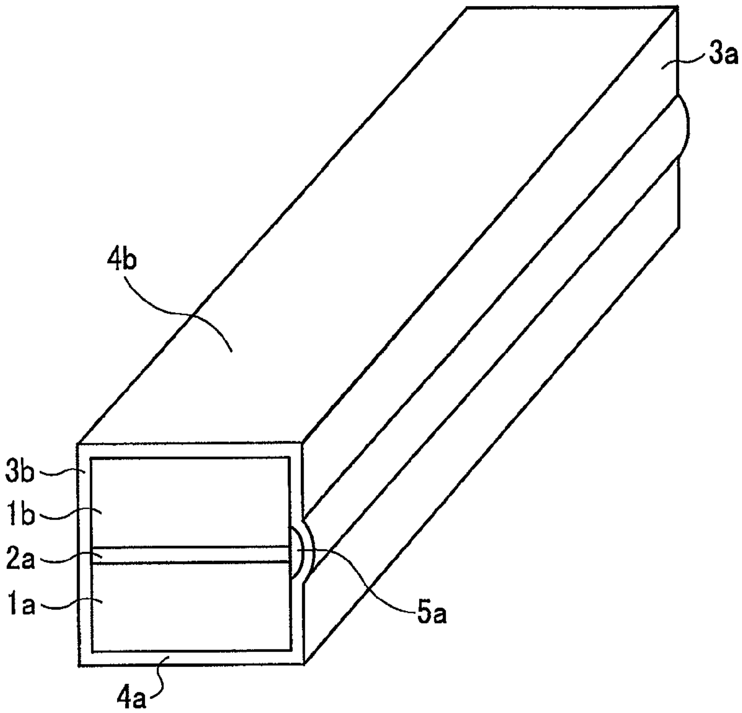


FIG.2D

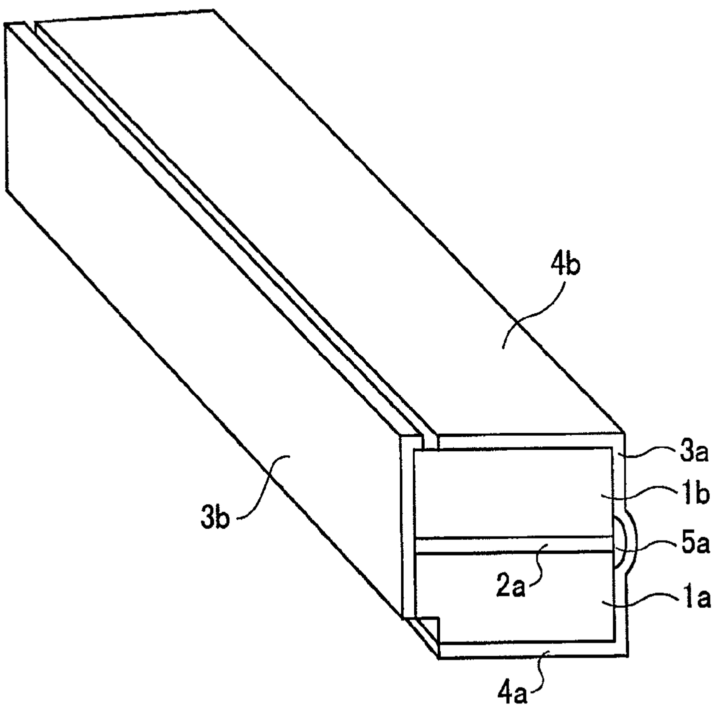


FIG.2E

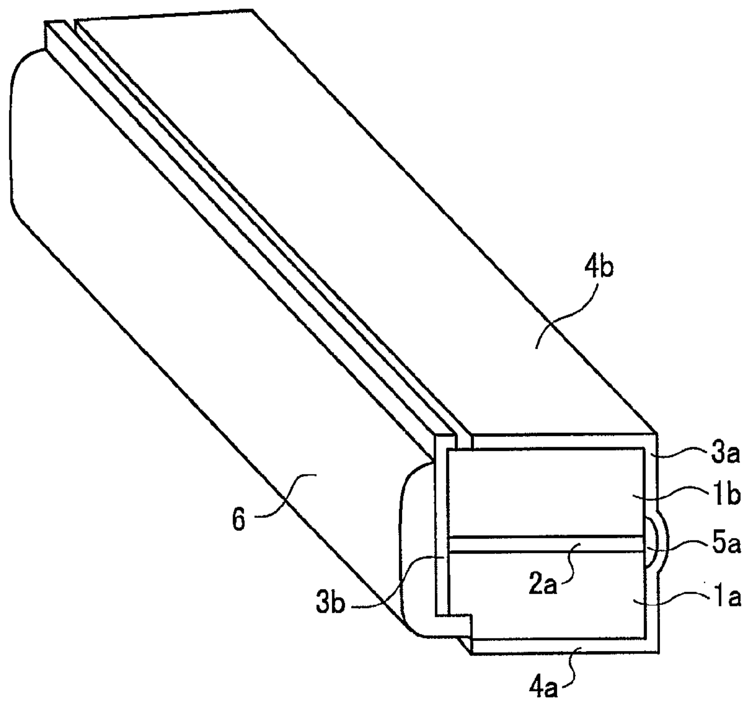


FIG.2F

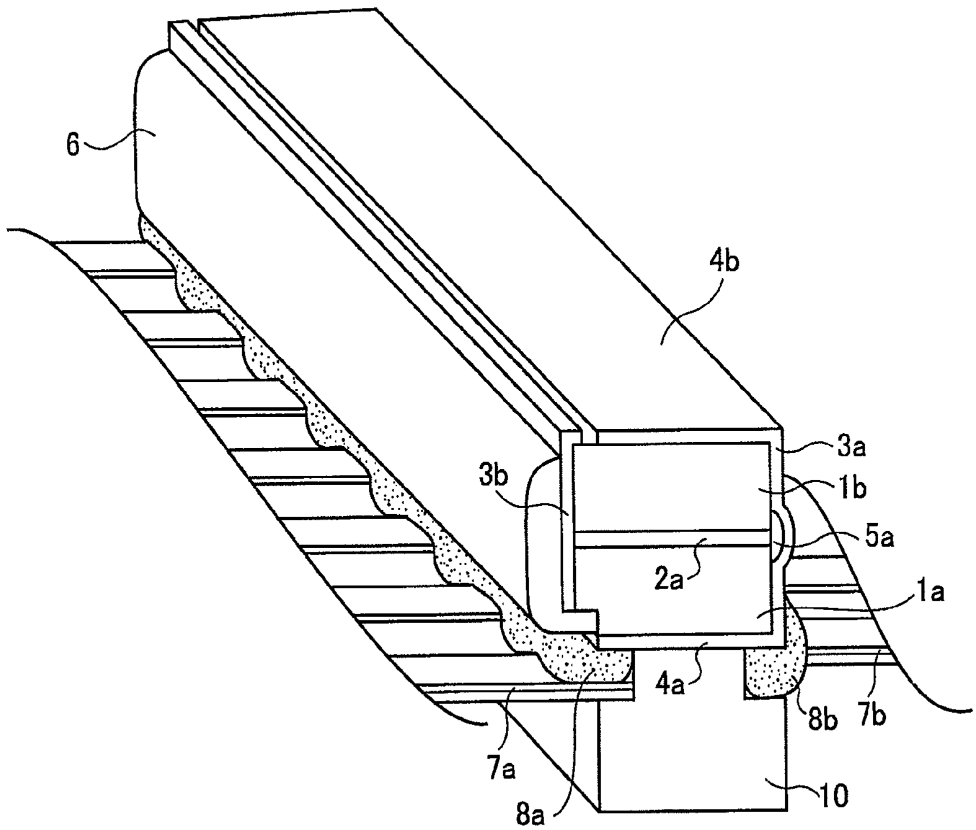


FIG.2G

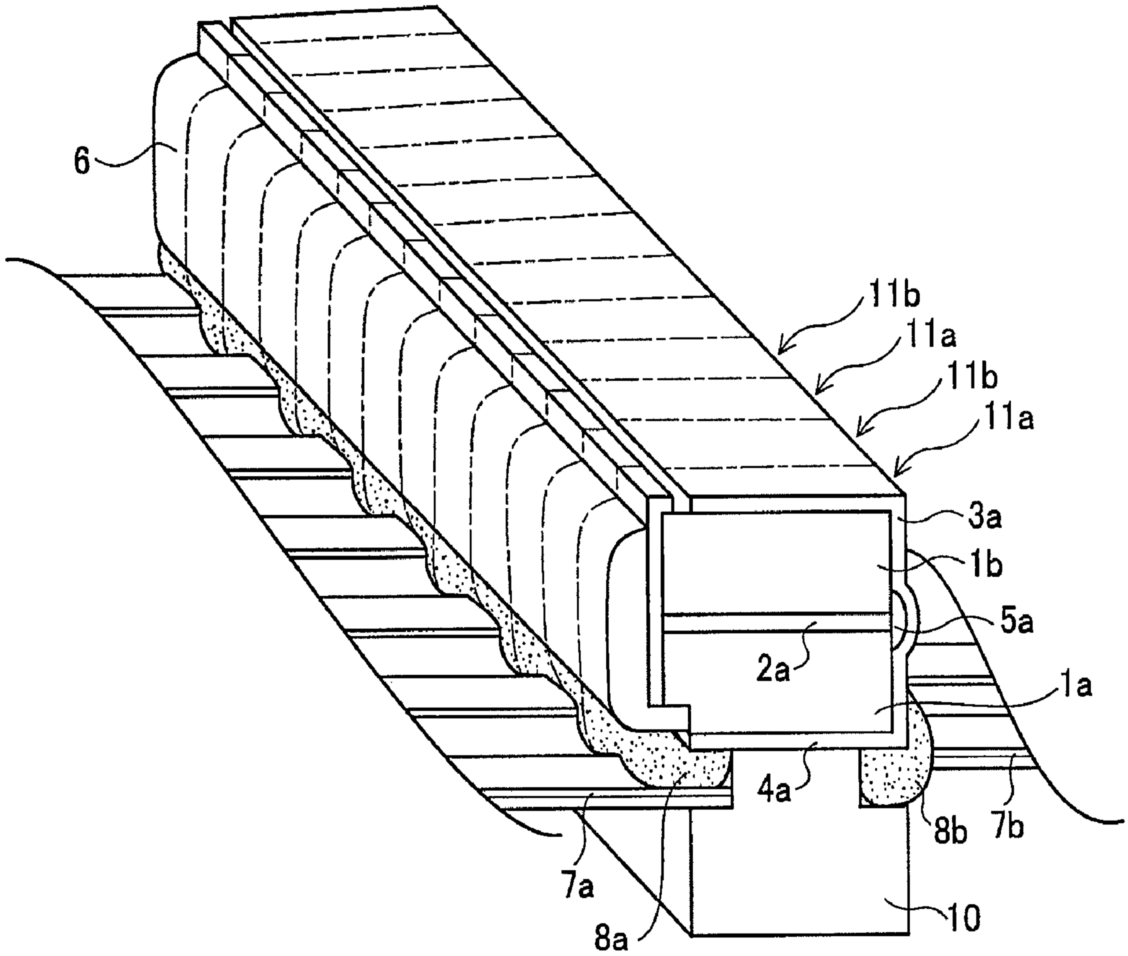
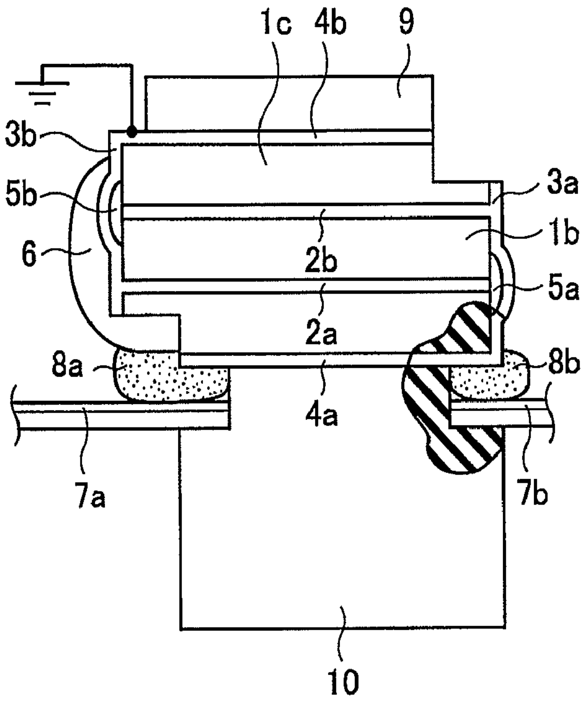


FIG.3


1c
4b
9
3b
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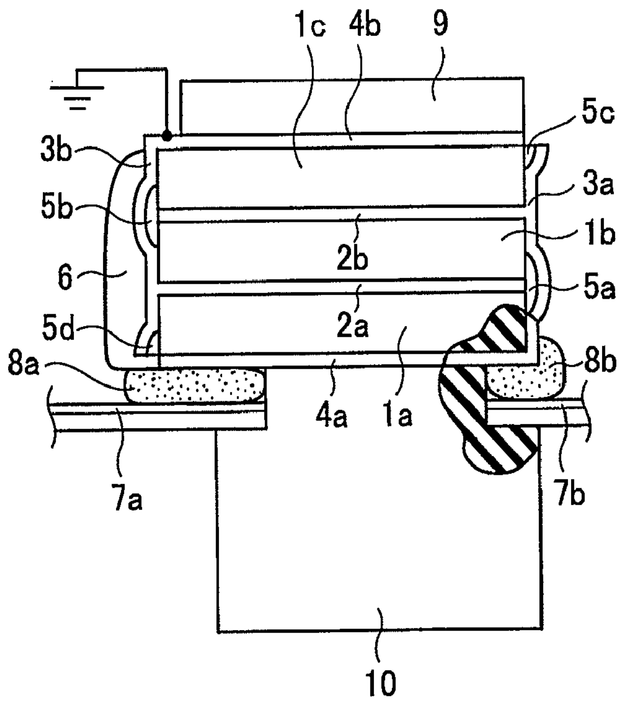
5b
1b
6
2b
5a
2a
8a
8b
4a
7a
7b
10

FIG.4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5a
5d
2a
8a
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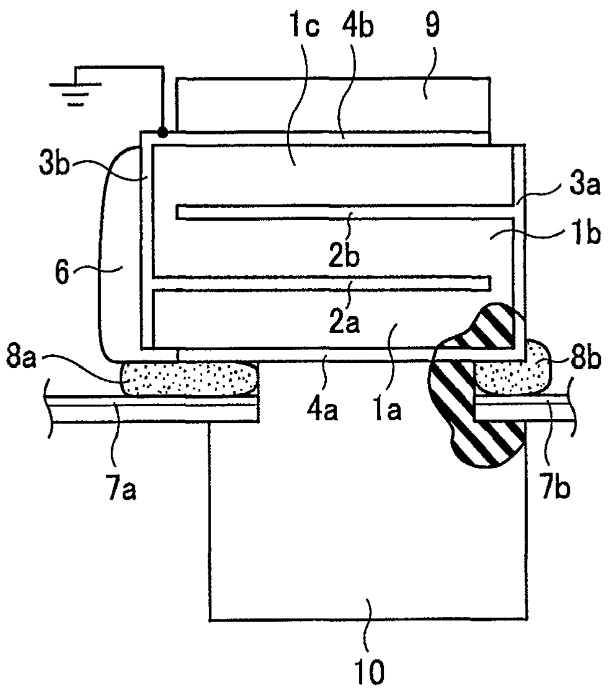
7a
7b
10

FIG.5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4b
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3b
3a
1b
2b
6
2a
8a
8b
4a
1a
7a
7b
10

FIG.6

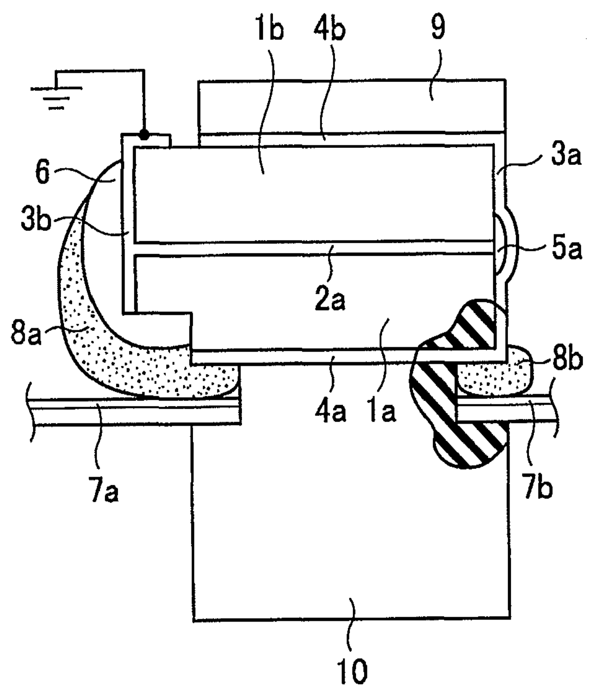
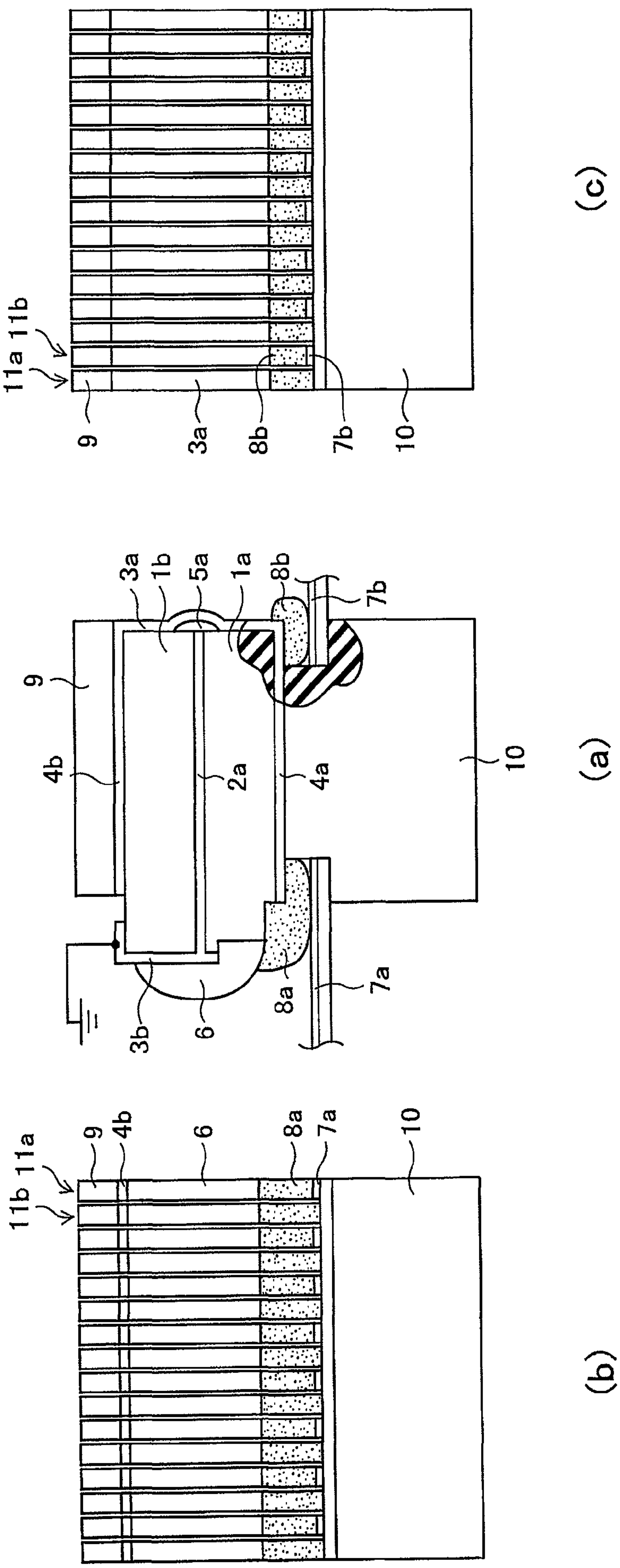

1b
4b
9
3a
6
3b
5a
2a
8a
8b
4a
1a
7a
7b
10

FIG. 7


11a 11b
9
3a
8b
7b
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(c)
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7b
9
4b
2a
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8a
7a
(a)
11b 11a
9 4b
6
8a 7a
10
(b)

FIG.8A

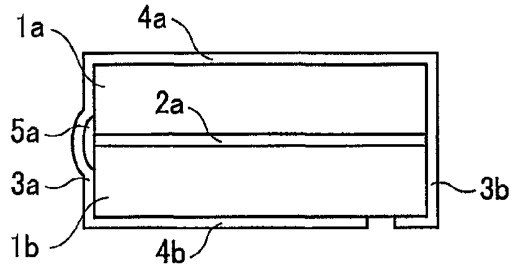


FIG.8B

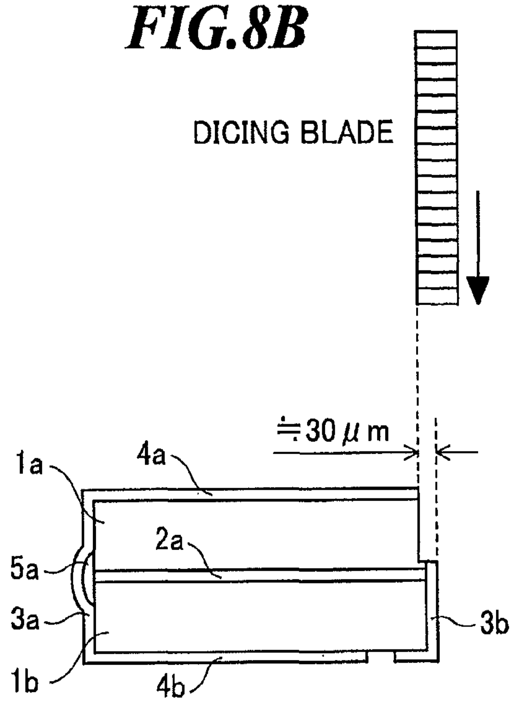
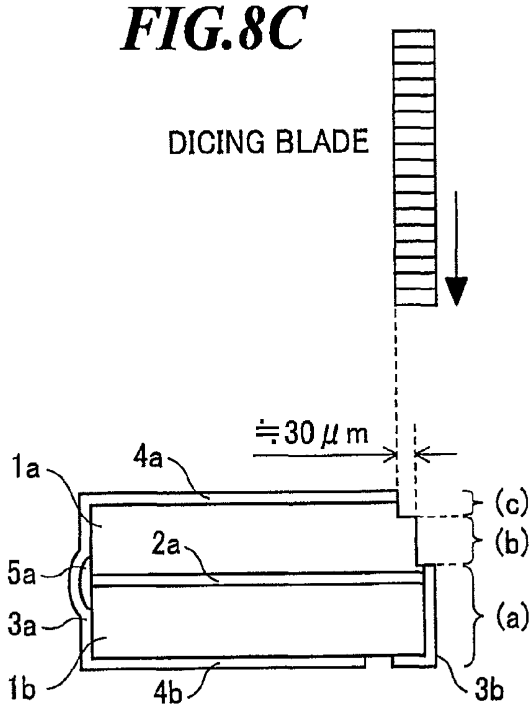


FIG.8C



ULTRASONIC PROBE AND METHOD OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an ultrasonic probe including plural ultrasonic transducers for transmitting and/or receiving ultrasonic waves in an ultrasonic diagnostic apparatus for medical use or structure flaw detection, and a method of manufacturing such an ultrasonic probe.

2. Description of a Related Art

In medical fields, various imaging technologies have been developed in order to observe the interior of an object to be inspected and make diagnoses. Especially, ultrasonic imaging for acquiring interior information of the object by transmitting and receiving ultrasonic waves enables image observation in real time without exposure to radiation like other medical image technologies such as X-ray photography or RI (radio isotope) scintillation camera. Accordingly, ultrasonic imaging is utilized as an imaging technology at a high level of safety in a wide range of departments including not only the fetal diagnosis in the obstetrics, but also gynecology, circulatory system, digestive system, and so on.

The ultrasonic imaging is an image generation technology utilizing the nature of ultrasonic waves that the waves are reflected at a boundary between regions with different acoustic impedances (e.g., a boundary between structures). Typically, an ultrasonic diagnostic apparatus (or referred to as an ultrasonic imaging apparatus or an ultrasonic observation apparatus) is provided with an ultrasonic probe to be used in contact with the object or ultrasonic probe to be used by being inserted into a body cavity of the object. Alternatively, an ultrasonic endoscope of an endoscope for optically observing the interior of the object in combination with an ultrasonic probe for intracavity is also used.

In the ultrasonic probe, for example, a piezoelectric vibrator (piezoelectric element) having electrodes formed on both ends of a piezoelectric material is used as an ultrasonic transducer for transmitting and/or receiving ultrasonic waves. When a voltage is applied to the electrodes of the vibrator, the piezoelectric material expands and contracts to generate ultrasonic waves. Further, plural vibrators are one-dimensionally or two-dimensionally arranged and the vibrators are sequentially driven by drive signals provided with predetermined delays, and thereby, an ultrasonic beam can be formed toward a desired direction. On the other hand, the vibrator receives the propagating ultrasonic waves, expands and contracts, and generates an electric signal. The electric signal is used as a reception signal of ultrasonic waves.

In an array type ultrasonic probe as described above, a common electrode (ground electrode) and individual electrodes (address electrodes) are provided for the respective elements. In order to lead out wires from the individual electrodes of the respective elements, at least one substrate for wiring is bonded to the electrodes formed on the upper or lower surface of the piezoelectric materials by using a conducting adhesive material.

The structure of a piezoelectric element is basically a single-layer structure in which electrodes are formed on both ends of one piezoelectric material. However, according to microfabrication and integration of piezoelectric elements with recent developments of MEMS (micro electro mechanical systems) related devices, multilayered piezoelectric elements each having plural piezoelectric materials and plural electrodes alternately stacked have been used. In such a piezoelectric element, the capacitance of the multilayered structure as a whole can be made larger by connecting electrodes for applying electric fields to the respective plural piezoelectric material layers in parallel. Accordingly, the rise in electrical impedance can be suppressed even when the size of the piezoelectric element is made smaller.

The multilayered piezoelectric elements used in the ultrasonic probe are roughly classified into (i) elements having internal electrodes with a whole-surface electrode structure and (ii) elements internal electrodes with an alternating electrode structure. In either structure, the internal electrodes are alternately connected to the common electrode and the individual electrodes respectively formed on the upper and lower surfaces of the multilayered piezoelectric element via side electrodes so as to apply electric fields to the piezoelectric materials in the respective layers.

By the way, as the probe is made smaller, the widths of the vibrators included in the array become smaller, the wiring pattern widths on the substrate for individual wiring become narrower, and the spacings between adjacent wiring patterns become narrower, and thus, the work for leading out the individual wires becomes difficult. In order to solve the problem, a technique of connecting the substrate for individual wiring to the piezoelectric elements such that the individual wires are led out from not only one side along the longitudinal direction of the piezoelectric elements but both sides along the longitudinal direction at twice pitch to be arranged in a staggered manner. In the case where the individual wires are led out in such a manner, the individual wires are divided into odd number channels and even number channels at both sides along the longitudinal direction of the piezoelectric elements. Hereinafter, a manner according which the individual wires are led out as described above is called "staggered manner" for convenience. According to the technique, the lead-out parts of the individual wires are alternately formed on both sides of the piezoelectric materials, and the spacings between adjacent electrodes become wider and the workability is improved. However, at the same time, another substrate for individual wiring is bonded on the same side of the common electrode and, if the conducting adhesive flows out when the other substrate for individual wiring is bonded, it is highly likely that the conducting adhesive is short-circuited to the side electrodes of the multilayered piezoelectric element.

In the case of an ultrasonic probe using single-layered piezoelectric elements, especially, the distance between electrodes becomes smaller as the piezoelectric material becomes thinner for higher frequency. If the conducting adhesive is spread out for bonding the substrates for individual wiring, it easily runs along the side surfaces of the piezoelectric materials and causes short-circuit. For example, when the distance between electrodes is 130 μm, the yield is 50%. In the case of using the multilayered piezoelectric elements, the electrodes are also on the side surfaces of the piezoelectric elements and the distance between electrodes becomes extremely small. If the conducting adhesive flows out when the substrates for individual wiring are bonded, the conducting adhesive easily contacts the side electrodes and causes short-circuit.

As a related technology, Japanese Patent Application Publication JP-P2000-117973A discloses a piezoelectric vibrator unit in which even when the widths of piezoelectric vibrators are made narrower, the continuity between the electrodes at the piezoelectric vibrator side and the conducting pattern of flexible tapes is reliably secured and short-circuit due to excessive solder is not caused. The piezoelectric vibrator unit is configured such that the effective continuity widths of the conducting pattern in the connecting part of the flexible tapes are provided wider than the widths of the piezoelectric vibrators and a non-superposing area that does not superpose on the conducting patterns in the connecting part of the piezoelectric vibrators is provided, and thereby, the excessive solder melted at bonding of the conducting patterns is escaped to the non-superposing area.

Further, Japanese Patent Application Publication JP-P2006-320512A discloses an ultrasonic vibrator that provides increased acoustic output by multilayered connection of plural electromechanical conversion elements with connecting members. The ultrasonic vibrator includes electromechanical conversion elements that convert electric signals into mechanical operation to radiate ultrasonic waves, an acoustic matching layer material provided at the ultrasonic radiation surface side of the electromechanical conversion elements, a backing material provided on the opposite surface to the ultrasonic radiation surface side of the electromechanical conversion elements, a connecting member plastically deformed for electric connection to the electromechanical conversion elements, and an insulating member provided on the surface of the connecting member other than the part that is electrically connected.

However, JP-P2000-117973A and JP-P2006-320512A do not disclose prevention of short-circuit to the side electrodes of the multilayered piezoelectric element caused by the conducting adhesive flowing out when individual wires are bonded in the case where the individual wires lead out from the multilayered piezoelectric elements are arranged in a staggered manner.

SUMMARY OF THE INVENTION

The present invention has been achieved in view of the above-mentioned problems. A purpose of the present invention is, in an ultrasonic probe including plural multilayered piezoelectric elements, in the case where individual wires led out from the multilayered piezoelectric elements are arranged in a staggered manner, to prevent short-circuit to side electrodes of the multilayered piezoelectric elements caused if a conducting adhesive flows out when the individual wires are bonded. A further purpose of the present invention is to improve mechanical strength of the side electrodes.

In order to accomplish the purposes, an ultrasonic probe according to one aspect of the present invention is an ultrasonic probe including plural multilayered piezoelectric elements arranged in a row, and each of the plural multilayered piezoelectric elements includes: a multilayered structure in which plural piezoelectric material layers and at least one internal electrode are alternately stacked; a first flat electrode formed on a piezoelectric material layer located on one end of the multilayered structure; a second flat electrode formed on a piezoelectric material layer located on the other end of the multilayered structure; a first side electrode formed on a first side surface of the multilayered structure and connected to odd-numbered electrodes of the first and second flat electrodes and the at least one internal electrode, the odd-numbered electrodes including the first flat electrode; a second side electrode formed on a second side surface of the multilayered structure and connected to even-numbered electrodes of the first and second flat electrodes and the at least one internal electrode; an insulating film formed at a second side surface side of the multilayered structure; a wiring member bonded to the first flat electrode on the one end of the multilayered structure by using a conducting adhesive material; wherein the wiring member is provided at the second side surface side of the multilayered structure in a first multilayered piezoelectric element of the plural multilayered piezoelectric elements, the wiring member is provided at a first side surface side of the multilayered structure in a second multilayered piezoelectric element adjacent to the first multilayered piezoelectric element of the plural multilayered piezoelectric elements, and the insulating film electrically separates the second side electrode and the conducting adhesive material in the first multilayered piezoelectric element.

Further, a method of manufacturing an ultrasonic probe according to one aspect of the present invention is a method of manufacturing an ultrasonic probe including plural multilayered piezoelectric elements arranged in a row, and the method includes the steps of: (a) fabricating a multilayered structure in which plural piezoelectric material layers and at least one internal electrode are alternately stacked; (b) applying a coating around the multilayered structure with a conducting film and removing parts of the conducting film to form a first flat electrode formed on a piezoelectric material layer located on one end of the multilayered structure, a second flat electrode formed on a piezoelectric material layer located on the other end of the multilayered structure, a first side electrode formed on a first side surface of the multilayered structure and connected to odd-numbered electrodes of the first and second flat electrodes and the at least one internal electrode, the odd-numbered electrodes including the first flat electrode, and a second side electrode formed on a second side surface of the multilayered structure and connected to even-numbered electrodes of the first and second flat electrodes and the at least one internal electrode; (c) forming an insulating film at a second side surface side of the multilayered structure; (d) bonding a wiring member to the first flat electrode on the one end of the multilayered structure by using a conducting adhesive material; and (e) cutting the multilayered structure to manufacture the plural multilayered piezoelectric elements; wherein the wiring member is provided at the second side surface side of the multilayered structure in a first multilayered piezoelectric element of the plural multilayered piezoelectric elements, the wiring member is provided at a first side surface side of the multilayered structure in a second multilayered piezoelectric element adjacent to the first multilayered piezoelectric element of the plural multilayered piezoelectric elements, and the insulating film electrically separates the second side electrode and the conducting adhesive material in the first multilayered piezoelectric element.

According to one aspect of the present invention, since the insulating film electrically separates the second side electrode and the conducting adhesive material in the first multilayered piezoelectric element, the short-circuit to side electrodes of the multilayered piezoelectric elements caused if the conducting adhesive flows out when the individual wires are bonded can be prevented. As a result, the difficulty level of working at manufacturing can be reduced and the yield can be improved. Further, the side electrodes are physically weak, but the resistance to the mechanical damage in manufacturing can be provided when the side electrodes are covered by the insulating film.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an internal structure of an ultrasonic probe according to the first embodiment of the present invention;

FIGS. **2**A-**2**G are diagrams for explanation of a method of manufacturing the ultrasonic probe according to the first embodiment of the present invention;

FIG. **3** is a front view showing an ultrasonic probe according to the second embodiment of the present invention;

FIG. **4** is a front view showing an ultrasonic probe according to the third embodiment of the present invention;

FIG. **5** is a front view showing an ultrasonic probe according to the fourth embodiment of the present invention;

FIG. **6** is a front view showing an ultrasonic probe according to the fifth embodiment of the present invention;

FIG. **7** shows an internal structure of an ultrasonic probe according to the sixth embodiment of the present invention; and

FIGS. **8**A-**8**C are diagrams for explanation of the method of manufacturing the ultrasonic probe according to the sixth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of the present invention will be explained in detail with reference to the drawings. The same reference numerals will be assigned to the same component elements and the description thereof will be omitted.

FIG. **1** shows an internal structure of an ultrasonic probe according to the first embodiment of the present invention. In FIG. **1**, (a) is a front view, (b) is a left-side view, and (c) is a right-side view.

The ultrasonic probe includes plural multilayered piezoelectric elements **11***a* and **11***b* arranged in a row. Each of the multilayered piezoelectric elements has a multilayered structure in which plural piezoelectric layers **1***a* and **1***b* and at least one internal electrode **2***a* are alternately stacked, a flat electrode **4***a* formed on the piezoelectric layer **1***a* located at the lower end of the multilayered structure, a flat electrode **4***b* formed on the piezoelectric layer **1***b* located at the upper end of the multilayered structure, an insulating film **5***a* formed on the right side surface of the multilayered structure, a side electrode **3***a* formed on the right side surface of the multilayered structure and connected to odd-numbered electrodes of the flat electrodes **4***a* and **4***b* and the at least one internal electrode **2***a*, in which the odd-numbered electrodes includes the flat electrode **4***a*, a side electrode **3***b* formed on the left side surface of the multilayered structure and connected to even-numbered electrodes of the flat electrodes **4***a* and **4***b* and the at least one internal electrode **2***a*, an insulating film **6** formed on the left side surface of the multilayered structure, and a wiring member **7***a* or **7***b* connected to the flat electrode **4***a* using a conducting adhesive material **8***a* or **8***b* at the lower end of the multilayered structure.

The two kinds of multilayered piezoelectric elements **11***a* and **11***b* are one-dimensionally and alternately arranged and supported by a backing material **10**. An acoustic matching layer **9** for providing acoustic matching to reduce the reflection of ultrasonic waves at the boundary of an object to be inspected is provided on the multilayered piezoelectric elements **11***a* and **11***b*.

Here, the flat electrode **4***a*, the side electrode **3***a*, and the main part of the flat electrode **4***b* correspond to individual electrodes, and the side electrode **3***b* and a part of the flat electrode **4***b* correspond to the common electrode. Generally, the common electrode is connected to the ground potential. As the wiring member **7***a* or **7***b*, for example, plural wiring patterns for individual wiring formed on a flexible substrate is used. To arrange the lead wires of the individual electrodes from the multilayered piezoelectric elements in a staggered manner, the wiring member **7***a* is provided at the left side surface side of the multilayered structure in the multilayered piezoelectric element **11***a*, and the wiring member **7***b* is provided at the right side surface side of the multilayered structure in the multilayered piezoelectric element **11***b*.

In the embodiment, in the multilayered piezoelectric element **11***a*, the insulating film **6** electrically isolates the side electrode **3***b* and the conducting adhesive material **8***a*, and thereby, the short-circuit caused between them is prevented and the mechanical strength of the side electrode **3***b* is improved. In the example shown in FIG. **1**, the insulating film **6** covers nearly the entire exposed surfaces of the side electrode **3***b*.

The piezoelectric material layers **1***a* and **1***b* are formed by using a piezoelectric material of PZT (Pb(lead) zirconate titanate) or the like, and have thicknesses of about 130 μm or less, for example. Further, the internal electrode **2***a* is formed by using a metal material of platinum (Pt), silver palladium (Ag—Pd), or the like, and has a thickness of 1 μm to 3 μm, for example.

As the side electrodes **3***a* and **3***b* and the flat electrodes **4***a* and **4***b*, for example, electrodes of one kind of material selected from gold (Au), platinum (Pt), titanium (Ti), or the like, two-layer structure electrodes of chromium (Cr) and gold (Au), or three-layer structure electrodes of nickel (Ni), titanium (Ti), and platinum (Pt) are used.

As the insulating films **5***a* and **6**, for example, a highly insulating resin including a thermoplastic resin such as an epoxy or silicone resin and a light curing resin such as urethane acrylate or oxetane resin, for example. In such a resin, the Young's modulus is 1.3×10^9 Pa to 2.0×10^9 Pa, which is much smaller than that of glass or the like. Accordingly, when the piezoelectric material layers **1***a* and **1***b* are expanding and contracting, the insulating films **5***a* and **6** can follow the expansion and contraction (deformation) of the piezoelectric material layers **1***a* and **1***b*, and thus, there is little braking of the deformation of the piezoelectric material layers **1***a* and **1***b* due to the insulating films **5***a* and **6**.

FIGS. **2**A-**2**G are diagrams for explanation of a method of manufacturing the ultrasonic probe according to the first embodiment of the present invention. Here, the case where an ultrasonic probe including multilayered piezoelectric elements having two piezoelectric material layers is manufactured will be explained.

First, as shown in FIG. **2**A, a multilayered structure is fabricated by stacking the piezoelectric material layer **1***a*, the internal electrode **2***a*, and the piezoelectric material layer **1***b*. The multilayered structure may be fabricated, for example, using the green sheet method, by stacking piezoelectric bulk materials having internal electrode formed therein, or using the aerosol deposition (AD) method of depositing a powdery material by spraying the material toward the lower layer at a high speed. The AD method is a film forming method that has recently attracted attention as a method of forming a ceramics film.

Then, as shown in FIG. **2**B, the insulating film **5***a* for covering the end of the internal electrode **2***a* is formed on one side surface (on the right side in the drawing) of the multilayered structure. Here, the step of forming the insulating film can be made easier using a light curing resin. Further, a liquid-state light curing resin can be provided in a predetermined region of the multilayered structure using a dispenser.

Then, as shown in FIG. **2**C, the multilayered structure is coated with electrode materials (conducting films) to be the side electrodes **3***a* and **3***b* and the flat electrodes **4***a* and **4***b* by physical deposition method such as sputtering, for example. The formation of the electrode materials may be performed continuously or separately with respect to the two side surfaces and the two flat surfaces. Further, the formation of the electrode materials is avoided on the front surface and the rear surface of the multilayered structure.

Then, as shown in FIG. **2**D, in order to electrically divide the flat electrode **4***a* and the side electrode **3***b*, a groove is formed in the corner part of the multilayered structure (including a part of the piezoelectric material layer **1***a*) where the surface including the flat electrode **4**a and the surface including the side electrode **3**b intersect. In this example, using a dicing blade attached to a dicing saw or cutting saw and rotated, the corner part of the multilayered structure is cut off in the array arrangement direction. Further, in order to electrically divide the flat electrode **4**a and the side electrode **3**b, another groove is formed in the flat electrode **4**b. In this example, using the dicing blade, the electrode material of the flat electrode **4**b near the end at the side electrode **3**b is cut off in the array arrangement direction.

Then, as shown in FIG. **2**E, the insulating film **6** is formed by applying a highly insulating resin to the surface of the side electrode **3**b and a part of the cut off part (groove) including the end of the side electrode **3**b. In this example, the insulating film **6** covers nearly the entire exposed surface of the side electrode **3**b, however, the insulating film **6** may cover the only the part near the end of the side electrode **3**b as long as the conducting adhesive material **8**a (FIG. **1**) do not contact the side electrode **3**b. Further, in the cut off part, the insulating film **6** covers the end of the side electrode **3**b but does not cover the end of the flat electrode **4**a. Here, the step of forming the insulating film can be made easier using a light curing resin. Further, a liquid-state light curing resin can be provided in a predetermined region of the multilayered structure using a dispenser.

Then, as shown in FIG. **2**F, under the condition that the multilayered piezoelectric element is supported by the backing material **10**, the left wiring member **7**a and the right wiring member **7**b are provided such that the left and right wiring patterns are alternately arranged in the array arrangement direction. Then, using the conducting adhesive materials **8**a and **8**b, the wiring member **7**a is bonded to the end of the flat electrode **4**a at the side electrode **3**b side and the wiring member **7**b is bonded to the end of the flat electrode **4**a at the side electrode **3**a side. Here, the conducting adhesive material **8**a is formed on the insulating film **6** as well, and electrically insulated from the side electrode **3**b by the insulating film **6**.

As shown in FIG. **2**G, the multilayered structure on which the side electrodes **3**a and **3**b, the flat electrodes **4**a and **4**b, and the insulating films **5**a and **6** have been formed is cut at predetermined distances (corresponding to the half of the arrangement pitch of the wiring members **7**a or **7**b), and thus, a group of one-dimensionally arranged multilayered piezoelectric elements are formed. At the same time, also the conducting adhesive material **8**a and the conducting adhesive material **8**b are cut and the adjacent multilayered piezoelectric elements are insulated. Thereby, array structures in which the multilayered piezoelectric element **11**a and the multilayered piezoelectric element **11**b are alternately stacked are completed, and those multilayered piezoelectric elements **11**a and **11**b function as ultrasonic transducers (piezoelectric vibrators) of the ultrasonic probe.

In the multilayered piezoelectric element, the area of opposed electrodes becomes larger than that of the single-layered vibrator, and the electric impedance becomes lower. Therefore, the multilayered piezoelectric element operates more efficiently for the applied voltage than a single-layered piezoelectric vibrator having the same size. Specifically, given that the number of piezoelectric material layers is N, the number of the piezoelectric material layers is N-times the number of that of the single-layered piezoelectric vibrator and the thickness of each piezoelectric layer is 1/N of the thickness of that of the single-layered piezoelectric vibrator, and the electric impedance of the vibrator is $1/N^2$-times that of the single-layered piezoelectric vibrator. Therefore, the electric impedance of the vibrator can be adjusted by increasing or decreasing the number of stacked piezoelectric material layers, and thus, the electric impedance matching between a drive circuit or signal cable and itself is easily provided, and the sensitivity can be improved.

Next, the second embodiment of the present invention will be explained. In the first embodiment, the example of multilayered structure of whole surface electrode structure having two piezoelectric material layers has been shown, however, in the second embodiment, an example of multilayered structure of whole surface electrode structure having three piezoelectric material layers will be shown.

FIG. **3** is a front view showing an ultrasonic probe according to the second embodiment of the present invention. As shown in FIG. **3**, as the third piezoelectric material layer, a piezoelectric material layer **1**c is provided on the piezoelectric material layer **1**b via an internal electrode **2**b. An insulating film **5**b is formed on the end of the internal electrode **2**b at the side electrode **3**b side, and the internal electrode **2**b is electrically connected to the side electrode **3**a and electrically insulated from the side electrode **3**b. Further, a notch part (groove) that cuts the side electrode **3**a side in the array arrangement direction is provided in the flat electrode **4**b and the piezoelectric material layer **1**c. Accordingly, the flat electrode **4**b is electrically connected to the side electrode **3**b and electrically insulated from the side electrode **3**a. Thereby, the same electric field as that for the piezoelectric material layer **1**a is applied to the piezoelectric material layer **1**c.

In this manner, in the case of the multilayered piezoelectric element having three or more piezoelectric material layers, the end of the internal electrode is connected to either of the side electrode **3**a or **3**b and the insulating film is formed on the opposite end such that the opposed two electrodes have reverse polarity to each other. Further, the flat electrode **4**b is also connected to either of the side electrode **3**a or **3**b so as to have reverse polarity to the facing electrode. Note that the second embodiment is the same as the first embodiment in that the side electrode **3**b is used as the common electrode and the side electrode **3**a is used as the individual electrode. Further, the second embodiment is the same as first embodiment in that the insulating film **6** is provided such that the short-circuit of the conducting adhesive material **8**a for bonding the wiring members to the individual electrodes to the side electrode **3**b is prevented.

Next, the third embodiment of the present invention will be explained. In the second embodiment, the example in which the notch is formed in the corner part of the multilayered structure to insulate the flat electrode **4**a from the side electrode **3**b and insulate the flat electrode **4**b from the side electrode **3**a has been shown, however, in the third embodiment, an example in which insulating films of an insulating resin is provided in the corner parts of the multilayered structure will be shown.

FIG. **4** is a front view showing an ultrasonic probe according to the third embodiment of the present invention. As shown in FIG. **4**, an insulating film **5**c of an insulating resin is provided inside of the end part of the side electrode **3**a at the flat electrode **4**b, and an insulating film **5**d of the insulating resin is provided inside of the end part of the side electrode **3**b at the flat electrode **4**a.

The insulating film **6** covers the corner part where the side electrode **3**b and the flat electrode **4**a are separated by the insulating film **5**d. In the third embodiment, the end part of the side electrode **3**b at the flat electrode **4**a side is covered by the insulating film **6**, and the short-circuit of the conducting adhesive material **8**a to the side electrode **3**b can be prevented.

Next, the fourth embodiment of the present invention will be explained. In the first to third embodiments, the example of multilayered structure of whole surface electrode structure has been shown, however, in the fourth embodiment, an example of multilayered structure of alternating electrode structure will be shown.

FIG. **5** is a front view showing an ultrasonic probe according to the fourth embodiment of the present invention. As shown in FIG. **5**, the internal electrode **2***a* does not reach the side surface of the side electrode **3***a* but ends within the piezoelectric material, and the internal electrode **2***b* does not reach the side surface of the side electrode **3***b* but ends within the piezoelectric material. Accordingly, the internal electrode **2***a* is insulated from the side electrode **3***a*, and the internal electrode **2***b* is insulated from the side electrode **3***b*. Further, the flat electrode **4***a* does not reach the side surface of the side electrode **3***b* like the internal electrode **2***b*, and the flat electrode **4***b* does not reach the side surface of the side electrode **3***a* like the internal electrode **2***a*. Thereby, the flat electrode **4***a* is insulated from the side electrode **3***b*, and the flat electrode **4***b* is insulated from the side electrode **3***a*.

The insulating film **6** covers nearly the entire exposed surface of the side electrode **3***b* and covers the corner part of the piezoelectric material layer **1***a* at the side electrode **3***b* side. In the case of the alternating electrode structure, the end part of the side electrode **3***b* at the flat electrode **4***a* side is covered by the insulating film **6** and the short-circuit of the conducting adhesive material **8***a* to the side electrode **3***b* can be prevented.

Next, the fifth embodiment of the present invention will be explained.

FIG. **6** is a front view showing an ultrasonic probe according to the fifth embodiment of the present invention. As shown in FIG. **6**, the conducting adhesive material **8***a* is formed to the upper part of the insulating film **6**. The conducting adhesive material **8***a* flows out from the notch part (groove) and covers the greater part of the insulating film **6** at the flat electrode **4***a* side.

In this manner, the conducting adhesive material **8***a* not only covers the joint part of the end of the flat electrode **4***a* and the wiring member **7***a* but also widely covers the insulating film **6**, and thus, the mechanical strength of the joint part and the side surface of the multilayered structure can be improved. Further, the electric disconnection can be prevented by sufficient filling of the conducting adhesive.

Next, the sixth embodiment of the present invention will be explained. The sixth embodiment is a modification of the first embodiment, however, the second or fifth embodiment may be modified in the same manner.

FIG. **7** shows an internal structure of an ultrasonic probe according to the sixth embodiment of the present invention. In FIG. **7**, (a) is a front view, (b) is a left-side view, and (c) is a right-side view.

When the ultrasonic probe according to the first embodiment is manufactured, as shown in FIG. **2**E, the insulating film **6** is formed by applying a highly insulating resin to the surface of the side electrode **3***b* and the part of the notch part (groove) including the end part of the side electrode **3***b*. At the step, in order to reliably cover the end part of the side electrode **3***b* exposed on the notch part, the amount of highly insulating resin should be made larger and the highly insulating resin may flow out from the notch part. If the highly insulating resin flows out from the notch part, the highly insulating resin spreads out on the flat electrode **4***a* and the physical connection and electric connection between the flat electrode **4***a* and the wiring member **7***a* (FIG. **2**F) becomes defective. On this account, in the sixth embodiment, the notch part for dividing the side electrode **3***b* and the flat electrode **4***a* has a two-step configuration as shown in FIG. **7**.

Next, a method of manufacturing the ultrasonic probe according to the sixth embodiment of the present invention will be explained. The process prior to the steps of applying a coating to the multilayered structure with electrode materials (conducting films) to be the side electrodes **3***a* and **3***b* and the flat electrodes **4***a* and **4***b* as shown in FIG. **2**C and forming the groove on the flat electrode **4***b* such that the flat electrode **4***b* and the side electrode **3***b* are electrically divided as shown in FIG. **2**D is the same as that in the first embodiment.

FIGS. **8**A-**8**C are diagrams for explanation of the method of manufacturing the ultrasonic probe according to the sixth embodiment of the present invention. In the multilayered structure shown in FIG. **8**A, in order to electrically divide the flat electrode **4***b* and the side electrode **3***b*, as shown in FIG. **8**B, a groove is formed at a first depth from the surface including the flat electrode **4***a* and at a second depth (e.g., about 30 μm) from the surface including the side electrode **3***b* on the corner part of the multilayered structure (including a part of the piezoelectric material layer **1***a*) where the surface including the flat electrode **4***a* and the surface including the side electrode **3***b* intersect. In this example, using a dicing blade attached to a dicing saw or cutting saw and rotated, the corner part of the multilayered structure is cut off in the array arrangement direction.

Furthermore, as shown in FIG. **8**C, a groove is formed at a third depth shallower than the first depth from the surface including the flat electrode **4***a* and at a fourth depth deeper than the second depth (e.g., about 60 μm=30 μm+30 μm) from the surface including the side electrode **3***b*. Thereby, the notch part having a two-step configuration is formed. In this example, using the dicing blade, the corner part of the multilayered structure is cut off in the array arrangement direction. By repeating the steps, a notch part having a multi-step configuration may be formed.

In the example shown in FIG. **8**C, three regions (a) to (c) at different levels are formed on the side surface of the multilayered structure. When a highly insulating resin is applied to a part of the region (a) and the region (b), the surface tension is made stronger by the level difference between the region (b) and the region (c), and thereby, the highly insulating resin is prevented from spreading out to the region (c). In addition, the highly insulating resin can reliably cover the end part of the side electrode **3***b* exposed on the notch part, the yield of the ultrasonic probe can be improved.

The invention claimed is:

1. An ultrasonic probe including plural multilayered piezoelectric elements arranged in a row, each of said plural multilayered piezoelectric elements comprising:

a multilayered structure in which plural piezoelectric material layers and at least one internal electrode are alternately stacked;

a first flat electrode formed on a piezoelectric material layer located on one end of said multilayered structure;

a second flat electrode formed on a piezoelectric material layer located on the other end of said multilayered structure;

a first side electrode formed on a first side surface of said multilayered structure and connected to odd-numbered electrodes of said first and second flat electrodes and said at least one internal electrode, said odd-numbered electrodes including said first flat electrode;

a second side electrode formed on a second side surface of said multilayered structure and connected to even-numbered electrodes of said first and second flat electrodes and said at least one internal electrode;

an insulating film formed at a second side surface side of said multilayered structure;

a wiring member bonded to said first flat electrode on said one end of said multilayered structure by using a conducting adhesive material;

wherein said wiring member is provided at the second side surface side of said multilayered structure in a first multilayered piezoelectric element of said plural multilayered piezoelectric elements, said wiring member is provided at a first side surface side of said multilayered structure in a second multilayered piezoelectric element adjacent to said first multilayered piezoelectric element of said plural multilayered piezoelectric elements, and said insulating film electrically separates said second side electrode and said conducting adhesive material in said first multilayered piezoelectric element.

2. The ultrasonic probe according to claim **1**, wherein a first groove is formed in a corner part of said multilayered structure where a surface including said first flat electrode and a surface including said second side electrode intersect, and a second groove is formed in parallel with said first groove in said second flat electrode, and thereby, (i) an individual electrode including said first flat electrode, said first side electrode, and a part of said second flat electrode and (ii) a common electrode including said second side electrode and a part of said second flat electrode are formed.

3. The ultrasonic probe according to claim **2**, wherein said first groove is formed by forming a groove at a first depth from the surface including said first flat electrode and at a second depth from the surface including said second side electrode, and further forming a groove at a third depth shallower than the first depth from the surface including said first flat electrode and at a fourth depth deeper than the second depth from the surface including said second side electrode in the corner part of said multilayered structure where the surface including said first flat electrode and the surface including said second side electrode intersect.

4. The ultrasonic probe according to claim **1**, wherein said conducting adhesive material is formed to cover a part of said insulating film.

5. The ultrasonic probe according to claim **1**, wherein said insulating film includes a resin.

6. The ultrasonic probe according to claim **1**, wherein each of said plural piezoelectric material layers has a thickness not larger than 130 μm.

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patsnap

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摘要(译)

在超声波探头中，从多层压电元件引出的各个导线以交错的方式排列，防止了短路。每个元件包括：多层结构，其中堆叠压电材料层和至少一个内电极;第一和第二扁平电极;第一和第二侧电极;绝缘膜形成在多层结构的第二侧表面侧;通过使用导电粘合材料粘合到多层结构的一端上的第一扁平电极的布线构件;布线构件设置在多层结构的第二侧表面侧，并且绝缘膜将第二侧电极和导电粘合材料电隔离在第一元件中，并且布线构件设置在第一侧表面侧的第一侧表面侧。第二个元素中的多层结构。