



(11) **EP 1 825 815 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 158(3) EPC

(43) Date of publication:
29.08.2007 Bulletin 2007/35

(51) Int Cl.:
A61B 8/12 (2006.01)

(21) Application number: **05790237.1**

(86) International application number:
PCT/JP2005/018358

(22) Date of filing: **04.10.2005**

(87) International publication number:
WO 2006/040962 (20.04.2006 Gazette 2006/16)

(84) Designated Contracting States:
DE FR GB

(30) Priority: **15.10.2004 JP 2004301572**
05.11.2004 JP 2004321470
31.01.2005 JP 2005024385

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(54) **ULTRASONIC VIBRATOR, AND MANUFACTURING METHOD THEREOF**

(57) An ultrasonic transducer in which lead wire connection is facilitated even when piezoelectric devices are divided in order to prevent lateral vibrations from affecting longitudinal vibrations is manufactured by a method comprising: a step in which first dicing grooves are formed on an acoustic matching layer and a piezoelectric device plate that are mounted together in order to form a plurality of piezoelectric devices; a step in which a board and the respective piezoelectric devices are connected together; a step in which surfaces in the vicinity of locations at which the board and the piezoelectric devices are connected together are coated with a conductive sheet; and a step in which the plurality of transducer elements are formed by forming second dicing grooves between the first dicing grooves formed on the piezoelectric devices and the board that is coated with the conductive sheet and on the acoustic matching layer.

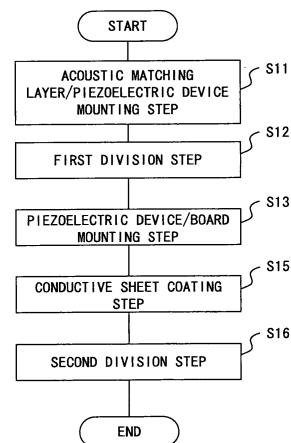


FIG. 16

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Description

Technical Field

[0001] The present invention relates to an ultrasonic transducer, to be used in an endoscope, for obtaining ultrasonic cross-sectional images by transmitting and receiving ultrasound to and from body cavities and to a method of manufacturing such an ultrasonic transducer, and particularly to an ultrasonic transducer that does not cause crosstalk or disturbances in ultrasonic beams, and to a method of manufacturing such an ultrasonic transducer.

Background Art

[0002] Conventionally, a diagnostic ultrasound system formed for clinics. This system comprises an ultrasonic transducer, a signal transmitting unit, a signal receiving unit and a display unit. The signal transmitting unit is generated the pulse signals and connected with the ultrasonic transducer to have the pulse signals transmitted into the ultrasound by above transducer. The signal receiving unit is connected with ultrasonic transducer for receiving echo signals varied with the ultrasonic pulse echo from the tissues. The receiving unit is adapted to process the echo signals from the ultrasonic transducer in order to generate output signals to be converted into the image of the tissues. The display unit is connected with the signal receiving unit to display the image of the tissues, on the basis of the output signals from the signal receiving unit.

[0003] An ultrasonic transducer comprises a plurality of piezoelectric transducers, and each consisting of a rectangular plate of a piezoelectric device, which were cut out (dicing process) one piezoelectric material. On the side of the piezoelectric device from which acoustic waves are transmitted, an acoustic matching layer is formed for matching acoustic impedances, and an acoustic lens is formed on the surface of the acoustic matching layer. Also, a backing material that is made of rubber or the like, being high loss coefficient (sound attenuation), is adhered to the back side of the piezoelectric device.

[0004] An example of an ultrasonic transducer (used in diagnostic ultrasound systems as described above) for transmitting and receiving ultrasound is an array-arranged transducer. The dimensions of the piezoelectric device generally used in the array-arranged transducer are width W , thickness T , and length L . The piezoelectric device used in the array-arranged transducer has electrodes (a ground electrode and a signal electrode) arranged on the upper and lower surfaces. Each electrode area is multiply width W by length L .

[0005] When the pulse signal voltage is applied to the above electrodes, longitudinal vibrations in accordance with the thickness T are caused as the principal vibrations, and the lateral vibrations (lengthwise vibrations) in accordance with the width W are also caused as the sub-

sidary vibrations. In other words, the power of lateral vibrations become strong, when the width W is almost equal to thickness T , and these lateral vibrations may sometimes be superposed on the longitudinal vibrations depending on the shape of the piezoelectric device, such that the longitudinal vibrations are affected. Accordingly, piezoelectric device divided it into two or three pieces in such a manner that each piezoelectric device does not have one proper resonant frequency in the lateral direction.

[0006] Here, explanations are given for the steps of manufacturing an ultrasonic transducer; these steps are generally employed in order to configure the piezoelectric device in such a manner that the piezoelectric device does not have a proper resonant frequency (see Patent Document 1, for example).

(1) A backing layer is formed into the decided shape. (backing material forming step)

(2) Lead wires in the form of an FPC (Flexible Printed Circuit) board or the like are connected to electrodes that are formed on the piezoelectric device in a prescribed shape, before or after the backing material forming step. (wiring step)

(3) The first stacked body is formed by mounting the piezoelectric device and the backing layer. (piezoelectric transducer mounting step)

(4) A transducer unit serving as the second stacked body is formed by mounting the first acoustic matching layer to the piezoelectric device included in the first stacked body. (first matching layer mounting step)

(5) Dicing grooves are formed on the transducer unit from the side of the first acoustic matching layer, such that the piezoelectric device is divided into a plurality of transducer elements. (dicing step)

(6) The dicing grooves are filled with resin with particles for reinforcement. (filling step)

(7) The third stacked body is formed by mounting the second acoustic matching layer to the first acoustic matching layer. (second acoustic matching layer mounting step)

(8) An acoustic lens is cast on the third stacked body. (lens casting step)

(9) The third stacked body, including the acoustic lens, is encased. (packaging step)

[0007] Ultrasonic transducers are manufactured using the above steps in the conventional process.

[0008] Electronically scanning ultrasonic transducer is formed at the distal end of endoscope insertion tube. The ultrasonic transducer on the endoscope is transmitted the ultrasounds in the digestive tract, so this transducer can be received the ultrasounds from the digestive organ such as the stomach, the pancreas, the liver without interfered with the gas or bone. In the electronically scanning ultrasonic transducer, tens or more piezoelectric transducers are arrayed.

[0009] Fig. 1 shows a conception of piezoelectric transducers.

[0010] As shown in Fig. 1, a piezoelectric transducer 2101 is generally a rectangular shape (hexahedron) whose width is W , thickness is T , and length is L . When a voltage is applied to electrodes (not shown) on the upper and lower surfaces (thickness direction) of the rectangular shape (hexahedron) shown in Fig. 1, the rectangular shape (hexahedron) vibrates in the thickness direction and generates ultrasounds.

[0011] It has been disclosed that ultrasonic transducers such as the one described above are very efficient in the coefficient of electromechanical coupling when the W/T ratio of their piezoelectric transducer is equal to or lower than 0.8, and that the smaller the interval "a" between adjacent piezoelectric transducers, the higher the image quality (Patent Document 2 for example). Accordingly, ultrasonic transducers have conventionally been designed in such a manner that the interval "a" between adjacent piezoelectric transducers is as small as possible, and the W/T ratio is equal to or lower than 0.8.

[0012] Fig. 2 is a perspective view showing a first example of a conventional ultrasonic transducer. Fig. 3 is a cross-sectional view of the first example of the conventional ultrasonic transducer.

[0013] In Figs. 2 and 3, the ultrasonic transducer comprises piezoelectric transducers 2123 that formed electrode layers on the upper and lower surfaces thereof, acoustic matching layers 2124 (first acoustic matching layer 2124a and second acoustic matching layer 2124b) formed under the piezoelectric transducer 2123, a GND conduction unit 2125 for connecting to GND the electrodes formed under the piezoelectric transducer 2123, dicing grooves 2126 formed by using a dicing saw (a precision cutting machine) or the like for dividing the piezoelectric transducer 2123 into plural pieces, lead wires 2131 connected to the electrodes on the lower surface of the piezoelectric transducer 2123, and a backing material 2130. In this configuration, an acoustic matching layer and piezoelectric transducers or the like having dicing grooves 2126 between them is referred to in whole as an ultrasonic transducer element.

[0014] Fig. 4 is a perspective view showing a second example of a conventional ultrasonic transducer. Fig. 5 is a cross-sectional view of the second example of the conventional ultrasonic transducer.

[0015] The transducer shown in Figs. 4 and 5 is different from that shown in Figs. 2 and 3 in that one lead wire 2131 is connected to two piezoelectric transducers 2123 (2123a and 2123b) and two acoustic matching layers 2124 (2124a and 2124b), and one transducer element consists of a plurality (two in Fig. 5) of transducer sub elements. By employing the configuration of sub elements as described above, it is possible to improve the ultrasonic transmission/reception characteristics (sensitivity, for example) of the ultrasonic transducer.

[0016] Here, a method of designing a conventional ultrasonic transducer is described.

(1) The effective width S of the emitting window of an ultrasonic transducer is determined on the basis of the size S_0 of the object that is to be observed by the ultrasonic transducer in such a manner that $S_0 < S$.

(2) The arraying pitch p in the ultrasonic transducer is calculated S/N : where N is the maximum number of driving channels of diagnostic ultrasound system, S is the effective width.

(3) The element number n of piezoelectric transducers with a W/T ratio of 0.8 or lower that can be included in the arraying pitch p is calculated. In the example of Figs. 2 and 3, the number of transducer elements is n , and in the example of Figs. 4 and 5, the number of sub elements is $2n$.

[0017] In the conventional methods, configurations are employed in which a plurality of piezoelectric elements are formed such that an effective W/T ratio is achieved, as described above. Also, in some cases, fine modification has been performed on the effective width S , such that the effective W/T ratio is achieved.

[0018] The electronically scanning ultrasonic transducer is formed at the insertion tube of an endoscope.

The ultrasonic transducer on the endoscope is transmitted the ultrasounds in the digestive tract, so this transducer can be received the ultrasounds from the digestive organ such as the stomach, the pancreas, the liver without interfered with the gas or bone. Examples of types of such electronically scanning ultrasonic transducers applied to the endoscopes include the convex type, the linear type, the radial type and the like.

[0019] The ultrasonic transducers generally employ the configuration in which a plurality of ultrasonic transducer elements are arrayed for transmitting and receiving the ultrasound, and only the grooves formed at the both side of each element (slots between adjacent transducer elements) are filled with resin (see Patent Document 3 for example).

[0020] Also, a method is disclosed in which adhesive is applied to several locations, including the centers of the grooves (see Patent Document 4 for example).

Patent Document 1
Japanese Patent Application Publication No. 2001-46368

Patent Document 2
Japanese Patent No. 56-17026

Patent Document 3
Japanese Patent Application Publication No. 8-107598

Patent Document 4
Japanese Patent Application Publication No. 2000-253496

Disclosure of the Invention

[0021] However, the conventional device has a problem in which, when a transducer element is divided into smaller elements such that the transducer elements do not have a proper resonant frequency in the lateral direction in order to prevent lateral vibrations that are superposed on longitudinal vibrations from affecting the longitudinal vibrations, the number of transducer elements inevitably increases and the width of each transducer element becomes narrower, such that the difficulty in connecting lead wires to the elements increases.

[0022] Also, there has been a problem in which, when an FPC board is directly connected to transducer sub elements each having a small width, the stiffness of the FPC board remains as a residual stress such that the reliabilities of the ultrasonic transducers are reduced.

[0023] The present invention has been achieved in view of the above problems, and it is an object of the present invention to provide a method of manufacturing an ultrasonic transducer that is highly reliable and allows easy lead wire connections even when transducer elements are divided into smaller elements, and to provide an ultrasonic transducer manufactured on the basis of such a method.

[0024] In order to attain the above objects, the present invention employs the configurations as follows.

[0025] According to one aspect of the present invention, one method of manufacturing an ultrasonic transducer according to the present invention is a method of manufacturing an ultrasonic transducer comprising a plurality of transducer elements each having a plurality of transducer sub elements.

[0026] The above method of manufacturing an ultrasonic transducer comprises:

a first division step in which first dicing grooves are formed on an acoustic matching layer and a piezoelectric device plate that are mounted together in order to form a plurality of piezoelectric devices; a piezoelectric device/board connection step in which a board and the respective piezoelectric devices formed in the first division step are connected together; a conductive sheet coating step in which surfaces in the vicinity of locations at which the board and the piezoelectric devices are connected together in the piezoelectric device/board mounting step are coated with a conductive sheet; and a second division step in which the plurality of transducer elements are formed by dicing the second grooves between the first dicing grooves, and these grooves are divided from in the first division step, on the piezoelectric devices and the board being coated with the conductive sheet in the conductive sheet coating step=and on the acoustic matching layer.

[0027] Also, the above method of manufacturing an

ultrasonic transducer comprises:

a first division step in which first dicing grooves are formed on a backing material and a piezoelectric device plate that are mounted together in order to form a plurality of piezoelectric devices; a piezoelectric device/board connecting step in which a board and the respective piezoelectric devices formed in the first division step are connected together; a conductive sheet coating step in which surfaces in the vicinity of locations at which the board and the piezoelectric devices are connected together in the piezoelectric device/board mounting step are coated with a conductive sheet; and a second division step in which the plurality of transducer elements are formed by forming second dicing grooves between the first dicing grooves formed, in the first division step, on the piezoelectric devices and the board being coated with the conductive sheet in the conductive sheet coating step and on the backing material.

[0028] Also, a method of manufacturing an ultrasonic transducer according to the present invention is desired to further comprise:

a masking step in which the first dicing grooves formed, in the first division step, on a surface of the respective piezoelectric devices connected to the board in the piezoelectric device/board connection step are masked, said masking step being executed after the piezoelectric device/board connecting step and before the conductive sheet coating step.

[0029] Also, in a method of manufacturing an ultrasonic transducer according to the present invention, it is desired that:

the thickness of the conductive sheet is thin.

[0030] Also, according to one aspect of the present invention, an ultrasonic transducer according to the present invention is characterized in that:

the transducer elements include a conductive sheet for electrically connecting:

piezoelectric devices; a board connected to the piezoelectric devices in such a manner that the board is adjacent to the piezoelectric devices; electrodes formed on main surfaces of the piezoelectric devices; and electrode patterns formed on main surfaces of the board, and wherein:

the piezoelectric device (plate-shape de-

vice) is in a divided state in such a manner that the piezoelectric devices respectively correspond to the transducer sub elements; and the board are in a divided state in such a manner that the board respectively correspond to the transducer elements.

[0031] Additionally, when severe limitations are placed upon dimensions, as occurs in an ultrasonic transducer to be used in body cavities (like a ultrasound endoscope), there is a problem that wiring to elements consisting of two or more sub element is difficult.

[0032] When a plurality of sub elements are connected to one lead wire as shown in Figs. 4 and 5, the area that can be used for the connection is reduced, such that fine wiring is required. Accordingly, when thermal or mechanical stress is applied during reprocessing, the load on the sub elements caused by the residual stress of wiring patterns increases, such that the risk of breakage increases, which decreases the reliability. Of course, the machinability also decreases.

[0033] When, in contrast, the transducer element is not divided into a plurality of sub elements in order to avoid the difficulty of wiring connection (see Figs. 2 and 3), the aspect ratio of the piezoelectric device increases to 0.8 or higher, the efficiency in coefficient of electromechanical coupling deteriorates such that the sensitivity decreases, and the frequency characteristics deteriorate, being affected by the occurrence of an unnecessary vibration mode. In view of this, the effective width S of the emitting window needs to be changed; however, the effective width S of the emitting window in ultrasonic transducers that are to be used in body cavities cannot be changed, which is problematic.

[0034] In the case of cylindrical shaped ultrasonic transducer that are designed to be used in body cavities, functions (such as an optical observation function) that are necessary for safely inserting the transducer into body cavities are formed, and thus the diameter cannot be reduced. In contrast, the diameter cannot be increased in view of the fact that the cylindrical shaped ultrasonic transducer will be inserted into body cavities and an increase in diameter would result in an increase in tenderness that patients feel.

[0035] In view of the above problems, it is an object of the present invention to provide an ultrasonic transducer that has a high efficiency in coefficient of electromechanical coupling, is shaped so as to not result in entering the mode in which unnecessary vibrations occur, and has an excellent machinability and a high reliability.

[0036] According to one aspect of the present invention, the above object can be achieved by providing an ultrasonic transducer comprising a plurality of piezoelectric transducers for transmitting and receiving ultrasounds, wherein:

the dielectric constant ($\epsilon_{T_{33}} / \epsilon_0$) of the piezoelectric

transducer is equal to or higher than 2500; the ratio W/t between lateral width W and thickness t of the piezoelectric transducer is equal to or lower than 0.6; and the interval between each pair of adjacent piezoelectric transducers is equal to or smaller than the wavelength of the ultrasound.

[0037] According to one aspect of the present invention, the above object can be achieved by providing an ultrasound endoscope comprising the above described ultrasonic transducer.

[0038] According to one aspect of the present invention, the above object can be achieved by providing an electronic radial scanning ultrasonic transducer in which a plurality of piezoelectric transducers for transmitting and receiving ultrasounds are arrayed in a cylindrical shape and at a constant interval, and the radius of an outer periphery of the cylindrical shape is equal to or smaller than ten millimeters, wherein:

the dielectric constant ($\epsilon_{T_{33}} / \epsilon_0$) of the piezoelectric transducer is equal to or higher than 2500; the ratio W/t between lateral width W and thickness t of the piezoelectric transducer is equal to or lower than 0.6; and the interval between each pair of adjacent piezoelectric transducers is equal to or smaller than the wavelength of the ultrasound.

[0039] According to one aspect of the present invention, the above object can be achieved by providing the above electronic radial scanning ultrasonic transducer, wherein:

the ratio between the width W of each of the piezoelectric transducers and the interval between each pair of adjacent piezoelectric transducers is approximately 1:2.

[0040] According to one aspect of the present invention, the above object can be achieved by providing an ultrasound endoscope comprising the above electronic radial scanning ultrasonic transducer.

[0041] Also, in the technique disclosed in Patent Document 3, a relatively large crosstalk is caused between the adjacent piezoelectric transducers and cannot be suitably applied to the radial type or the convex type in which the transducers are curved.

[0042] Also, when the technique disclosed in Patent Document 4 is applied to a device such as an ultrasound endoscope having a small transducer, the crosstalk increases and beam patterns deteriorate and become uneven; i.e., the characteristics of the endoscope deteriorate.

[0043] Further, the techniques disclosed in Patent Documents 3 and 4 respectively require the grooves, which have a width of several tens of micrometers, to be

evenly filled with resin. However, it is actually impossible to fill the grooves with resin as accurately as is required in Patent Documents 3 and 4, such that when the techniques disclosed in Patent Documents 3 and 4 are applied to an ultrasonic transducer to be used in an ultrasound endoscope having small transducers, the characteristics (sensitivity, example for) of the transducer vary greatly.

[0044] In view of the above problems that the conventional techniques have, it is an object of the present invention to provide an ultrasonic transducer in which crosstalk or disturbances are not caused.

[0045] A first ultrasonic transducer according to the present invention is an ultrasonic transducer in which a plurality of ultrasonic transducer elements for transmitting and receiving ultrasounds are arrayed, and acoustic matching layers are stacked, wherein:

adhesive is applied to locations that are at both ends, in the longitudinal direction, of grooves between the adjacent ultrasonic transducer elements and that do not contact a transducer element; and a vibration damping (sound attenuation) agent is applied between the adhesive applied to the grooves and the transducer element.

[0046] A second ultrasonic transducer according to the present invention is the above first ultrasonic transducer, wherein:

the adhesive is applied to both ends, in the longitudinal direction, of each of the grooves.

[0047] A third ultrasonic transducer according to the present invention is the above first ultrasonic transducer, wherein:

the adhesive is a hard resin.

[0048] A fourth ultrasonic transducer according to the present invention is one of the above first through third ultrasonic transducers, wherein:

the vibration damping (sound attenuation) agent is a backing material applied to back surfaces of the ultrasonic transducer elements.

[0049] A fifth ultrasonic transducer according to the present invention is one of the above first through fourth ultrasonic transducers, wherein:

the ultrasonic transducer is an electronic radial scanning ultrasonic transducer.

[0050] An ultrasound endoscope according to the present invention is characterized by comprising one of the above first through fifth ultrasonic transducers.

Brief Description of the Drawings

[0051]

- 5 Fig. 1 shows a conception of piezoelectric transducers;
 Fig. 2 is a perspective view of a first example of a conventional ultrasonic transducer;
 Fig. 3 is a cross-sectional view of the first example of the conventional ultrasonic transducer;
 10 Fig. 4 is a perspective view of a second example of a conventional ultrasonic transducer;
 Fig. 5 is a cross-sectional view of the second example of the conventional ultrasonic transducer;
 15 Fig. 6 is a flowchart showing a method of manufacturing an ultrasonic transducer according to a first embodiment;
 Fig. 7 is a perspective view of an acoustic matching layer/piezoelectric device mounting step;
 20 Fig. 8 is a perspective view of the first division step;
 Fig. 9 is a top view of the first division step;
 Fig. 10 is a perspective view of the piezoelectric/board mounting step;
 25 Fig. 11 is a top view of the piezoelectric device/board mounting step;
 Fig. 12 is a perspective view of the masking step;
 Fig. 13 is a top view of the conductive sheet coating step in the first embodiment;
 Fig. 14 is a top view of the second division step in the first embodiment;
 30 Fig. 15 is a top view of the step after a masking member is removed;
 Fig. 16 is a flowchart of a method of manufacturing an ultrasonic transducer according to a second embodiment;
 35 Fig. 17 is a perspective view of the conductive sheet coating step in the second embodiment;
 Fig. 18 is a perspective view of the second division step in the second embodiment;
 Fig. 19 is a top view of the second division step in the second embodiment;
 40 Fig. 20 is a perspective view of one transducer element;
 Fig. 21 shows an outline of an ultrasound endoscope;
 45 Fig. 22 is an enlarged view of a distal end 2003 in the ultrasound endoscope 2001 shown in Fig. 21;
 Fig. 23 is a perspective view of the manufacturing process of a structure that constitutes an ultrasonic transducer;
 50 Fig. 24 is a perspective view showing structure A in the third embodiment of the present invention;
 Fig. 25 is a cross-sectional view showing structure A in the third embodiment;
 55 Fig. 26 shows the relationship between $\epsilon_{33}^T/\epsilon_0$ and impedance in the third embodiment;
 Fig. 27 shows the relationship between the W/t ratio and the electromechanical coupling coefficients in

the third embodiment (in the case when $\epsilon_{33}^T/\epsilon_0$ is approximately 1500);

Fig. 28 shows the relationship between W/t ratio and the electromechanical coupling coefficients in the third embodiment (in the case when $\epsilon_{33}^T/\epsilon_0$ is approximately 2500);

Fig. 29 shows an outline of an ultrasound endoscope according to the present invention;

Fig. 30 is an enlarged view of a distal rigid section of the ultrasound endoscope shown in Fig. 29;

Fig. 31 shows a method of manufacturing an ultrasonic transducer (first view);

Fig. 32 shows a method of manufacturing an ultrasonic transducer (second view);

Fig. 33 shows a method of manufacturing an ultrasonic transducer (third view);

Fig. 34 is an enlarged view that schematically shows the state of structure A, shown in Fig. 31, in which adhesive is applied;

Fig. 35 shows structure A, shown in Fig. 31, to which the adhesive is applied (plan view);

Fig. 36 shows structure A, shown in Fig. 31, to which the adhesive is applied (cross-sectional view);

Fig. 37 shows a method of manufacturing an ultrasonic transducer (fourth view);

Fig. 38 shows a method of manufacturing an ultrasonic transducer (fifth view);

Fig. 39 shows a method of manufacturing an ultrasonic transducer (sixth view);

Fig. 40 shows a method of manufacturing an ultrasonic transducer (seventh view);

Fig. 41 shows a method of manufacturing an ultrasonic transducer (eighth view); and

Fig. 42 is a lateral cross-sectional view showing the distal end of the electronic radial scanning ultrasound endoscope shown in Fig. 36.

Best Modes for Carrying Out the Invention

[0052] Hereinafter, embodiments of the present invention will be explained by referring to the drawings.

[0053] First, the first embodiment to which the present invention is applied is explained by referring to Figs. 6 through 15.

[0054] Fig. 6 is a flowchart showing a method of manufacturing an ultrasonic transducer according to the first embodiment. Fig. 7 is a perspective view of the acoustic matching layer/piezoelectric device mounting step. Fig. 8 is a perspective view of the first division step. Fig. 9 is a top view of the first division step. Fig. 10 is a perspective view of the piezoelectric device/board mounting step. Fig. 11 is a top view of the piezoelectric device/board mounting step. Fig. 12 is a perspective view of the masking step. Fig. 13 is a top view of the conductive sheet coating step in the first embodiment. Fig. 14 is a top view of the second division step in the first embodiment. Fig. 15 is a top view of the step after a masking member is removed.

[0055] First, in the acoustic matching layer/piezoelec-

tric device mounting step executed in step S11 shown in Fig. 6, an acoustic matching layer 1021 is connected to a piezoelectric device 1022 as shown in Fig. 7. On the piezoelectric device 1022, electrodes such as a piezoelectric device emitting surface electrode (an electrode to which a ground wire is connected) and a piezoelectric device back surface electrode (an electrode to which a drive wire is connected) are formed by using, for example, a silver firing method.

[0056] In the first division step executed in step s12 shown in Fig. 6, on the acoustic matching layer 1021 and the piezoelectric device 1022 that were connected to each other, first dicing grooves 1031 are formed at a certain pitch by using a dicing machine, as shown in Figs. 8 and 9. Thereby, the acoustic matching layer 1021 and the piezoelectric device 1022 in a connected state are divided into a plurality of piezoelectric devices 1032.

[0057] Then, in the piezoelectric device/board mounting step executed in step s13 shown in Fig. 6, the respective piezoelectric devices 1032 obtained through the first division step in step s12 are connected to a circuit board 1051 to which conveyance cables and other circuit boards such as FPC boards are connected, as shown in Figs. 10 and 11. The communication cables and other circuit boards are used for sending drive signals used for transmitting ultrasound or for accepting reception signals that are created on the basis of ultrasound received. A three-dimensional circuit board, an alumina board, a glass epoxy board, a rigid/flexible board, an FPC board or the like can be employed as the circuit board 1051. On the circuit board 1051, electrode patterns 1052 are formed at a certain pitch (the pitch corresponding to the arraying pitch of transducer elements 1082 that will be explained later). Also, it is possible for the electrode patterns to be formed only on the upper surface of the circuit board 1051, or to be formed in such a manner that the patterns cover the lower surface, the side surfaces, and the upper surfaces of the circuit board 1051. In Fig. 10, the conductive surface of the circuit board 1051 is approximately at the same level as the conductive surfaces of the respective piezoelectric devices 1032. However, when conductive resin, a conductive thin sheet, a thin metallic foil (about eight micrometers, for example) or a flexible printed circuit board using such materials is employed, the level of the conductive surface of the circuit board 1051 and that of the respective piezoelectric device 1032 can be different from each other by several tens of micrometers, and it does not make a difference which is higher.

[0058] Next, in the masking step executed in step S14 shown in Fig. 6, the portions on the respective piezoelectric devices 1032 that have been connected to the circuit board 1051 in the piezoelectric device/board mounting step executed in step S13 are masked with masking members 1121 in such a manner that the first dicing grooves 1031 that have been formed in the division step executed in step s12 are not masked, as shown in Fig. 12. As the masking member 1121, printing screens

such as, for example, a metallic mask or a mesh mask; plates made of metal such as stainless steel, steel, nickel, or bronze; tapes using, as the substrate, resins such as polyimide PTFE (polytetrafluoroethylene), PET (polyethylene terephthalate), or the like; and materials such as PET, fused quartz, ceramics, FRP (fiber reinforced plastic) or the like can be employed.

[0059] Next, in the conductive sheet coating step executed in step s15 shown in Fig. 6, the portions that are close to the mounting portions between the piezoelectric devices 1032 and the circuit board 1051 that have been connected to each other in the piezoelectric device/board mounting step executed in step s13, and that are close to the portions that have been masked with the masking members 1121 in step s14 are coated, as shown in Fig. 13, with a conductive sheet 1071 made of a conductive thick sheet or of a conductive thin sheet.

[0060] In the second division step executed in step s16 shown in Fig. 6 (after forming the conductive sheet 1071), second dicing grooves 1081 are formed, by using a dicing machine, at a certain pitch on the respective piezoelectric devices 1032 and the circuit board 1051, which are coated with the conductive sheet 1071 in the conductive sheet coating step executed in step s15 between the first dicing grooves 1031 formed in the first division step executed in step s12 and on the acoustic matching layer 1021, and thereby a plurality of transducer elements 1151 are formed as shown in Fig. 14.

[0061] In the masking member removal step executed in step s17 shown in Fig. 6, the masking members 1121 are removed, and thereby the ultrasonic transducer comprising a plurality of transducer elements 1151 each consisting of two transducer sub elements can be manufactured.

[0062] Next, a second embodiment to which the present invention is applied is explained by referring to Figs. 16 through 20. The points that are different from the first embodiments are mainly described, and explanations of the points that are similar between the first and second embodiments are omitted.

[0063] Fig. 16 is a flowchart showing a method of manufacturing an ultrasonic transducer according to the second embodiment. Fig. 17 is a perspective view showing the conductive sheet coating step in the second embodiment. Fig. 18 is a perspective view showing the second division step in the second embodiment. Fig. 19 is a top view showing the second division step in the second embodiment. Fig. 20 is a perspective view showing one transducer element.

[0064] The flowchart shown in Fig. 16 is different from that shown in Fig. 6 in that the flowchart shown in Fig. 16 does not include the masking step executed in step s14 or the masking member removal step executed in step s17, both of which are shown in Fig. 6. In other words, the method of manufacturing an ultrasonic transducer according to the second embodiment is characterized by not requiring the masking step.

[0065] Specifically, in the conductive sheet coating

step executed in step S15 that is executed subsequently to the piezoelectric device/board mounting step executed in step s13, portions that are close to the mounting portions between the piezoelectric devices 1032 and the circuit board 1051 that were connected to each other in the piezoelectric device/board mounting step executed in step s13 are coated with the conductive sheet 1071 in such a manner that the conductive sheet 1071 covers the portions on both piezoelectric device 1032 and circuit board 1051. The conductive sheet 1071 can be made of a conductive thin sheet that is fabricated by using a conductive sheet made of conductive paint, conductive resin, conductive adhesive or the like, or a conductive thin sheet obtained by plating, sputtering, vapor deposition, CVD (chemical vapor deposition) or the like.

[0066] When the conductive sheet 1071 is hardened, then in the second division step executed in step s16 shown in Fig. 16 the second dicing grooves 1081 are formed, by using a dicing machine, at a certain pitch on the respective piezoelectric devices 1032 and the circuit board 1051, which are coated with the conductive sheet 1071 in the conductive sheet coating step executed in step s15 and are between the first dicing grooves 1031 formed in the first division step executed in step s12 and on the acoustic matching layer 1021, and thereby a plurality of transducer elements 1082 are formed, as shown in Figs. 18 and 19.

[0067] Thereby, an ultrasonic transducer can be manufactured, that comprising a plurality of transducer elements 1082 each of which consists of two transducer sub elements connected to one communication cable (not shown) for sending drive signals used for transmitting ultrasound or accepting reception signals created on the basis of ultrasound received.

[0068] Fig. 20 is a perspective view of one transducer element.

[0069] Fig. 20 shows one of the transducer elements 1082 that is obtained through the second division step executed in step s16 shown in Fig. 16; the transducer element 1082 consists of the acoustic matching layer 1021, the piezoelectric device 1022, the circuit board 1051 with the electrode pattern 1052, and the conductive sheet 1071 in their divided states. Also, the transducer element 1082 consists of two piezoelectric sub elements between which there is the first dicing trench 1031.

[0070] Additionally, when a conductive adhesive or conductive paint having a viscosity of 3000cps or higher is employed and the width of each first dicing trench 1031 is 100 micrometers or smaller, it is not necessary to cover the first dicing grooves 1031 because the conductive sheet 1071 rarely flows into the first dicing grooves 1031. In particular, if the conductive sheet 1071 is fabricated on the basis of a printing method by using a conductive adhesive or a conductive paint having a thixotropic characteristic, it is possible to securely prevent the conductive sheet 1071 from flowing into the first dicing grooves 1031.

[0071] The first and second embodiments have been explained by referring to the drawings; however, the

scope of the present invention is not limited to the above embodiments, and various alterations, modifications and the like are allowed without departing from the spirit of the present invention.

[0072] For example, although in the embodiments described above the transducer elements each consisting of two transducer sub elements has been explained, each transducer element can consist of three or more transducer sub elements.

[0073] Also, the material of the piezoelectric device is not limited to silver, and electrodes fabricated by sputtering, vapor deposition, CVD, plating or the like with a metallic material such as gold, chrome, copper, nickel or the like can be used.

[0074] Similarly, the method of masking is not limited to the above methods of masking in the drawings as long as the function of covering the portions at which the conductive sheet on the first dicing grooves is formed is achieved. For example, a method of masking in which the masking is in the form of the teeth of a comb can be applied to masking for printing or for thin sheets.

[0075] Similarly, although the piezoelectric device plate and the board are mounted on the acoustic matching layer in the above embodiments, the same steps and configurations can be employed even when the piezoelectric device and the board are mounted on a member that is not the acoustic matching member, such as, for example, a backing material that is another representative acoustic member or temporary fixation plates that are to be removed when manufacturing is completed.

[0076] According to the present invention, the degree of freedom in the setting of positions of connection with lead wire terminals is high even when the width of each transducer sub elements is small; thus it is possible to facilitate the manufacture of ultrasonic transducers.

[0077] According to the present invention, all the transducer sub elements can be in connected states by connecting the lead wires for each transducer element in a lump; accordingly, it is possible to facilitate the manufacture of ultrasonic transducers.

[0078] Also, according to the present invention, a thin sheet or a thick sheet (conductive sheet) made of conductive resin is used for lead wires; accordingly, it is possible to manufacture an ultrasonic transducer having a reduced space for wiring.

[0079] Also, according to the present invention, because there is no residual stress such as bending stress or the like, it is possible to manufacture an ultrasonic transducer having a high reliability.

[0080] Next, the third embodiment of the present invention will be explained.

[0081] Fig. 21 shows an outline of an ultrasound endoscope according to the third embodiment of the present invention.

[0082] An ultrasound endoscope 2001 comprises an operation unit 2006 at the proximal end of an insertion unit 2002. A universal cord 2007 extends from a side portion of the operation unit 2006. The universal cord

2007 comprises, at one end thereof, a scope connector 2008 that is to be connected to a light source (not shown). Further, the scope connector 2008 is connected to an ultrasonic observation device (not shown) via a cable.

[0083] The insertion unit 2002 comprises a distal end 2003, a bending unit 2004 that can arbitrarily curve, and a flexible tube 2005, in this order from the distal end side and in the connected state. The operation unit 2006 comprises an angulation control knob 2006a, and by operating this angulation control knob 2006a, the bending unit 2004 can be curved.

[0084] Fig. 22 is an enlarged view showing the distal end 2003 in the ultrasound endoscope 2001 shown in Fig. 21.

[0085] The distal end 2003 comprises an ultrasonic transducer 2010 and comprises a slanting surface portion 2012 between the bending unit 2004 and the ultrasonic transducer 2010. The ultrasonic transducer 2010 is coated with a material from which an acoustic lens (ultrasonic wave transmitting and receiving unit) 2011 is formed. The slanting surface portion 2012 comprises a lighting lens cover 2013 that constitutes a lighting optical unit for casting illumination light to observation target sites, an objective lens cover 2014 that constitutes an optical observation unit that captures the optical images of the observation target sites, and an instrument channel outlet 2015 from which a treatment tool is drawn out. Because the diameter of the endoscope is 20 mm at most, the radius of the outer periphery of the ultrasonic transducer 2010 mounted on the endoscope has to be 10 mm or smaller.

[0086] Fig. 23 is a perspective view showing a structure that constitutes an ultrasonic transducer in the manufacturing process.

[0087] In Fig. 23, when the ultrasonic transducer is to be formed, a structure, A, is first fabricated; structure A comprises a wiring board 2020, an electric conductor 2021, electrodes 2022 (2022a and 2022b), piezoelectric transducers 2023, acoustic matching layers 2024 (first acoustic matching layer 2024a and second acoustic matching layer 2024b), a GND conductive unit 2025, and grooves 2026. Herein below, the fabrication of structure A is explained.

[0088] First, the first acoustic matching layer 2024a is formed after the second acoustic matching layer 2024b is formed. Next, grooves are formed on the first acoustic matching layer 2024a by using, for example, a dicing saw (a precision cutting machine), and the GND conductive unit 2025 is formed by casting conductive resin into the grooves. Next, the piezoelectric transducer 2023 having the electrode layers 2022a and 2022b formed on its opposing surfaces is connected to the piezoelectric transducer 2023. Next, the wiring board 2020 is attached to the first acoustic matching layer 2024a in such a manner that the attached wiring board 2020 is adjacent to the piezoelectric transducer 2023. On the surface of the wiring board 2020, the electrode layer 2020a is formed. Then, the electric conductor 2021 is attached to the wiring

board 2020 and the piezoelectric transducer 2023 in order to cause the electrode layer 2020a and the electrode 2022a to be electrically conductive to each other.

[0089] Slots are formed on structure A by using a dicing saw such that a plurality of grooves (dicing grooves) 2026 each having a width of several tens of micrometers at a constant interval are formed. The width of these grooves is desirably in the range of 20 micrometers through 50 micrometers. The above slots are formed in such a manner that only the second acoustic matching layer 2024b is not completely cut such that portions each having a thickness of several tens of micrometers remain uncut.

[0090] Thereafter, processes that are in accordance with types (such as the convex type, the radial type, and the like) of the ultrasonic transducer are performed. In the case of, for example, Fig. 22, the ultrasonic transducer shown is of the electronic radial scanning type; accordingly, structure A is formed into a cylindrical shape such that the sides X1 and X2 thereof face each other.

[0091] Fig. 24 is a perspective view showing structure A in the third embodiment of the present invention. Fig. 25 is a cross-sectional view showing structure A in the third embodiment of the present invention.

[0092] Fig. 24 shows structure A from Fig. 23 in a simplified manner, which comprises the piezoelectric transducer 2023 having the electrode layers 2022 formed on its opposing surfaces, the acoustic matching layer 2024 (first acoustic matching layer 2024a and second acoustic matching layer 2024b) formed on the lower surface of the piezoelectric transducer 2023, the GND conductive unit 2025 formed of conductive resin so as to be able to connect to the GND the electrode 2022b formed on the lower surface of the piezoelectric transducer 2023, and the grooves 2026 formed by a dicing saw (a precision cutting machine) or the like in order to form a plurality of piezoelectric transducers 2023.

[0093] Fig. 25 is a cross-sectional view of a structure, B, having the configuration in which lead wires 2031 are connected to the electrodes 2022a that are on the upper surface of the piezoelectric transducer 2023, and a backing material 2030 is formed in structure A. In Fig. 25, it is assumed that the width of each of the ultrasonic transducers (ultrasonic transducer elements) is W, and the interval between the adjacent transducer elements is "a". As already described, the narrower the interval "a" is, the better the display quality is. Accordingly, it is desirable that the arraying pitch "a" of these transducer elements be equal to or smaller than the wavelength λ of the ultrasonic wave. In the third embodiment of the present invention, it is assumed that $W : a = 2 : 1$ where W is 100 μm , a is 50 μm , and the length L is 5 mm. At this interval, two hundred transducer elements are arrayed in a cylindrical shape.

[0094] As already described, the lower the W/t ratio, the higher the efficiency in the coefficient of electromechanical coupling, and thus the W/t is desired to be as low as possible. Further, when the compatibility with the observation device connected is taken into considera-

tion, it is ideal that the piezoelectric transducers used for the ultrasonic transducer yield an impedance, in the employed frequency domain, that is around the characteristic impedance (50 Ω for example) of the cables connected to the transducers. Accordingly, the impedance in the case when the material PZT-5 disclosed in Patent Document 2 is employed and the impedance leading to 50 Ω are calculated.

[0095] When the dielectric constant $\epsilon_{33}^T / \epsilon_0$ of PZT-5 is assumed to be 1700, the result shown in Fig. 26 is obtained. In the frequency domain used in the third embodiment, the calculation is performed on the assumption that $f = 7.5$ MHz, and the impedance $Z = 1/2\pi fC$.

$\epsilon_{33}^T / \epsilon_0 = 1700$ represents the case when PZT-5 disclosed in Patent Document 2 is employed, and the capacitance C is fixed to be 75.259[pF] from height $t = 0.2$ [mm], width $W = 0.1$ [mm], and length $L = 10$ [mm]. In this case, the impedance $Z = 282.0$ [ohm].

[0096] Next, when a material with $\epsilon_{33}^T / \epsilon_0 = 1700$ is used, the capacitance $C = 110.675$ [pF] is obtained from height $t = 0.2$ [mm], width $W = 0.1$ [mm], and length $L = 10$ [mm], and in this case the impedance $Z = 191.7$ [ohm].

[0097] Alternatively, if a material with $\epsilon_{33}^T / \epsilon_0 = 8000$ is used, the capacitance $C = 354.16$ [pF] is obtained from height $t = 0.2$ [mm], width $W = 0.1$ [mm], and length $L = 10$ [mm]. In this case, the impedance $Z = 59.9$ [ohm]. However, this condition is based on the simulated ideal material, which is described herein for reference purposes.

[0098] As described above, the piezoelectric transducer used in an ultrasonic transducer to be used in body cavities has to be very small in size, and when a material with $\epsilon_{33}^T / \epsilon_0 = 1000$ or lower disclosed in Patent Document 2 is employed, the impedance becomes very high. Additionally, only discrete selection can be performed on the dielectric constant of the piezoelectric material. Also, machinability is required because a dicing process has to be performed with an accuracy on the order of several tens of micrometers.

[0099] It has been found that it is best if the material employed in the third embodiment is a material that is readily available, is advantageous in view of the impedance and machinability, and has a dielectric constant $\epsilon_{33}^T / \epsilon_0$ of approximately 2500.

[0100] Figs. 27 and 28 respectively show relationships between the W/t ratios and the electromechanical coupling coefficients in the third embodiment. Fig. 27 shows the case when a material with a $\epsilon_{33}^T / \epsilon_0$ of approximately 1500 is used. Fig. 28 shows the case when a material with a $\epsilon_{33}^T / \epsilon_0$ of approximately 2500 is used.

[0101] In Fig. 27, the electromechanical coupling coefficient is at its peak when W/t is approximately 0.7. In Fig. 28, the electromechanical coupling coefficient is at its peak when W/t is approximately 0.6. It is understood that the higher $\epsilon_{33}^T / \epsilon_0$ is, the lower the W/t ratio is when the electromechanical coupling coefficient is at its peak.

[0102] It is known that the necessary vibrations in the thickness direction is not affected by an unnecessary vi-

bration when the W/t ratio is 0.8 or lower (see Patent Document 2) ; in the third embodiment, the W/t ratio is 0.6, and thus the unnecessary vibration is not caused.

[0103] Also, in the graph in Fig. 28, the line slopes downward on the left and right with the peak occurring at a W/t ratio of approximately 0.6, and in the portion in which the W/t is higher than 0.6, the slope is greater than that in the portion in which the W/t is equal to or lower than 0.6. The graphs seems to be roughly symmetrical about the center line, and the same ultrasonic characteristic seems to be achieved also in the portion in which the W/t ratio is equal to or higher than 0.6. However, in actual manufacturing processes, when the width W is adjusted highly accurately it is difficult to form slots such that the width W has variation. Due to this variation, the W/t ratio is slightly different from the value specified in the design phase. With the variation of the W/t ratio, the electromechanical coupling coefficient varies greatly with the sharply slanting surface slope, as shown in Fig. 28. In other words, the influence on the acoustic characteristic of a W/t ratio higher than 0.6 is greater than that of a W/t ratio lower than 0.6. Accordingly, it is desirable to adjust the W/t ratio so that it has a value equal to or lower than 0.6.

[0104] As described above, when the W/t is equal to or lower than 0.6, the value of the electromechanical coupling coefficient is high, and an unnecessary vibration mode is not caused; accordingly, the proper acoustic characteristic can be maintained. Also, it is not necessary to make sub elements of the transducer element; accordingly, wiring is facilitated, and the reliability is enhanced (reduction of failure probability) because the number of required lead wires is reduced.

[0105] By applying the present invention, it is possible to facilitate wiring and enhance the reliability (reduction of failure probability) because the number of lead wires is reduced while the proper acoustic characteristics are maintained.

[0106] Next, the fourth embodiment of the present invention is explained.

[0107] Fig. 29 shows an outline of an ultrasound endoscope according to the present invention.

[0108] An ultrasound endoscope 3001 comprises an insertion unit 3002 that is to be inserted into body cavities, an operation unit 3003 at the proximal end of the insertion unit 3002, and a universal cord 3004 that extends from a side portion of the operation unit 3003.

[0109] The universal cord 3004 comprises, at one end thereof, an endoscope connector 3004a that is to be connected to a light source device (not shown). Further, an electrical signal cable 3005 detachably connected to a camera control unit (not shown) via an electrical connector 3005a and an ultrasonic cable 3006 detachably connected to an ultrasonic observation device (not shown) via an ultrasonic connector 3006a both extend from the endoscope connector 3004a.

[0110] The insertion unit 3002 comprises, in the connected state and in the following order starting from the

distal end side, a distal rigid section 3007 formed of hard resin, a curved unit 2004, at the proximal end of the distal rigid section 3007, that can arbitrarily bend, and a flexible tube 3009 that connects the proximal end of the bending unit 2004 and the distal end of the operation unit 3003 and that is elongate and has a small diameter. The ultrasonic transducer 2010 is formed at the distal end of the distal rigid section 3007. The ultrasonic transducer 2010 comprises a plurality of transducer elements that are arrayed for transmitting and receiving ultrasound.

[0111] The operation unit 3003 comprises an angulation control knob 3011 for bending the bending unit 2004 to desired directions, an air/water valve 3012 to be used for controlling air-feed and water-feed operations, a suction valve 3013 to be used for controlling suction operations, an instrument channel port 3014 into which instruments that are to be inserted into body cavities are inserted, and the like.

[0112] Fig. 30 is an enlarged view of the distal rigid section 3007 of the ultrasound endoscope 3001 shown in Fig. 29. This distal rigid section 3007 is explained by referring also to the perspective view in Fig. 22.

[0113] At the distal end of the distal rigid section 3007 is the ultrasonic transducer 2010 that allows electronic radial scanning. The ultrasonic transducer 2010 is coated with a material from which the acoustic lens (ultrasonic wave transmitting and receiving unit) 2011 is formed. The distal rigid section 3007 comprises the slanting surface portion 2012. The slanting surface portion 2012 comprises a lighting lens 3018b that constitutes a lighting optical unit for casting illumination light to observation target sites, an objective lens 3018c that constitutes an optical observation unit that captures the optical images of the observation target sites, a instrument-channel-outlet/suction-channel 3018d into which removed sites are sucked and from which instruments are drawn out, and an air/water nozzle 3018a serving as an opening through which air and water are fed.

[0114] Fig. 31 shows a first method of manufacturing an ultrasonic transducer.

[0115] In Fig. 31, when the ultrasonic transducer is to be formed, structure A is first formed; structure A comprises a circuit board 3020, an electric conductor 3021, electrode layers 3022 (3022a and 3022b), a transducer element (piezoelectric device) 3023, acoustic matching layers 3024 (a first acoustic matching layer 3024a and a second acoustic matching layer 3024b), conductive resin 3025, and grooves 3026. Herein below, the manufacture of structure A is explained.

[0116] After forming the second acoustic matching layer 3024b, the first acoustic matching layer 3024a is formed. Next, grooves that are to be filled with the conductive resin are formed on the first acoustic matching layer 3024a by using, for example, a dicing saw (a precision cutting machine), and the grooves are filled with the conductive resin 3025. Next, the transducer element 3023 having the electrode layers 3022a and 3022b on its opposing surfaces is connected to the first acoustic

matching layer 3024a. Then, the circuit board 3020 is attached adjacent to the transducer element 3023. On the surface of the circuit board 3020, an electrode layer 3020a is formed. Then, the electric conductor 3021 is attached in order to cause the electrode layer 3020a and 3022a to be electrically conductive to each other.

[0117] Slots are formed on structure A by using a dicing saw such that a plurality of grooves (dicing grooves) 3026 each having a width of several tens of micrometers are formed at a constant interval. The width of these grooves is desirably in the range of 20 micrometers to 50 micrometers. The above slots are formed in such a manner that only the second acoustic matching layer 3024b is not completely cut such that portions each having a thickness of several tens of micrometers remain uncut. For example, approximately two hundred grooves 3026 are formed evenly on the entirety of structure A. In this configuration, each of the transducers obtained by the dividing process is referred to as a transducer element 3027.

[0118] Because the configuration of the two layers is employed in the fourth embodiment, it is desirable that epoxy resin containing resin with particles such as alumina, titania (TiO_2) or the like be used as a material for the first acoustic matching layer 3024a, and epoxy resin not containing the filler agent is used as a material for the second acoustic matching layer 3024b. Also, when the configuration of three layers is employed, epoxy resin or carbon containing machinable ceramics, resin with particles or fibers is used as a material for the first acoustic matching layer, epoxy resin slightly containing (at a content lower than that in the case of the structure of two layers) resin with particles such as alumina or titania (TiO_2) is used as a material for the second acoustic matching layer, and epoxy resin not containing the filler agent is used for the third acoustic matching layer.

[0119] Next, as shown in Fig. 32, structure A shown in Fig. 31 is formed into a cylindrical shape such that the sides X1 and X2 thereof face each other. Thereafter, masking tape is pasted on the surface of each trench 3026, except for a portion within a certain length from each end. Then, hard resin 3028 is spread over the surface of each trench 3026 including the masked portions. Thereby, only the portions that are not masked by the masking tape, i.e., only the portions around the ends are filled with the hard resin 3028 (as shown in Fig. 34).

[0120] Next, as shown in Fig. 33, a ring-shaped structural member 3030 (3030a) is formed at the inside wall of one of the openings of structure B. The ring-shaped structural member 3030a is attached in such a manner that the attached structural member 3030a is positioned on the circuit board 3020 (as shown in Fig. 37). A structural member 3030 (3030b) is formed at the other opening in a similar manner. The structural member 3030b is attached in such a manner that the attached structural member 3030b is positioned on the conductive resin 3025 (as shown in Fig. 37).

[0121] Fig. 34 is an enlarged view that schematically shows the state of structure B shown in Figs. 32 and 33

in which adhesive is applied. Figs 35 and 36 are views respectively showing structure B above in a flattened manner for the convenience of explanation.

[0122] As shown in Figs. 34 through 36, the hard resin 3028 serving as the adhesive is applied to the locations on each trench 3026 that are at both ends in the longitudinal direction and that do not contact the transducer element 3023. When the portions to which the hard resin is applied are long, tenderness caused in the patients being examined with the ultrasound endoscope device increases; for this reason it is desirable that the hard resin 3028 be at the ends of the grooves 3026 and that the intervals between the transducer elements 3023 and the hard resin 3028 be as long as possible in order to reduce the influence of the crosstalk. Also, as the hard resin 3028, a material such as hard resin containing resin with particles of inorganic substances (calcium carbonate or alumina) is used to increase the viscosity.

[0123] Figs. 37 through 39 respectively show the cross sections of structure B to which the structural members 3030 have been attached.

[0124] After attaching the structural members 3030 (3030a and 3030b) (as shown in Fig. 37), the space between the structural members 3030a and 3030b is filled with a backing material 3040 (as shown in Fig. 38). For the backing material, gel epoxy resin containing resin with particles of alumina is used. Thereafter, an electric conductor (copper wire) 3041 is attached on the conductive resin 3025 (as shown in Fig. 39). Hereinafter, the structure that is formed as shown in Figs. 37 through 39 is referred to as structure C.

[0125] Next, acoustic lenses 3017 are formed over the surface of a cylinder as shown in Fig. 33. The acoustic lenses 3017 may be realized by integrating, with cylindrical shaped structure A, the lenses that have been manufactured independently, and also may be realized in such a manner that molds are inserted into cylindrical shaped structure A and filled with the material of the acoustic lenses. Additionally, among the acoustic lenses 3017, the lens that actually serves as an acoustic lens is lens unit 3017a.

[0126] Next, a cylindrical shaped structural member 3050 is inserted into structure C through one of the openings (the opening on the side having the circuit board 3020) as shown in Fig. 40. This cylindrical shaped structural member 3050 consists of a cylindrical shaped part 3053 and a ring-shaped collar 3052 at one end of the cylindrical shaped part 3053. A printed circuit board 3054 is formed on the surface of the collar 3052, and on the surface of the printed circuit board 3054, several tens to several hundreds of electrode pads 3051 are formed. Further, a bundle of cables 3062 runs through the cylindrical shaped structural member 3050, and one of the ends of each of the cables 3062 is soldered to its corresponding pad 3051 (each of the cables 3062 is soldered to a location, on each of the electrode pads, that is close to the center of the ring). Additionally, for the cables 3062, coaxial cables are usually used for reducing noise.

[0127] The cylindrical shaped structural member 3050 is made of an insulative material (for example engineering plastic). Examples of the insulative materials include polysulfone, polyether-imide, polyphenylene oxide, epoxy resin and the like. The surface of the cylindrical shaped part 3053 is plated with a conductive material. When the cylindrical shaped structural member 3050 to which the cables 3062 are connected is inserted into structure C, the collar 3052 in the cylindrical shaped structural member 3050 contacts the structural member 3030, and the position of the cylindrical shaped structural member 3050 is fixed in structure C, i.e., is fixed in the transducer.

[0128] Fig. 41 shows a state of the transducer in which the location, on each of the electrode pads 3051, that is close to the periphery of the electrode pad 3051 is connected to its corresponding electrode layer 3020a on the transducer element 3027 via a lead wire 3090.

[0129] Fig. 42 is a lateral cross-sectional view showing the distal end of the electronic radial scanning ultrasound endoscope shown in Fig. 41.

[0130] The distal end comprises the transducer element 3023, the backing material 3040, and the like, as described above. Also, the cables 3062 are connected to the electrode pad 3051 at locations on the cables that are close to the center of the collar. On each of the electrode pads 3051, the location close to the periphery of the collar is connected to one of the ends of its corresponding lead wires 3090 via solder 3101, and the other end of the lead wire 3090 is connected, via solder 3102, to the electrode layer 3020a on the circuit board 3020 of the transducer element. Additionally, in order to prevent a short circuit, lead wires that are short in length are used for lead wires 3090 such that the lead wires do not contact the adjacent electrode layer 3020a. Also, in order to prevent the cable 3062 from being disconnected from the electrode pad 3051 when tension is applied to the cable 3062, each connection location between the cable 3062 and the electrode pad 3051 is entirely covered with potting resin 3100. Also, the surface of structural member 3030b is coated with a copper foil 3103. Further, the surfaces of the structural members 3030, the acoustic matching layer 3024, and the walls of the cylindrical shaped structural member 3050 are connected via a conductive resin 3014 such as solder. The distal end of the transducer employing the above described configuration comprises a distal end structural member 3106. The distal end also comprises a structural member (hose connection unit) 3105 at the connection portion with the distal rigid section 3007.

[0131] As described above, according to the present embodiment, the hard resin is applied to the locations, on each trench between the adjacent ultrasonic transducer elements, that are at both ends in the longitudinal direction and that do not contact the transducer device, and a backing material is applied between the hard resin applied to the trench and the ultrasonic device so that the hard resin does not contact the transducer element;

accordingly, the vibrations of the transducer device are not restrained. Also, it is possible to reduce the crosstalk, and to achieve a mechanical strength that allows transducers to be used in endoscopes whose entire length is 20mm or less.

[0132] Also, the hard resin, which restrains vibrations of transducer devices, does not contact the transducer device, and accordingly it is possible to prevent the disturbances in ultrasonic beams.

[0133] Additionally, the fourth embodiment has been explained by using the example of an electronic radial scanning ultrasonic transducer; however, the same effect can be achieved by the same configuration even in the convex type in which transducers are arrayed in an arc, and in the linear type in which transducers are arrayed in a line, the explanations of which are omitted.

[0134] Additionally, the fourth embodiment can be applied not only to the ultrasonic transducer using the piezoelectric devices as transducer elements, but also to an electronic radial scanning ultrasonic transducer employing the configuration of a capacitive micromachined ultrasonic transducer (C-MUT).

[0135] According to the present invention, adhesive is applied to the locations, on the trench between each pair of adjacent ultrasonic transducer elements, that are at both ends in the longitudinal direction and that do not contact the transducer device, and a vibration damping (sound attenuation) agent is applied between the transducer elements. Thereby, the crosstalk and disturbances in ultrasonic beams are prevented while the adhesive does not restrain the vibrations of the transducer elements.

[0136] In the above configuration, it is desired that the locations to which the adhesive is applied be at both ends in the longitudinal direction on the grooves that are to be prevented from being affected by the crosstalk; however, the scope of the present invention is not limited to this configuration. The desired effect can be achieved by applying the adhesive to any location that is close to the ends in the longitudinal direction on the grooves.

[0137] Additionally, the present invention can be applied to ultrasonic transducers of the radial type, the convex type, and the linear type without changing the configuration of the present invention, and can improve the performance of various types of ultrasound endoscopes.

Claims

1. A method of manufacturing an ultrasonic transducer including a plurality of transducer elements, each of said transducer elements including a plurality of transducer sub elements, said method comprising:

a first division step in which first dicing grooves are formed on an acoustic matching layer and a piezoelectric device plate that are mounted together in order to form a plurality of piezoelec-

- tric devices;
 a piezoelectric device/board connection step in which a board and the respective piezoelectric devices formed in the first division step are connected together;
 a conductive sheet coating step in which surfaces in the vicinity of locations at which the board and the piezoelectric devices are connected together in the piezoelectric device/boardmounting step are coated with a conductive sheet; and a second division step in which the plurality of transducer elements are formed by dicing the second grooves between the first dicing grooves formed, in the first division step, on the piezoelectric devices and the board being coated with the conductive sheet in the conductive sheet coating step and on the acoustic matching layer.
2. The method of manufacturing an ultrasonic transducer according to claim 1, further comprising:
- a masking step in which the first dicing grooves formed, in the first division step, on a surface of the respective piezoelectric devices connected to the board in the piezoelectric device/board connection step are masked, said masking step being executed after the piezoelectric device/board connecting step and before the conductive sheet coating step.
3. The method of manufacturing an ultrasonic transducer according to claim 1, wherein:
- the conductive sheet has sufficient viscosity so as not to flow into the first dicing grooves formed in the first division step.
4. The method of manufacturing an ultrasonic transducer according to claim 1, wherein:
- the thickness of the conductive sheet is thin.
5. A method of manufacturing an ultrasonic transducer including a plurality of transducer elements, each of said transducer elements including a plurality of transducer sub elements, said method comprising:
- a first division step in which first dicing grooves are formed on a backing material and a piezoelectric device plate that are mounted together in order to form a plurality of piezoelectric devices;
 a piezoelectric device/board connecting step in which a board and the respective piezoelectric devices formed in the first division step are connected together;
 a conductive sheet coating step in which surfaces in the vicinity of locations at which the board
- and the piezoelectric devices are connected together in the piezoelectric device/board mounting step are coated with a conductive sheet; and a second division step in which the plurality of transducer elements are formed by forming second dicing grooves on the backing material and between the first dicing grooves formed, in the first division step, on the piezoelectric devices and the board coated with the conductive sheet in the conductive sheet coating step.
6. The method of manufacturing an ultrasonic transducer according to claim 5, further comprising:
- a masking step in which the first dicing grooves formed, in the first division step, on a surface of the respective piezoelectric devices connected to the board in the piezoelectric device/board connection step are masked, said masking step being executed after the piezoelectric device/board connecting step and before the conductive sheet coating step.
7. The method of manufacturing an ultrasonic transducer according to claim 5, wherein:
- the thickness of the conductive sheet is thin.
8. An array ultrasonic transducer comprising transducer elements each including a plurality of transducer sub elements, wherein:
- the transducer elements include a conductive sheet for electrically connecting:
- piezoelectric devices;
 a board connected to the piezoelectric devices in such a manner that the board is adjacent to the piezoelectric devices;
 electrodes formed on main surfaces of the piezoelectric devices; and
 electrode patterns formed on main surfaces of the board, and wherein:
- the piezoelectric device is divided in such a manner that the piezoelectric devices respectively correspond to the transducer sub elements; and
 the board is divided in such a manner that the board respectively correspond to the transducer elements.
9. An ultrasonic transducer comprising a plurality of piezoelectric transducers for transmitting and receiving ultrasound, wherein:
- the dielectric constant of the piezoelectric transducer is equal to or higher than 2500;

- the ratio W/t between lateral width W and thickness t of the piezoelectric transducer is equal to or lower than 0.6; and
the interval between each pair of adjacent piezoelectric transducers is equal to or smaller than the wavelength of the ultrasound.
- 10.** The ultrasound endoscope comprising the ultrasonic transducer according to claim 9.
- 11.** An electronic radial scanning ultrasonic transducer in which a plurality of piezoelectric transducers for transmitting and receiving ultrasounds are arrayed in a cylindrical shape and at a constant interval, and the radius of the outer periphery of the cylindrical shape is equal to or smaller than ten millimeters, wherein:
- the dielectric constant of the piezoelectric transducer is equal to or higher than 2500;
the ratio W/t between lateral width W and thickness t of the piezoelectric transducer is equal to or lower than 0.6; and
the interval between each pair of adjacent piezoelectric transducers is equal to or smaller than the wavelength of the ultrasound.
- 12.** The electronic radial scanning ultrasonic transducer according to claim 11, wherein:
- the ratio between the width W of each of the piezoelectric transducers and the interval between each pair of adjacent piezoelectric transducers is approximately 1:2.
- 13.** An ultrasound endoscope comprising the electronic radial scanning ultrasonic transducer according to claim 11.
- 14.** An ultrasonic transducer in which a plurality of ultrasonic transducer elements for transmitting and receiving ultrasounds are arrayed, and acoustic matching layers are stacked, wherein:
- adhesive is applied to locations that are at both ends, in the longitudinal direction, of grooves between the adjacent ultrasonic transducer elements and that do not contact a transducer element; and
vibration damping agent is applied between the adhesive applied to the grooves and the transducer element.
- 15.** The ultrasonic transducer according to claim 14, wherein:
- the adhesive is applied to both ends, in the longitudinal direction, of each of the grooves.
- 16.** The ultrasonic transducer according to claim 14, wherein:
- the adhesive is hard resin.
- 17.** The ultrasonic transducer according to claim 14, wherein:
- the vibration damping agent is a backing material applied to back surfaces of the ultrasonic transducer elements.
- 18.** The ultrasonic transducer according to claim 14, wherein:
- the ultrasonic transducer is an electronic radial scanning ultrasonic transducer.
- 19.** An ultrasound endoscope comprising the ultrasonic transducer according to claim 14.

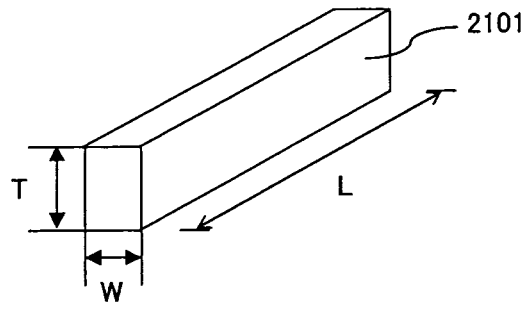


FIG. 1

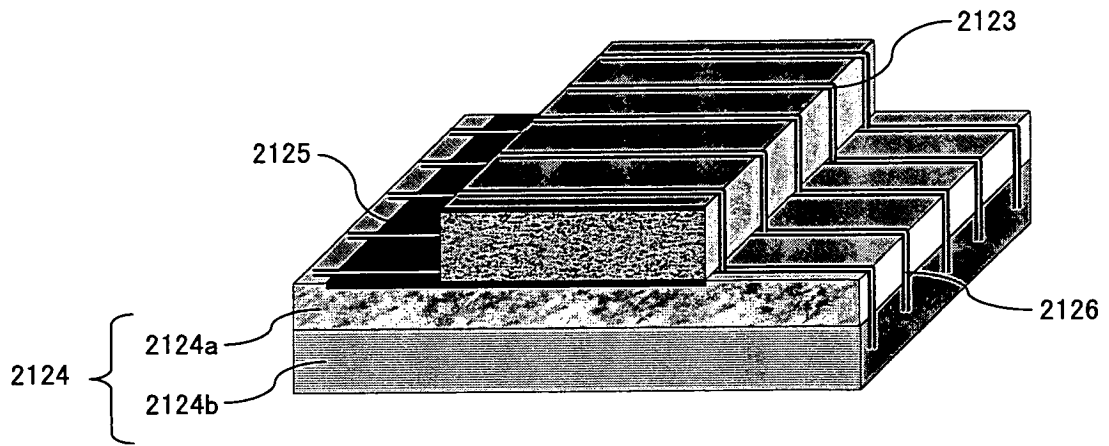


FIG. 2

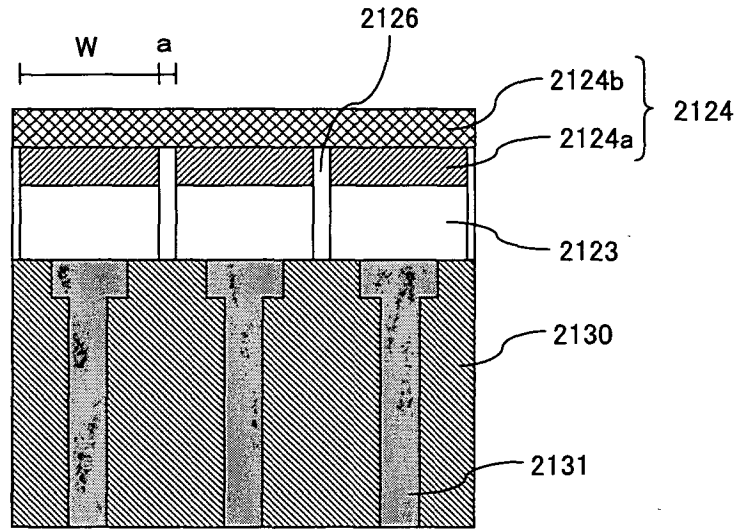


FIG. 3

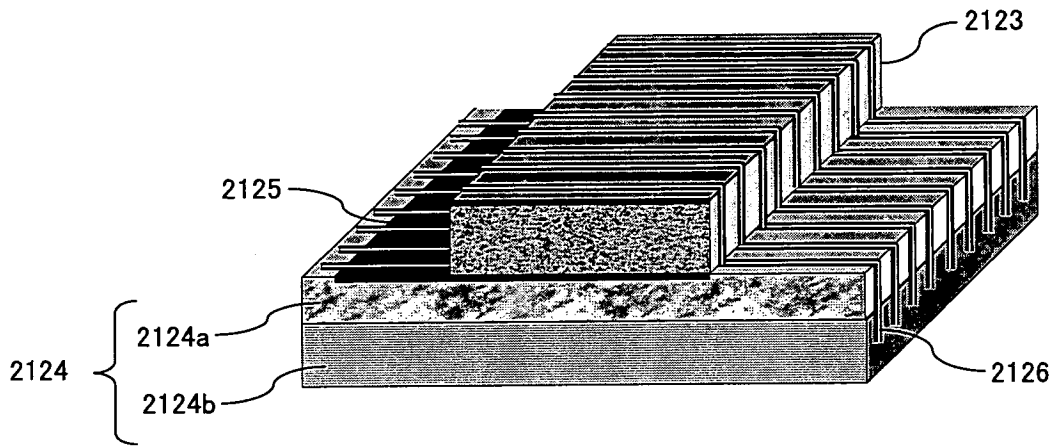


FIG. 4

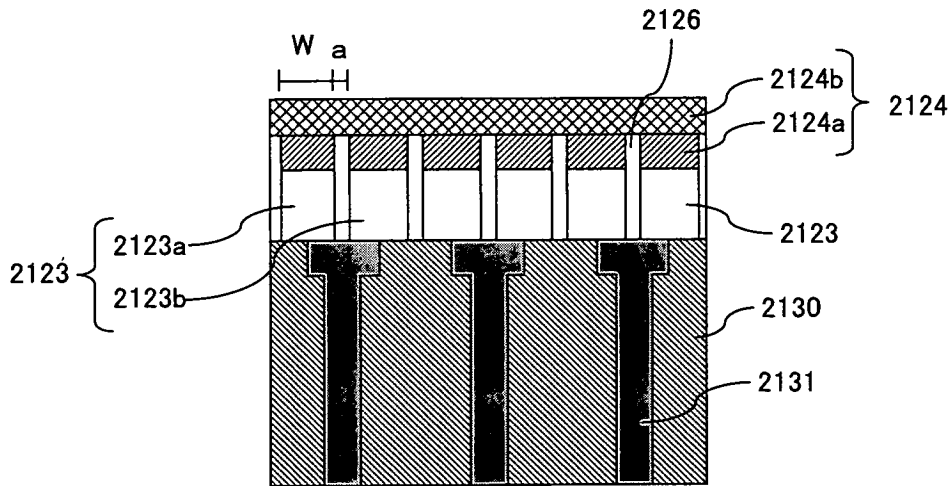


FIG. 5

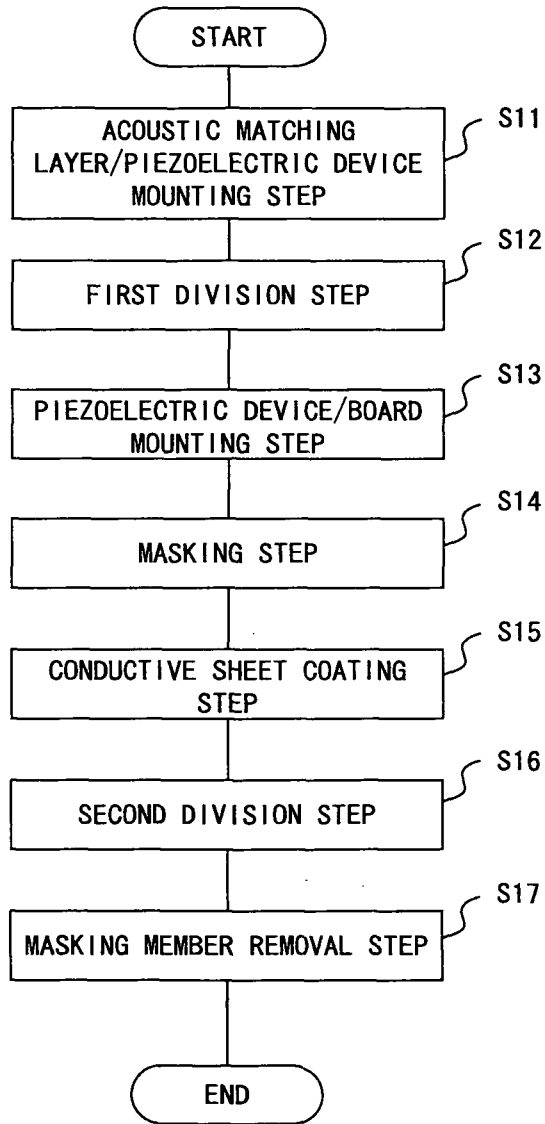


FIG. 6

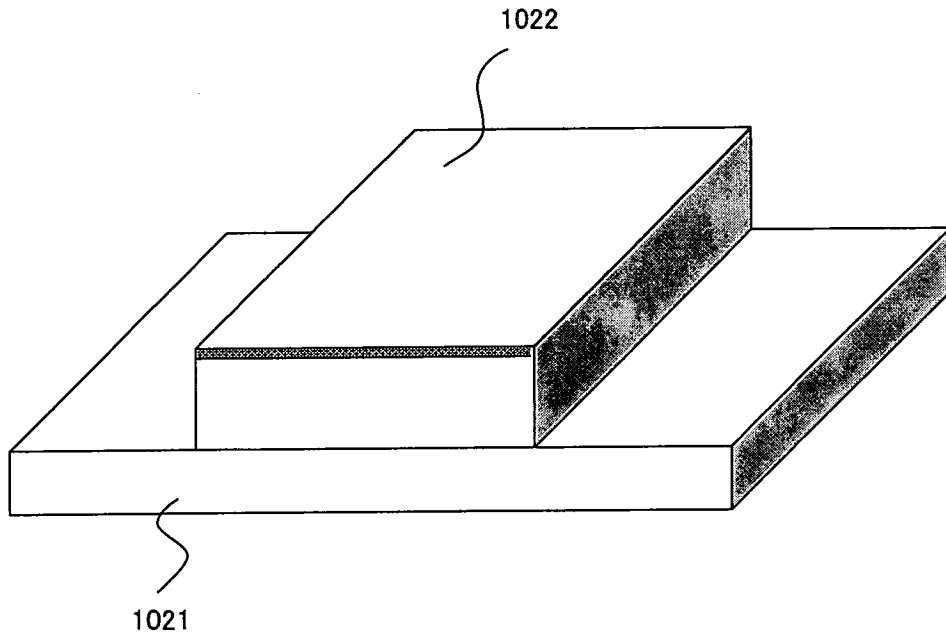


FIG. 7

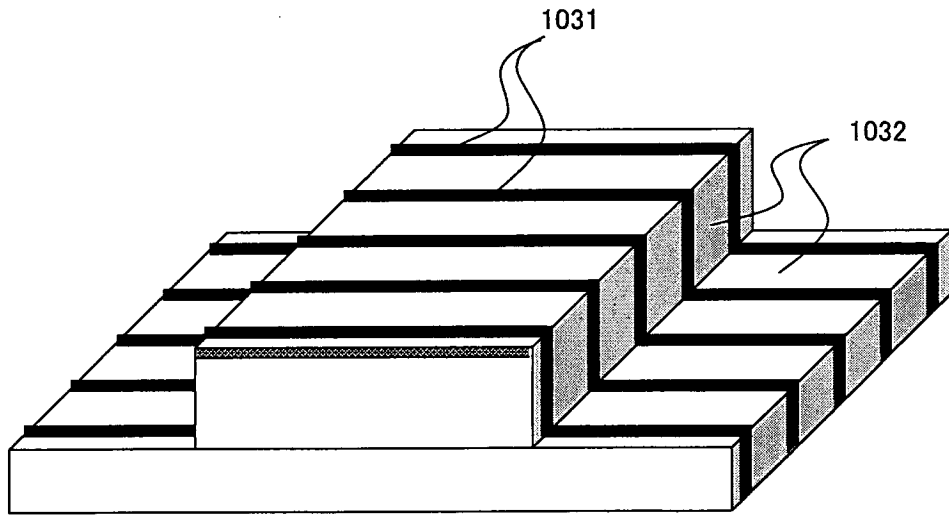


FIG. 8

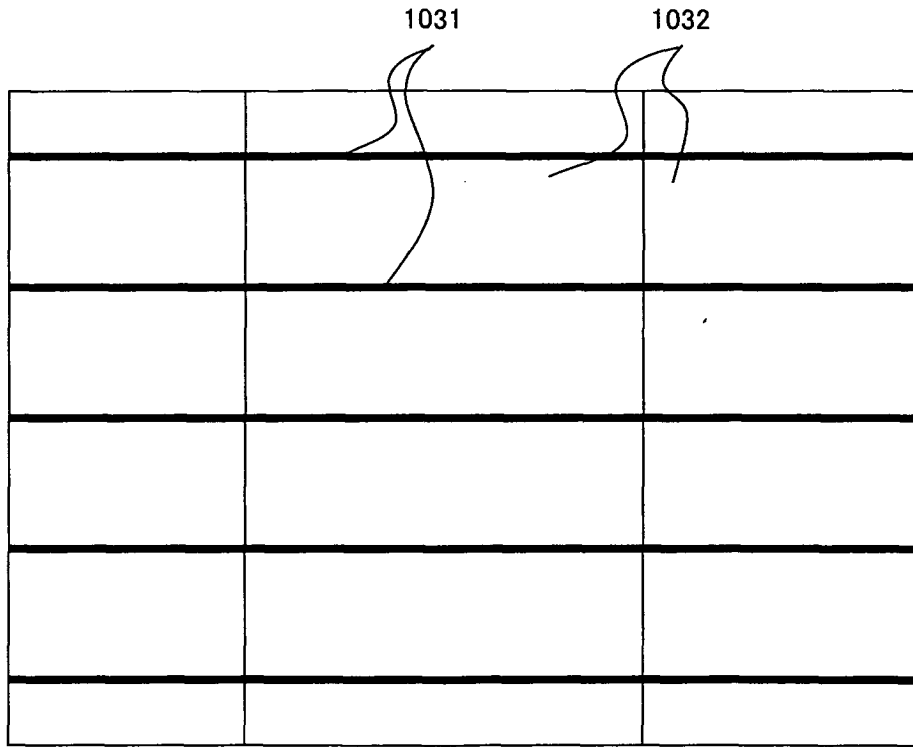


FIG. 9

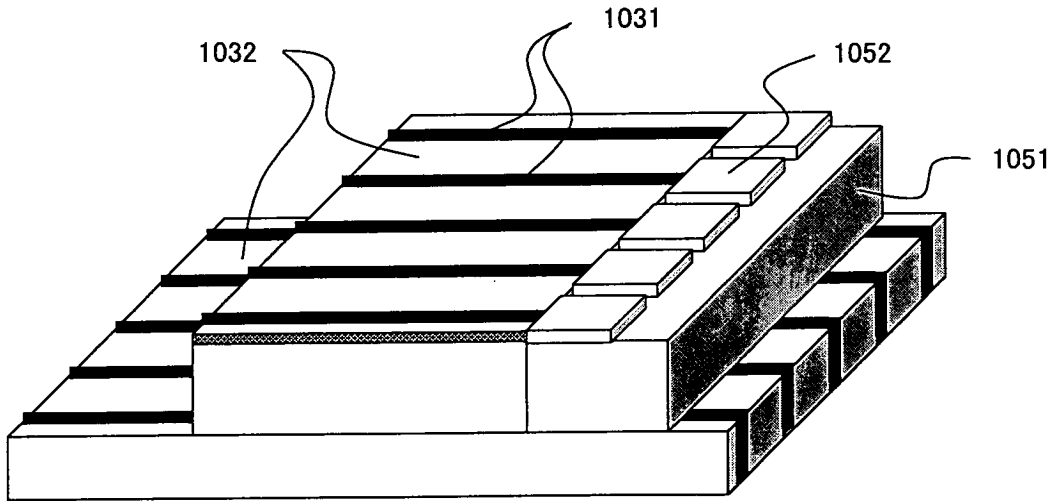


FIG. 10

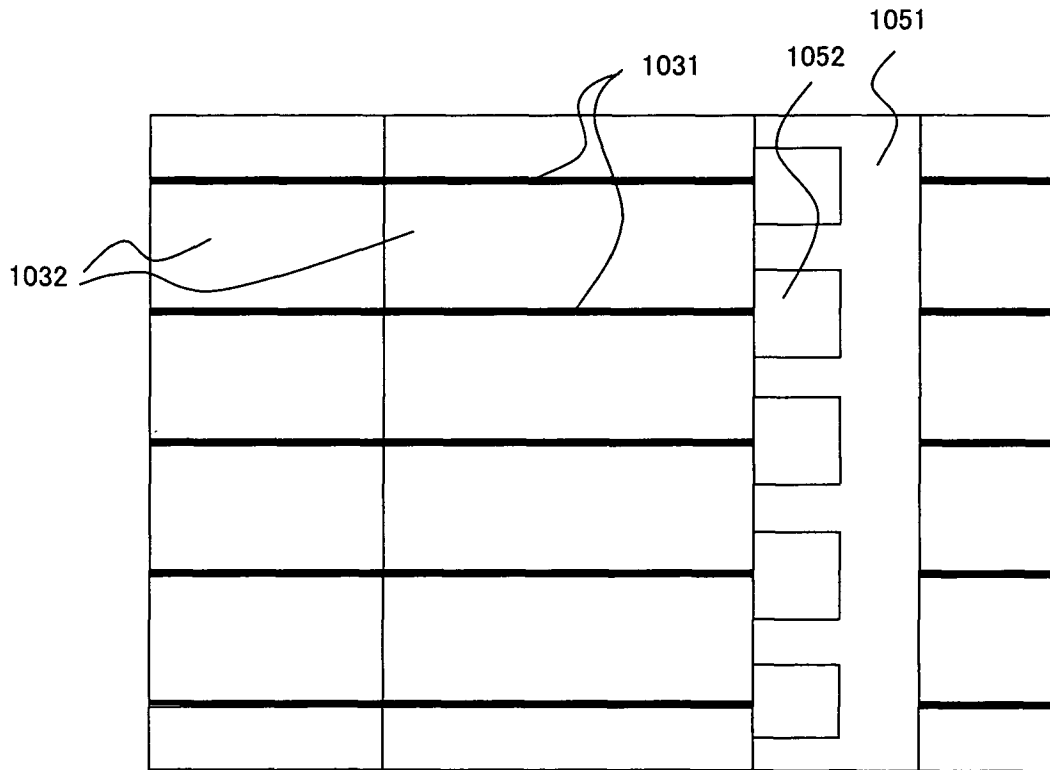


FIG. 11

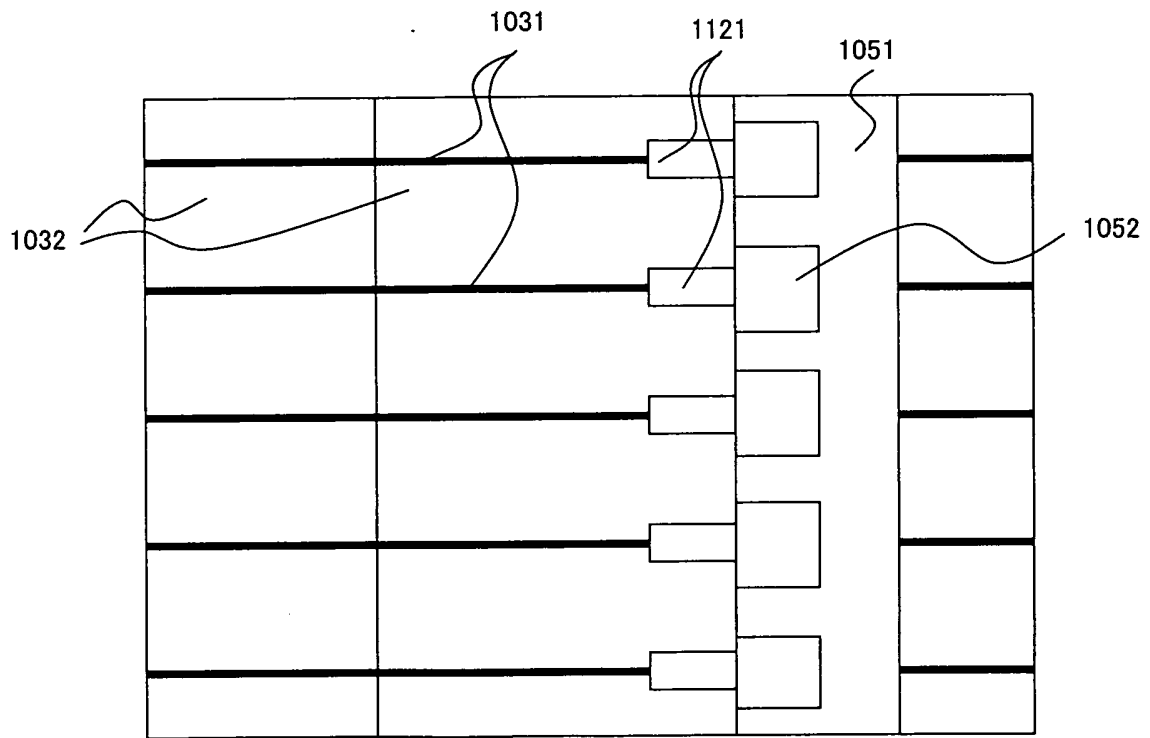


FIG. 12

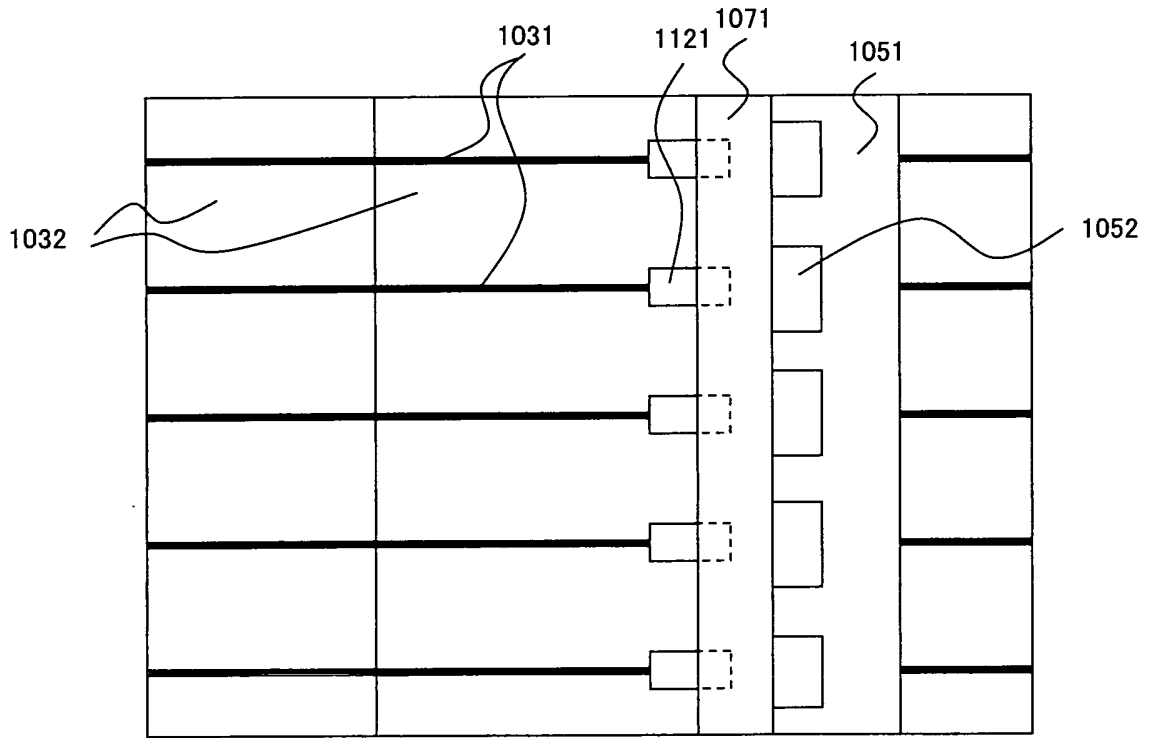


FIG. 13

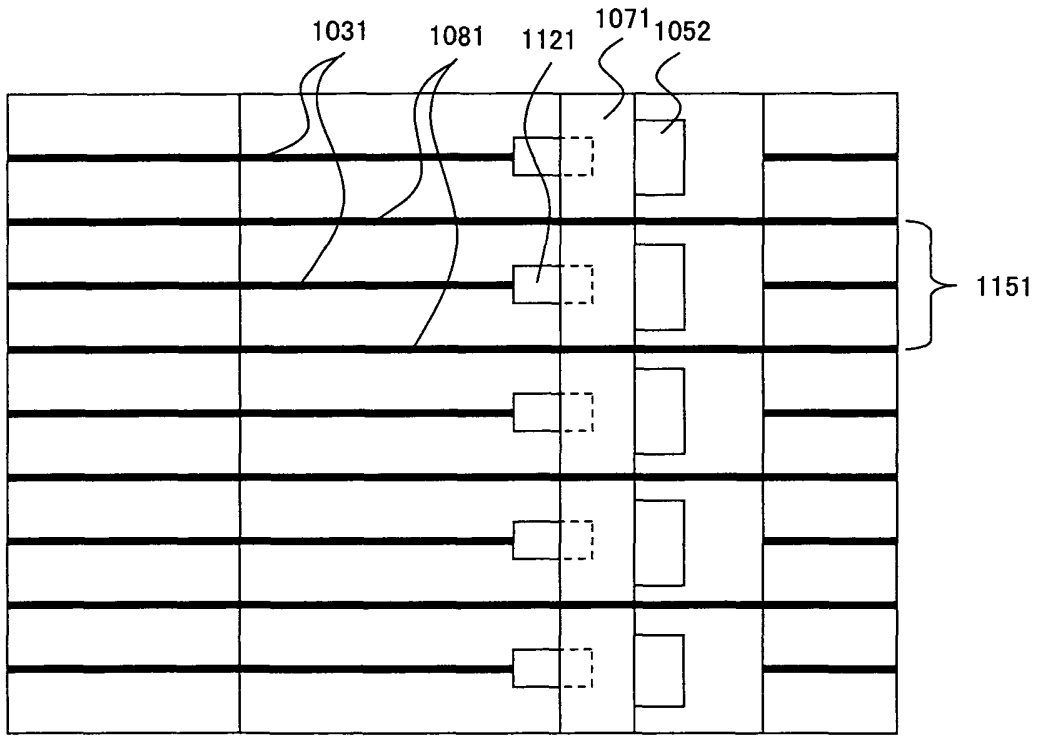


FIG. 14

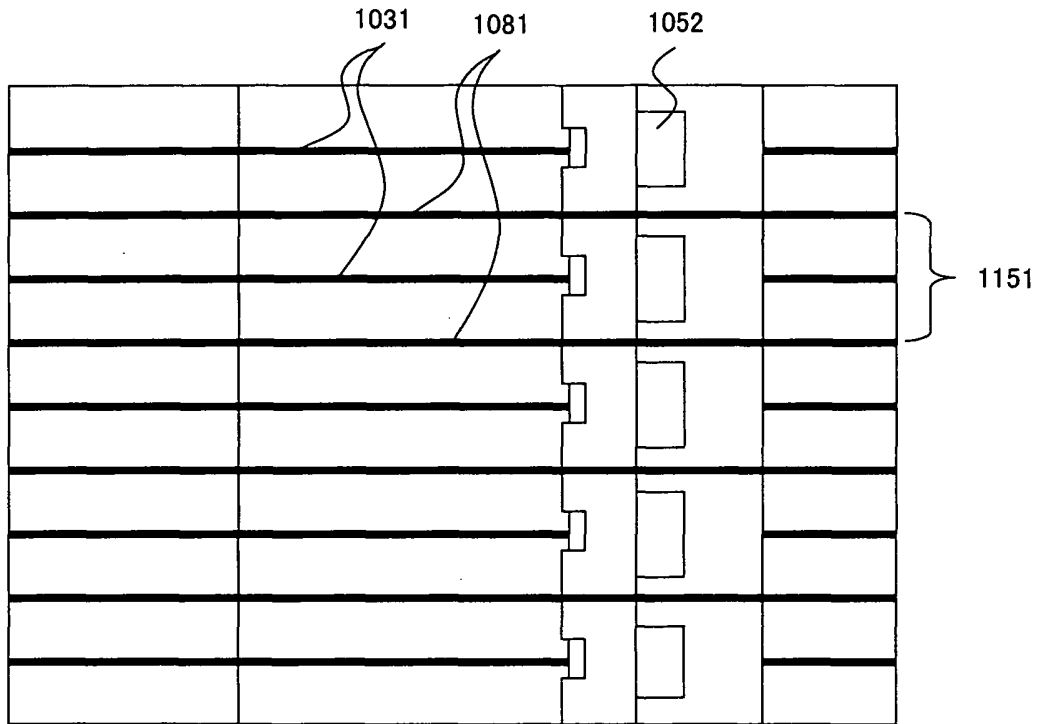


FIG. 15

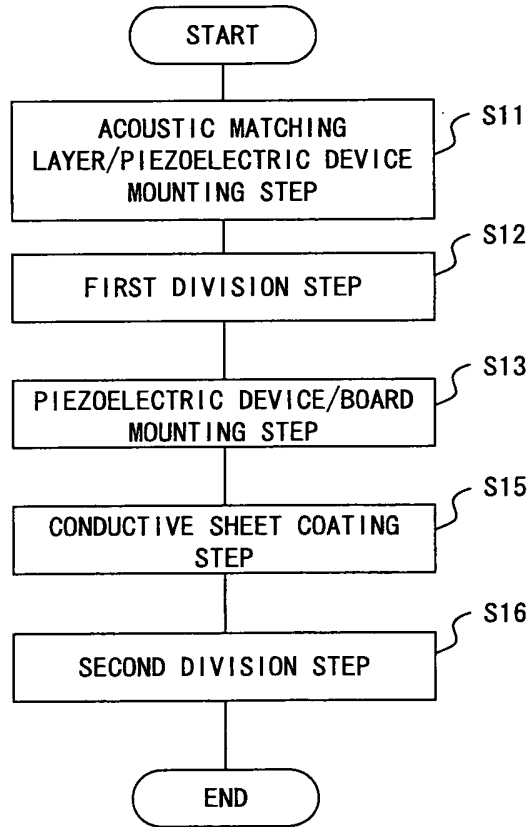


FIG. 16

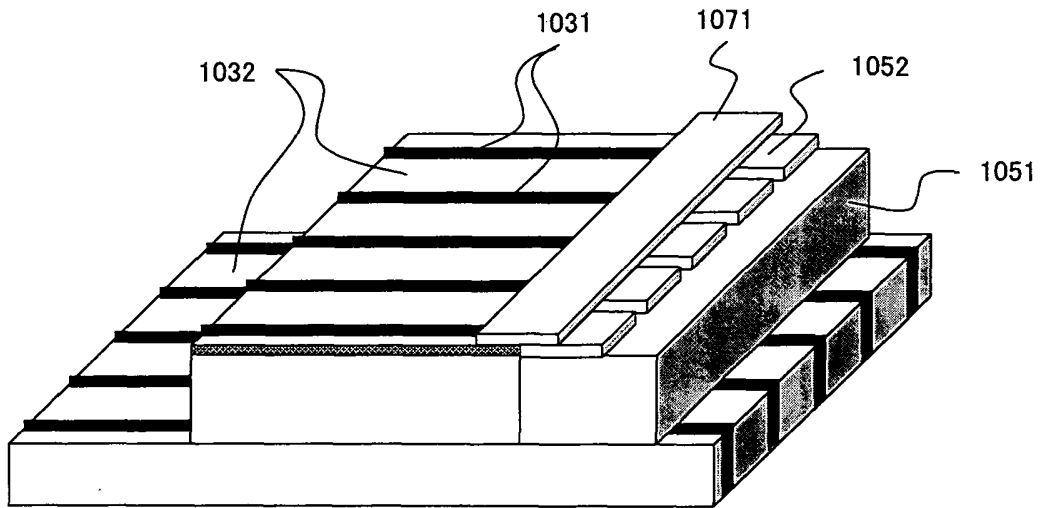


FIG. 17

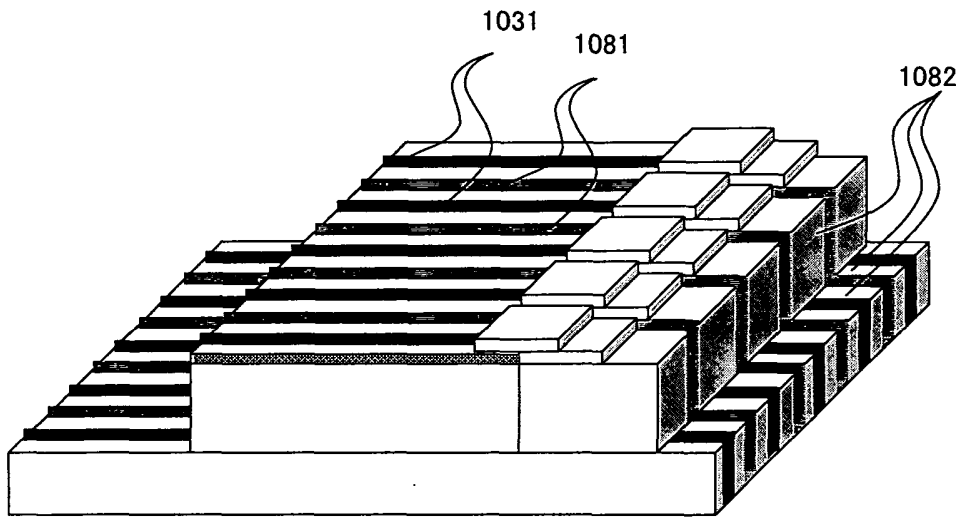


FIG. 18

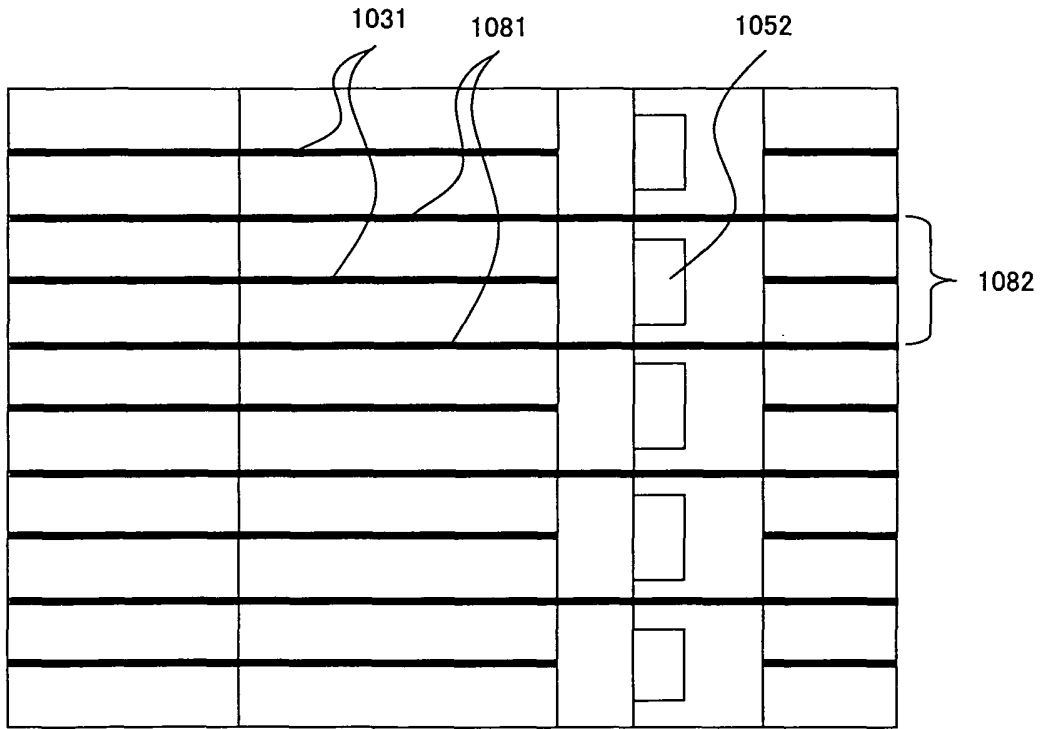


FIG. 19

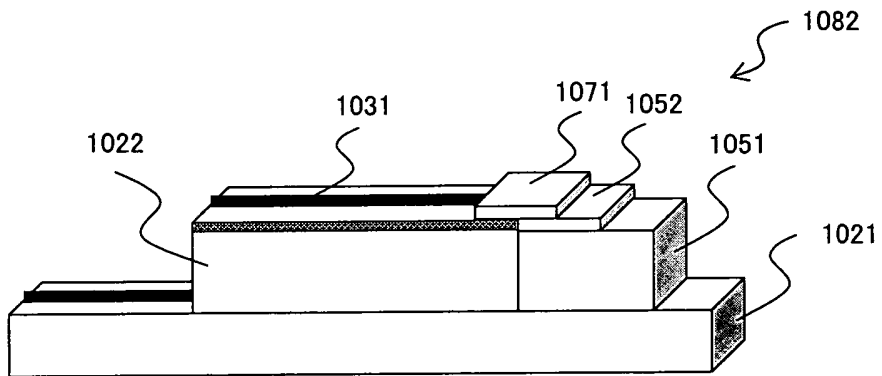


FIG. 20

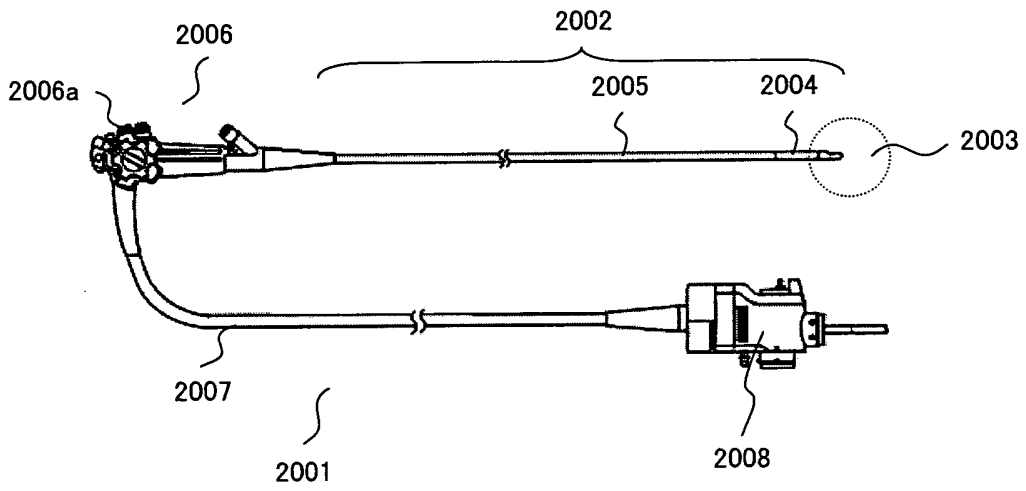


FIG. 21

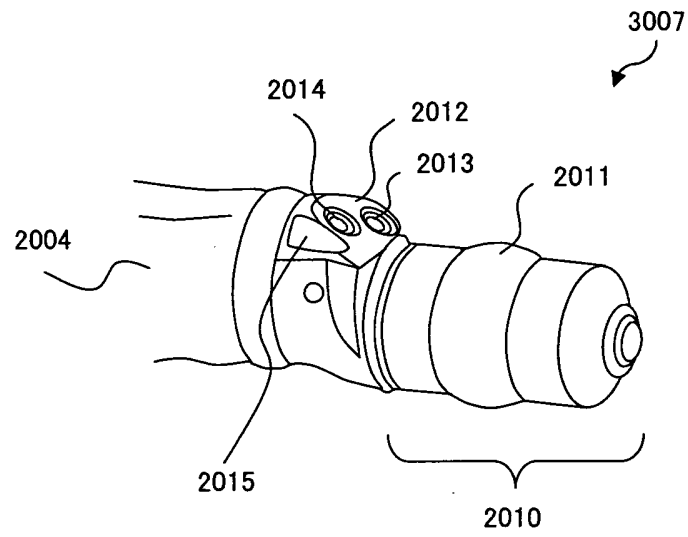


FIG. 22

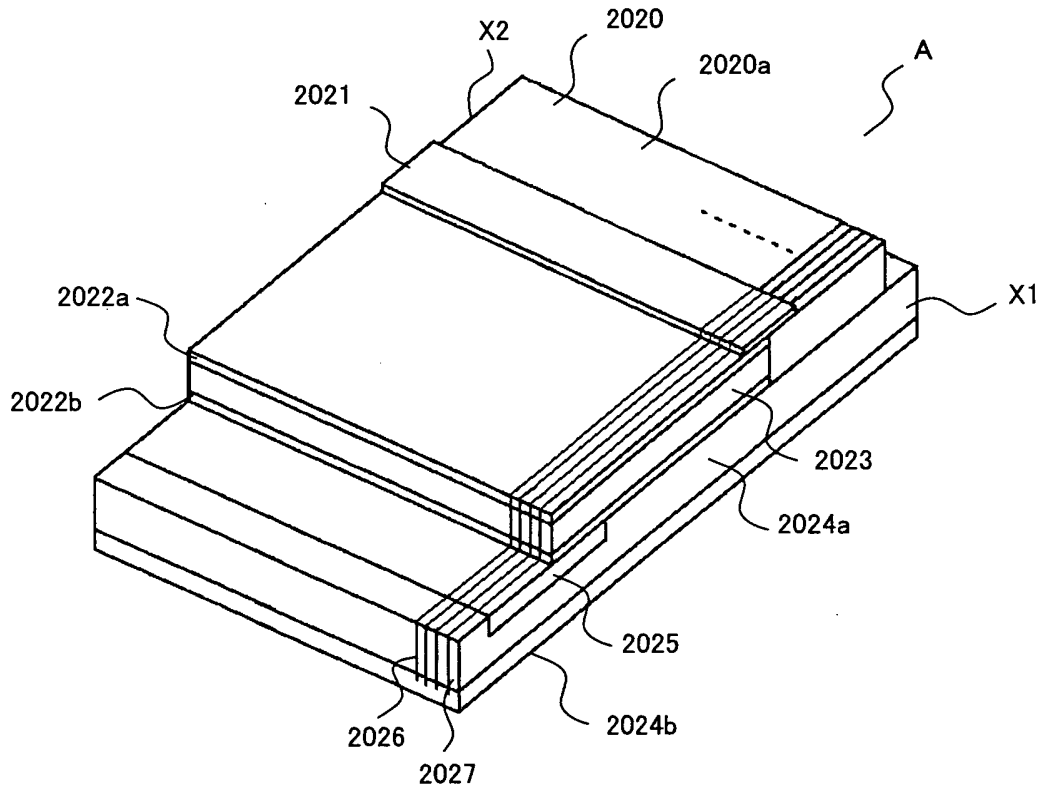


FIG. 23

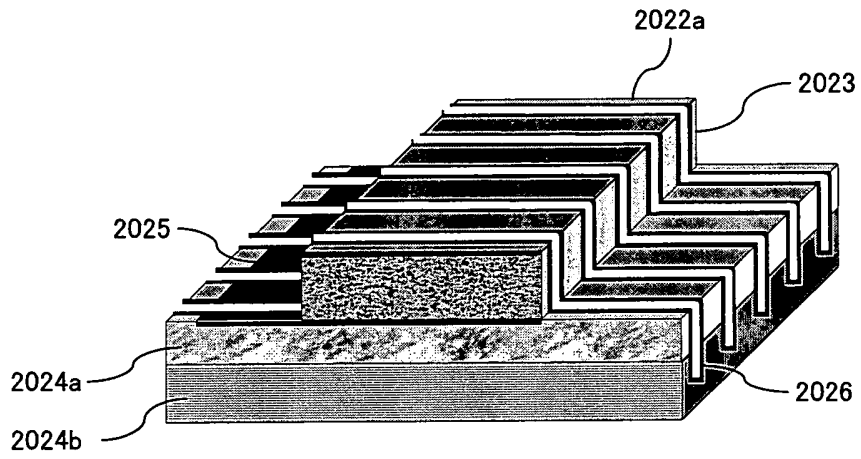


FIG. 24

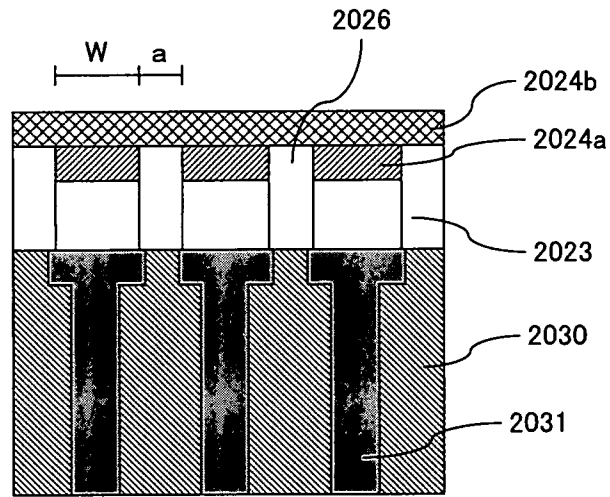


FIG. 25

$\epsilon_{33}^T / \epsilon_0$	t[mm]	W[mm]	L[mm]	C[pF]	Z[ohm]
1700	0.2	0.1	10	75.259	282.0
2500	0.2	0.1	10	110.675	191.7
8000	0.2	0.1	10	354.16	59.9

FIG. 26

$\epsilon_{33}^T/\epsilon_0$ IS APPROXIMATELY 1500

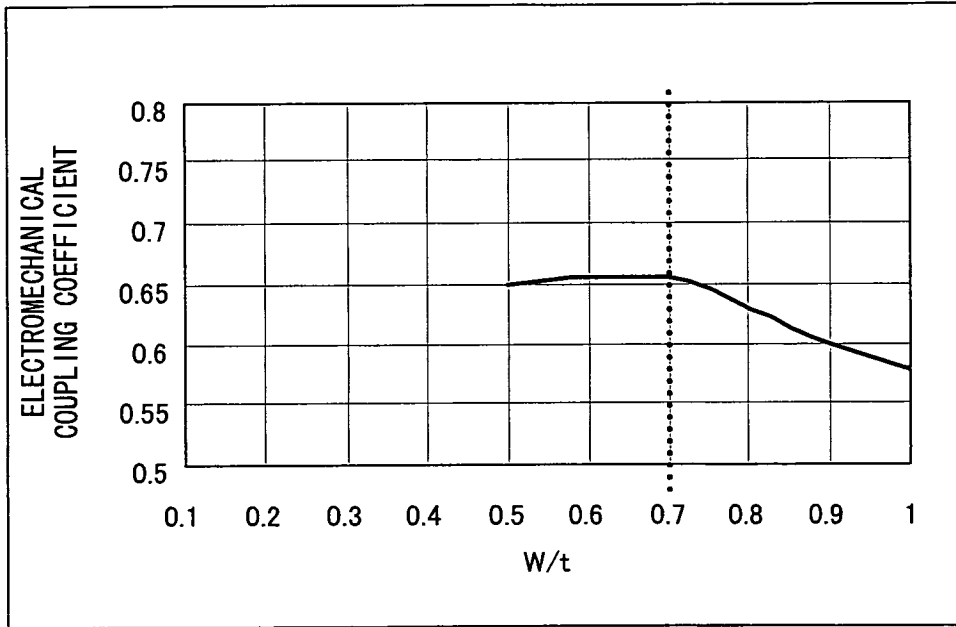


FIG. 27

$\epsilon_{33}^T / \epsilon_0$ IS APPROXIMATELY 2500

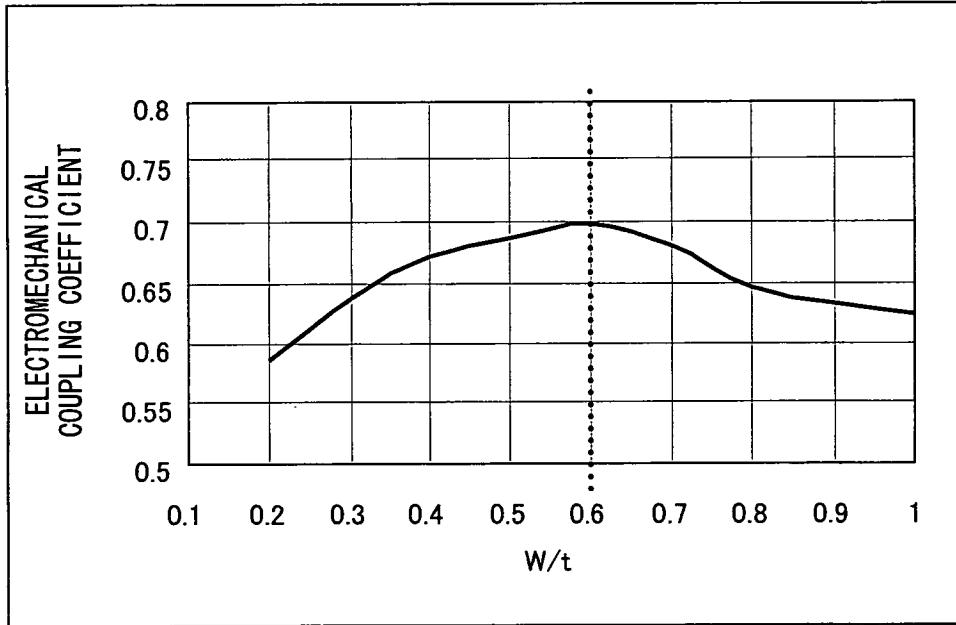


FIG. 28

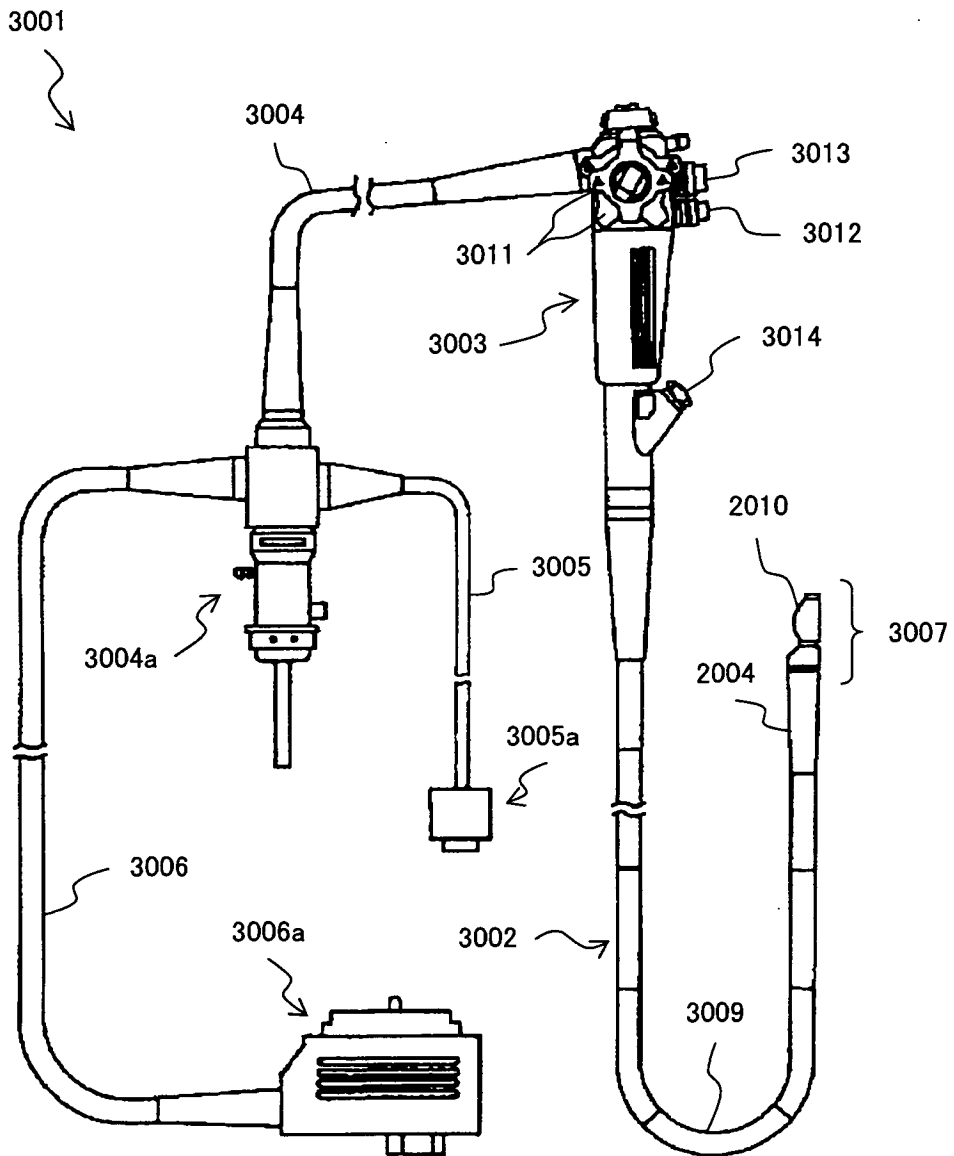


FIG. 29

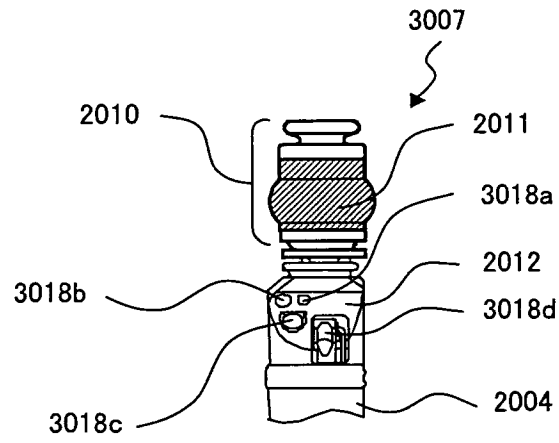


FIG. 30

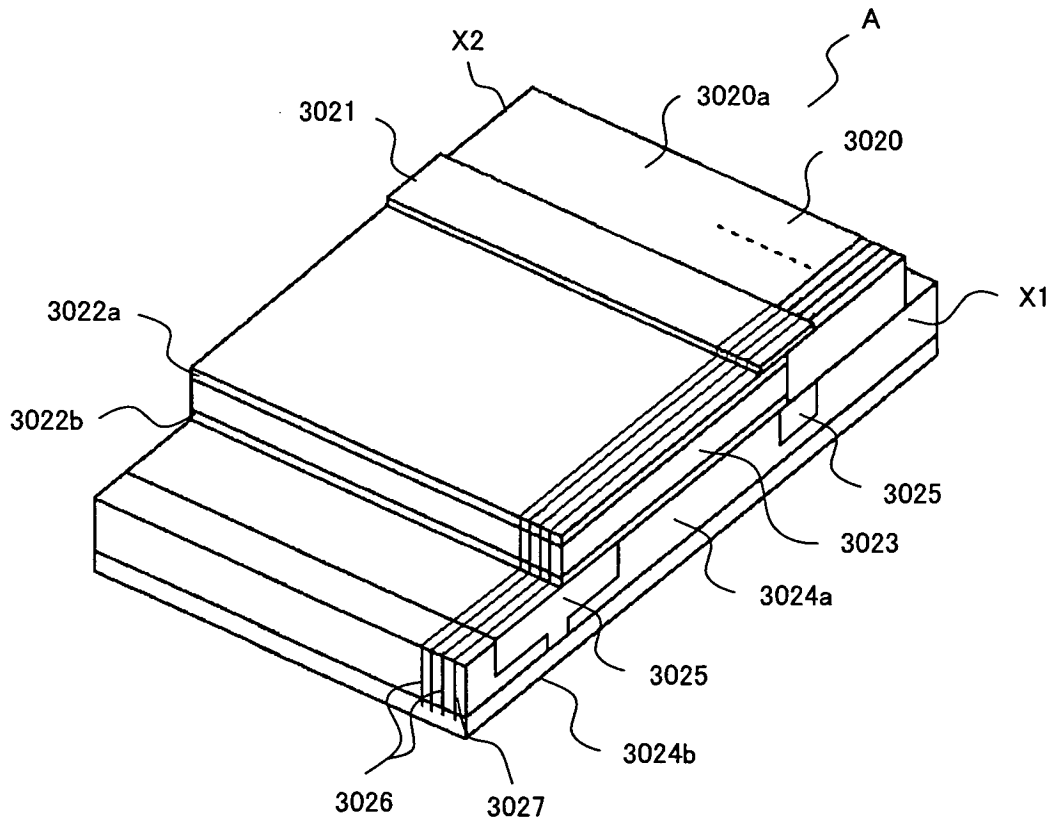


FIG. 31

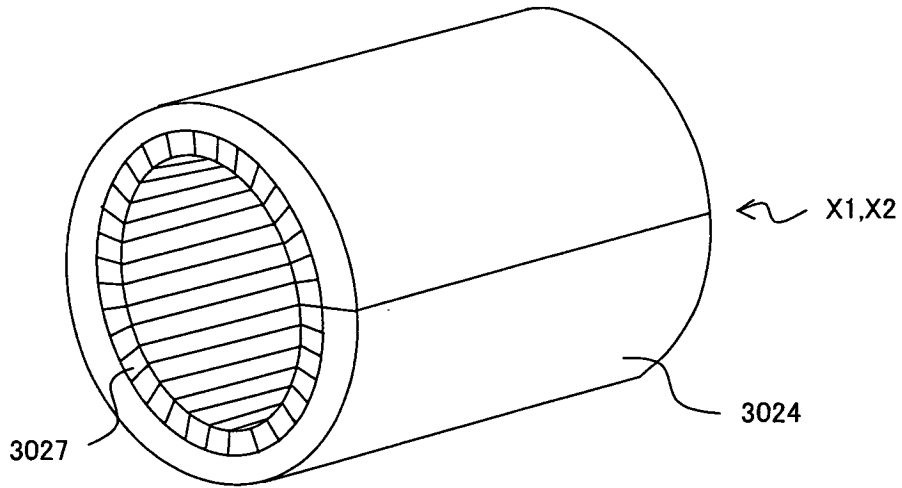


FIG. 32

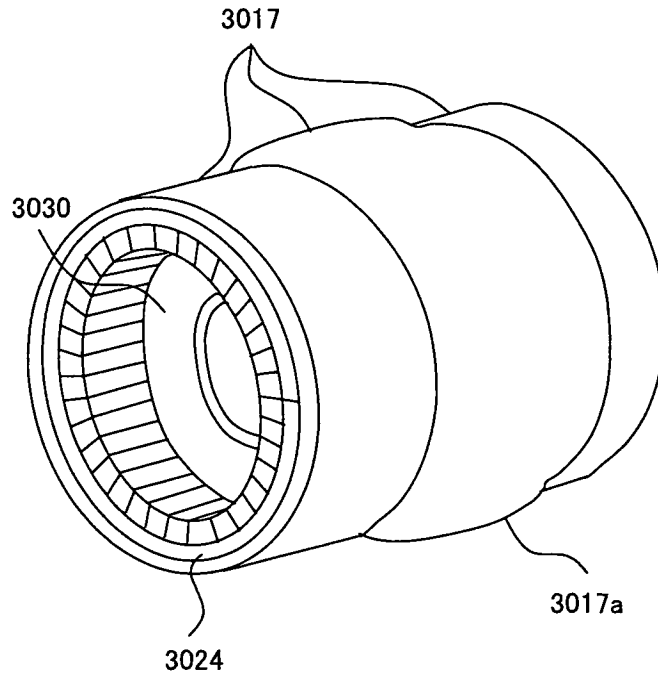


FIG. 33

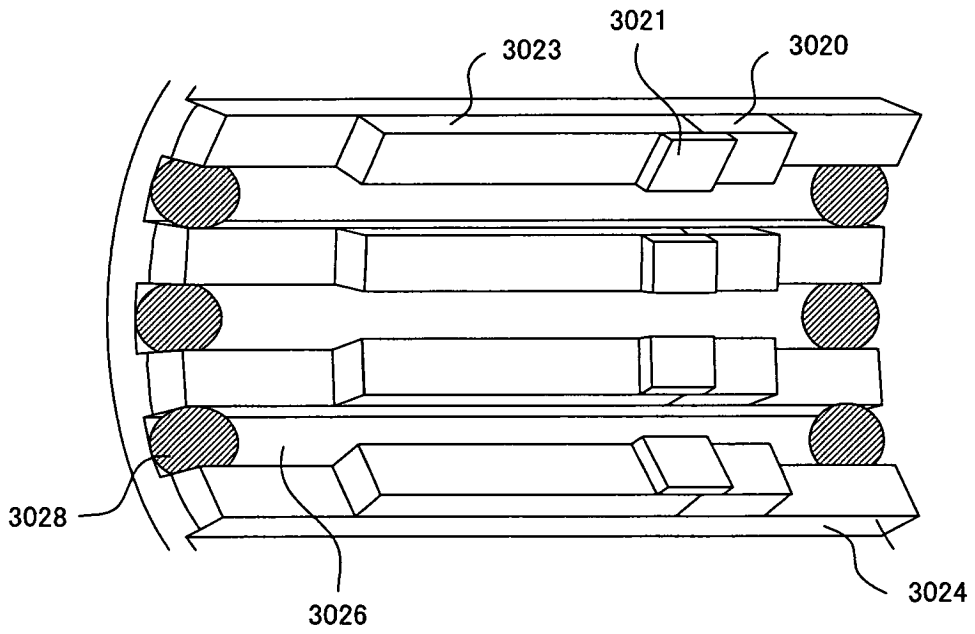


FIG. 34

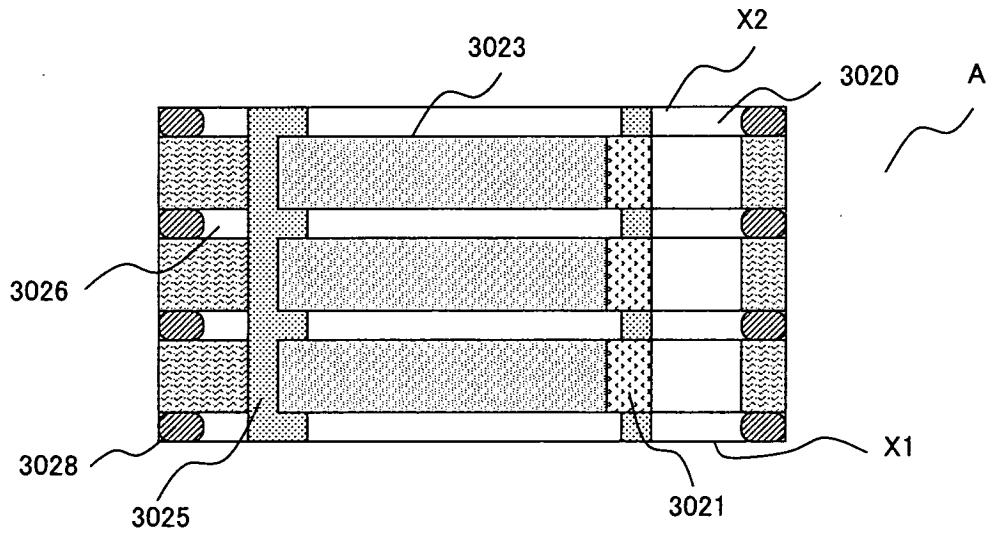


FIG. 35

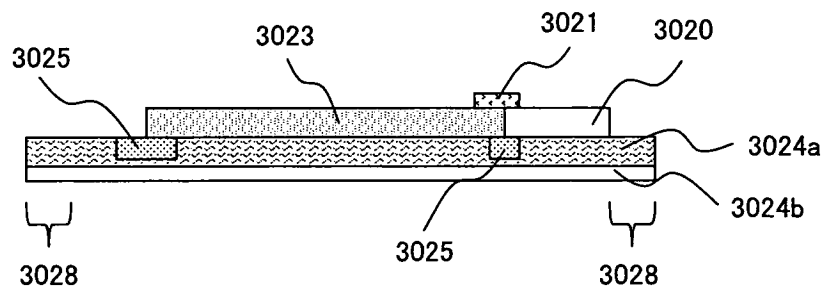


FIG. 36

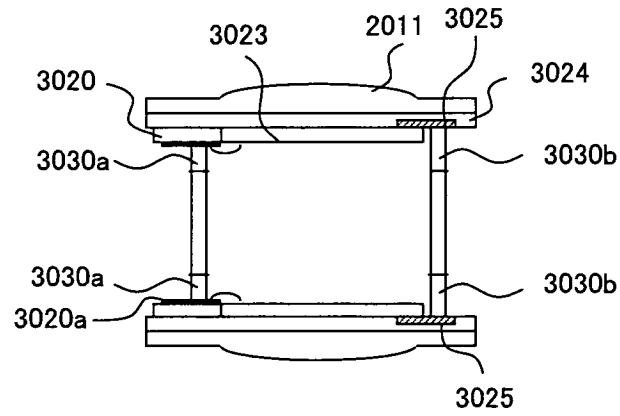


FIG. 37

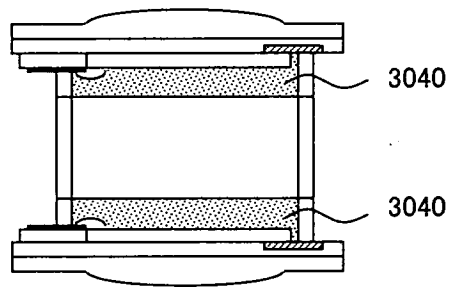


FIG. 38

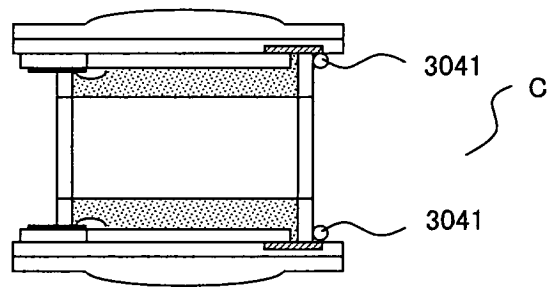


FIG. 39

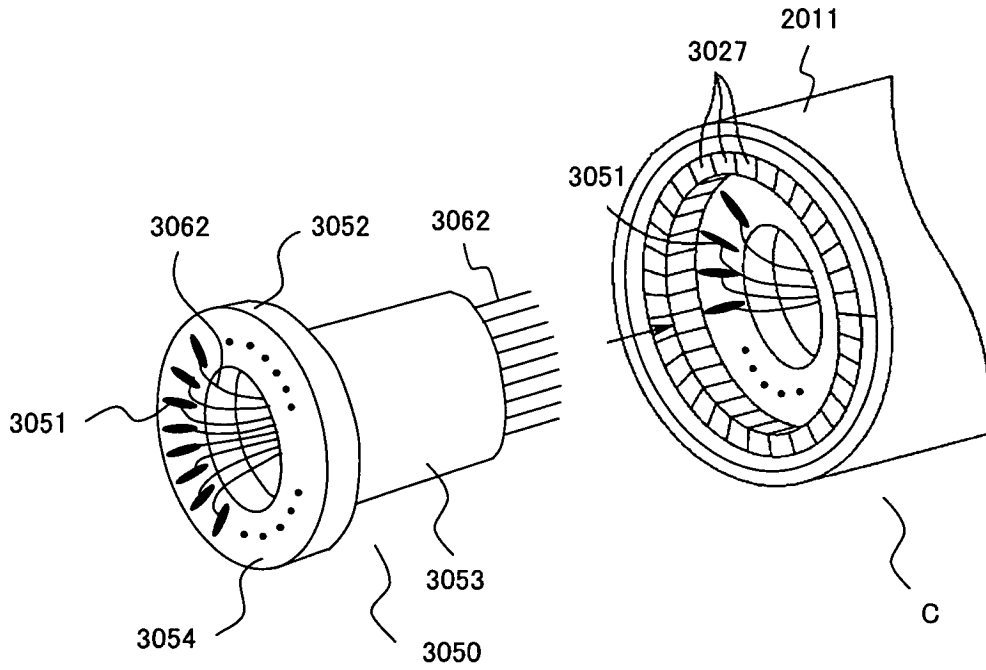


FIG. 40

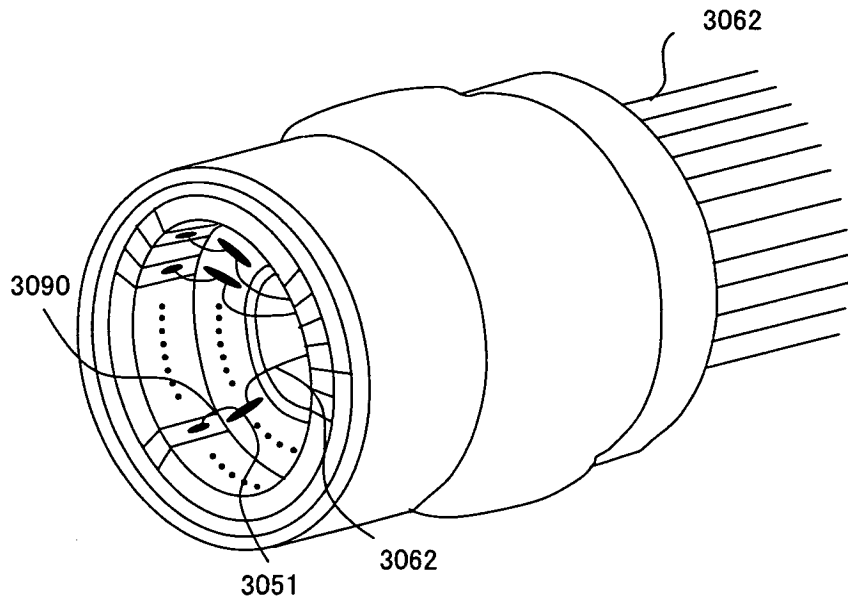


FIG. 41

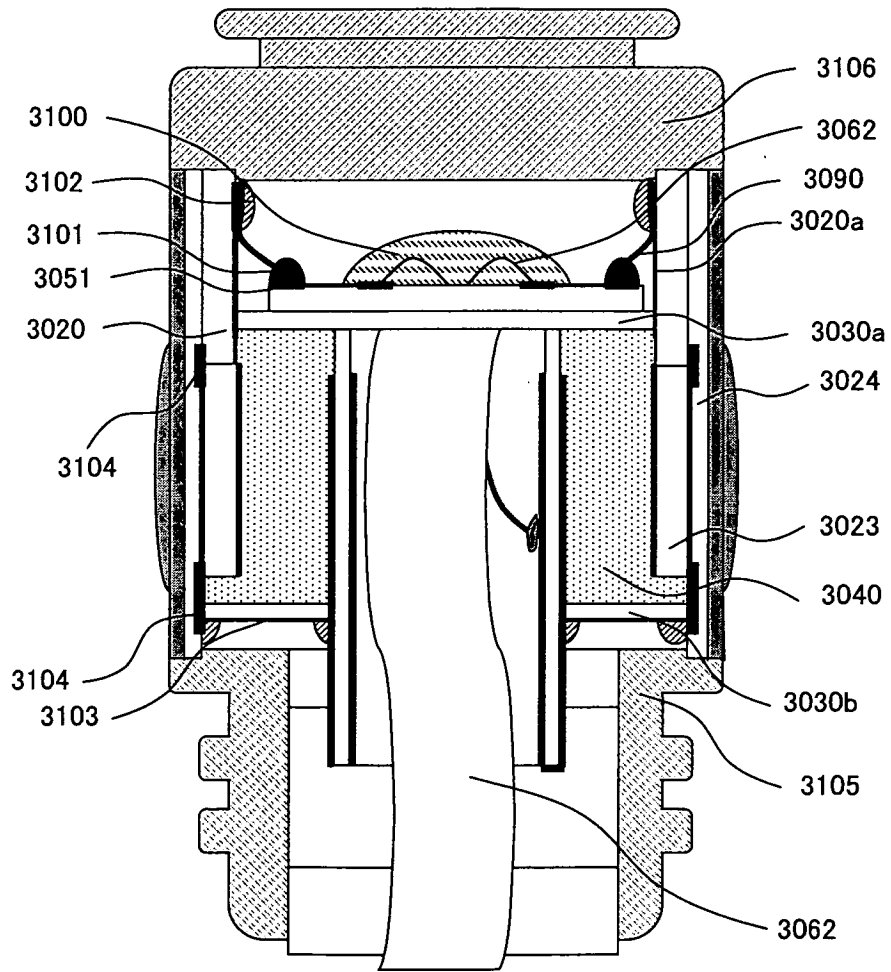


FIG. 42

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/018358

A. CLASSIFICATION OF SUBJECT MATTER A61B8/12 (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) A61B8/00-8/15		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2006 Kokai Jitsuyo Shinan Koho 1971-2006 Toroku Jitsuyo Shinan Koho 1994-2006		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2004-517521 A (Parallel Design, Inc.), 10 June, 2004 (10.06.04), Full text; all drawings & WO 2002/052544 A2 & US 2003/0009873 A1	8 1-7
A	JP 2000-253496 A (GE Yokogawa Medical Systems, Ltd.), 14 September, 2000 (14.09.00), Full text; all drawings (Family: none)	1-8
A	JP 3-270500 A (Fujitsu Ltd.), 02 December, 1991 (02.12.91), Full text; all drawings (Family: none)	1-8
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 10 January, 2006 (10.01.06)		Date of mailing of the international search report 17 January, 2006 (17.01.06)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/018358

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2004-120283 A (Toshiba Corp.), 15 April, 2004 (15.04.04), Full text; all drawings (Family: none)	1-8
A	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 17609/1992 (Laid-open No. 41708/1994) (Terumo Corp.), 03 June, 1994 (03.06.94), Full text; all drawings (Family: none)	1-8

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/018358

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

(See extra sheet.)

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- the
- The additional search fees were accompanied by the applicant's protest and, where applicable, payment of a protest fee..
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/018358

Continuation of Box No.III of continuation of first sheet(2)

Examinations are made on the inventions of independent claims 1, 5, 8, 9, 11 and 14.

The "special technical feature" of the inventions of claims 1, 5 and 8 relates to an ultrasonic probe "wherein the piezoelectric element is divided at the vibrator sub-element unit and wherein the substrate is divided at the unit of vibrator element", the "special technical feature" of the inventions of claims 9 and 11 relates to an ultrasonic probe "wherein the piezoelectric vibrator has a specific dielectric constant of 2,500 or more, wherein the ratio W/t of the width W and the thickness t of the piezoelectric vibrator is 0.6 or less, and wherein the spacing between the adjoining piezoelectric vibrators is the wavelength of the ultrasonic waves or less", and the "special technical feature" of the invention of claim 14 is an ultrasonic probe "wherein an adhesive is fitted at the positions which are located on the two sides of the longitudinal direction of a groove between the adjoining ultrasonic vibrator elements but which do not contact with the vibrator elements, and wherein a vibration attenuator is fitted between the adhesive fitted in the grooves and the vibrator elements".

Since these inventions are not so technically correlated as to involve one or two or more of the same or corresponding special technical features, they cannot be considered so correlated as to form a single general inventive concept.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2001046368 A [0020]
- JP 56017026 A [0020]
- JP 8107598 A [0020]
- JP 2000253496 A [0020]

专利名称(译)	超声波振动器及其制造方法		
公开(公告)号	EP1825815A1	公开(公告)日	2007-08-29
申请号	EP2005790237	申请日	2005-10-04
[标]申请(专利权)人(译)	奥林巴斯医疗株式会社 奥林巴斯株式会社		
申请(专利权)人(译)	奥林巴斯医疗系统股份有限公司. OLYMPUS CORPORATION		
当前申请(专利权)人(译)	OLYMPUS CORPORATION		
[标]发明人	SAWADA YUKIHIKO MIZUNUMA AKIKO WAKABAYASHI KATSUHIRO IMAHASHI TAKUYA SATO SUNAO		
发明人	SAWADA, YUKIHIKO MIZUNUMA, AKIKO WAKABAYASHI, KATSUHIRO IMAHASHI, TAKUYA SATO, SUNAO		
IPC分类号	A61B8/12		
CPC分类号	B06B1/0622 Y10T29/42 Y10T29/49005		
优先权	2005024385 2005-01-31 JP 2004301572 2004-10-15 JP 2004321470 2004-11-05 JP		
外部链接	Espacenet		

摘要(译)

一种超声换能器，其中即使当压电装置被分开以便防止横向振动影响纵向振动时也易于引线连接通过一种方法制造，该方法包括：在声匹配层和压电层上形成第一切割槽的步骤装配板，它们安装在一起以形成多个压电装置；板和各个压电器件连接在一起的步骤；在板和压电器件连接在一起的位置附近的表面涂有导电片的步骤；以及通过在形成在压电器件上的第一切割槽和涂有导电片的板之间以及声匹配层之间形成第二切割槽来形成多个换能器元件的步骤。

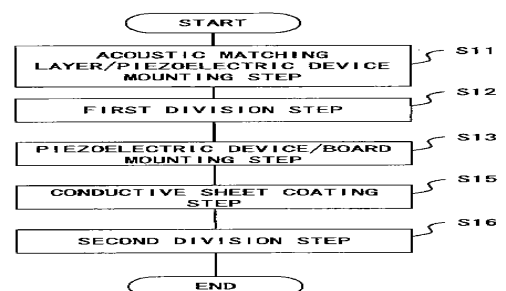


FIG. 16