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(54) ULTRASONIC PROBE AND PRODUCING METHOD THEREFOR

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(57) **ABSTRACT**

Ultrasonic transducers disposed at a head of an ultrasonic probe are joined to a flexible sheet having a curved surface shape. Through holes are formed in the flexible sheet. The through hole is filled with conductive paste for electrically connecting to an individual electrode of the ultrasonic transducer. The flexible sheet is attached to a semicircular support. A surface of the support is provided with device-side terminals for electrically connecting to the conductive paste. The inside of the support is provided with wiring for connecting the device-side terminal to a wiring cable, which is connected to an ultrasonic observing unit.

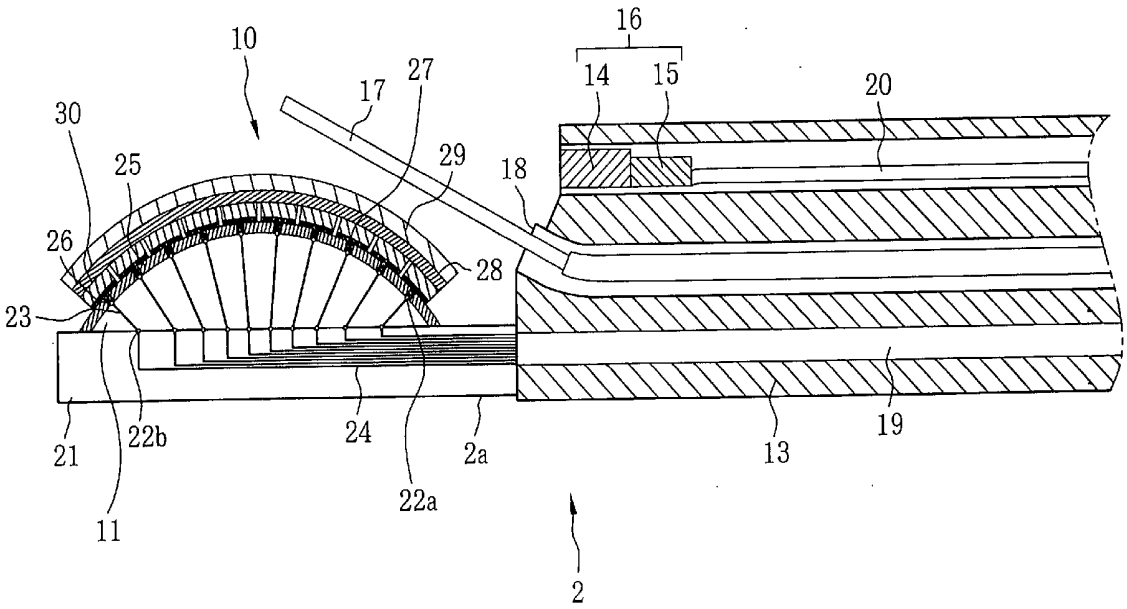


FIG. 1

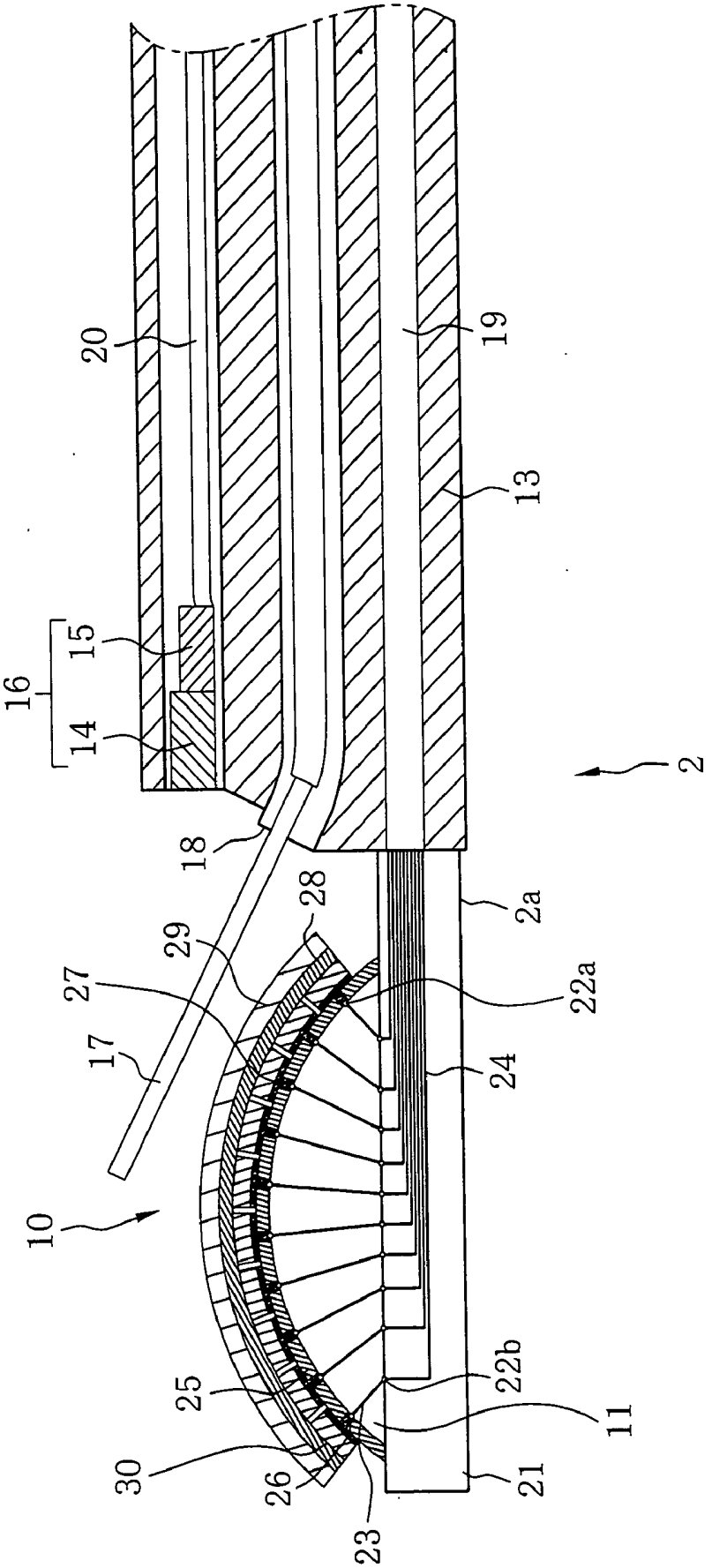


FIG. 2

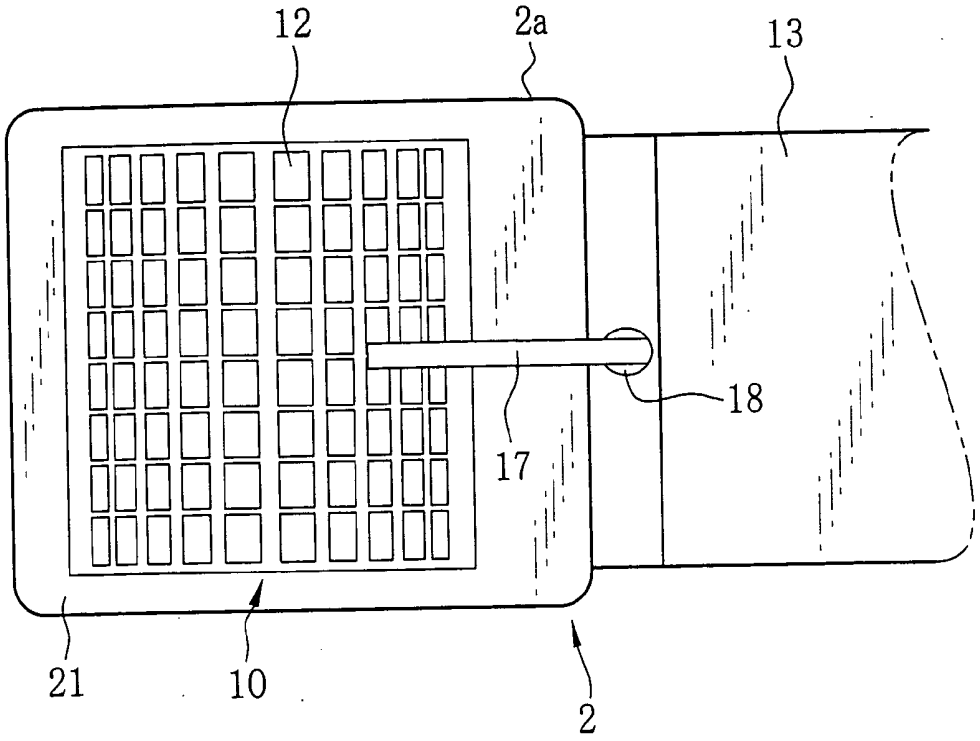


FIG. 7

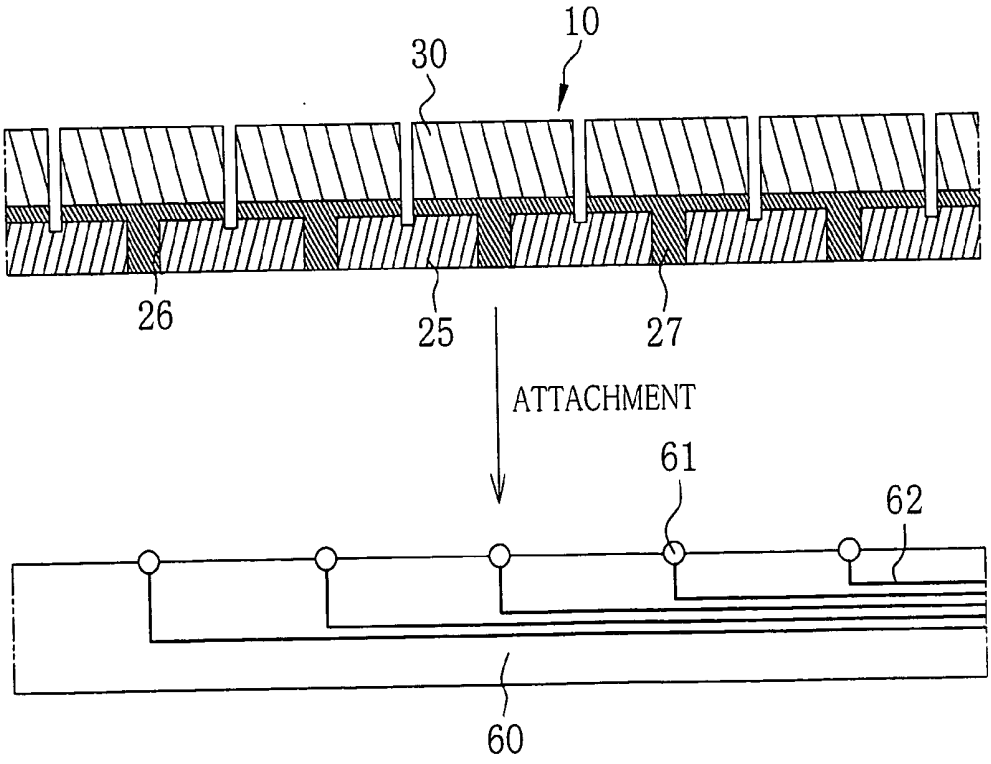


FIG. 3

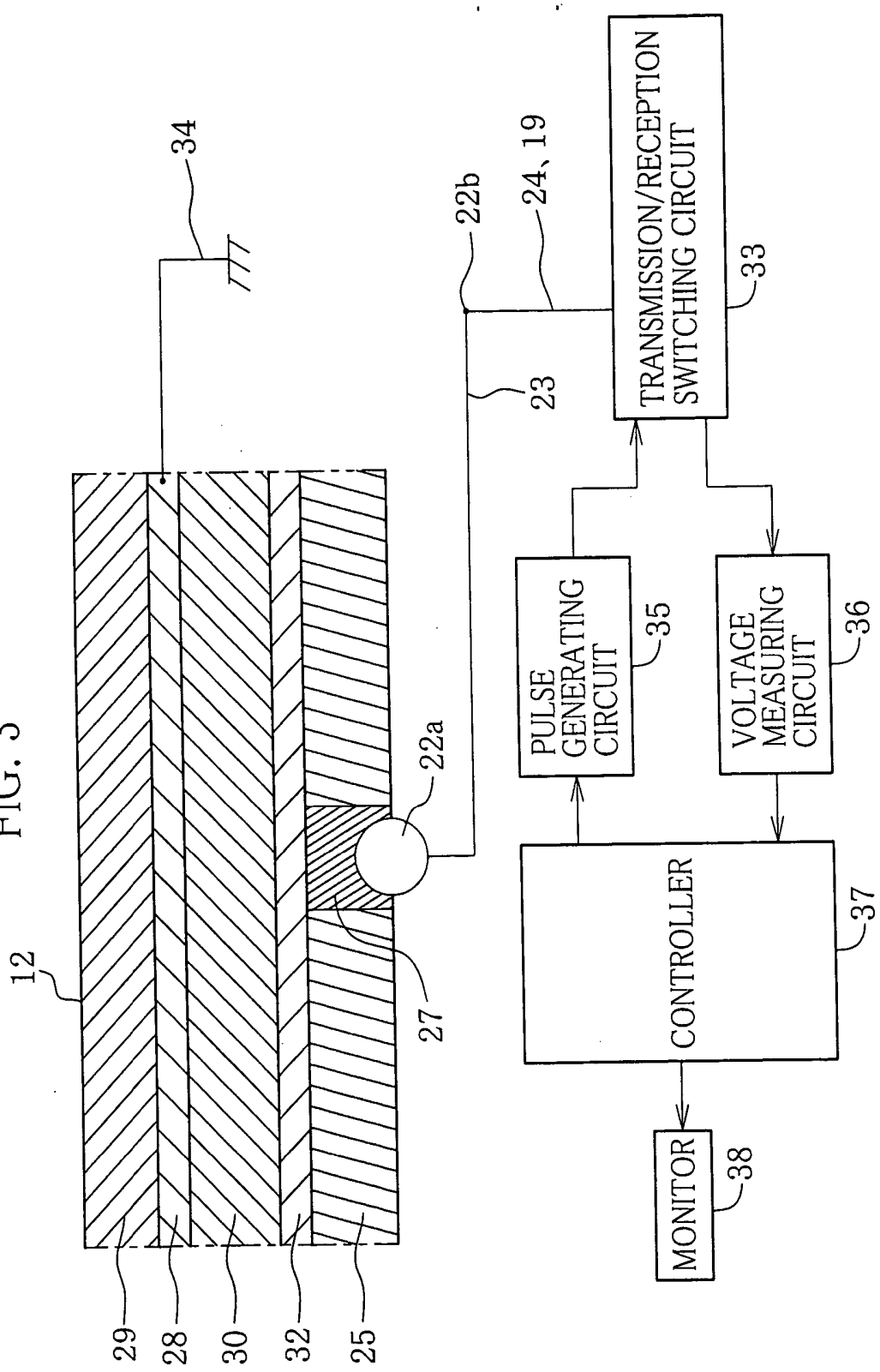

34
22b
24, 19
TRANSMISSION/RECEPTION SWITCHING CIRCUIT
33
23
PULSE GENERATING CIRCUIT
35
VOLTAGE MEASURING CIRCUIT
36
22a
12
27
CONTROLLER
37
MONITOR
38
29
28
30
32
25

FIG. 4A

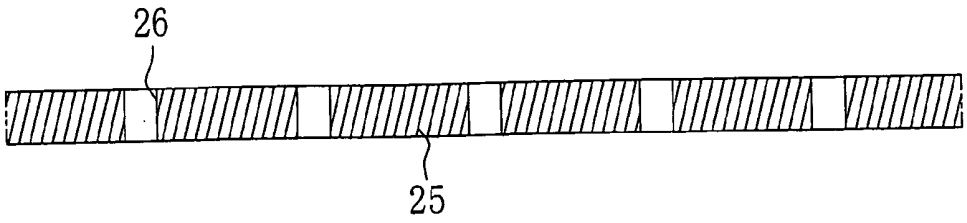


FIG. 4B

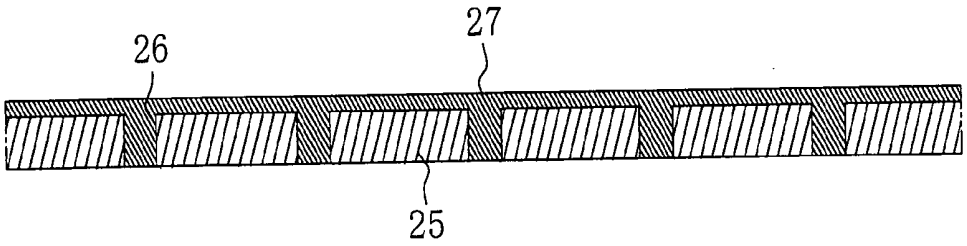


FIG. 4C

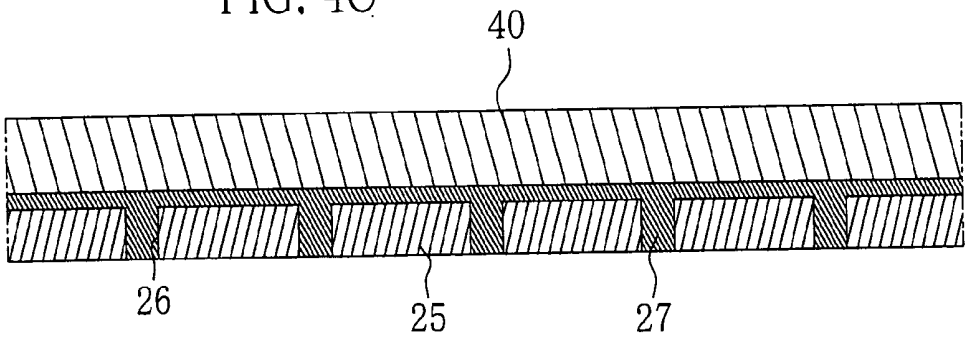


FIG. 4D

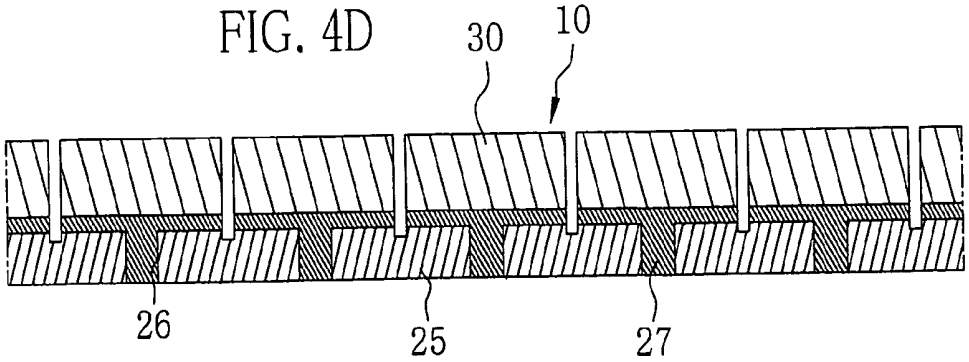
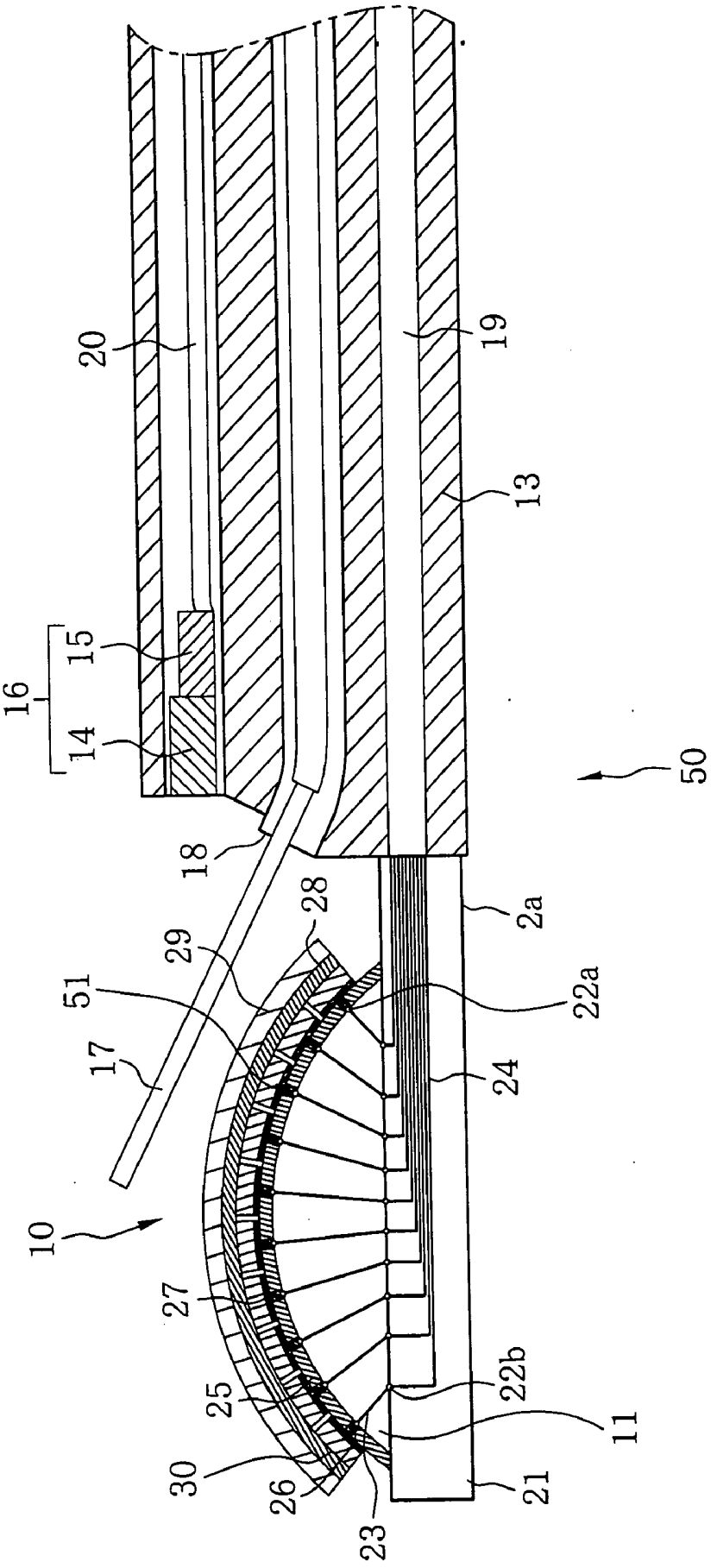


FIG. 5


20
19
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16
14
50
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28
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2a
51
22a
17
24
10
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22b
11
30
26
21
23

FIG. 6A

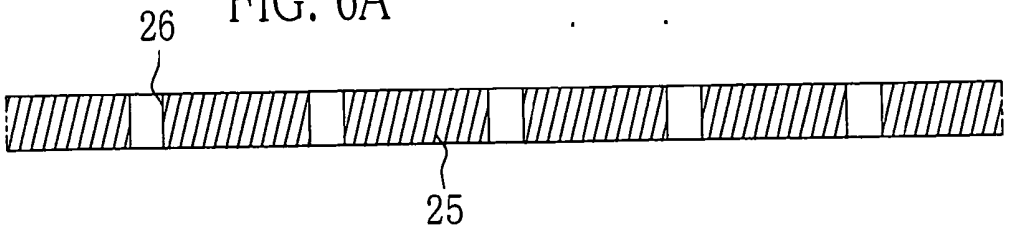


FIG. 6B

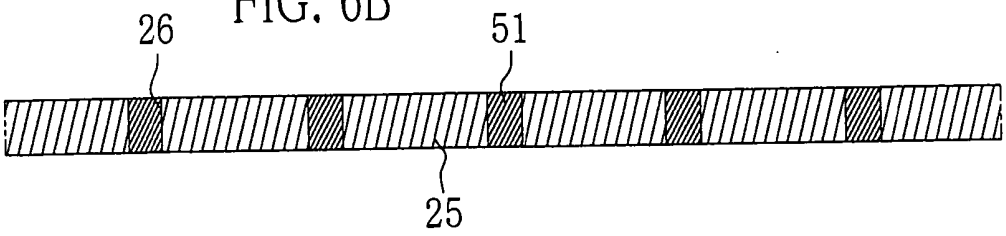


FIG. 6C

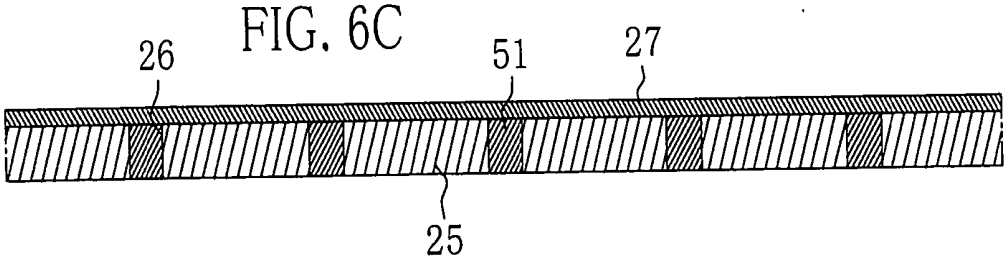


FIG. 6D

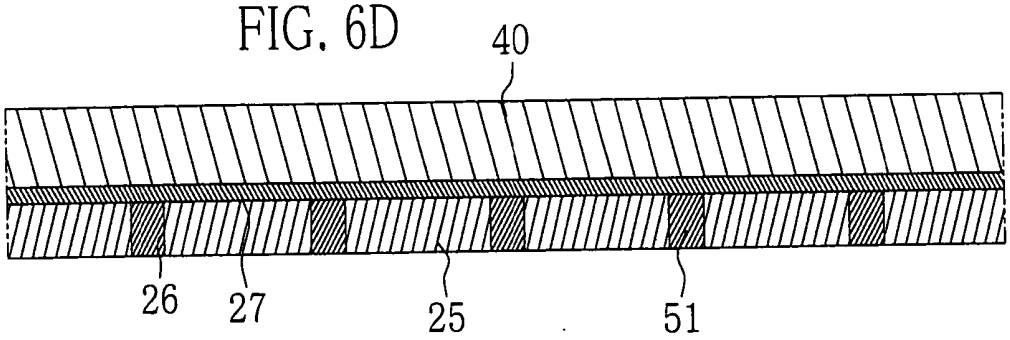


FIG. 6E

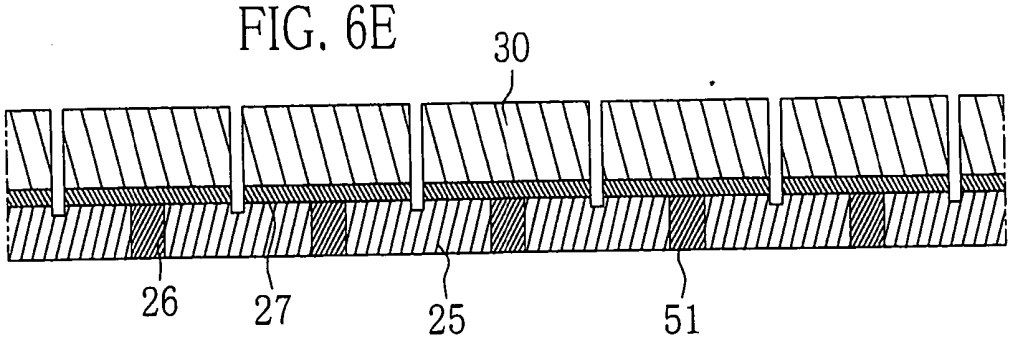
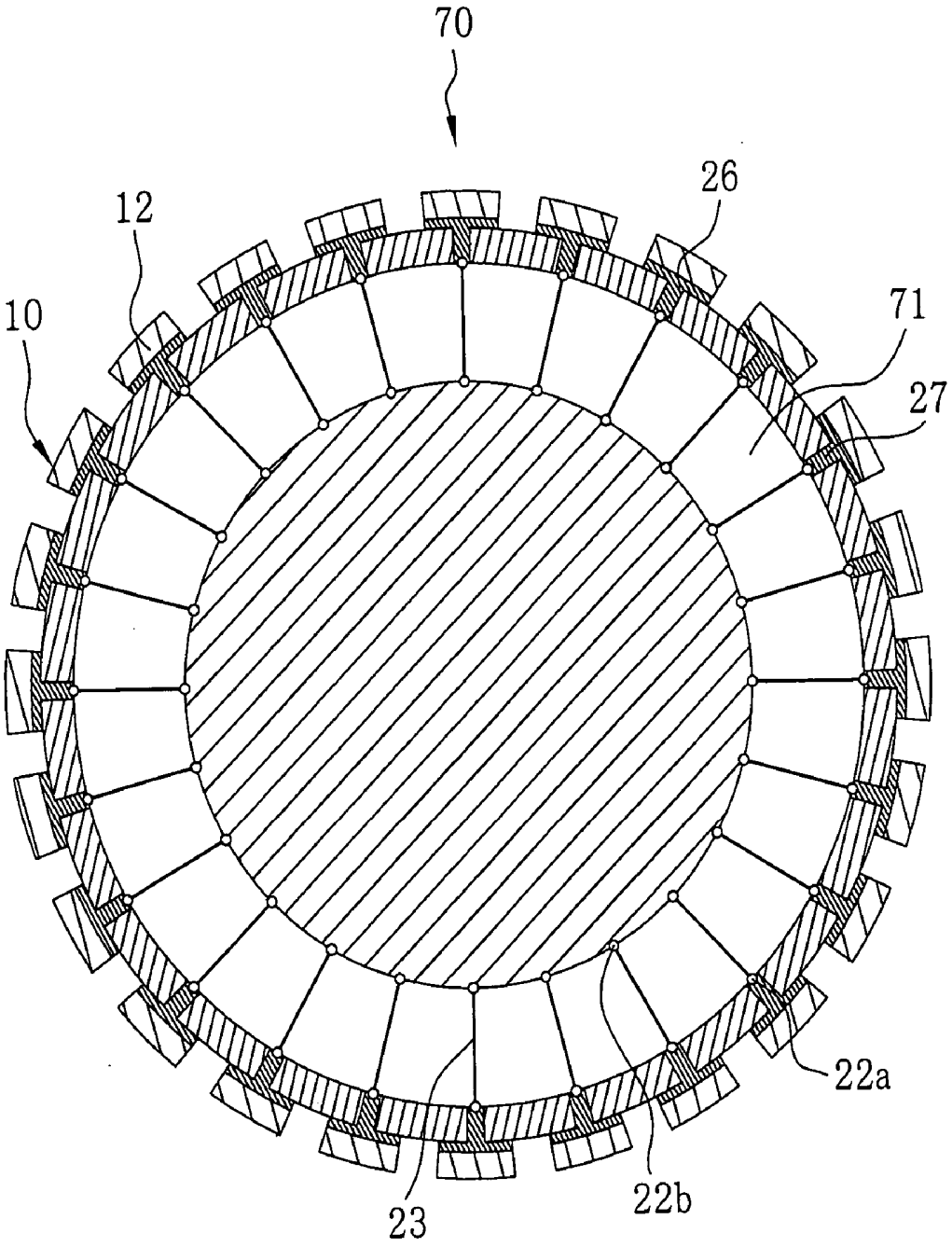


FIG. 8



ULTRASONIC PROBE AND PRODUCING METHOD THEREFOR

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention The present invention relates to an ultrasonic probe comprising ultrasonic transducers for applying ultrasonic waves to a relevant part of a biologic body and for receiving echo signals from the biologic body, and the present invention further relates to a producing method for the ultrasonic probe.

[0002] 2. Description of the Related Art

[0003] In the medical field of recent years, medical diagnostics utilizing ultrasound images is put to practical use. The ultrasound image is obtained by electrically detecting echo signals, which are sent from a biologic body, with an ultrasonic observing unit connected to an ultrasonic probe via a connector. The ultrasonic observing unit applies ultrasonic waves to a relevant part of the biologic body from the ultrasonic probe. As to a mode for driving the ultrasonic probe, is known an electronic scan mode in which a plurality of ultrasonic transducers are disposed to transmit and receive the ultrasonic waves. In this mode, the ultrasonic transducers to be driven are selectively changed by electronic switches and so forth.

[0004] Regarding the ultrasonic probe of the electronic scan mode, there is a convex electronic scan mode in which the ultrasonic transducers (a number of which is 94 to 128, for example) are disposed at the top of the probe in a fan-like form. Beside this mode, there is a radial electronic scan mode in which the ultrasonic transducers (a number of which is 360, for example) are disposed at the periphery of the top of the probe. Further, these modes are classified into a one-dimensional array type and a two-dimensional array type in accordance with arrangement manners of the ultrasonic transducers.

[0005] With respect to methods for producing the ultrasonic transducers of the one-dimensional array type, various methods are proposed. In one of the proposed methods, a piezoelectric element is joined to a flexible backing material so as to interpose a flexible circuit board (see Japanese Patent Laid-Open Publication No. 7-327299). In another of the proposed methods, a piezoelectric element is attached to a flexible backing material and a flexible circuit board is joined to terminals of individual electrodes formed on an end portion of the piezoelectric element (see Japanese Patent Laid-Open Publication No. 8-89505).

[0006] As to the ultrasonic transducers produced by the technology described in the Publication No. 7-327299, there is a possibility that interference is caused between the piezoelectric element and wiring of the flexible circuit board to generate noises in a signal passing through the wiring. In the meantime, as to the ultrasonic transducers produced by the technology described in the Publication No. 8-89505, a space is necessary for forming the terminal on the end portion. Thus, there arises a problem in that it is impossible to prevent a size from enlarging. In addition, the technologies described in the above-noted Publications are unsuitable for producing the ultrasonic transducers of the two-dimensional array type.

SUMMARY OF THE INVENTION

[0007] In view of the foregoing, it is a primary object of the present invention to provide an ultrasonic probe in which a compact and high-density ultrasonic transducer array is easily mounted.

[0008] It is a second object of the present invention to provide a producing method for an ultrasonic probe in which a compact and high-density ultrasonic transducer array is easily mounted.

[0009] In order to achieve the above and other objects, the ultrasonic probe according to the present invention comprises ultrasonic transducers disposed at a head of the ultrasonic probe in an array form. The ultrasonic transducers are joined to a flexible sheet having a curved surface shape. In the flexible sheet, through holes are formed. The though hole is filled with a conductive member for electrically connecting to an individual electrode of the ultrasonic transducer.

[0010] In a preferred embodiment, the flexible sheet is attached to a support having a curved surface shape. For instance, the support is formed in a semicircular shape including a convex shape and a concave shape, and a cylindrical shape. A surface of the support is provided with a terminal for electrically connecting to the conductive member, and the inside of the support is provided with wiring for connecting the terminal to a wiring cable electrically connecting to an ultrasonic observing unit.

[0011] In another embodiment, the flexible sheet is attached to a flexible wiring substrate, a surface of which is provided with a terminal for electrically connecting to the conductive member. Further, the inside of the flexible wiring substrate is provided with wiring for connecting the terminal to a wiring cable connecting to an ultrasonic observing unit. It is preferable that the flexible wiring substrate is attached to a support having a curved surface shape. For instance, the support is formed in a semicircular shape including a convex shape and a concave shape, and a cylindrical shape.

[0012] It is preferable that the conductive member is an adhesive which is applied to the flexible sheet when the ultrasonic transducers are attached to the flexible sheet. Alternatively, the conductive member may be a metal pin.

[0013] A method for producing the above-mentioned ultrasonic probe comprises the steps of forming the through holes in the flexible sheet and filling the through hole with the conductive member for electrically connecting to the individual electrode of the ultrasonic transducer. The ultrasonic-probe producing method further comprises the steps of joining a wafer of a piezoelectric element, which constitutes the ultrasonic transducer, to the flexible sheet, and dicing the wafer in an array form, and curving the flexible sheet.

[0014] According to the ultrasonic probe and the producing method therefor of the present invention, the ultrasonic transducers are joined to the flexible sheet having the through hole filled with the conductive member for electrically connecting to the individual electrode of the ultrasonic transducer. Further, the flexible sheet is curved. Thus, it is possible to easily mount the ultrasonic transducers of an array form having a compact curved shape and high-density curved surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The above objects and advantages of the present invention will become apparent from the following detailed description of the preferred embodiments of the invention when read in conjunction with the accompanying drawings, in which:

[0016] **FIG. 1** is an enlarged sectional view showing a structure of a head of an ultrasonic probe according to the present invention;

[0017] **FIG. 2** is an explanatory illustration showing arrangement of ultrasonic transducers of the ultrasonic probe;

[0018] **FIG. 3** is an enlarged sectional view showing a structure of the ultrasonic transducer;

[0019] **FIGS. 4A** to **4**D are illustrations showing a producing sequence of the ultrasonic probe, wherein **FIG. 4A** shows a process for forming through holes, **FIG. 4B** shows a process for applying conductive paste, **FIG. 4C** shows a process for joining a wafer of the ultrasonic transducer, and **FIG. 4D** shows a process for dicing the wafer of the ultrasonic transducer;

[0020] **FIG. 5** is an enlarged sectional view showing a structure of a head of an ultrasonic probe using metal pins as conductive members;

[0021] **FIGS. 6A** to **6**E are illustrations showing a producing sequence of the ultrasonic probe using the metal pins, wherein **FIG. 6A** shows a process for forming through holes, **FIG. 6B** shows a process for fitting the pin into the through hole, **FIG. 6C** shows a process for applying conductive paste, **FIG. 6D** shows a process for joining a wafer of the ultrasonic transducer, and **FIG. 6E** shows a process for dicing the wafer of the ultrasonic transducer;

[0022] **FIG. 7** is a sectional view showing an embodiment in that a flexible wiring substrate is used; and

[0023] **FIG. 8** is a sectional view showing an ultrasonic probe of a radial electronic scan mode.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0024] In **FIGS. 1 and 2**, an ultrasonic probe **2** according to the present invention is provided with an ultrasonic transducer array **10** disposed at a head **2***a* of the ultrasonic probe **2**. The ultrasonic transducer array **10** adopts so-called convex electronic scan mode in which ultrasonic transducers **12** are arranged on a semicircular support **11** in a two-dimensional array form, such as explanatorily shown in **FIG. 2**.

[0025] An imaging device **16** is disposed at an upper portion of a sheath **13** connected to the head **2***a*. The imaging device **16** comprises an objective optical system **14** for receiving image light of a body part to be observed, and a CCD **15** for taking the image light to output image signals. A middle portion of the sheath **13** is provided with a channel **18** into which a puncture needle **17** is inserted. Further, wiring cables **19** and **20** are inserted into the sheath **13** so as to interpose the channel **18** used for the puncture needle **17**. The wiring cable **19** electrically connects the ultrasonic transducer array **10** to an ultrasonic observing unit (not shown), and the wiring cable **20** electrically connects the imaging device **16** to the ultrasonic observing unit.

[0026] The support **11** is placed on a base **21** of the head **2***a*. The support **11** is made of a material having stiffness, which is a hard rubber and so forth and in which ultrasonic-wave attenuation material is added as need arises. The support **11** may have a concave shape.

[0027] The front and the rear of the support **11** are respectively provided with device-side terminals **22***a* and cable-side terminals **22***b* by a number of the ultrasonic transducers **12**. Moreover, the inside of the support **11** is provided with wiring **23** for connecting the device-side terminal **22***a* and the cable-side terminal **22***b*. A conductive paste **27** described later is electrically connected to the device-side terminal **22***a*. Meanwhile, wiring **24** extending from the wiring cable **19** to the inside of the base **21** is electrically connected to the cable-side terminal **22***b*.

[0028] The ultrasonic transducer array **10** is joined to a flexible sheet **25** via which this array **10** is attached to the support **11**. Through holes **26** are formed in the flexible sheet **25** and are filled with the conductive paste **27**, which is applied to the flexible sheet **25** when the ultrasonic transducer array **10** is joined to the flexible sheet **25**. By the way, for the purpose of avoiding complication, hatching is not drawn relative to the support **11** and the base **21**. Although illustration is abbreviated, interspace formed between the ultrasonic transducers **12** is loaded with a filler of epoxy resin. Incidentally, reference numeral **28** denotes a metal film being as a common electrode (see **FIG. 3**) of the ultrasonic transducers **12**, and reference numeral **29** denotes an acoustic matching layer, which is for matching acoustic impedance with a biologic body.

[0029] In **FIG. 3**, the ultrasonic transducer **12** comprises a piezoelectric element **30** and the acoustic matching later **29** of epoxy resin, which are located in this order from the flexible sheet **25**. The piezoelectric element **30** comprises a thin film of PZT (lead zirconate titanate) and is interposed between an individual electrode **32** and the common electrode **28**.

[0030] The individual electrode **32** is connected to a transmission/reception switching circuit **33** of the ultrasonic observing unit via the conductive paste **27** of the through hole **26**, the device-side terminal **22***a*, the wiring **23**, the cable-side terminal **22***b*, the wiring **24** and the wiring cable **19**. Meanwhile, the common electrode **28** is grounded via wiring **34**. In fact, such as described above, the common electrode **28** is the metal film superposed on the entire surfaces of the piezoelectric elements **30**.

[0031] The transmission/reception switching circuit **33** changes transmission and reception of the ultrasonic waves, which are performed by the ultrasonic transducer **12**, at predetermined time intervals. This circuit **33** is connected to a pulse generating circuit **35** and a voltage measuring circuit **36**. The pulse generating circuit **35** applies pulse voltage to the piezoelectric element **30** when to emit the ultrasonic waves from the ultrasonic transducer **12** (when to transmit the ultrasonic waves). In virtue of this, the ultrasonic transducer **12** generates the ultrasonic wave having predetermined frequency.

[0032] The voltage measuring circuit **36** measures a voltage generated by the piezoelectric element **30** when the

ultrasonic transducer **12** has received an echo signal from the biologic body (when the ultrasonic wave has been received). The voltage measuring circuit **36** sends a result of this measurement to a controller **37** in which the measurement result sent from the voltage measuring circuit **36** is converted into an ultrasonic image. The converted ultrasonic image is displayed on a monitor **38**.

[**0033**] When obtaining in vivo ultrasonic images, an insert portion of the ultrasonic probe **2** is inserted into the biologic body. While optical images obtained by the imaging device **16** are observed with an endoscopic monitor, a relevant part is searched inside the biologic body. After the head **2***a* has reached the relevant part, an instruction is given to obtain the ultrasonic image. Upon this instruction, the ultrasonic wave is emitted from the ultrasonic transducer **12** in accordance with the pulse voltage, which is applied from the pulse generating circuit **35**, to scan the biologic body while the transmission/reception switching circuit **33** switches the ultrasonic transducer **12** to transmit and receive the ultrasonic wave.

[**0034**] The echo signal from the biologic body is received by the ultrasonic transducer **12**, and the voltage generated in the piezoelectric element **30** is measured by the voltage measuring circuit **36**. The measurement result of the voltage measuring circuit **36** is sent to the controller **37** and is converted into the ultrasonic image therein. The converted ultrasonic image is displayed on the monitor **38**. In addition, while the optical image or the ultrasonic image is observed, the puncture needle **17** is operated, if necessary, to take the relevant part of the biologic body.

[**0035**] Next, a process for producing the ultrasonic probe **2** having the above structure is described below, referring to **FIG. 4**. First of all, as shown in **FIG. 4A**, the through holes **26** are formed in predetermined positions of the flexible sheet **25** by means of a laser, a punch, a drill and so forth. Then, as shown in **FIG. 4B**, the conductive paste **27** is screen-printed on the flexible sheet **25** by using a squeeze. In virtue of this, the through hole **26** is filled with the conductive paste **27**.

[**0036**] After the conductive paste **27** has been screen-printed on the flexible sheet **25**, a wafer **40** of the piezoelectric element **30** is joined to the flexible sheet **25** via the conductive paste **27**, such as shown in **FIG. 4C**. Successively, as shown in **FIG. 4D**, the wafer **40** is diced in a two-dimensional array form. At this time, the conductive paste **27** is divided so as to correspond to each of the diced piezoelectric elements **30**. Thus, the piezoelectric elements **30** are isolated from each other. Incidentally, the divided conductive past **27**, which confronts the piezoelectric element **30**, is regarded as the individual electrode **32**.

[**0037**] After that, the flexible sheet **25** is bent so as to fit a curved surface shape of the support **11** and is attached to the support **11**. Thereupon, the conductive paste **27** is electrically connected to the device-side terminal **22***a* disposed at the surface of the support **11**. After filling the interspaces of the piezoelectric elements **30** with the filler, the metal film being as the common electrode **28** is attached to the surfaces of the piezoelectric elements **30**. Finally, the acoustic matching layer **29** is attached to the common electrode **28** to complete the ultrasonic probe **2**.

[**0038**] As described above in detail, the ultrasonic transducers **12** are joined to the flexible sheet **25** in which the through holes **26** are formed. The through hole **26** is filled with the conductive paste **27** electrically connecting to the individual electrode **32** of the ultrasonic transducer **12**. Further, the surface shape of the flexible sheet **12** is curved. Thus, it is possible to easily mount the ultrasonic transducers **12** of the two-dimensional array form having the compact curved shape and the high-density curved surface.

[**0039**] The surface of the support **11** is provided with the device-side terminal **22***a* for electrically connecting to the conductive paste **27**, and the inside of the support **11** is provided with the wiring **23** for connecting the device-side terminal **22***a* to the wiring cable **19**. It is prevented that noises are added to the signals passing through the wiring **23**. In virtue of this, receiver sensitivity of the ultrasonic wave becomes good so that the ultrasonic image of high quality is obtained.

[**0040**] In the above embodiment, the conductive paste **27** is used as the conductive member. However, such as an ultrasonic probe **50** shown in **FIG. 5**, a metal pin **51** may be used instead of the conductive paste **27**. In **FIG. 5**, hatching is not drawn relative to the support **11** and the base **21** similarly to **FIG. 1**.

[**0041**] In this embodiment, a process for producing the ultrasonic probe **50** is as shown in **FIGS. 6A** to **6**E. First of all, such as shown in **FIG. 6A**, the through holes **26** are formed in predetermined positions of the flexible sheet **25** similarly to the foregoing embodiment. After that, such as shown in **FIG. 6B**, the pin **51** is fitted into the through hole **26**. Successively, such as shown in **FIG. 6C**, the conductive paste **27** is screen-printed on the flexible sheet **25** similarly to the foregoing embodiment. And then, such as shown in **FIG. 6D**, the wafer **40** of the piezoelectric element is joined to the flexible sheet **25**. Finally, such as shown **FIG. 6E**, the wafer **40** is diced in a two-dimensional array form and the conductive paste **27** is divided so as to correspond to each of the diced piezoelectric elements **30**. Thus, the piezoelectric elements **30** are isolated from each other. By the way, in a case using a commercial anisotropic conductive sheet into which metal pins are fitted in advance, the processes shown in **FIGS. 6A and 6B** are omitted. In this case, the flexible sheet **25** is attached to the support **11** after joining the wafer **40** of the piezoelectric element to the flexible sheet **25**, and then the wafer **40** is diced in the two-dimensional array form. At this time, the anisotropic conductive sheet is completely divided every diced piezoelectric element **30** to isolate the piezoelectric elements **30** from each other.

[**0042**] Instead of providing the support **11** with the device-side terminal **22***a* and the wiring **23**, a flexible wiring substrate **60** shown in **FIG. 7** maybe used. A surface of the flexible wiring substrate **60** is provided with terminals **61** for electrically connecting to the conductive paste **27** (or the pin **51**). The inside of the flexible wiring substrate **60** is provided with wiring **62** for connecting the terminals **61** to the wiring cable **19**. In this case, when producing the ultrasonic probe, the flexible sheet **25** to which the ultrasonic transducer array **10** is attached is joined to the flexible wiring substrate **60**, and then, this wiring substrate **60** is mounted on a support. Incidentally, a plurality of the flexible wiring substrates may be stacked to construct a multilayer form. In **FIG. 7**, hatching is not drawn relative to the flexible wiring substrate **60** for the similar reason with the support **11** and the base **21** shown in **FIGS. 1 and 5**.

[0043] In the above embodiments, the ultrasonic transducer array **10** of the convex electronic scan mode is described. The present invention, however, may be adopted to an ultrasonic probe **70** of so-called radial electronic scan mode in which the ultrasonic transducers **12** are attached to a cylindrical support **71** via the flexible sheet **25** such as shown in **FIG. 8**.

[0044] Further, besides the ultrasonic transducer arrays **10** described in the above embodiments, the present invention may be adopted to an actuator for driving a focus lens and a zoom lens of a camera, a vibrating gyro to be used for an angular rate sensor, and the other transducer arrays.

[0045] Although the present invention has been fully described by way of the preferred embodiments thereof with reference to the accompanying drawings, various changes and modifications will be apparent to those having skill in this field. Therefore, unless otherwise these changes and modifications depart from the scope of the present invention, they should be construed as included therein.

What is claimed is:

1. An ultrasonic probe, at a head of which a plurality of ultrasonic transducers are arranged in an array form, said ultrasonic probe comprising:

a flexible sheet to which said ultrasonic transducers are joined, said flexible sheet being bent so as to have a curved surface shape;

a through hole formed in said flexible sheet; and

a conductive member fitted into said through hole, said conductive member electrically connecting to an individual electrode of said ultrasonic transducer.

2. An ultrasonic probe according to claim 1, further comprising:

a support to which said flexible sheet is attached, said support having a curved surface shape.

3. An ultrasonic probe according to claim 2, wherein said support is formed in either of a semicircular shape and a cylindrical shape.

4. An ultrasonic probe according to claim 2, further comprising:

a terminal disposed at a surface of said support, said terminal electrically connecting to said conductive member; and

wiring led through the inside of said support, said wiring connecting said terminal to a wiring cable contained in said ultrasonic probe.

5. An ultrasonic probe according to claim 1, further comprising;

a flexible wiring substrate to which said flexible sheet is attached;

a terminal disposed at a surface of said flexible wiring substrate, said terminal electrically connecting to said conductive member; and

wiring led through the inside of said flexible wiring substrate, said wiring connecting said terminal to a wiring cable contained in said ultrasonic probe.

6. An ultrasonic probe according to claim 5, further comprising:

a support to which said flexible wiring substrate is attached, said support having a curved surface shape.

7. An ultrasonic probe according to claim 6, wherein said support is formed in either of a semicircular shape and a cylindrical shape.

8. An ultrasonic probe according to claim 1, wherein said conductive member is a conductive paste being as an adhesive applied to said flexible sheet at a time when said transducers are joined to said flexible sheet.

9. An ultrasonic probe according to claim 8, wherein said individual electrode of said ultrasonic transducer is said conductive paste applied to a surface of said flexible sheet.

10. An ultrasonic probe according to claim 1, wherein said conductive member is a metal pin.

11. A producing method for an ultrasonic probe, at a head of which a plurality of ultrasonic transducers are arranged in an array form, said producing method comprising the steps of:

forming through holes in a flexible sheet to be joined to said ultrasonic transducers;

fitting a conductive member into said through hole, said conductive member being for electrically connecting to an individual electrode of said ultrasonic transducer;

joining a wafer of a piezoelectric element of said ultrasonic transducer to said flexible sheet; and

dicing said wafer in said array form.

12. A producing method for the ultrasonic probe according to claim 11, further comprising the steps of:

bending said flexible sheet so as to have a curved surface shape; and

attaching said flexible sheet to a support having a curved surface shape.

13. A producing method for the ultrasonic probe according to claim 12, wherein said support is formed in either of a semicircular shape and a cylindrical shape.

14. A producing method for the ultrasonic probe according to claim 12, wherein a surface of said support is provided with a terminal for electrically connecting to said conductive member, and the inside of said support is provided with wiring for connecting said terminal to a wiring cable contained in said ultrasonic probe.

15. A producing method for the ultrasonic probe according to claim 11, further comprising the step of:

attaching said flexible sheet to a flexible wiring substrate, a surface of said flexible wiring substrate being provided with a terminal for electrically connecting to said conductive member, and the inside of said flexible wiring substrate being provided with wiring for connecting said terminal to a wiring cable contained in said ultrasonic probe.

16. A producing method for the ultrasonic probe according to claim 15, further comprising the step of:

bending said flexible wiring substrate so as to have a curved surface shape; and

attaching said flexible wiring substrate to a support having a curved surface shape.

17. A producing method for the ultrasonic probe according to claim 16, wherein said support is formed in either of a semicircular shape and a cylindrical shape.

18. A producing method for the ultrasonic probe according to claim 11, wherein said conductive member is a conductive paste being as an adhesive applied to said flexible sheet at a time when said transducers are joined to said flexible sheet.

19. A producing method for the ultrasonic probe according to claim 18, wherein said individual electrode of said ultrasonic transducer is said conductive paste applied to a surface of said flexible sheet.

20. A producing method for the ultrasonic probe according to claim 11, wherein said conductive member is a metal pin.

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专利名称(译)	超声波探头及其制造方法		
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摘要(译)

设置在超声探头的头部的超声换能器连接到具有弯曲表面形状的柔性片。在柔性片中形成通孔。通孔填充有导电膏，用于电连接到超声换能器的单个电极。柔性片附接到半圆形支撑件。支撑件的表面设置有用于电连接到导电膏的器件侧端子。支撑件的内部设置有用于将设备侧端子连接到布线电缆的布线，布线电缆连接到超声波观察单元。