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(54) ULTRASOUND TRANSDUCER, ULTRASOUND ENDOSCOPE, AND METHOD OF MANUFACTURING ULTRASOUND TRANSDUCER

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H01L 41/338	(2006.01)

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(57) **ABSTRACT**

A radial type ultrasound transducer is arranged in an ultrasound endoscope including a bending portion on a distal end side of an insertion portion. The ultrasound transducer includes: a plurality of piezoelectric elements arranged at predetermined intervals in a circumferential manner and configured to transmit and receive ultrasound waves; a plurality of electrodes arranged in the respective piezoelectric elements; and a flexible printed circuit electrically connected to each of the electrodes. The flexible printed circuit includes a plurality of wires that extend such that at least parts of the wires cross a direction perpendicular to an arrangement direction of the piezoelectric elements, and the plurality of wires are electrically connected to the respective electrodes of the piezoelectric elements at positions where at least parts of the wires cross the direction perpendicular to the arrangement direction of the piezoelectric elements.

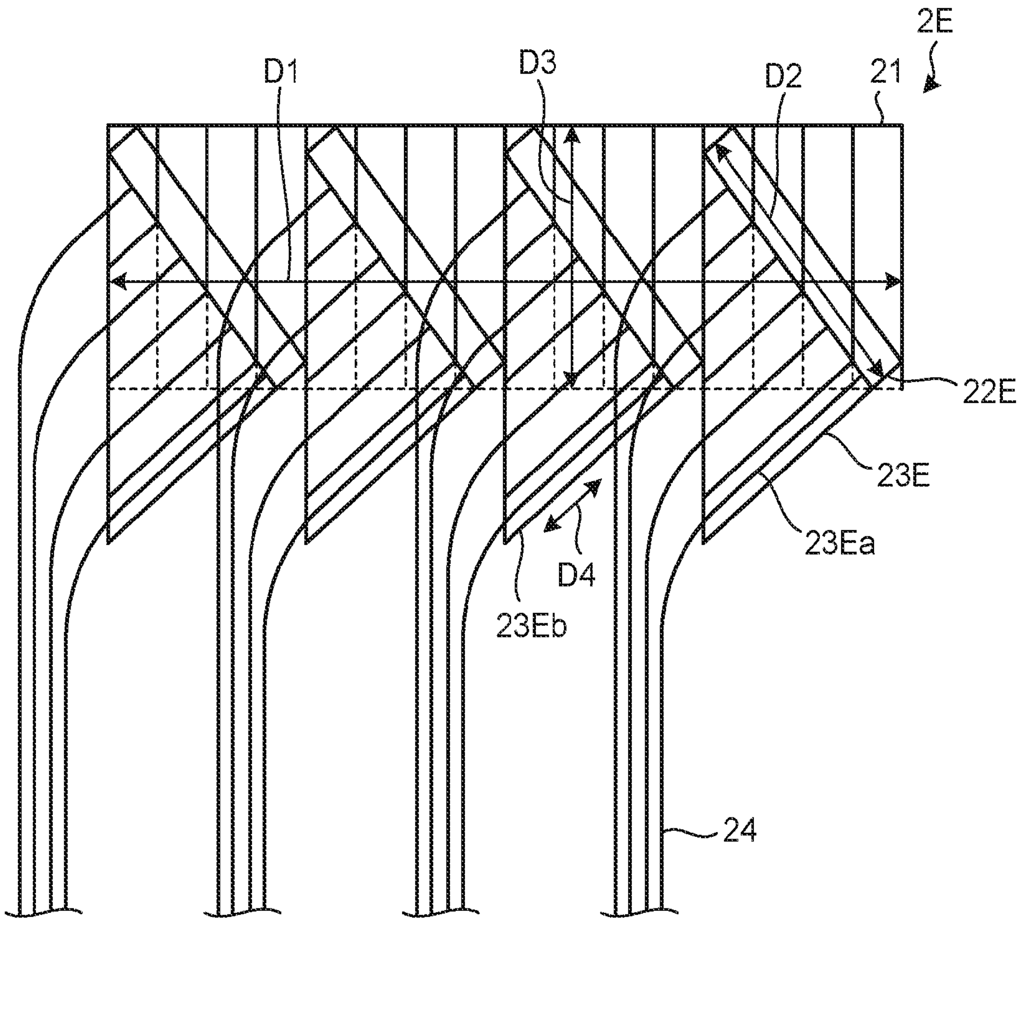


FIG.1

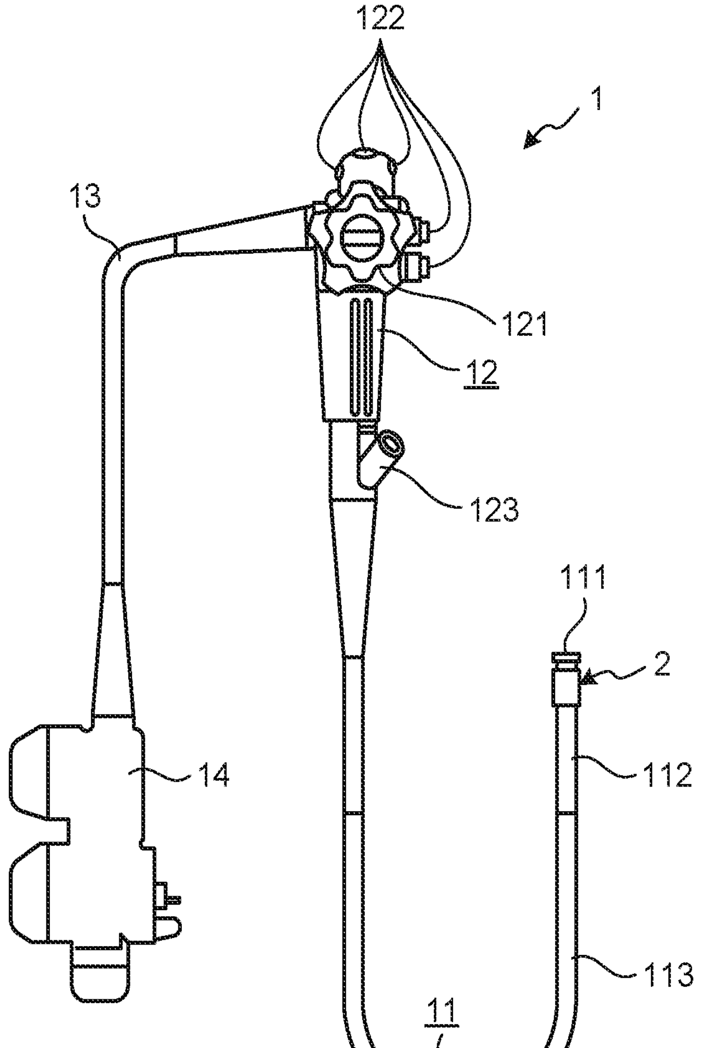


FIG.2

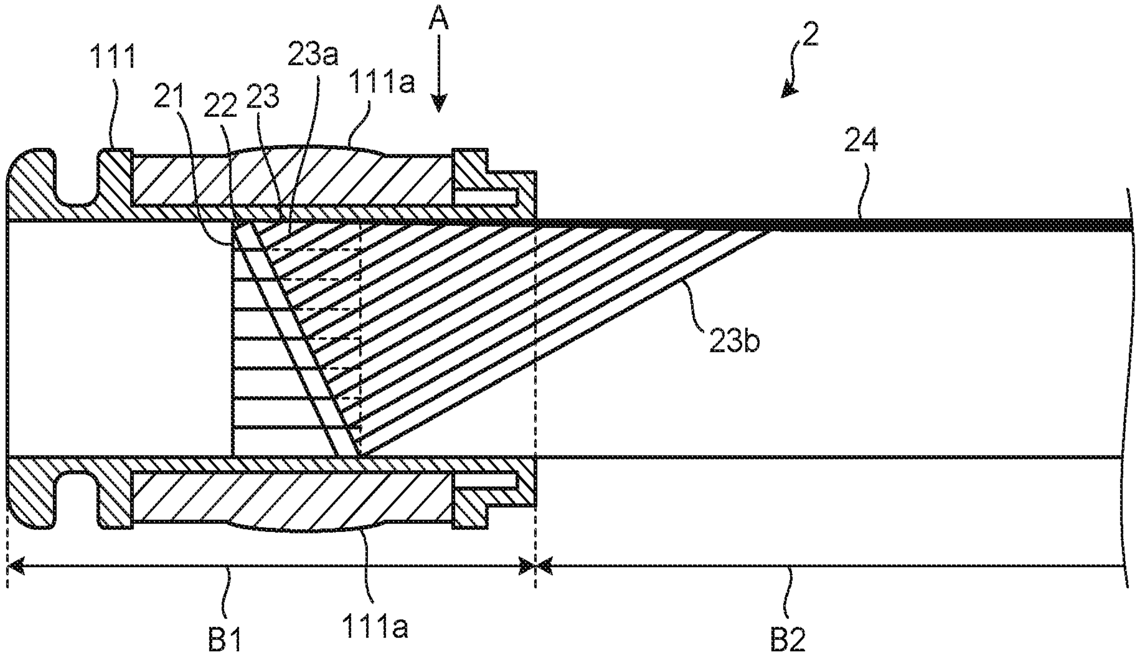

A
111
23a
111a
2
21
22
23
24
23b
B1
111a
B2

FIG.3

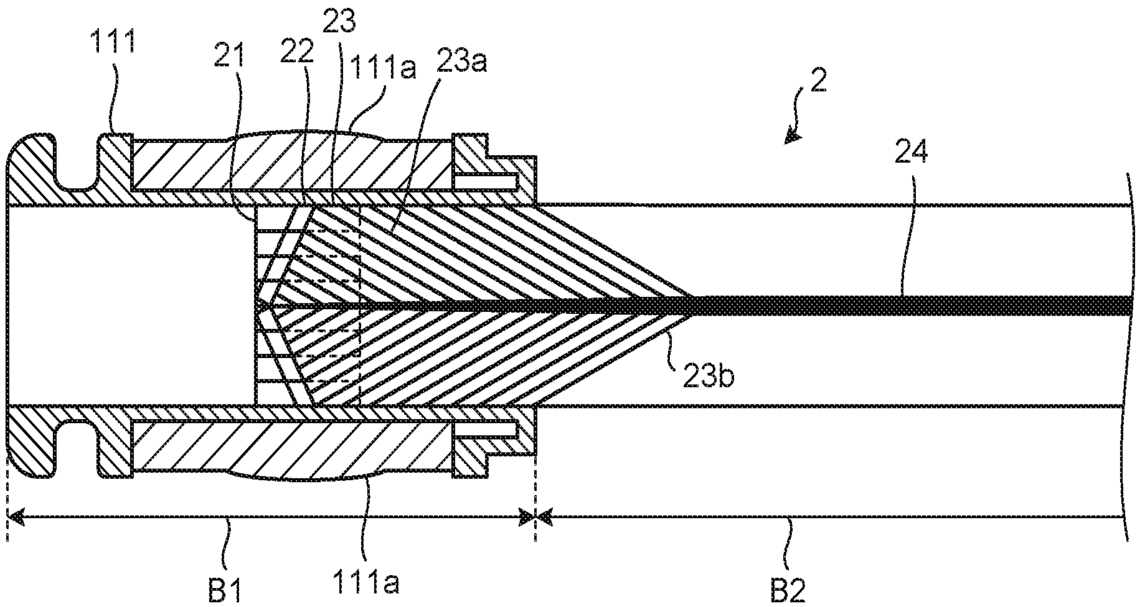

111
23
21
22
111a
23a
2
24
23b
B1
111a
B2

FIG.4

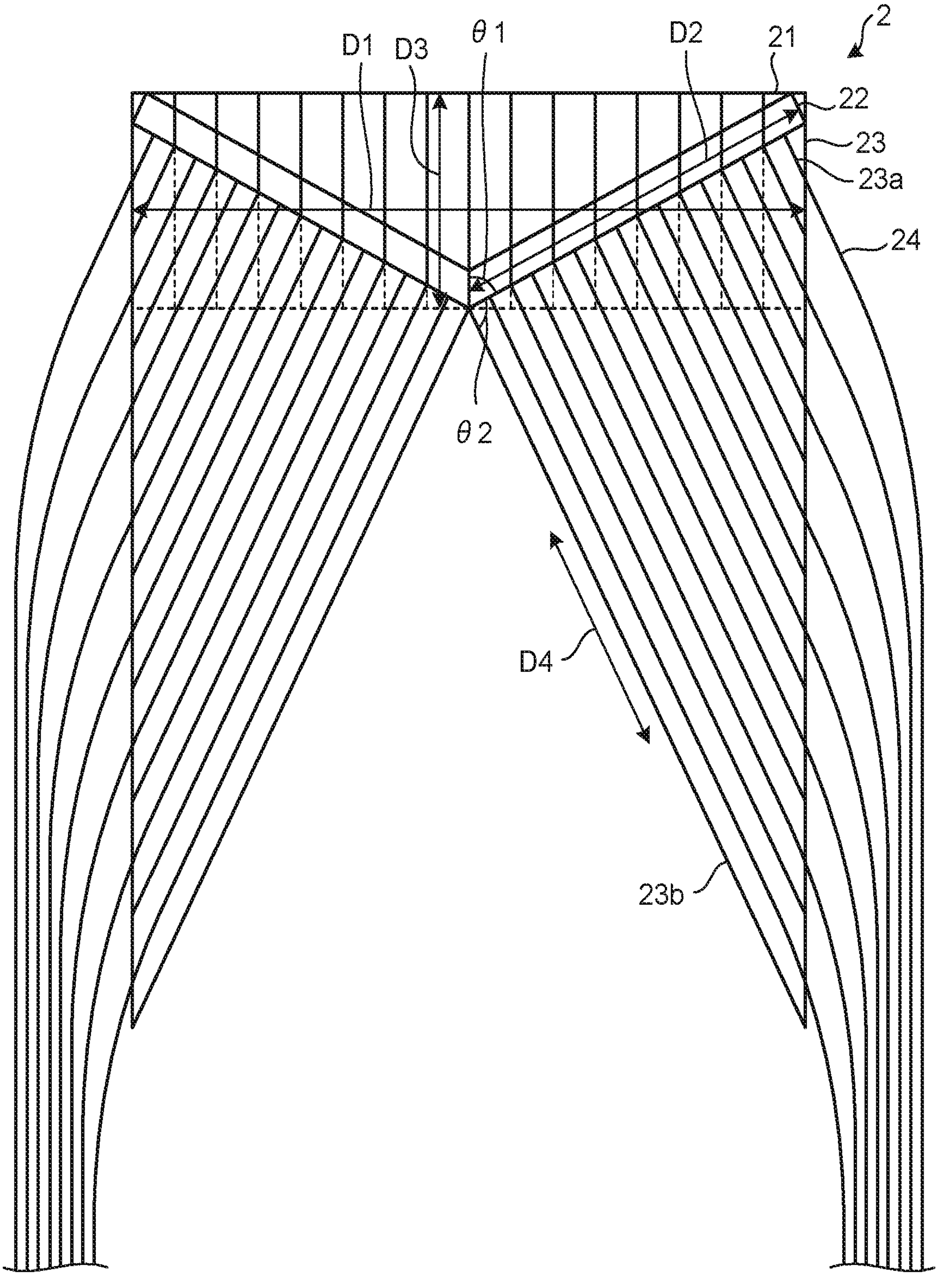


FIG.5

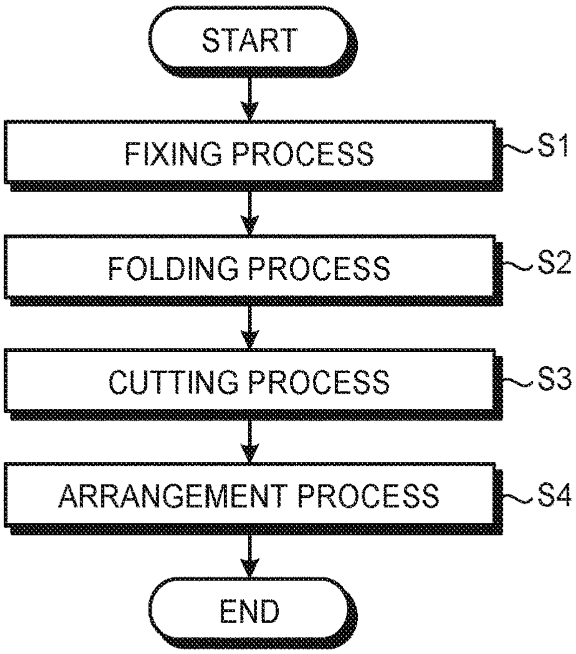

START
FIXING PROCESS
S1
FOLDING PROCESS
S2
CUTTING PROCESS
S3
ARRANGEMENT PROCESS
S4
END

FIG.6

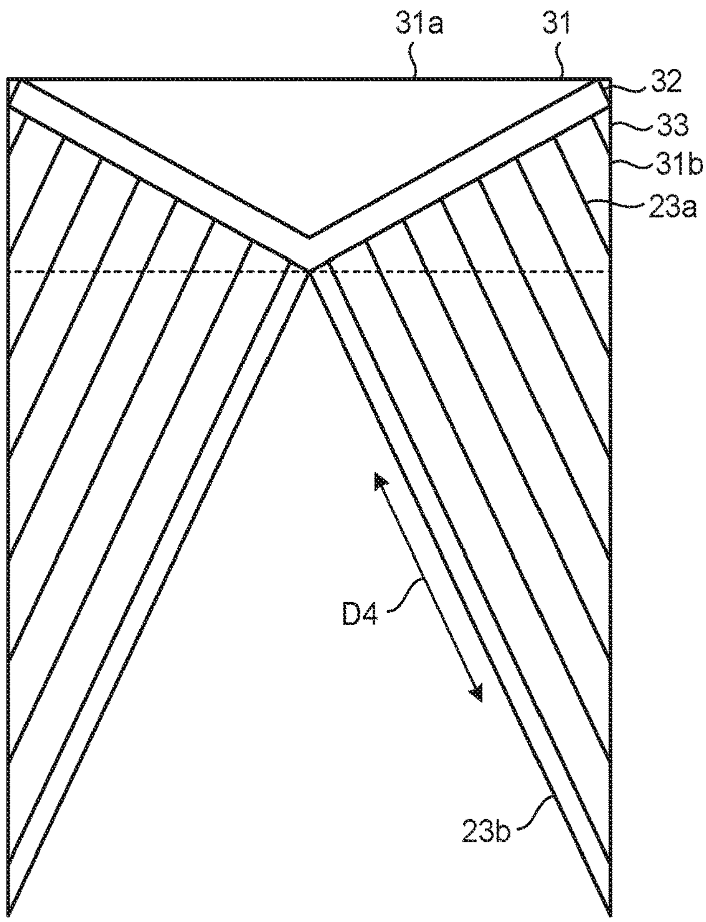

31a
31
32
33
31b
23a
D4
23b

FIG.7

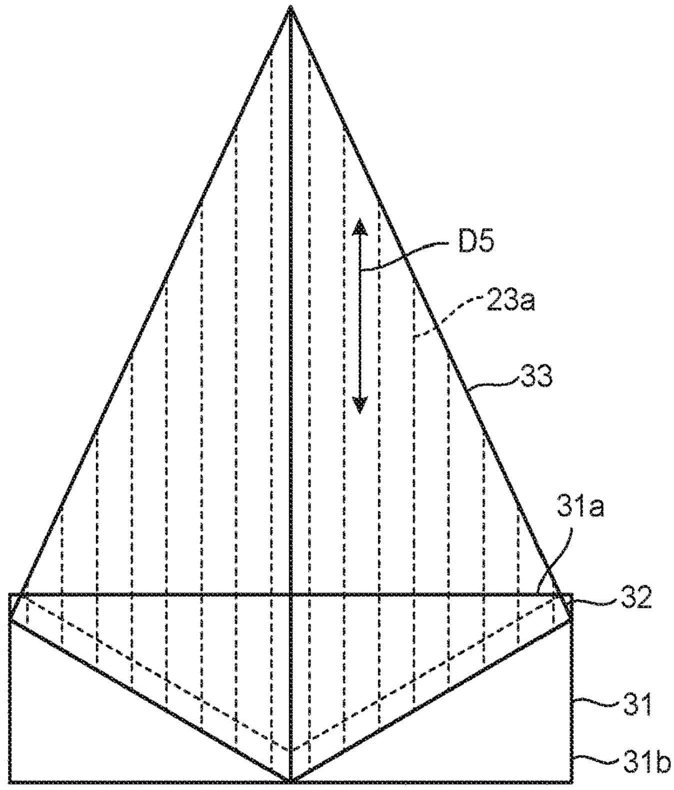


FIG.8

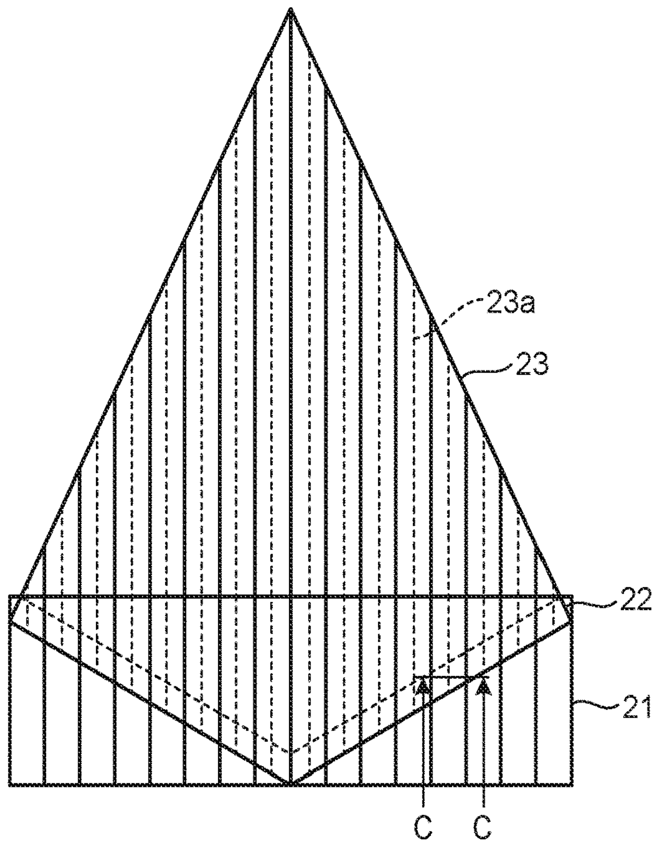


FIG.9

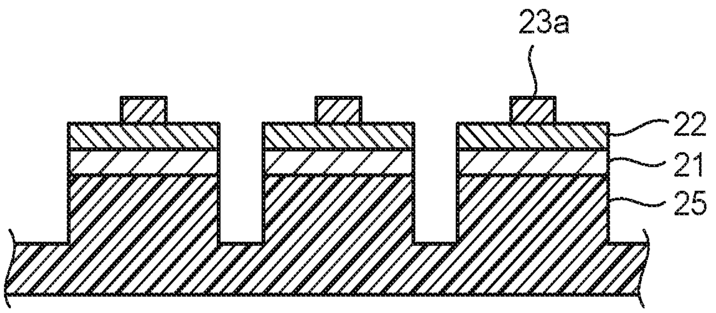


FIG.10

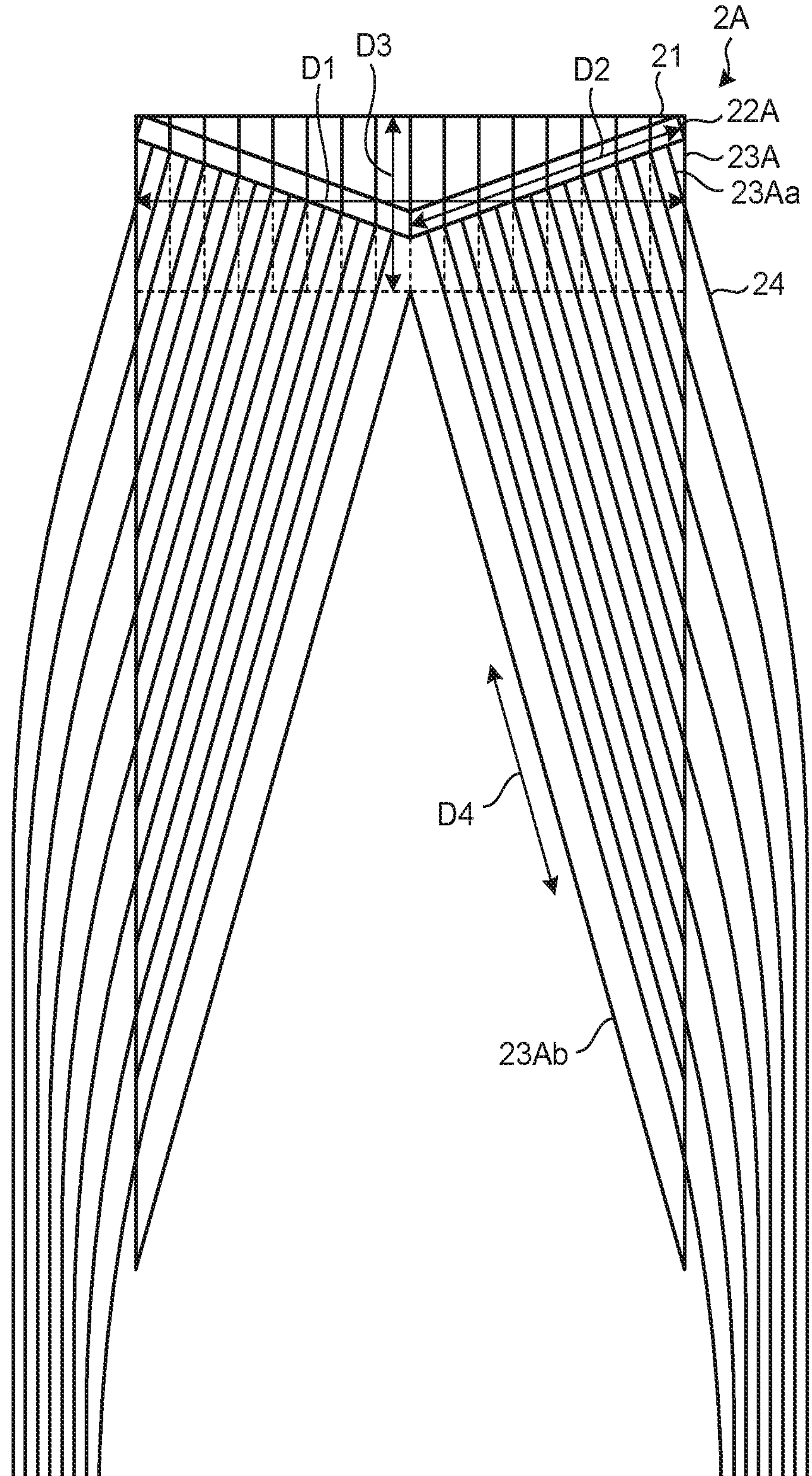


FIG.11

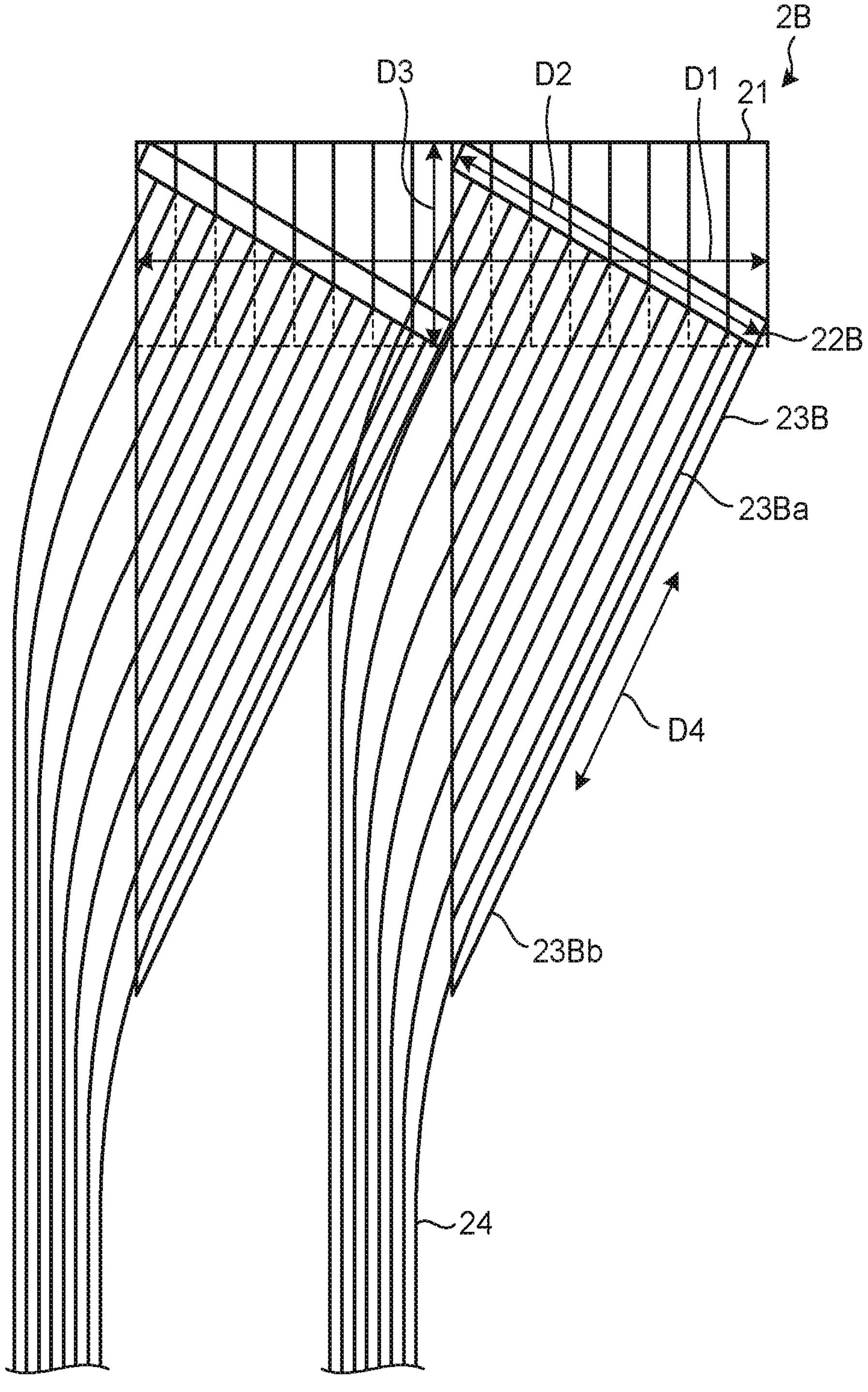


FIG.12

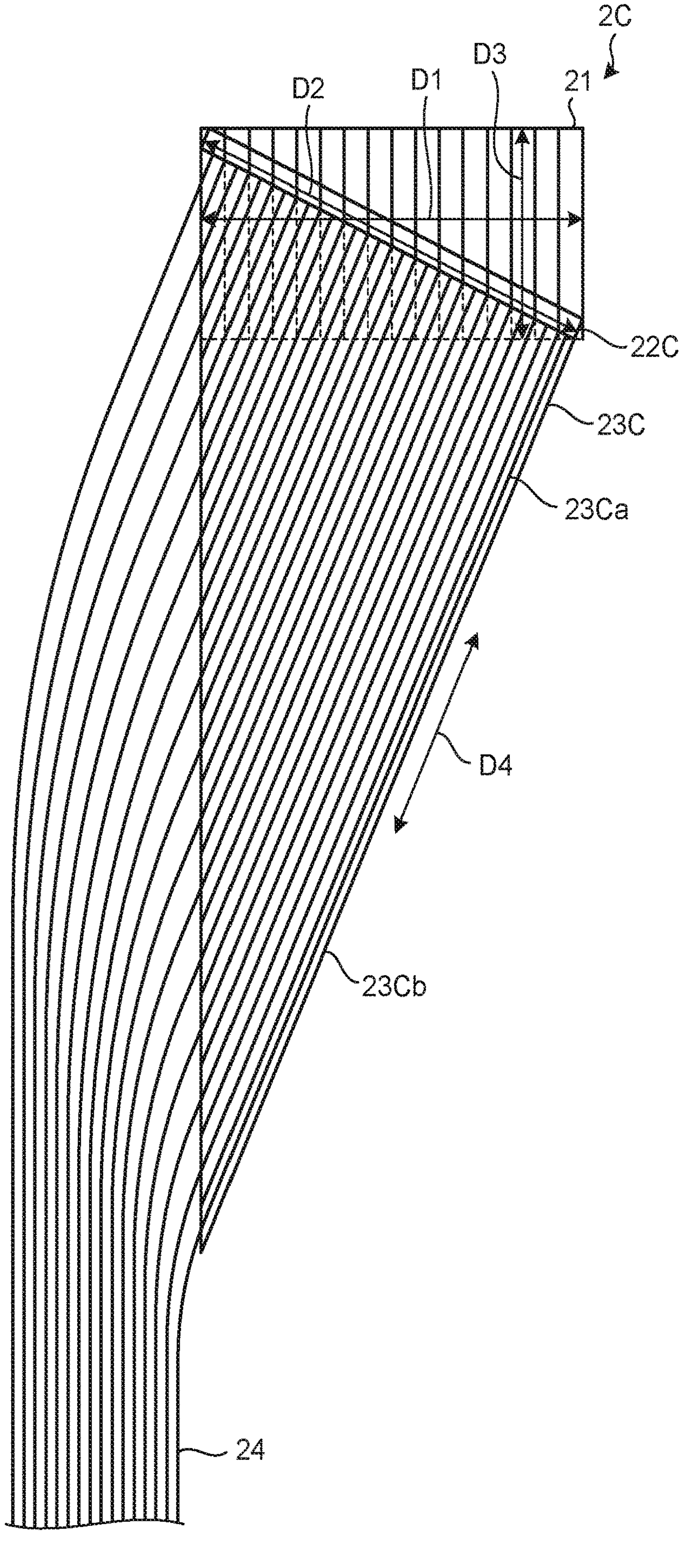


FIG.13

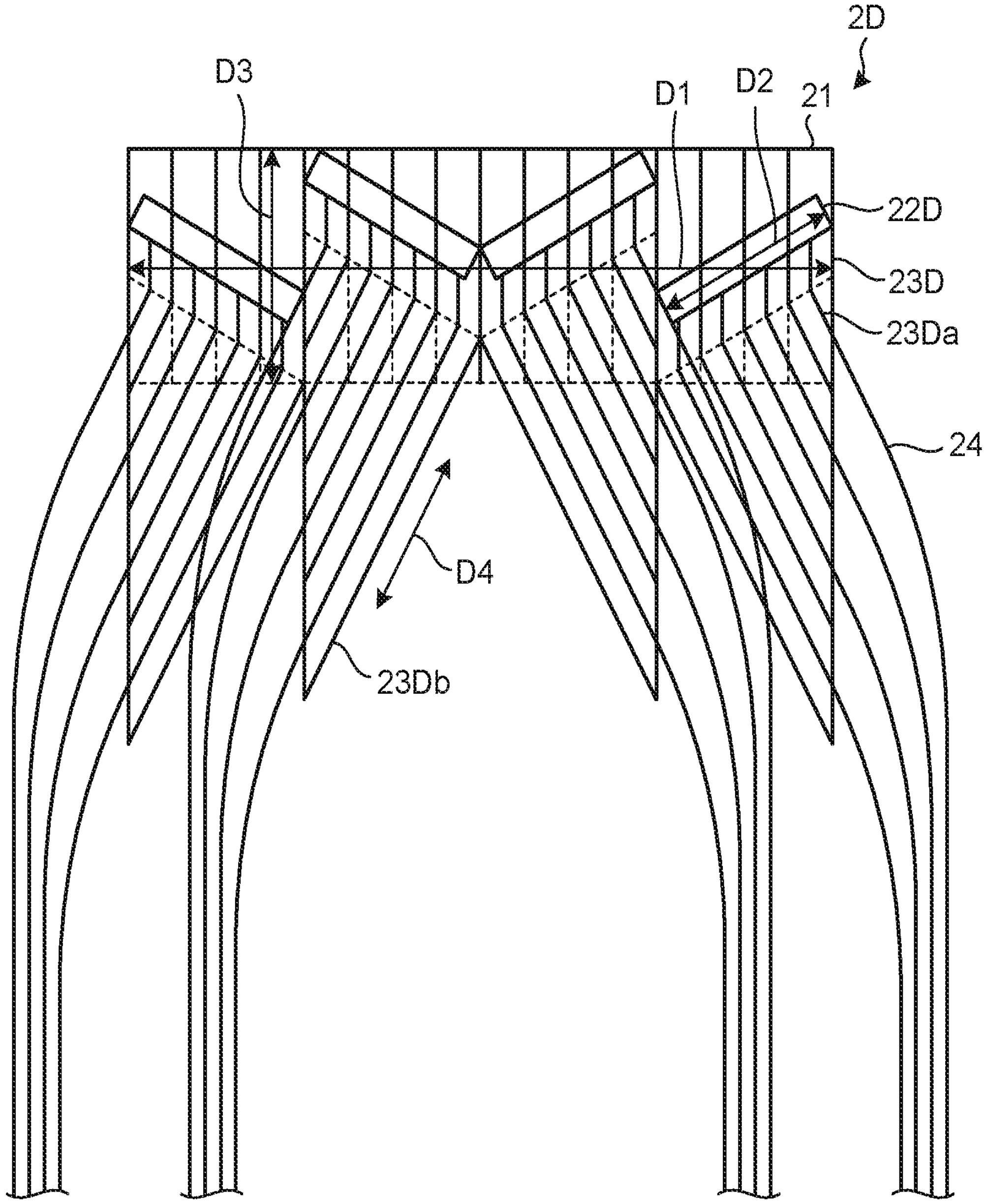


FIG.14

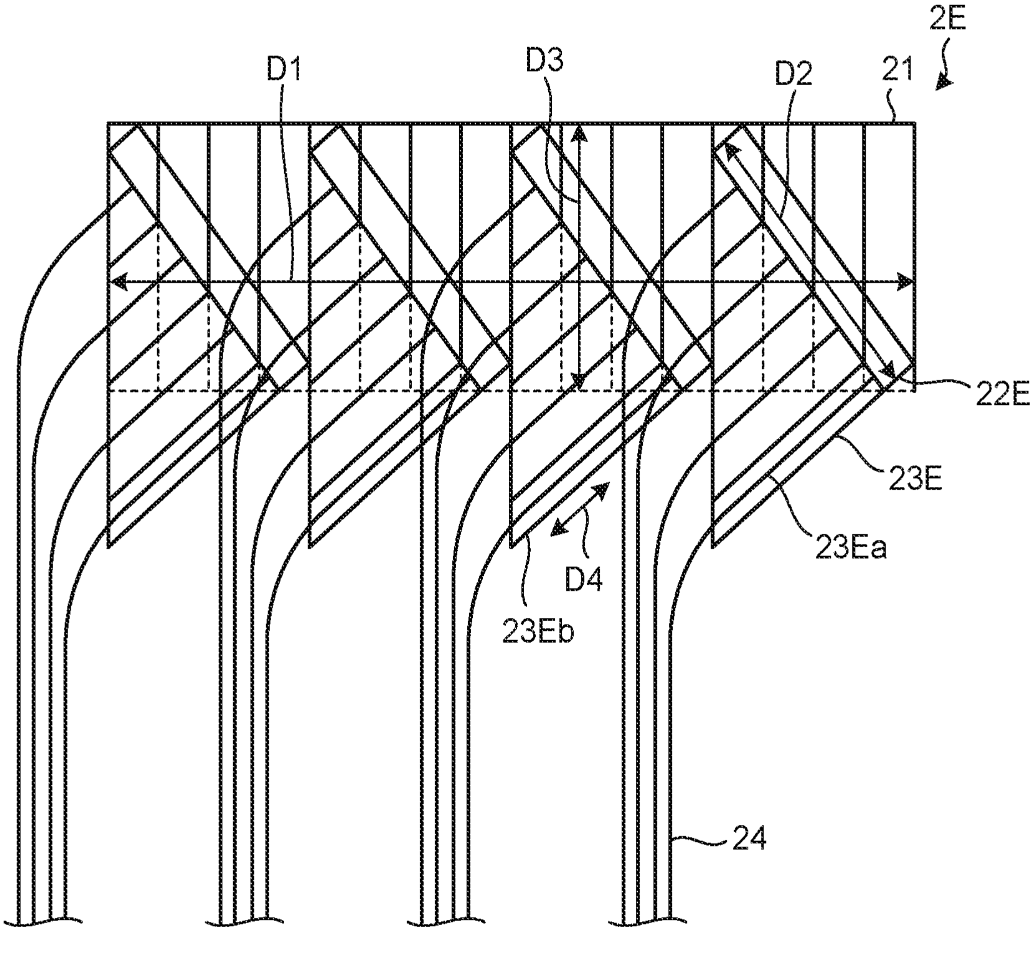
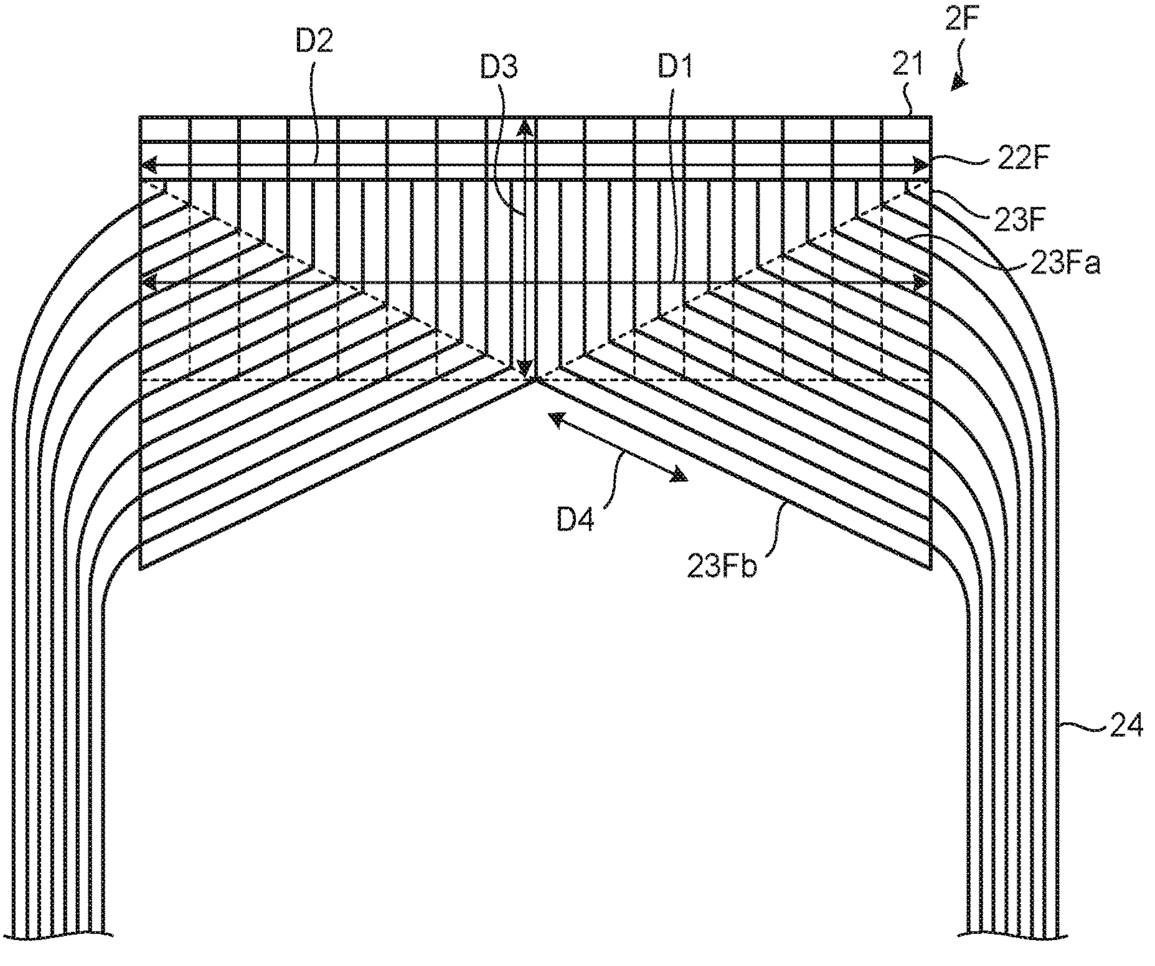


FIG.15



ULTRASOUND TRANSDUCER, ULTRASOUND ENDOSCOPE, AND METHOD OF MANUFACTURING ULTRASOUND TRANSDUCER

[0001] This application is a continuation of PCT International Application No. PCT/JP2018/014424 filed on Apr. 4, 2018, which designates the United States, incorporated herein by reference, and which claims the benefit of priority from Japanese Patent Application No. 2017-082069, filed on Apr. 18, 2017, incorporated herein by reference.

BACKGROUND

[0002] The present disclosure relates to an ultrasound transducer, an ultrasound endoscope, and a method of manufacturing the ultrasound transducer.

[0003] In the related art, an ultrasound endoscope that inserts a flexible elongated insertion portion into a subject, such as a human being, and observes the inside of the subject by using an ultrasound transducer disposed at a distal end of the insertion portion has been known. In addition, as the ultrasound transducer, a radial type ultrasound transducer in which a plurality of piezoelectric elements are arranged at predetermined pitch intervals in a circumferential manner has been known (see, for example, Japanese Patent Laid-open Publication No. H5-42146 and Japanese Patent Laid-open Publication No. H4-166139).

[0004] A plurality of electrodes are electrically connected to the respective piezoelectric elements. Further, a flexible printed circuit (FPC) is fixed to a proximal end side of the electrodes, and a plurality of wires printed on the FPC are electrically connected to the respective electrodes.

[0005] Furthermore, a certain ultrasound endoscope includes a distal end rigid portion, which is made of a rigid member, which is disposed on a distal end of an insertion portion to be inserted into a subject, and which houses piezoelectric elements, and a bending portion, which is arranged on a proximal end side of the distal end rigid portion and which is bent in accordance with operation on an operating unit that is arranged on a proximal end side of the insertion portion.

SUMMARY

[0006] According to one aspect of the present disclosure, there is provided a radial type ultrasound transducer arranged in an ultrasound endoscope including a bending portion on a distal end side of an insertion portion, the ultrasound transducer including: a plurality of piezoelectric elements arranged at predetermined intervals in a circumferential manner and configured to transmit and receive ultrasound waves; a plurality of electrodes arranged in the respective piezoelectric elements; and a flexible printed circuit electrically connected to each of the electrodes, wherein the flexible printed circuit includes a plurality of wires that extend such that at least parts of the wires cross a direction perpendicular to an arrangement direction of the piezoelectric elements, and the plurality of wires are electrically connected to the respective electrodes of the piezoelectric elements at positions where at least parts of the wires cross the direction perpendicular to the arrangement direction of the piezoelectric elements.

[0007] The above and other features, advantages and technical and industrial significance of this disclosure will be better understood by reading the following detailed description of presently preferred embodiments of the disclosure, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a schematic diagram illustrating an ultrasound endoscope including an ultrasound transducer according to an embodiment;

[0009] FIG. **2** is a partial cutaway diagram of a distal end of an insertion portion of the ultrasound endoscope illustrated in FIG. **1**;

[0010] FIG. **3** illustrates the ultrasound transducer when viewed from a direction of arrow A in FIG. **2**;

[0011] FIG. **4** illustrates a state before the ultrasound transducer illustrated in FIG. **2** is arranged in a circumferential manner;

[0012] FIG. **5** is a flowchart illustrating a process of manufacturing the ultrasound transducer illustrated in FIG. **2**;

[0013] FIG. **6** is a diagram for explaining a fixing process illustrated in FIG. **5**;

[0014] FIG. **7** is a diagram for explaining a folding process illustrated in FIG. **5**;

[0015] FIG. **8** is a diagram for explaining a cutting process illustrated in FIG. **5**;

[0016] FIG. **9** is a diagram illustrating cross sections of cut piezoelectric elements;

[0017] FIG. **10** is a diagram illustrating a state before an ultrasound transducer according to a first modification is arranged in a circumferential manner;

[0018] FIG. **11** is a diagram illustrating a state before an ultrasound transducer according to a second modification is arranged in a circumferential manner;

[0019] FIG. **12** is a diagram illustrating a state before an ultrasound transducer according to a third modification is arranged in a circumferential manner;

[0020] FIG. **13** is a diagram illustrating a state before an ultrasound transducer according to a fourth modification is arranged in a circumferential manner;

[0021] FIG. **14** is a diagram illustrating a state before an ultrasound transducer according to a fifth modification is arranged in a circumferential manner; and

[0022] FIG. **15** is a diagram illustrating a state before an ultrasound transducer according to a sixth modification is arranged in a circumferential manner.

DETAILED DESCRIPTION

[0023] Embodiments of an ultrasound transducer, an ultrasound endoscope, and a method of manufacturing the ultrasound transducer according to the present disclosure will be described below with reference to the drawings. The present disclosure is not limited by the embodiments below. The present disclosure is generally applicable to a radial type ultrasound transducer, an ultrasound endoscope, and a method of manufacturing the ultrasound transducer.

[0024] Further, in the description of the drawings, the same or corresponding components are denoted by the same reference symbols appropriately. Furthermore, it is necessary to note that the drawings are schematic, and dimensional relations among the components, ratios among the components, and the like may be different from the actual ones. Moreover, the drawings may include portions that have different dimensional relations or ratios.

Embodiment

[0025] FIG. **1** is a schematic diagram illustrating an ultrasound endoscope including an ultrasound transducer according to an embodiment. An ultrasound endoscope **1**, in a distal end portion thereof, converts an electrical pulse signal received from an ultrasound observation device into an ultrasound pulse (acoustic pulse), applies the ultrasound pulse to a subject, converts an ultrasound echo reflected by the subject into an electrical echo signal that represents the ultrasound echo by a voltage change, and outputs the echo signal.

[0026] The ultrasound endoscope **1** generally includes an imaging optical system and an imaging element, is inserted into a digestive tract (an esophagus, a stomach, a duodenum, or a large intestine) or a respiratory organ (a trachea or a bronchus) of the subject, and is able to capture images of the digestive tract or the respiratory organ. Further, the ultrasound endoscope **1** is able to capture images of a surrounding organ (a pancreas, a gallbladder, a bile duct, a biliary tract, lymph nodes, a mediastinal organ, a blood vessel, or the like) by using ultrasound waves. Furthermore, the ultrasound endoscope **1** includes a light guide that guides illumination light to be applied to the subject at the time of optical imaging. A distal end portion of the light guide reaches a distal end of an insertion portion of the ultrasound endoscope **1** to be inserted in the subject, and a proximal end portion of the light guide is connected to a light source device that emits the illumination light.

[0027] As illustrated in FIG. **1**, the ultrasound endoscope **1** includes an insertion portion **11**, an operating unit **12**, a universal cable **13**, and a connector **14**.

[0028] The insertion portion **11** is a portion to be inserted into the subject. As illustrated in FIG. **1**, the insertion portion **11** includes an ultrasound transducer **2** that is disposed on the distal end thereof, a distal end rigid portion **111** that houses a part of the ultrasound transducer **2**, a bending portion **112** that is arranged on a proximal end side of the distal end rigid portion **111** and that is bent in accordance with operation on the operating unit **12**, and a flexible tube portion **113** that is connected to a proximal end side of the bending portion **112** and that has flexibility. While details are not illustrated in the figures, in the insertion portion **11**, the light guide that transmits illumination light supplied from the light source device and a plurality of signal cables for transmitting various signals are arranged and a treatment tool insertion path for inserting a treatment tool is formed.

[0029] The operating unit **12** is a portion that is arranged on a proximal end side of the insertion portion **11** and receives various kinds of operation from a doctor or the like. As illustrated in FIG. **1**, the operating unit **12** includes a bending knob **121** for receiving operation of bending the bending portion **112** and a plurality of operating members **122** for performing various kinds of operation. Further, the operating unit **12** includes a treatment tool insertion opening **123** that communicates with the treatment tool insertion path and allows a treatment tool to be inserted into the treatment tool insertion path.

[0030] The universal cable **13** is a cable which extends from the operating unit **12** and in which a plurality of signal cables for transmitting various signals, an optical fiber for transmitting the illumination light supplied from the light source device, and the like are arranged.

[0031] The connector **14** is disposed on a distal end of the universal cable **13**. The connector **14** is connected to the ultrasound observation device, an endoscope observation device, and the light source device via various cables.

[0032] The ultrasound transducer **2** is a radial type ultrasound transducer. A plurality of piezoelectric elements are arranged in a circumferentially-arrayed manner as the ultrasound transducer **2**, and the ultrasound endoscope **1** causes the ultrasound transducer **2** to electronically perform scanning by electronically switching among the piezoelectric elements involved in transmission and reception of ultrasound waves or delaying transmission and reception of ultrasound waves in each of the piezoelectric elements.

[0033] FIG. **2** is a partial cutaway diagram of the distal end of the insertion portion of the ultrasound endoscope illustrated in FIG. **1**. FIG. **3** illustrates the ultrasound transducer when viewed from a direction of arrow A in FIG. **2**. As illustrated in FIG. **2** and FIG. **3**, the ultrasound transducer **2** includes a plurality of piezoelectric elements **21** that are arranged at predetermined pitch intervals in a circumferential manner and that transmit and receive ultrasound waves, a plurality of electrodes **22** that are arranged in the respective piezoelectric elements **21**, an FPC **23** serving as a flexible printed circuit on which a plurality of wires **23***a* are printed and which is fixed on a proximal end side of the plurality of electrodes **22**, and a plurality of lead wires **24** that are electrically connected to the respective wires **23***a*.

[0034] The piezoelectric elements **21** are housed in the distal end rigid portion **111**, and transmit and receive ultrasound waves via an acoustic lens **111***a* that is disposed on an outer periphery of the distal end rigid portion **111**. A portion **B1** including the distal end rigid portion **111** is a portion that is not bendable in the distal end of the insertion portion **11**. The piezoelectric elements **21** are arranged along an arrangement direction that is perpendicular to a direction in which the insertion portion **11** is extended. The piezoelectric elements **21** convert electrical pulse signals into acoustic pulses, apply the acoustic pulses to a subject, converts ultrasound echoes reflected by the subject into electrical echo signals that represent the ultrasound echoes by voltage changes, and output the echo signals.

[0035] The piezoelectric elements **21** are constructed with lead zirconate titanate (PZT) ceramic material, a PMN-PT single crystal, a PMN-PZT single crystal, a PZN-PT single crystal, a PIN-PZN-PT single crystal, or a relaxer material. The PMN-PT single crystal is an abbreviation of a solid solution of lead magnesium niobate and lead titanate. The PMN-PZT single crystal is an abbreviation of a solid solution of lead magnesium niobate and lead zirconate titanate. The PZN-PT single crystal is an abbreviation of a solid solution of lead zinc niobate and lead titanate. The PIN-PZN-PT single crystal is an abbreviation of a solid solution of lead indium niobate, lead zinc niobate, and lead titanate. The relaxer material is a generic term of a three-component piezoelectric material that is obtained by adding lead-based complex perovskite that is a relaxer material to PZT in order to increase a piezoelectric constant or permittivity. The lead-based complex perovskite is represented by $Pb(B1, B2)O_3$, where B1 is any of magnesium, zinc, indium, and scandium, and B2 is any of niobium, tantalum, and tungsten. These materials have excellent piezoelectric effects. Therefore, these materials make it possible to reduce an electrical impedance value even when the size of a device is reduced, and are preferable from the viewpoint of impedance matching with film electrodes arranged in the piezoelectric elements **21**.

[0036] The single electrode **22** is electrically connected to an inner periphery of each of the piezoelectric elements **21**. In each of FIG. **2** and subsequent drawings, the piezoelectric elements **21** on the outer side are indicated by dashed lines in order to explain inner configurations of the piezoelectric elements **21**. Further, a ground electrode (not illustrated) for grounding is arranged on an outer periphery of each of the piezoelectric elements **21**.

[0037] FIG. **4** illustrates a state before the ultrasound transducer illustrated in FIG. **2** is arranged in a circumferential manner. By rolling up, in a circumferential manner, the ultrasound transducer **2** in a planar state as illustrated in FIG. **4** such that the piezoelectric elements **21** are arranged on the outer side, the radial type ultrasound transducer **2** as illustrated in FIG. **2** and FIG. **3** is obtained. The plurality of electrodes **22** are arranged along a direction D2 that crosses an arrangement direction D1 of the piezoelectric elements **21**. The electrodes **22** and the ground electrodes are made of metal or resin with conductivity.

[0038] The FPC **23** is fixed to the proximal end side of the electrodes **22** by soldering the electrodes **22** and the wires **23***a*. The FPC **23** is made of, for example, film resin and has flexibility. The FPC **23** has a hypotenuse **23***b* that obliquely extends from a proximal end side (lower side in FIG. **4**) along a direction D4 crossing the direction D3 that is perpendicular to the arrangement direction D1 of the piezoelectric elements **21**. Therefore, as illustrated in FIG. **2** and FIG. **3**, in a portion in which the FPC **23** protrudes from the distal end rigid portion **111**, the FPC **23** covers only a part of the insertion portion **11** that has a circular cross section, so that this portion has adequate flexibility. Consequently, a portion that can be bent in the distal end of the insertion portion **11** is a portion B2.

[0039] Referring back to FIG. **4**, the plurality of wires **23***a* are electrically connected to the respective electrodes **22** and extend along the direction D4 crossing the direction D3 that is perpendicular to the arrangement direction D1 of the piezoelectric elements **21**. More specifically, the plurality of wires **23***a* are arranged such that an angle θ1 between the direction D2 along which the plurality of electrodes **22** are arranged and the direction D3 that is perpendicular to the arrangement direction D1 of the piezoelectric elements **21** and an angle θ2 between the direction D2 along which the plurality of electrodes **22** are arranged and the direction D4 along which the wires **23***a* extend become equal to each other. The wires **23***a* are made of, for example, copper or copper foil, and printed on the FPC **23**.

[0040] The lead wires **24** include conductive wires made of metal, and coatings that are made of insulating material, such as rubber, and disposed on outer peripheries of the conductive wires. As illustrated in FIG. **3**, the lead wires **24** are collectively arranged on the proximal end side. The lead wires **24** are arranged such that, in a plane perpendicular to a distal end of the ultrasound endoscope **1**, a region in which centers of the piezoelectric elements **21** arranged in a circumferential manner and the lead wires **24** are connected does not cross a direction in which the ultrasound endoscope **1** is bent.

[0041] The ultrasound transducer **2** configured as described above applies ultrasound waves to an observation target via the acoustic lens **111***a* when the piezoelectric elements **21** vibrate in response to input of pulse signals. Further, ultrasound waves reflected from the observation target are transmitted to the piezoelectric elements **21** via the acoustic lens **111***a*. The piezoelectric elements **21** vibrate in response to the transmitted ultrasound waves, and the piezoelectric elements **21** convert the vibration into electrical echo signals and output them as echo signals to the ultrasound observation device.

[0042] FIG. **5** is a flowchart illustrating a process of manufacturing the ultrasound transducer illustrated in FIG. **2**. FIG. **6** is a diagram for explaining a fixing process illustrated in FIG. **5**. As illustrated in FIG. **6**, first, a conductive electrode member **32** is laminated on a plate-like piezoelectric material **31**, and a substrate member **33** is fixed on a proximal end side of the electrode member **32** such that the substrate member **33** includes the plurality of wires **23***a*, which are electrically connected to the electrode member **32** and extend along the direction D4 crossing a long side **31***a* of the piezoelectric material **31**, and the hypotenuse **23***b*, which obliquely extends from the proximal end side along the direction D4 crossing the long side **31***a* (Step S1: fixing process). Specifically, by soldering the electrode member **32** and the wires **23***a*, the substrate member **33** is fixed to the proximal end side of the electrode member **32**.

[0043] FIG. **7** is a diagram for explaining a folding process illustrated in FIG. **5**. As illustrated in FIG. **7**, the substrate member **33** is folded such that a direction D5 along which the wires **23***a* extend and a short side **31***b* of the piezoelectric material **31** become parallel to each other (Step S2: folding process).

[0044] FIG. **8** is a diagram for explaining a cutting process illustrated in FIG. **5**. As illustrated in FIG. **8**, the piezoelectric material **31**, the electrode member **32**, and the substrate member **33** are cut while the substrate member **33** is folded (Step S3: cutting process).

[0045] FIG. **9** is a diagram illustrating cross sections of cut piezoelectric elements. FIG. **9** illustrates the cross sections taken along a line C-C in FIG. **8**, but the FPC **23** is not illustrated in FIG. **9**. As illustrated in FIG. **9**, connection members **25** made of resin or the like are arranged on back surfaces of the piezoelectric elements **21** and connect the adjacent piezoelectric elements **21**. The connection members **25** may have a function as an acoustic matching layer that matches acoustic impedance between the piezoelectric elements **21** and the observation target in order to effectively transmit sounds (ultrasound waves) between the piezoelectric elements **21** and the observation target.

[0046] Thereafter, the FPC **23** obtained by cutting the substrate member **33** is folded back to a non-folded position from the folded state, so that the state as illustrated in FIG. **4** is obtained. Further, the plurality of piezoelectric elements **21** obtained by cutting the piezoelectric material **31**, the plurality of electrodes **22** obtained by cutting the electrode member **32**, and the FPC **23** are arranged in a circumferential manner such that the piezoelectric elements **21** are arranged on the outer side (Step S4: arrangement process). As a result, the radial type ultrasound transducer **2** as illustrated in FIG. **2** and FIG. **3** is manufactured.

[0047] According to the embodiment, as illustrated in FIG. **2** and FIG. **3**, the FPC **23** has the hypotenuse **23***b* and a portion in which the FPC **23** protrudes from the distal end rigid portion **111** has flexibility, a length of a portion that is not bendable due to the FPC **23** is increased. Therefore, a length of a non-bendable portion in the ultrasound transducer **2** is reduced.

[0048] Meanwhile, to increase the bendability, it may be possible to provide a structure, such as a slit, a clearance groove, or bellows, on the proximal end side of the FPC **23**.

[0049] In addition, according to the embodiment, the lead wires **24** are collectively arranged on the proximal end side, so that it is possible to easily handle the lead wires **24**. Further, the lead wires **24** are arranged such that, in the plane perpendicular to the distal end of the ultrasound endoscope **1**, the region in which the centers of the piezoelectric elements **21** arranged in a circumferential manner and the lead wires **24** are connected does not cross the direction in which the ultrasound endoscope **1** is bent, so that it is possible to prevent the collected lead wires **24** from interfering with bending operation.

First Modification

[0050] FIG. **10** is a diagram illustrating a state before an ultrasound transducer according to a first modification is arranged in a circumferential manner. As illustrated in FIG. **10**, an ultrasound transducer **2**A includes the piezoelectric elements **21**, electrodes **22**A, wires **23**Aa that extend along the direction D**4** crossing the direction D**3**, an FPC **23**A that is entirely integrated into a single piece and has a hypotenuse **23**Ab obliquely extending from a proximal end side along the direction D**4** crossing the direction D**3**, and the lead wires **24**.

[0051] According to the first modification, because the FPC **23**A has the hypotenuse **23**Ab, a portion in which the FPC **23**A protrudes from the distal end rigid portion **111** has flexibility, so that a length of a non-bendable portion is reduced. Further, because the FPC **23**A is entirely integrated into a single piece, it is possible to simplify the manufacturing process as compared to a case in which an FPC is separated into a plurality of pieces.

Second Modification

[0052] FIG. **11** is a diagram illustrating a state before an ultrasound transducer according to a second modification is arranged in a circumferential manner. As illustrated in FIG. **11**, an ultrasound transducer **2**B includes the piezoelectric elements **21**, electrodes **22**B, wires **23**Ba that extend along the direction D**4** crossing the direction D**3**, two FPCs **23**B that have the same shape, that are arranged side by side, and that have hypotenuses **23**Bb obliquely extending from proximal end sides along the direction D**4** crossing the direction D**3**, and the lead wires **24**.

[0053] According to the second modification, because the two FPCs **23**B have the hypotenuses **23**B*b*, a portion in which each of the two FPCs **23**B protrudes from the distal end rigid portion **111** has flexibility, so that a length of a non-bendable portion is reduced. Further, because the two FPCs **23**B have the same shape, it is possible to reduce the number of components as compared to a case in which a plurality of FPCs having different shapes are prepared.

[0054] Furthermore, even in the second modification, it is preferable that the lead wires **24** are arranged such that, in the plane perpendicular to the distal end of the ultrasound endoscope **1**, the region in which the centers of the piezoelectric elements **21** arranged in a circumferential manner and the lead wires **24** are connected does not cross the direction in which the ultrasound endoscope **1** is bent. Specifically, it is sufficient that two directions along which the lead wires **24** that are collected with respect to the centers of the piezoelectric elements **21** arranged in a circumferential manner extend and the direction in which the insertion portion **11** is bent are shifted by 45°. In this case, it is possible to prevent the collected lead wires **24** form interfering with bending operation.

Third Modification

[0055] FIG. **12** is a diagram illustrating a state before an ultrasound transducer according to a third modification is arranged in a circumferential manner. As illustrated in FIG. **12**, an ultrasound transducer **2**C includes the piezoelectric elements **21**, electrodes **22**C that are arranged on diagonal lines of the piezoelectric elements **21**, wires **23**Ca that extend along the direction D**4** crossing the direction D**3**, an FPC **23**C that is entirely integrated into a single piece and that has a hypotenuse **23**Cb obliquely extending from a proximal end side along the direction D**4** crossing the direction D**3**, and the lead wires **24**.

[0056] According to the third modification, because the FPC **23**C has the hypotenuse **23**Cb, a portion in which the FPC **23**C protrudes from the distal end rigid portion **111** has flexibility, so that a length of a non-bendable portion is reduced. Further, because the FPC **23**C is entirely integrated into a single piece, it is possible to simplify the manufacturing process as compared to a case in which an FPC is separated into a plurality of pieces.

Fourth Modification

[0057] FIG. **13** is a diagram illustrating a state before an ultrasound transducer according to a fourth modification is arranged in a circumferential manner. As illustrated in FIG. **13**, an ultrasound transducer **2**D includes the piezoelectric elements **21**, electrodes **22**D, wires **23**Da that extend along the direction D**4** crossing the direction D**3**, and four FPCs **23**D that have hypotenuses **23**Db obliquely extending from proximal end sides along the direction D**4** crossing the direction D**3**, and the lead wires **24**.

[0058] According to the fourth modification, because the four FPCs **23**D have the hypotenuses **23**Db, a portion in which each of the four the FPCs **23**B protrudes from the distal end rigid portion **111** has flexibility, so that a length of a non-bendable portion is reduced.

[0059] Further, even in the fourth modification, similarly to the second modification, it is preferable to arrange the lead wires **24** such that four directions along which the lead wires **24** that are collected with respect to the centers of the piezoelectric elements **21** arranged in a circumferential manner extend and the direction in which the insertion portion **11** is bent are shifted by 45°. Meanwhile, the direction in which the insertion portion **11** is bent may be, for example, one direction, two directions, or four directions. Even if the direction in which the insertion portion **11** is bent is four directions, it is possible to prevent interference with bending operation in each of the directions by shifting each of the four directions along which the collected lead wires **24** extend and each of the four direction in which the insertion portion **11** is bent by 45°.

Fifth Modification

[0060] FIG. **14** is a diagram illustrating a state before an ultrasound transducer according to a fifth modification is arranged in a circumferential manner. As illustrated in FIG. **14**, an ultrasound transducer **2**E includes the piezoelectric elements **21**, electrodes **22**E, wires **23**Ea that extend along the direction D**4** crossing the direction D**3**, four FPCs **23**E that have hypotenuses **23**Eb obliquely extending from proximal end sides along the direction D**4** crossing the direction D**3**, and the lead wires **24**.

[0061] According to the fifth modification, because the four FPCs **23**E have the hypotenuses **23**Eb, a portion in which each of the four FPCs **23**E protrudes from the distal end rigid portion **111** has flexibility, so that a length of a non-bendable portion is reduced.

[0062] Further, even in the fifth modification, similarly to the second modification, it is preferable to arrange the lead wires **24** such that four directions along which the lead wires **24** that are collected with respect to the centers of the piezoelectric elements **21** arranged in a circumferential manner extend and the direction in which the insertion portion **11** is bent are shifted by 45°.

Sixth Modification

[0063] FIG. **15** is a diagram illustrating a state before an ultrasound transducer according to a sixth modification is arranged in a circumferential manner. As illustrated in FIG. **15**, an ultrasound transducer **2**F includes the piezoelectric elements **21**, electrodes **22**F, wires **23**Fa, some parts of which extend along the direction D**4** crossing the direction D**3** and other parts of which extend along the direction D**3** perpendicular to the arrangement direction D**1** of the piezoelectric elements **21**, an FPC **23**F that has a hypotenuse **23**Fb obliquely extending from a proximal end side along the direction D**4** crossing the direction D**3**, and the lead wires **24**.

[0064] According to the sixth modification, because the two FPCs **23**F have the hypotenuses **23**Fb, a portion in which each of the two FPCs **23**F protrudes from the distal end rigid portion **111** has flexibility, so that a length of a non-bendable portion is reduced. In this manner, it may be possible to arrange some parts of the wires along the direction D**3** perpendicular to the arrangement direction D**1** of the piezoelectric elements. Further, it may be possible to arrange the electrodes along the direction D**2** that extends along the arrangement direction D**1** of the piezoelectric elements.

[0065] According to the present disclosure, it is possible to realize an ultrasound transducer, an ultrasound endoscope, and a method of manufacturing the ultrasound transducer such that a length of a non-bendable portion of a radial type ultrasound transducer used in an ultrasound endoscope having a bendable distal end is reduced.

[0066] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the disclosure in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

What is claimed is:

1. A radial type ultrasound transducer arranged in an ultrasound endoscope including a bending portion on a distal end side of an insertion portion, the ultrasound transducer comprising:

a plurality of piezoelectric elements arranged at predetermined intervals in a circumferential manner and configured to transmit and receive ultrasound waves;

a plurality of electrodes arranged in the respective piezoelectric elements; and

a flexible printed circuit electrically connected to each of the electrodes, wherein

the flexible printed circuit includes a plurality of wires that extend such that at least parts of the wires cross a direction perpendicular to an arrangement direction of the piezoelectric elements, and

the plurality of wires are electrically connected to the respective electrodes of the piezoelectric elements at positions where at least parts of the wires cross the direction perpendicular to the arrangement direction of the piezoelectric elements.

2. The ultrasound transducer according to claim **1**, wherein the plurality of electrodes are arranged so as to cross the arrangement direction of the piezoelectric elements.

3. The ultrasound transducer according to claim **1**, wherein an angle between a direction along which the plurality of electrodes are arranged and the direction perpendicular to the arrangement direction of the piezoelectric elements and an angle between the direction along which the plurality of electrodes are arranged and a direction along which the plurality of wires extend are equal to each other.

4. The ultrasound transducer according to claim **1** further comprising:

a plurality of lead wires electrically connected to the respective wires, wherein

the plurality of lead wires are collectively arranged on a proximal end side.

5. The ultrasound transducer according to claim **3**, wherein the plurality of lead wires are arranged such that, in a plane perpendicular to a distal end of the ultrasound endoscope, a region in which centers of the plurality of piezoelectric elements arranged in a circumferential manner and the lead wires are connected does not cross a direction in which the ultrasound endoscope is bent.

6. An ultrasound endoscope comprising:

the ultrasound transducer according to claim **1**; and

a distal end rigid portion made of a rigid member and arranged on a distal end of an insertion portion to be inserted into a subject; and

a bending portion arranged on a proximal end side of the distal end rigid portion and bent in accordance with operation on an operating unit arranged on a proximal end side of the insertion portion.

7. A method of manufacturing an ultrasound transducer, the method comprising:

laminating conductive electrode members on a plate-like piezoelectric material;

fixing a substrate member on a proximal end side of the electrode members such that the substrate member includes a plurality of wires, the wires being arranged in the respective electrode members and extending so as to cross one side of the piezoelectric material, and a hypotenuse obliquely extending from a proximal end side so as to cross the one side;

folding at least a part of the substrate member such that a direction along which the wires extend and another side of the piezoelectric material different from the one side become parallel to each other;

cutting the piezoelectric material, the electrode members, and the substrate member while the substrate member is folded;

folding back a flexible printed circuit obtained by cutting the substrate member to a non-folded position from a folded state; and

arranging, in a circumferential manner, a plurality of piezoelectric elements obtained by cutting the piezoelectric material, a plurality of electrodes obtained by cutting the electrode members, and the flexible printed circuit.

8. A radial type ultrasound transducer arranged in a distal end of an ultrasound endoscope including a bending portion on a distal end side of an insertion portion, the ultrasound transducer comprising:

a plurality of piezoelectric elements arranged at predetermined intervals in a circumferential manner and transmit and receive ultrasound waves;

a plurality of electrodes arranged in the respective piezoelectric elements; and

a flexible printed circuit electrically connected to each of the electrodes, wherein

in the plurality of electrodes, connection positions for connecting to the flexible printed circuit are provided in positions in which at least parts of the electrodes are inclined with respect to a direction perpendicular to an arrangement direction of the piezoelectric elements.

* * * * *

patsnap

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摘要(译)

径向型超声换能器布置在超声内窥镜中，该超声内窥镜在插入部的远端侧上包括弯曲部。 超声波换能器包括：多个压电元件，该多个压电元件以预定间隔沿周向布置并且构造成发送和接收超声波；以及多个压电元件。 多个电极布置在各个压电元件中； 电连接到每个电极的柔性印刷电路。 柔性印刷电路包括多条导线，该多条导线延伸成使得至少一部分导线与垂直于压电元件的布置方向的方向交叉，并且多条导线在位置处电连接至压电元件的各个电极 其中线的至少一部分与垂直于压电元件的布置方向的方向交叉。