US 20200171538A1

(19) **United States**
(12) **Patent Application Publication**
TAKEZAKI et al.
(10) **Pub. No.: US 2020/0171538 A1**
(43) **Pub. Date: Jun. 4, 2020**

(54) **ULTRASONIC TRANSDUCER, MANUFACTURING METHOD THEREOF, AND ULTRASONIC IMAGING DEVICE**

(71) Applicant: **Hitachi, Ltd.**, Tokyo (JP)

(72) Inventors: **Taiichi TAKEZAKI**, Tokyo (JP); **Masakazu KAWANO**, Tokyo (JP); **Shuntaro MACHIDA**, Tokyo (JP)

(21) Appl. No.: **16/699,185**

(22) Filed: **Nov. 29, 2019**

(30) **Foreign Application Priority Data**

Dec. 3, 2018 (JP) 2018-226644

Publication Classification

(51) **Int. Cl.**

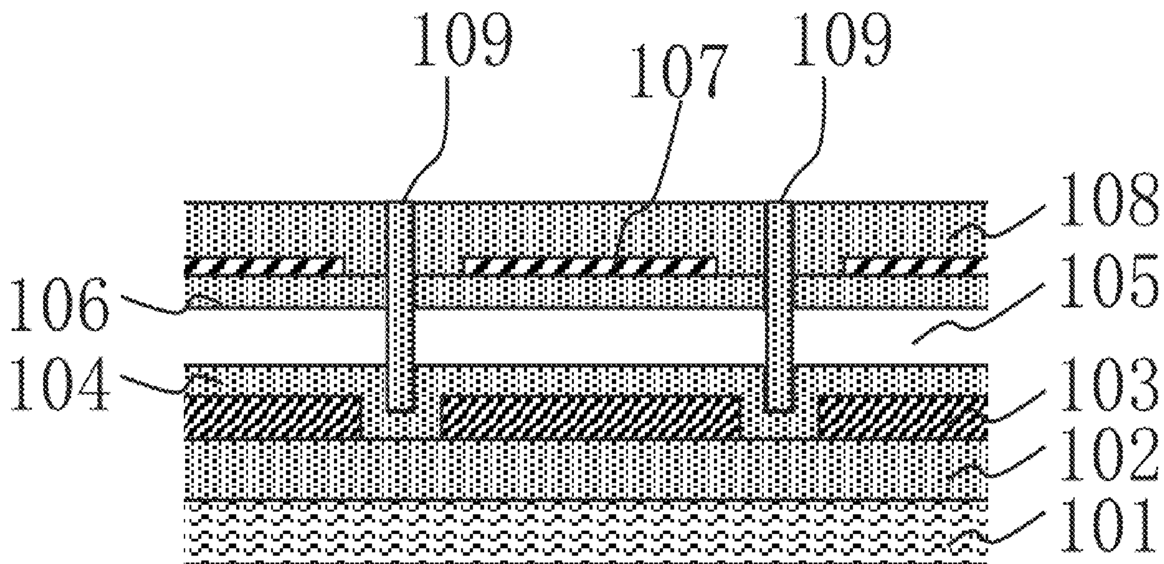
B06B 1/02	(2006.01)
B81B 3/00	(2006.01)
B81C 1/00	(2006.01)
A61B 8/12	(2006.01)
A61B 8/00	(2006.01)
A61B 5/00	(2006.01)
G01N 29/24	(2006.01)

(52) **U.S. Cl.**

CPC ***B06B 1/0292*** (2013.01); ***B81B 3/0021*** (2013.01); ***B81C 1/00158*** (2013.01); ***A61B 8/12*** (2013.01); ***A61B 8/4494*** (2013.01); ***A61B 5/0095*** (2013.01); *G01N 2291/101* (2013.01); *B81B 2201/0271* (2013.01); *B81B 2203/0127* (2013.01); *B81B 2203/0315* (2013.01); *B81B 2203/04* (2013.01); *B81C 2201/0105* (2013.01); ***G01N 29/2406*** (2013.01)

(57) **ABSTRACT**

A highly-sensitive ultrasonic transducer with good yield is provided. The ultrasonic transducer includes a cavity layer, a pair of electrodes positioned above and below the cavity layer, insulating layers disposed above and below each of the pair of electrodes, and a filled hole that penetrates, in a vertical direction, at least a portion of the insulating layers positioned above the cavity layer. When the ultrasonic transducer is viewed from above, each electrode of the pair of electrodes includes, at a position that overlaps the embedded hole, a non-electrode region where the electrodes are not formed.



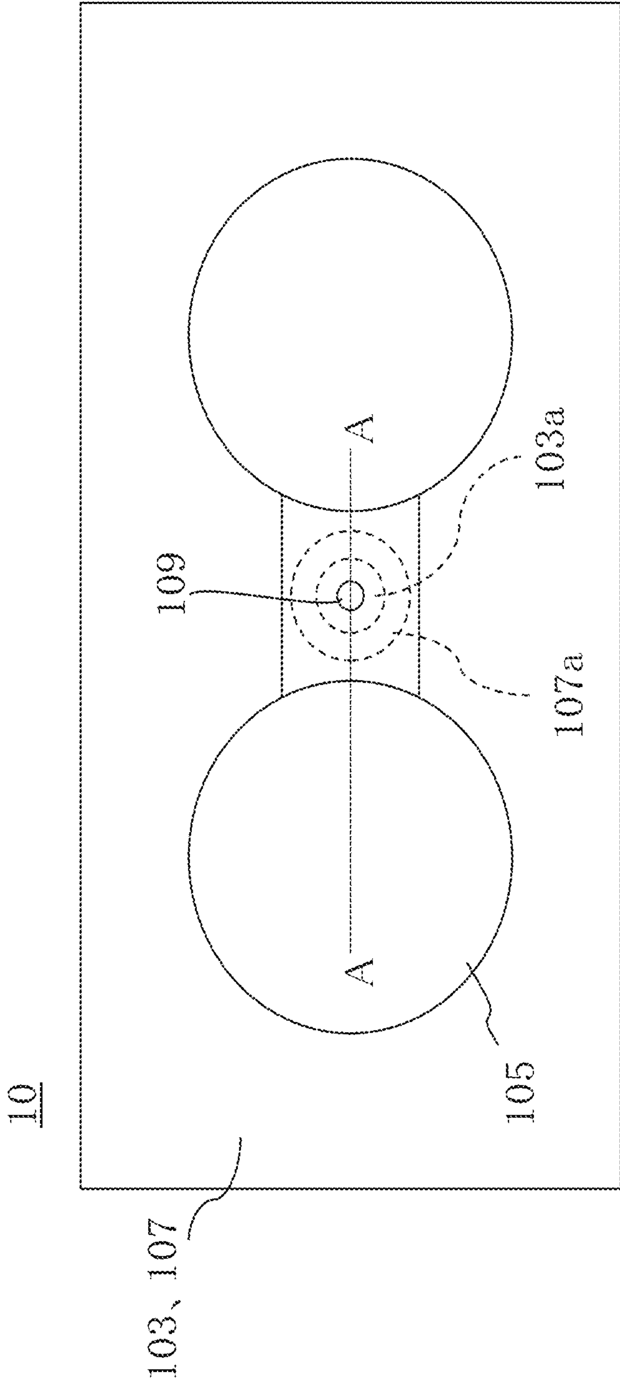
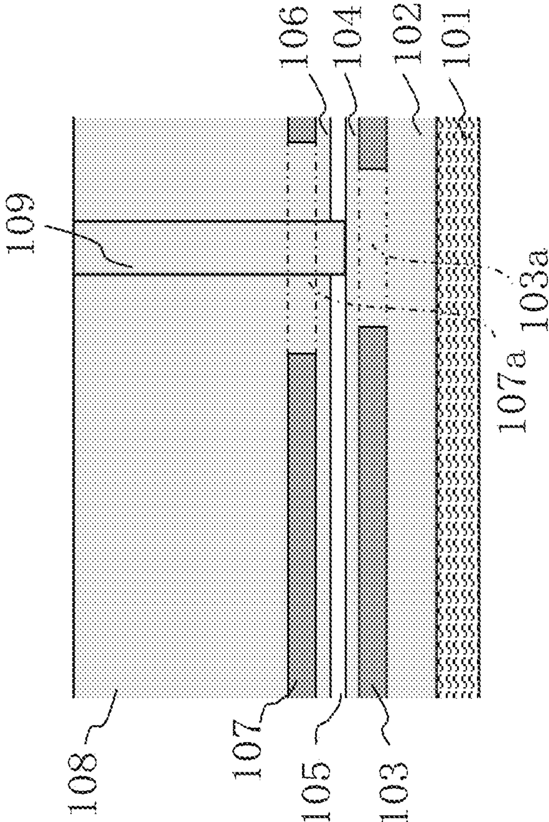


Fig. 1

Fig. 2

A-A CROSS-SECTIONAL VIEW



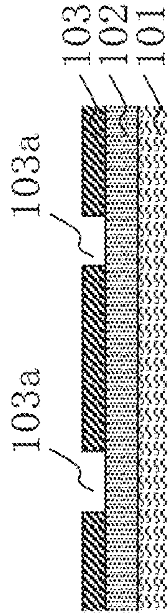


Fig. 3A

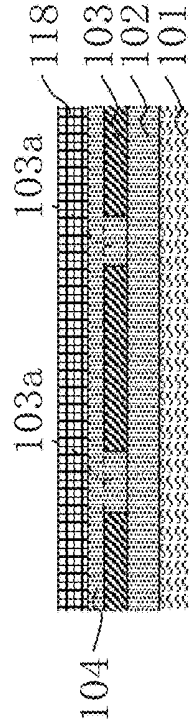


Fig. 3B

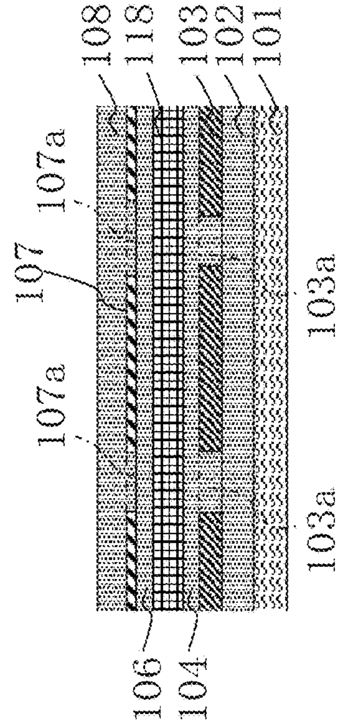


Fig. 3C

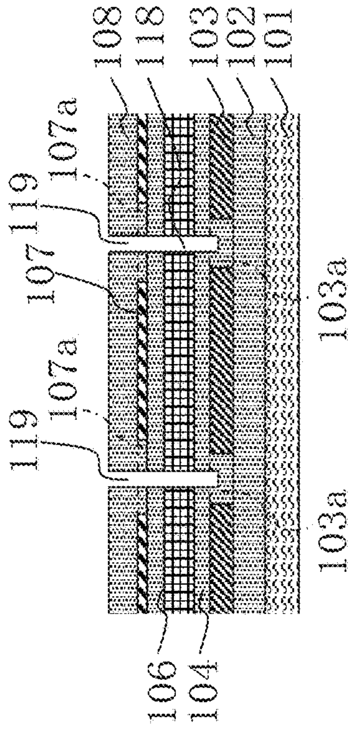


Fig. 3D

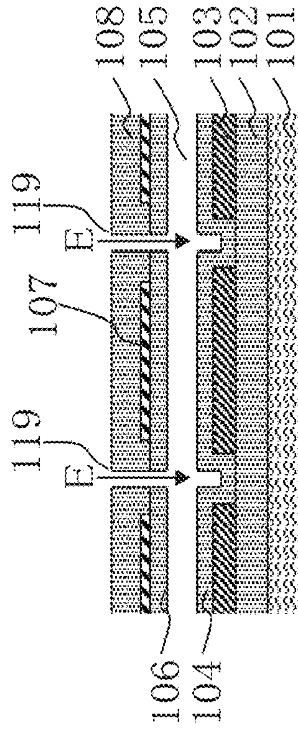


Fig. 3E

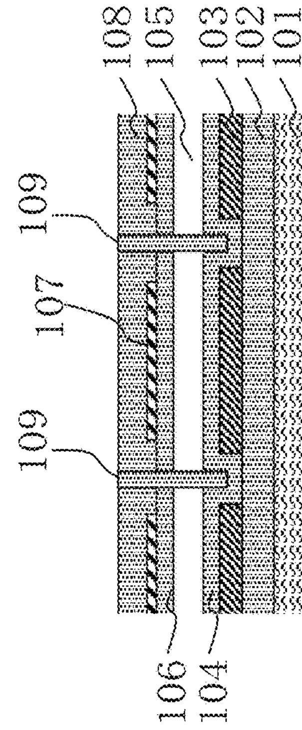


Fig. 3F

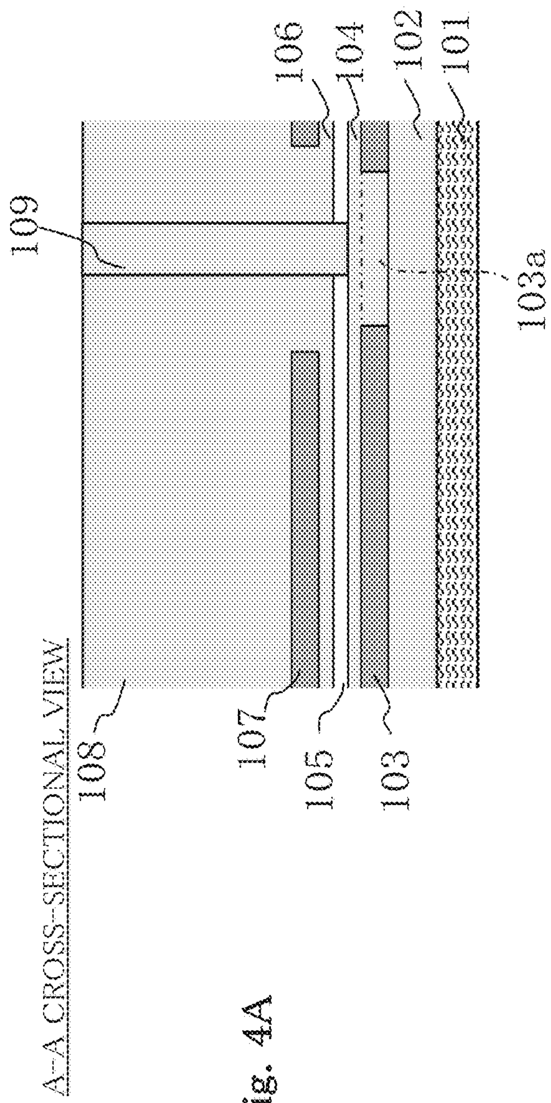


Fig. 4A

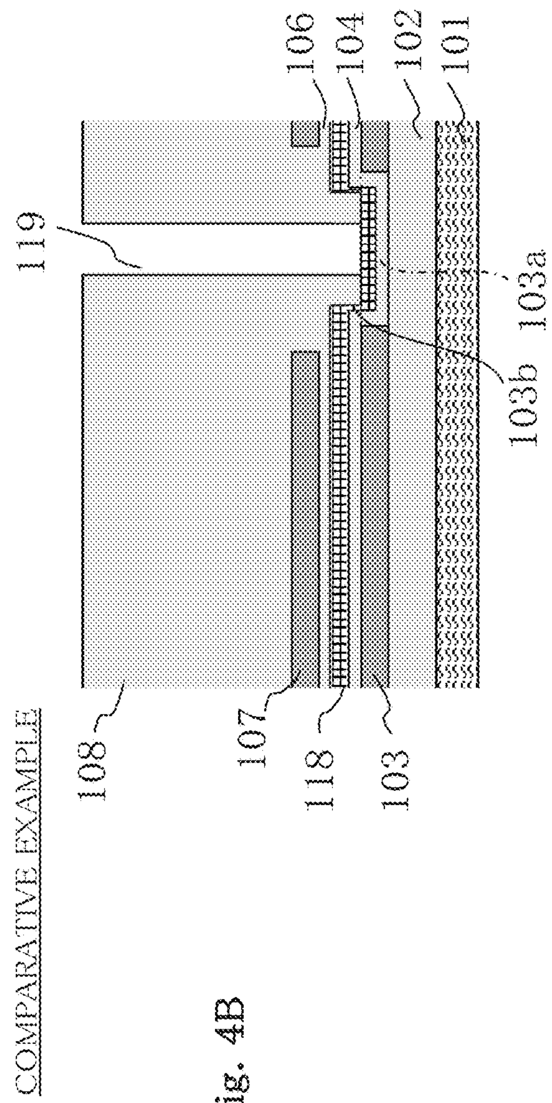


Fig. 4B

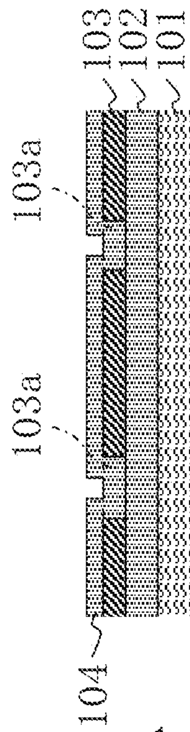


Fig. 5A

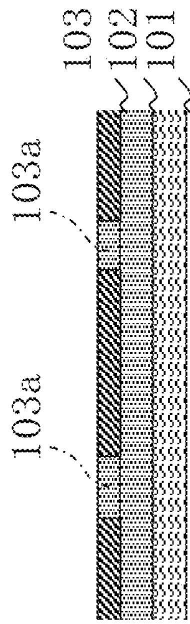


Fig. 5B

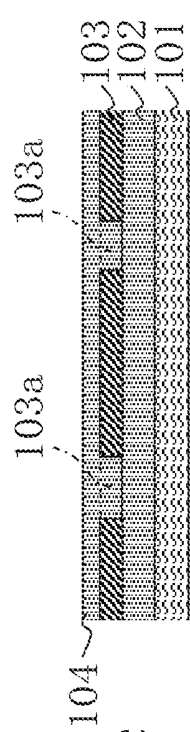


Fig. 5C

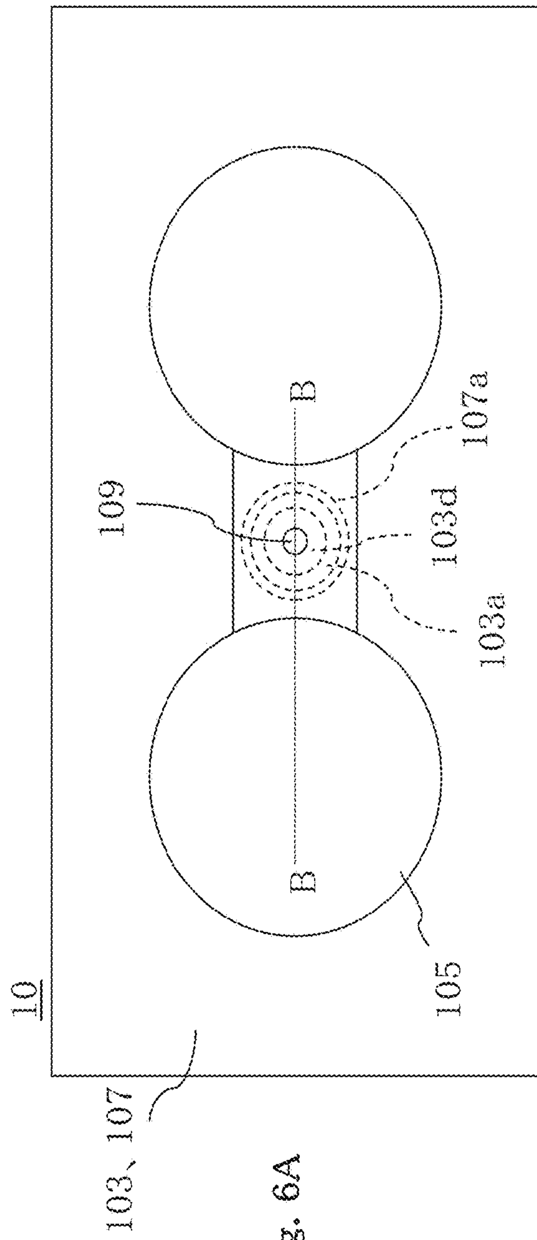


Fig. 6A

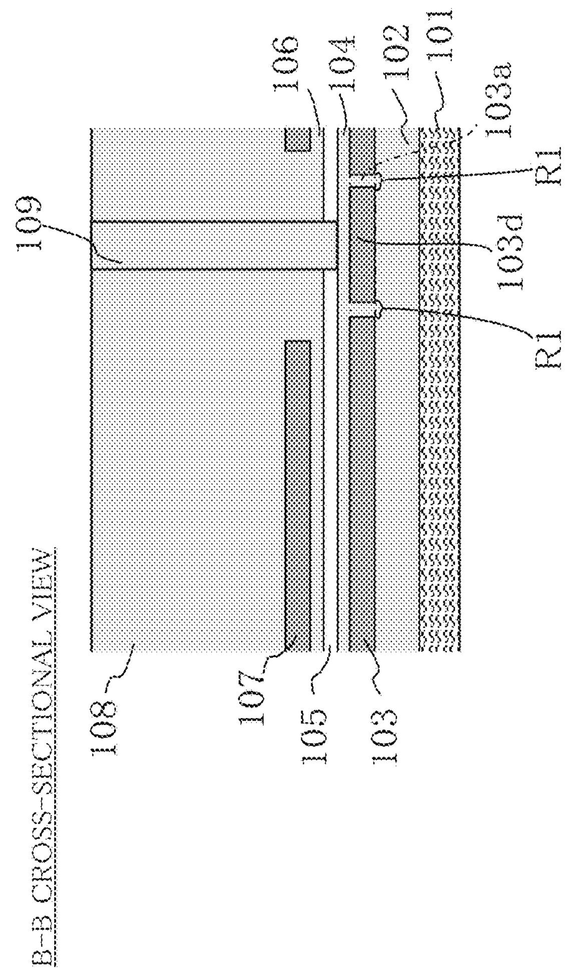
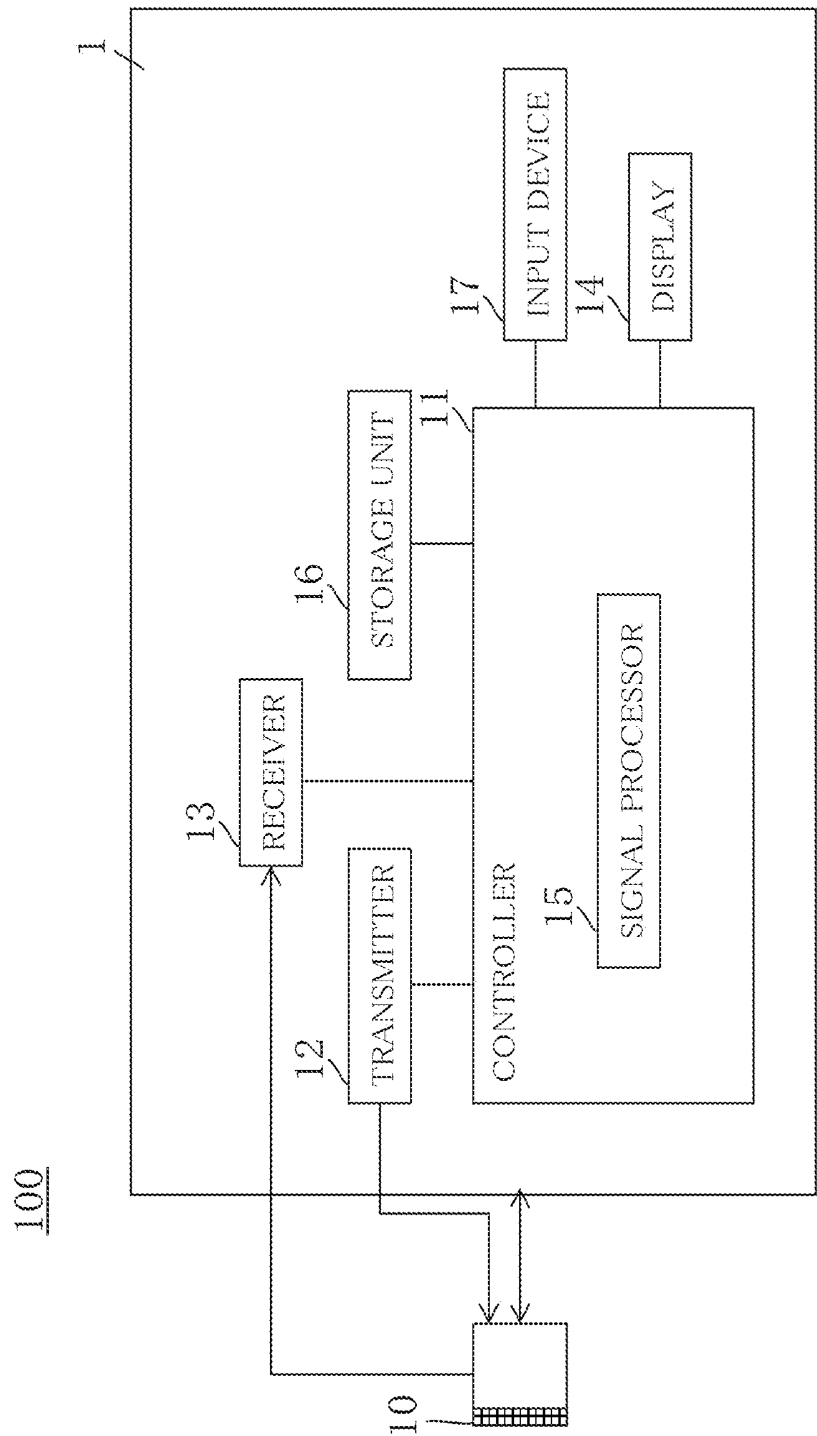


Fig. 6B

Fig. 7A

Fig. 7B

Fig. 8



ULTRASONIC TRANSDUCER, MANUFACTURING METHOD THEREOF, AND ULTRASONIC IMAGING DEVICE

INCORPORATION BY REFERENCE

[0001] The present application claims priority from Japanese patent application JP-2018-226644 filed on Dec. 3, 2018, the content of which is hereby incorporated by reference into this application.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a manufacturing technique for an ultrasonic transducer, and particularly relates to a technique that is effective for application to the structure of an ultrasonic transducer manufactured by micro electro mechanical system (MEMS) technology.

Description of the Related Art

[0003] Ultrasonic transducers are used in a variety of applications including ultrasonic imaging devices which, inspect human bodies, the internal structure of objects, and the like by transmitting and receiving ultrasonic waves.

[0004] Conventionally, ultrasonic transducers that utilize the vibration of piezoelectric materials have been used, but MEMS technology has advanced in recent years and capacitive micromachined ultrasonic transducers (CMUT) have been developed. In CMUTs, a vibration unit is fabricated on a silicon substrate.

[0005] A CMUT is a vibration device that has a structure in which upper and lower electrodes are disposed so as to sandwich a cavity layer, and the cavity layer is covered with insulating layers. CMUTs utilize the phenomenon whereby electrostatic force is generated in a membrane on top of the cavity as a result of voltage being applied between the upper electrode and the lower electrode to generate a potential difference.

[0006] Ultrasonic waves are transmitted by varying the voltage applied to the upper and lower electrodes over time to cause the membrane to vibrate. The ultrasonic waves are received by detecting, as voltage change or current change, displacement of the membrane while applying constant voltage between the upper and lower electrodes.

[0007] In a method for forming the cavity layer between the upper and lower electrodes, first, a metal membrane (sacrifice layer) is disposed between vertically laminated electrodes. Insulating layers are deposited around the electrodes and the sacrifice layer. Then, a through-hole that penetrates the insulating layer is formed and an etchant is introduced via the through-hole. As a result, the sacrifice layer is etched and removed, and the cavity layer is formed.

[0008] For example, the CMUT disclosed in Japanese Patent No. 4724501 includes a cavity layer formed between an upper electrode and a lower electrode, a through-hole for forming the cavity layer by etching, and first insulating layer that includes a projection that extends into the cavity layer from above, wherein the through-hole is filled with an insulating material. The projection provided in this CMUT fulfills the role of a support structure, thereby preventing the entire lower surface of the first insulating layer from contacting the insulating layer covering the lower electrode when voltage is applied, and reducing the amount of charge injected into the insulating layers.

[0009] Japanese Patent Application Publication No. 2009-165931 discloses a CMUT that uses a silicon single-crystal membrane with good mechanical properties as the membrane. In this CMUT, the through-hole and the lower electrode are disposed at positions that do not overlap when viewed from above.

SUMMARY OF THE INVENTION

[0010] It is known that the sensitivity of the ultrasonic transducers of the CMUTs such as the CMUTs disclosed in above patent documents increases as the distance between the upper and lower electrodes decreases. However, when the distance between the upper and lower electrodes is reduced, the through-hole for etchant introduction may reach the upper electrode or the lower electrode at the time of manufacturing. If the etchant is introduced via the through-hole in a state in which the through-hole reaches an electrode, the etchant may reach and dissolve the electrode.

[0011] An object of the present invention is to provide a highly-sensitive ultrasonic transducer with good yield.

[0012] To achieve the object described above, the ultrasonic transducer according to the present invention includes a cavity layer, a pair of electrodes positioned above and below the cavity layer, insulating layers disposed above and below each of the pair of electrodes, and a filled hole that penetrates, in a vertical direction, at least a portion of the insulating layer positioned above the cavity layer. In addition, when this ultrasonic transducer is viewed from above, each electrode of the pair of electrodes includes, at a position that overlaps the filled hole, a non-electrode region where the electrode is not formed.

[0013] In addition, a manufacturing method for the ultrasonic transducer according to the present invention includes sequentially laminating, on a substrate, a first electrode, a first insulating layer, a sacrifice layer, a second insulating layer, a second electrode, and a third insulating layer; forming a through-hole that penetrates from the third insulating layer to the sacrifice layer; forming a cavity layer by etching and removing, via the through-hole, a material of the sacrifice layer; and filling the through-hole with an insulating material. In this manufacturing method, when respectively laminating the first electrode and the second electrode, a region that includes a region corresponding to the through-hole when the ultrasonic transducer is viewed from above, is defined as a non-electrode region, and the first electrode and the second electrode are each deposited in regions other than the non-electrode region.

[0014] According to the present invention, the distance between the upper and lower electrodes can be reduced compared to conventional technology. With the ultrasonic transducer of the present invention, the lower electrode is disposed only below the cavity layer that vibrates when driving and is not disposed below the filled hole. As such, the capacitance component that does not contribute to lower electrode vibration, that is, parasitic capacitance, can be reduced. As a result, the sensitivity of the ultrasonic transducer can be increased.

[0015] Additionally, with the manufacturing method for the ultrasonic transducer according to the present invention, it is possible to provide a highly reliable ultrasonic transducer with good yield.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** is a top view of an ultrasonic transducer **10** that is common to Embodiments 1 and 2 according to the present invention;

[0017] FIG. **2** is a cross-sectional view of the ultrasonic transducer according to Embodiment 1, taken along line A-A of FIG. **1**;

[0018] FIGS. **3**A to **3**F are cross-sectional views illustrating a manufacturing method for the ultrasonic transducer according to Embodiment 1;

[0019] FIG. **4**A is a cross-sectional view of the ultrasonic transducer according to Embodiment 2, taken along line A-A of FIG. **1**;

[0020] FIG. **4**B is a cross-sectional view of an ultrasonic transducer according to a comparative example;

[0021] FIGS. **5**A to **5**C are cross-sectional views illustrating a filling and flattening method for a non-electrode region **103***a* and an upper region of the non-electrode region **103***a;*

[0022] FIG. **6**A is a top view of an ultrasonic transducer according to Embodiment 3;

[0023] FIG. **6**B is a cross-sectional view of the ultrasonic transducer according to Embodiment 3, taken along line B-B of FIG. **6**A;

[0024] FIG. **7**A is a cross-sectional view of an ultrasonic transducer according to Embodiment 4;

[0025] FIG. **7**B is a cross-sectional view illustrating a state in which an etchant E is introduced into the ultrasonic transducer according to Embodiment 4; and

[0026] FIG. **8** is a block diagram illustrating a configuration example of an ultrasonic imaging device according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0027] Next, embodiments of the present invention will be described using the drawings.

[0028] First, an overview of the configuration of an ultrasonic transducer **10** according to the present invention will be described while referencing FIGS. **1** and **2**. The ultrasonic transducer **10** is a so-called CMUT, which is formed by MEMS technology on a substrate **101**. The ultrasonic transducer **10** may be a single element or may be a CMUT array or CMUT chip in which a plurality of CMUT elements are arranged.

[0029] Hereinafter, a case in which a plurality of CMUT elements are disposed in the ultrasonic transducer **10** is described. FIG. **1** illustrates two elements of the plurality of CMUT elements of the ultrasonic transducer **10** according to the present invention. FIG. **2** illustrates a cross-sectional view of FIG. **1**, taken along line A-A. In FIG. **1**, the CMUT elements are depicted as circles for the sake of description but, in this example, the shape of the elements is not limited thereto.

[0030] The ultrasonic transducer **10** includes a cavity layer **105**, a pair of electrodes (upper electrode **107** and lower electrode **103**) positioned above and below the cavity layer **105**, insulating layers **102**, **104**, **106**, and **108** disposed above and below each of the pair of electrodes **107** and **103**, and a filled hole **109** that penetrates, in a vertical direction, at least a portion of the insulating layers **106** and **108** positioned above the cavity layer **105**. As illustrated in FIG. **1**, the upper electrode **107** includes a non-electrode region **107***a*, where an electrode is not formed, and the lower electrode **103** includes a non-electrode region **103***a* where an electrode is not formed. The non-electrode regions **107***a* and **103***a* are formed at positions that overlap the filled hole **109** when the ultrasonic transducer **10** is viewed from above.

[0031] The filled hole **109** is obtained by filling a through-hole used for forming the cavity layer **105** with an insulator, and is formed among the various CMUT elements. That is, the filled hole **109** is disposed in a region other than above the cavity layer **105**. Due to this configuration, the filled hole **109** does not vibrate when driving.

[0032] With the ultrasonic transducer **10** described above, the lower electrode **103** is disposed only below the cavity layer **105** that vibrates when driving and is not disposed below the filled hole **109**. As such, the capacitance component that does not contribute to the vibration of the lower electrode **103**, that is, the parasitic capacitance, can be reduced and the sensitivity of the ultrasonic transducer **10** can be increased.

[0033] In addition, when the ultrasonic transducer **10** is viewed from above, the filled hole **109** is disposed at a position that does not overlap with the pair of upper and lower electrodes **107** and **103**. As such, even if the distance between the upper and lower electrodes is reduced compared to conventional technology (on the order of tens of nm), the through-hole can be prevented from reaching the upper electrode **107** and the lower electrode layer **103** when forming the through-hole prior to filling the filled hole **109**, regardless of the depth accuracy of the through-hole. As a result, it is possible to provide a highly-sensitive ultrasonic transducer.

Embodiment 1

[0034] Hereinafter, the configuration of an ultrasonic transducer according to Embodiment 1 will be described in detail while referencing FIGS. **1** and **2**.

[0035] The components described above are disposed on a substrate **101** that is formed from a single-crystal silicon or similar semiconductor substrate. Specifically, the insulating layer **102**, a first electrode (lower electrode) **103**, a first insulating layer **104**, the cavity layer **105**, a second insulating layer **106**, a second electrode (upper electrode) **107**, and a third insulating layer **108** are laminated sequentially on a top surface of the substrate **101**. The non-electrode regions **107***a* and **103***a* are filled with an insulating material, and the non-electrode regions **107***a* and **103***a* are formed from insulators.

[0036] The filled hole **109** penetrates the non-electrode region **107***a* of the upper electrode **107** in the vertical direction. In Embodiment 1, when viewed from above, the non-electrode region **103***a* of the lower electrode **103** is smaller than the non-electrode region **107***a* of the upper electrode **107**. However, it is sufficient that, when viewed from above, the non-electrode region **103***a* and the non-electrode region **107***a* are larger than the filled hole **109**, and the sizes of the non-electrode region **103***a* and the non-electrode region **107***a* are not limited to the example described above. In addition, provided that the non-electrode regions **103***a* and **107***a* have shapes that surround the filled hole **109**, the shapes, when viewed from above, of the non-electrode regions **103***a* and **107***a* are not limited to round shapes such as those illustrated in FIG. **1**.

[0037] The non-electrode regions **107***a* and **103***a* are filled with an insulating material, and the non-electrode regions **107***a* and **103***a* are formed from insulators. The insulating

layers **102**, **104**, **106**, and **108** (described later) may be formed from the same material or may be formed from different materials.

[0038] Aside from single-crystal silicon, glass, quartz, sapphire, and the like can be used as the material of the substrate **101**.

[0039] Aluminum (Al) with a thickness of about 10 nm to 1000 nm may be used as the upper electrode **107** and the lower electrode **103**. Examples of materials other than Al that may be used include metal materials such as Al alloys, W, Ti, TiN, Ni, Co, Cr, Pt, and Au, polycrystalline silicon or amorphous silicon doped with impurities at high concentrations, and indium tin oxide (ITO). The upper electrode **107** and the lower electrode **103** may be formed from the materials described above as single layer or as laminated membranes.

[0040] The insulating layers **102**, **104**, **106**, and **108** may be formed from the same material or may be formed from different materials. These insulating layers may be configured as single layer or as a laminated membrane formed from one or two or more selected from silicon oxide (SiO_2), silicon nitride (Si_3N_4), aluminum oxide (Al_2O_3), titanium oxide (TiO_2), zirconium oxide (ZrO_2), hafnium oxide (HfO_2), silicon-doped hafnium oxide, and the like. The various insulating layers may be the same material or may be different materials. The filled hole **109** may be filled with the same material as the above-described insulating material.

[0041] For the insulating layer **102**, a material with good adhesiveness to the substrate material and the material of the lower electrode **103**, which is formed on the insulating layer **102**, is selected. Since the insulating layer **104** is a portion in which high electrical fields are generated, a material with high voltage resistance such as SiO_2 is preferable. The material of the insulating layer **106** preferably has high voltage resistance, similar to the insulating layer **104**. The insulating layers **106** and **108** form a membrane together with the upper electrode **107** and are displaced when transmitting and receiving ultrasonic waves. As such, it is preferable that the membrane shape is flat prior to displacement and, for the insulating layers **106** and **108**, a plurality of layers are laminated using a material with tensile stress such as SiN and a material with compressive stress such as SiO_2, thereby ensuring flatness.

[0042] A thickness of the insulating layer **102** may be set to about 10 nm to 10,000 nm, a thickness of the insulating layer **104** may be set to 1 nm to about 1,000 nm, a thickness of the insulating layer **106** may be set to about 1 nm to 1,000 nm, and a thickness of the insulating layer **108** may be set to about 10 nm to 10,000 nm.

[0043] The cavity layer **105** is formed on a top surface of the insulating layer **104** and with a thickness of about 1 nm to 1,000 nm such that the top and bottom of the cavity layer **105** are flat surfaces. The interior of the cavity layer **105** is hollow.

[0044] Manufacturing Method for the Ultrasonic Transducer according to Embodiment 1

[0045] Next, a manufacturing method for the ultrasonic transducer according to Embodiment 1 will be described while referencing FIGS. **3**A to **3**F.

[0046] First, as illustrated in FIG. **3**A, the insulating layer **102** and the lower electrode **103** are sequentially formed on the substrate **101**. The insulating layer **102** may be formed by a known film depositing technique such as plasma CVD or vapor deposition. The lower electrode **103** is deposited on an entire top surface of the insulating layer **102** by the same method used for depositing the insulating layer **102**. Then, the lower electrode **103** is patterned using a photolithographic method, a dry etching method, or the like. When the ultrasonic transducer is viewed from above, the lower electrode **103** is not formed in the non-electrode region **103***a*, which is the region (below the region where the through-hole **119** is to be formed) that includes the region corresponding to the through-hole **119**.

[0047] Next, as illustrated in FIG. **3**B, the insulating material is coated on a top surface of the lower electrode **103**, the non-electrode region **103***a*, and an upper region of the non-electrode region **103***a*. As a result, an insulating layer **104** with a flat top surface is formed. A known film depositing technique such as plasma CVD or vapor deposition may be used as the method for depositing the insulating layer **104**.

[0048] A metal membrane (sacrifice layer) **118** is formed on a top surface of the insulating layer **104** by sputtering or the like. The sacrifice layer **118** is a layer that is temporarily provided to form the cavity layer **105**, and is later etched and removed by an etchant. Polycrystalline silicon is used as the material of the sacrifice layer **118**. The thickness of the sacrifice layer determines the height of the cavity layer **105** and, as such, the sacrifice layer is formed with excellent thickness uniformity, and has a thickness of about 1 nm to 1,000 nm.

[0049] Next, as illustrated in FIG. **3**C, the insulating layer **106** is deposited on a top surface of the sacrifice layer **118** by a known film depositing technique such as plasma CVD or vapor deposition.

[0050] The upper electrode **107** is formed on a top surface of the insulating layer **106**. The upper electrode **107** is formed on the entire top surface of the insulating layer **106** and, then, is patterned using a photolithography method, a dry etching method, or the like. When the ultrasonic transducer **10** is viewed from above, the upper electrode **107** is deposited in a region other than the non-electrode region **107***a*, which includes the region corresponding to the through-hole **119** (through which the through-hole is to be opened). At this time, it is preferable that the upper electrode **107** is patterned such that the non-electrode region **107***a* of the upper electrode **107** is wider than the non-electrode region **103***a* of the lower electrode **103**.

[0051] After the upper electrode **107** is formed, the insulating material is coated on the top surface of the upper electrode **107**, the non-electrode region **107***a*, and the upper region of the non-electrode region **107***a*. As a result, an insulating layer **108** with a flat top surface is formed. A known film depositing technique such as plasma CVD or vapor deposition may be used as the method for forming the insulating layer **108**.

[0052] Next, as illustrated in FIG. **3**D, the through-hole **119** is formed so as to penetrate from the insulating layer **108** through the non-electrode region **107***a* and the insulating layer **106**, and reach the sacrifice layer **118**. The through-hole **119** is a hole for introducing the etchant that removes the sacrifice layer **118**. The through-hole **119** may penetrate the sacrifice layer **118** and reach the insulating layer **104** and/or the non-electrode region **103***a*.

[0053] Next, as illustrated in FIG. **3**E, the etchant E is introduced via the through-hole **119** and dissolves the sacrifice layer **118**, thereby forming the cavity layer **105**. For the

etchant, an etchant may be used that selectively dissolves the sacrifice layer **118** without dissolving the insulating layers around the cavity layer **105**. For example, potassium hydroxide may be used as the etchant E.

[0054] After the etching of the sacrifice layer **118** has sufficiently progressed and the formation of the cavity layer **105** has completed, the through-hole **119** is filled with the insulating material, thereby forming the filled hole **109** as illustrated in FIG. **3**F. The ultrasonic transducer is manufactured by the manufacturing method described above.

[0055] In the manufacturing method for the ultrasonic transducer described above, the through-hole **119** does not reach the upper electrode **107** or the lower electrode **103** even when the distance between the upper and lower electrodes is reduced to about tens of nm and the through-hole **119** penetrates the sacrifice layer **118**. Therefore, there is no risk of the electrodes being dissolved by the etchant. As a result, it is possible to provide an ultrasonic transducer with high yield.

[0056] In this manufacturing method, when viewed from above, the through-hole **119** is formed in a region different from the region in which the membrane on top of the cavity layer **105** is formed. As a result, there is no risk of the insulating material that fills the through-hole **119** adhering to the membrane, and a highly reliable ultrasonic transducer can be manufactured.

[0057] Additionally, in this manufacturing method, the through-hole **119** is formed from the side where the electrodes and the like are mounted on the substrate **101**. As such, the through-hole **119** can be formed without penetrating the substrate **101**. Therefore, the through-hole **119** can be formed without performing deep drilling of the substrate, and the ultrasonic transducer can be easily manufactured.

[0058] Furthermore, in this manufacturing method, the etchant is introduced after covering the sacrifice layer **118** with the insulating layers that are not etched. As such, only the sacrifice layer **118** is selectively etched and the cavity layer **105** is formed. As a result, in this manufacturing method, the need to control the etching time is eliminated and cavity layers **105** with uniform widths can be formed among the plurality of CMUT elements of the ultrasonic transducer.

Embodiment 2

[0059] Hereinafter, the features of an ultrasonic transducer according to Embodiment 2 that differ from the features of the ultrasonic transducer according to Embodiment 1 will be described while referencing FIGS. **4**A and **4**B. With the ultrasonic transducer according to Embodiment 2, as illustrated in FIG. **4**A, the non-electrode region **103***a* and the region above the non-electrode region **103***a* are filled with the insulating material to the same height as the insulating layer **104** disposed on the top surface of the lower electrode **103**, and are flattened.

[0060] As described in the manufacturing method for the ultrasonic transducer according to Embodiment 1, the insulating material is coated on the top surface of the lower electrode **103**, the non-electrode region **103***a*, and above the non-electrode region **103***a* using a known technique such as plasma CVD or vapor deposition. As a result, an insulating layer **104** with a flat top surface is formed. However, as illustrated in the Comparative Example of FIG. **4**B, in actuality, a step shape may form in the sacrifice layer **118**. In such cases, and particularly when the thickness of the sacrifice layer **118** is thin, the sacrifice layer **103***b* of the side wall portion of the step may break and the etchant introduced via the through-hole **119** may not reach the entire sacrifice layer **118**, thereby obstructing the formation of the cavity layer **105**.

[0061] In Embodiment 2, the non-electrode region **103***a* and the region above the non-electrode region **103***a* (below the region where the through-hole **119** is provided) are filled with an insulator to the same height as the insulating layer **104** disposed on the top surface of the lower electrode **103**, and are flattened. As such, the sacrifice layer **118** is formed on the insulating layer **104** in a flat manner and it is possible to suppress breakage of the sacrifice layer of the side wall portion **103***b* of the step described above, even when the thickness of the sacrifice layer **118** is thin. As a result, the etchant introduced via the through-hole **119** can reach the entire sacrifice layer **118** and the cavity layer **105** can be formed with good yield.

[0062] The insulator filling the non-electrode region **103***a* and the upper region of the non-electrode region **103***a* may be formed from the same material as the non-electrode region **103***a*, the insulating layer **104**, or the like, or may be formed from a different material. This insulator may be configured as single layer or as a laminated membrane formed from one or two or more selected from silicon oxide (SiO_2), silicon nitride (Si_3N_4)*,* aluminum oxide (Al_2O_3), titanium oxide (TiO_2), zirconium oxide (ZrO_2), hafnium oxide (HfO_2), silicon-doped hafnium oxide, and the like.

[0063] A filling and flattening method for the non-electrode region **103***a* and the upper region of the non-electrode region **103***a* is described using FIGS. **5**A to **5**C. First, as illustrated in FIG. **5**A, the insulating layer **102** and the lower electrode **103** are formed on the substrate **101**, and the insulating layer **104** is deposited. Next, as illustrated in FIG. **5**B, chemical mechanical polishing (CMP) technique or the like is used to remove the insulating layer **104** until the lower electrode **103** is exposed.

[0064] Next, as illustrated in FIG. **5**C, the insulating layer **104** is formed above the lower electrode **103** and above the non-electrode region **103***a*.

[0065] In the manufacturing method for the ultrasonic transducer according to Embodiment 2, the sacrifice layer **118** can be formed in a flat manner without any steps. As such, the etchant can easily reach the entire sacrifice layer **118** when etching/removing the sacrifice layer **118**. As a result, cavity layers **105** with more uniform widths can be formed among the plurality of CMUT elements of the ultrasonic transducer. Therefore, it is possible to manufacture, with increased yield, an ultrasonic transducer with high drive reliability.

Embodiment 3

[0066] Hereinafter, an ultrasonic transducer according to Embodiment 3 will be described while referencing FIGS. **6**A and **6**B. As with the ultrasonic transducer according to Embodiment 2, with the ultrasonic transducer according to Embodiment 3, steps in the sacrifice layer **118** are prevented by modifying the configuration of the portion below the region where the through-hole **119** is provided.

[0067] In Embodiment 3, as illustrated in FIGS. **6**A and **6**B, a non-electrode portion **103***d*, disposed separated from the lower electrode **103**, is provided in the non-electrode region **103***a*. The non-electrode portion **103***d* is provided in a region of the portion below the region where the filled hole

109 is formed, and an insulation region R**1** is formed on an outer edge of the non-electrode region **103***a* that contacts the lower electrode **103** (formed between the non-electrode portion **103***d* and the lower electrode **103**).

[0068] The non-electrode portion **103***d* may have a round shape when viewed from above as illustrated in FIG. **6**A, or may have a different shape when viewed from above. However, the non-electrode portion **103***d* preferably has a shape centered in the region directly below the filled hole **109**. The size of the non-electrode portion **103***d* when viewed from above is preferably larger than the size of the filled hole **109**. The size of the insulation region R**1** when viewed from above is preferably as small as possible.

[0069] The non-electrode portion **103***d* may be formed from the same material as the material of the lower electrode **103**, or may be formed from a different material. In one example, the non-electrode portion **103***d* is formed using Al. Examples of materials other than Al that may be used include metal materials such as Al alloys, W, Ti, TiN, Ni, Co, Cr, Pt, and Au, polycrystalline silicon or amorphous silicon doped with impurities at high concentrations, and indium tin oxide (ITO).

[0070] When forming the non-electrode portion **103***d* from a different material or as a different layer than the lower electrode **103**, a different mask than the mask for forming the lower electrode **103** is used and the non-electrode portion **103***d* is formed via a different process than that of the lower electrode **103**. However, in cases in which the non-electrode portion **103***d* is formed in the same layer and from the same electrode material as the lower electrode **103**, the non-electrode portion **103***d* is formed when forming the lower electrode **103** by using a mask and depositing the electrode material in the regions of the non-electrode region **103***a* other than the insulation region R**1**. Thus, in cases in which the non-electrode portion **103***d* and the lower electrode **103** are formed from the same material and in the same layer, the number of masks to be used and the number of steps can be reduced compared to when forming from different materials or in different layers. Accordingly, it is preferable that the non-electrode portion **103***d* and the lower electrode **103** be formed from the same material and in the same layer.

[0071] With the ultrasonic transducer according to Embodiment 3 described above, the non-electrode portion **103***d* is provided in the region of the portion of the non-electrode region **103***a* below the filled hole **109** and, as such, steps are not formed in the sacrifice layer **118**. As a result, it is possible to further enhance the accuracy of the ultrasonic transducer.

[0072] In addition, in this manufacturing method for the ultrasonic transducer, even in cases in which the through-hole **119** reaches the non-electrode portion **103***d* and the non-electrode portion **103***d* is removed by the etchant when etching/removing the sacrifice layer **118**, the etchant can be prevented from reaching the lower electrode **103** due to the insulation region R**1** being formed between the non-electrode portion **103***d* and the lower electrode **103**. Furthermore, in this manufacturing method, the need for the filling and flattening process described in Embodiment 2 is eliminated due to the non-electrode portion **103***d* being disposed.

Embodiment 4

[0073] In Embodiment 4, as illustrated in FIG. **7**A, the non-electrode portion **103***d* described in Embodiment 3 is divided into a plurality of non-electrode portions **103***d*. An insulation region R**1** is formed between the outermost non-electrode portion **103***d* and the lower electrode **103**, and insulation regions R**1** are formed among the plurality of non-electrode portions **103***d* as well.

[0074] The non-electrode portion **103***d* may be divided concentrically, in a fan shape, or randomly. The number of divisions of the non-electrode portion **103***d* is not particularly limited.

[0075] Even in cases in which the non-electrode portion **103***d* is divided into a plurality of non-electrode portions **103***d* such as in Embodiment 4, the non-electrode portion **103***d* can be manufactured by the same method described for the single non-electrode portion **103***d* of Embodiment 3. It is preferable that all of the divided non-electrode portions **103***d* are formed from the same electrode material and are formed in the same layer.

[0076] FIG. **7**B illustrates a case in which the through-hole **119** reaches the non-electrode portions **103***d* in the present embodiment. In this case, when the etchant E is introduced through the through-hole **119** in order to form the cavity layer **105**, the etchant E only reaches the non-electrode portions **103***d*, of the plurality of non-electrode portions **103***d*, that the through-hole **119** reaches. The non-electrode portions **103***d* that the etchant E reaches are selectively removed and, as a result, cavity portions **103***e* are formed.

[0077] In cases in which the non-electrode portions **103***d* are selectively removed and the cavity portions **103***e* are formed, a length by which a region (eave portion) **119***b*, which is around the through-hole **119** and sandwiched between the cavity layer **105** and the cavity portions **103***e*, protrudes toward the through-hole **119** is smaller than that in cases in which all of the non-electrode portions **103***d* are removed. Therefore, in the present embodiment, peeling of the eave portion **119***b* when introducing the etchant can be prevented and an ultrasonic transducer can be manufactured with better yield.

[0078] Ultrasonic Imaging Device

[0079] Hereinafter, an ultrasonic imaging device **100** of the present invention will be described using FIG. **8**.

[0080] The ultrasonic imaging device **100** includes the ultrasonic transducer **10**, and a device main body **1** that generates ultrasonic images while controlling the driving of the ultrasonic transducer **10**.

[0081] The ultrasonic transducer **10** may be provided on an ultrasonic probe that is brought into contact with an inspection subject or is made to contact the inspection subject via a contact medium to transmit and receive ultrasonic waves to and from the inspection subject, or may be provided on a catheter that is inserted into the inspection subject to transmit and receive ultrasonic waves. At least one of the ultrasonic transducers **10** described in Embodiments 1 to 4 above is used in the ultrasonic transducer **10** of the ultrasonic imaging device **100**.

[0082] The device main body **1** includes a transmitter **12** that transmits electric signals for transmission to the ultrasonic transducer **10**; a receiver **13** that receives ultrasonic waves that are the reflected waves from the inspection subject; a controller **11** that controls the operations of the various components; a signal processor **15** that is provided in the controller **11** and that processes the signals received by the receiver **13**, creates images, performs various types of calculations, and the like; and a storage unit **16**.

[0083] The device main body **1** also includes an input device **17** whereby an operator of the ultrasonic imaging device **100** inputs operating conditions of the ultrasonic imaging device **100** into the controller **11**, and a display **14** that displays processing results of the signal processor **15** and the like. The input device **17** and the display **14** may function as user interfaces whereby the operator performs interactive operations with the device main body **1**.

[0084] Configurations of the various components of the device main body **1** are the same as those of known ultrasonic imaging devices. As such, description thereof is omitted.

[0085] Next, the operations of the ultrasonic imaging device **100** are briefly described. First, an electric signal for transmission is transmitted, via a digital-analog (D/A) converter (not illustrated in the drawings), from a beamformer of the transmitter **12** to the electrodes **103** and **107** of the ultrasonic transducer **10**, and ultrasonic waves are emitted toward the inspection subject from the ultrasonic transducer **10**. Acoustic signals reflected during the process of the ultrasonic waves propagating through the inspection subject are received by the ultrasonic transducer **10**, converted to digital signals, and transmitted, via an A/D converter (not illustrated in the drawings), as reception data to a receive beamformer of the receiver **13**. The receive beamformer carries out addition processing of the signals received by the plurality of elements taking account of the time delay given during transmission. The received signals that have been subjected to the addition processing are then subjected to processing such as attenuation correction by a corrector (not illustrated in the drawings) and, thereafter, are transmitted as RF data to the signal processor **15**. The signal processor **15** creates images using the RF data.

[0086] The ultrasonic imaging device **100** according to the present invention includes the ultrasonic transducer described in any one of Embodiments 1 to 4. Accordingly, an ultrasonic imaging device capable of high-sensitivity ultrasonic imaging can be provided with good yield. Therefore, this ultrasonic imaging device **100** can be used as an imaging device in, for example, intravascular ultrasound (IVUS) imaging and intravascular photoacoustic (IVPA) imaging, where high-sensitivity imaging is required.

What is claimed is:

1. An ultrasonic transducer including a cavity layer, and a pair of electrodes positioned above and below the cavity layer, the ultrasonic transducer comprising:
- insulating layers disposed above and below each of the pair of electrodes; and
- a filled hole that penetrates, in a vertical direction, at least a portion of the insulating layers positioned above the cavity layer, wherein
- when the ultrasonic transducer is viewed from above, each electrode of the pair of electrodes includes, at a position that overlaps the filled hole, a non-electrode region where the electrode is not formed.

2. The ultrasonic transducer according to claim **1**, wherein the filled hole is filled with an insulator.

3. The ultrasonic transducer according to claim **1**, wherein the non-electrode region is formed from an insulator.

4. The ultrasonic transducer according to claim **1**, wherein the non-electrode region of the electrode, of the pair of electrodes, positioned on a lower side has a size when viewed from above that is smaller than a size of the non-electrode region of the electrode positioned on an upper side.

5. The ultrasonic transducer according to claim **1**, wherein the non-electrode region and a region above the non-electrode region are filled with an insulator to a same height as the insulating layer disposed on a top surface of the electrode, of the pair of electrodes, positioned on a lower side.

6. The ultrasonic transducer according to claim **1**, wherein:
- the non-electrode region of the electrode, of the pair of electrodes, positioned on a lower side includes a non-electrode portion formed from a material that is identical to a material of the electrode, and
- an insulation region is formed between the non-electrode portion and the electrode positioned on the lower side.

7. The ultrasonic transducer according to claim **6**, wherein a plurality of the non-electrode portions are provided.

8. A manufacturing method for an ultrasonic transducer, the method comprising:
- sequentially laminating, on a substrate, a first electrode, a first insulating layer, a sacrifice layer, a second insulating layer, a second electrode, and a third insulating layer;
- forming a through-hole that penetrates from the third insulating layer to the sacrifice layer;
- forming a cavity layer by etching and removing, via the through-hole, a material of the sacrifice layer; and
- filling the through-hole with an insulating material; wherein
- when laminating each of the first electrode and the second electrode, a region that includes a region corresponding to the through-hole when the ultrasonic transducer is viewed from above, is defined as a non-electrode region, and the first electrode and the second electrode are each deposited in regions other than the non-electrode region.

9. The manufacturing method for an ultrasonic transducer according to claim **8**, further comprising filling the non-electrode region with an insulating material after depositing the first electrode.

10. The manufacturing method for an ultrasonic transducer according to claim **8**, wherein when depositing the first electrode, a portion other than an outer edge of the non-electrode region that contacts the first electrode is deposited using an electrode material identical to that of the first electrode.

11. The manufacturing method for an ultrasonic transducer according to claim **10**, wherein the portion of the non-electrode region deposited using the electrode material identical to that of the first electrode is divided into a plurality of portions and deposited.

12. An ultrasonic imaging device comprising the ultrasonic transducer according to claim **1**.

* * * * *

patsnap

专利名称(译)	超声换能器及其制造方法和超声成像装置		
公开(公告)号	US20200171538A1	公开(公告)日	2020-06-04
申请号	US16/699185	申请日	2019-11-29
[标]申请(专利权)人(译)	株式会社日立制作所		
申请(专利权)人(译)	HITACHI，LTD.		
当前申请(专利权)人(译)	HITACHI，LTD.		
[标]发明人	TAKEZAKI TAIICHI KAWANO MASAKAZU MACHIDA SHUNTARO		
发明人	TAKEZAKI, TAIICHI KAWANO, MASAKAZU MACHIDA, SHUNTARO		
IPC分类号	B06B1/02 B81B3/00 B81C1/00 A61B8/12 A61B8/00 A61B5/00 G01N29/24		
CPC分类号	B81C2201/0105 B06B1/0292 G01N2291/101 B81C1/00158 G01N29/2406 B81B2203/04 B81B2203/0127 A61B5/0095 B81B2203/0315 A61B8/12 B81B2201/0271 A61B8/4494 B81B3/0021 A61B8/0891 A61B8/4483 A61B8/4488		
优先权	2018226644 2018-12-03 JP		
外部链接	Espacenet USPTO		

摘要(译)

提供了一种具有高成品率的高灵敏度超声换能器。 超声波换能器包括：空腔层；位于空腔层上方和下方的一对电极；设置在一对电极中的每个上方和下方的绝缘层；以及在垂直方向上穿透至少一部分的填充孔。 绝缘层位于空腔层上方。 当从上方观看超声换能器时，一对电极中的每个电极在与嵌入孔重叠的位置处包括未形成电极的非电极区域。