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(54) **CELL AND CHANNEL OF ULTRASONIC TRANSDUCER, AND ULTRASONIC TRANSDUCER INCLUDING THE SAME**

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B06B 3/00	(2006.01)
H01L 41/00	(2013.01)
G01S 15/89	(2006.01)

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

CPC ... ***A61B 8/44*** (2013.01); *A61B 8/14* (2013.01); ***B06B 1/0292*** (2013.01); *B06B 1/02* (2013.01); *B06B 3/00* (2013.01); *H01L 41/00* (2013.01); *G01S 15/8906* (2013.01)

USPC **600/459**; 600/437; 310/309; 310/311

(58) **Field of Classification Search**

None

See application file for complete search history.

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(57) **ABSTRACT**

A cell of an ultrasonic transducer is provided. The cell includes a substrate; a supporting portion disposed on the substrate; a thin film spaced apart from the substrate and the supporting portion; and a connection portion which connects the supporting portion and the thin film. The connection portion may include a deformation portion that is elastically deformable. A channel of the ultrasonic transducer includes a plurality of cells arranged in an array. The ultrasonic transducer includes a plurality of channels arranged in an array.

25 Claims, 9 Drawing Sheets

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FIG. 1A

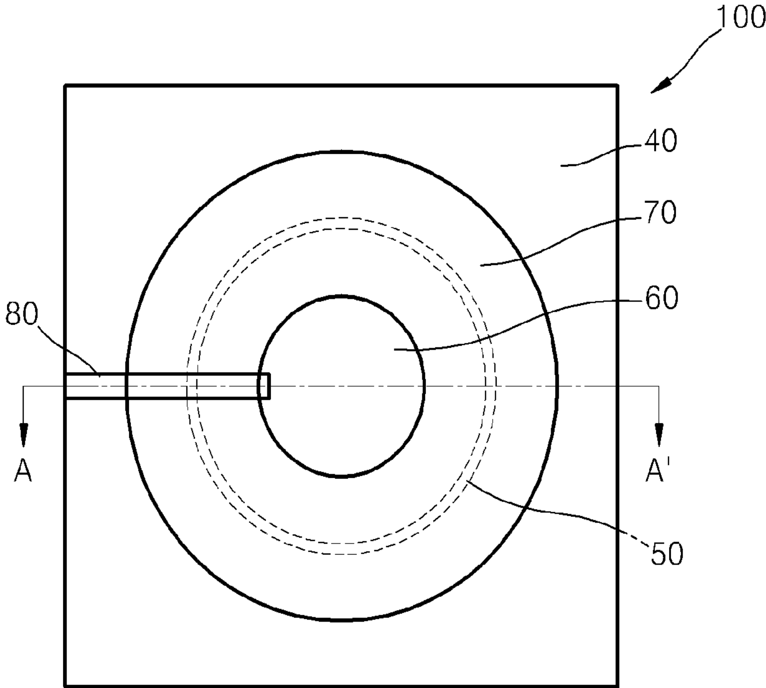


FIG. 1B

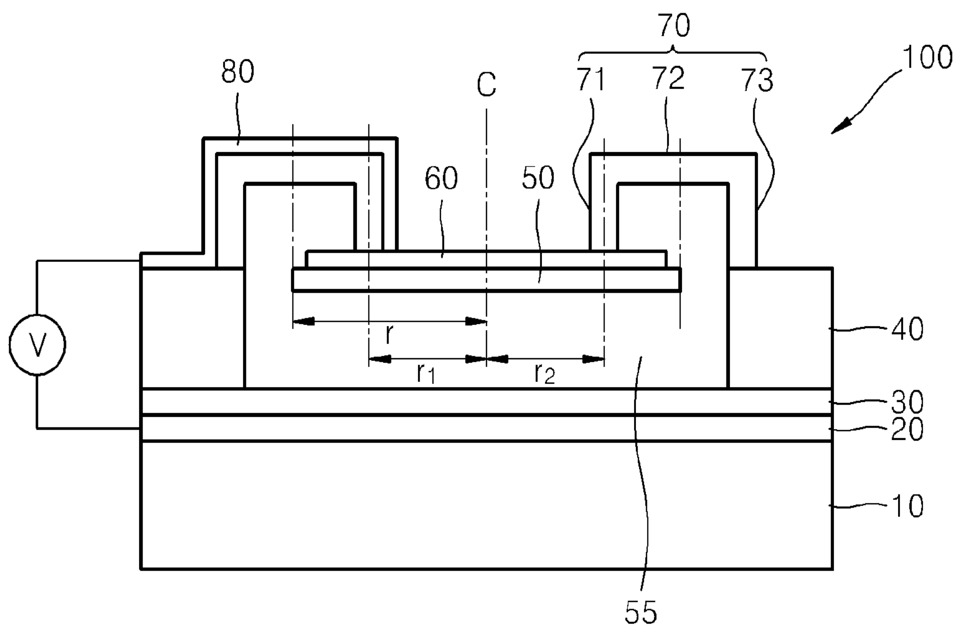


FIG. 1C

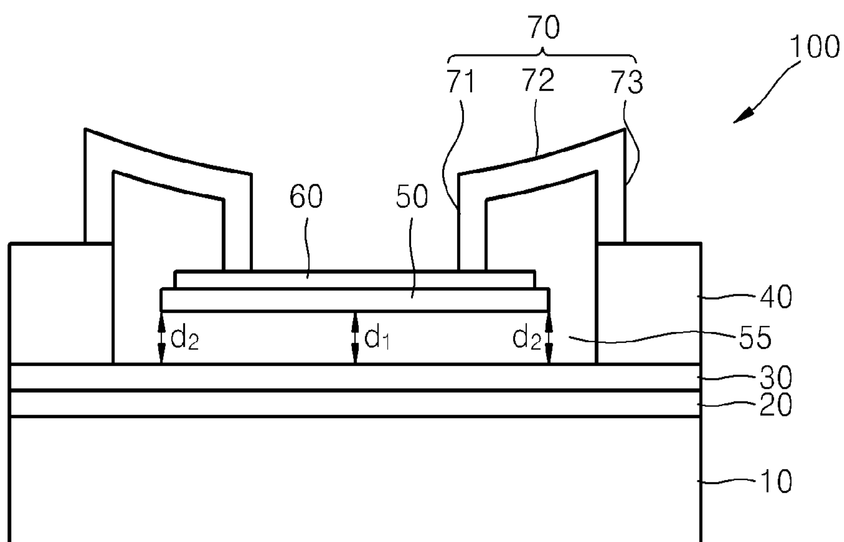


FIG. 2A

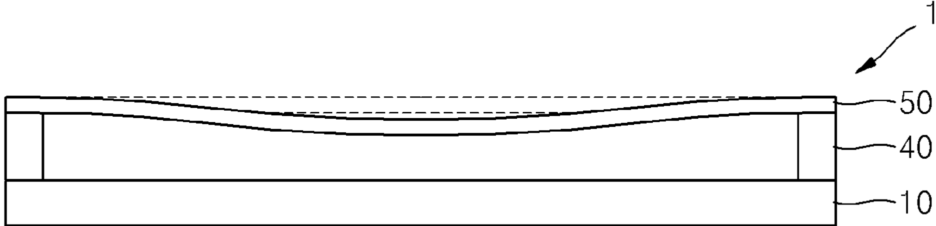


FIG. 2B

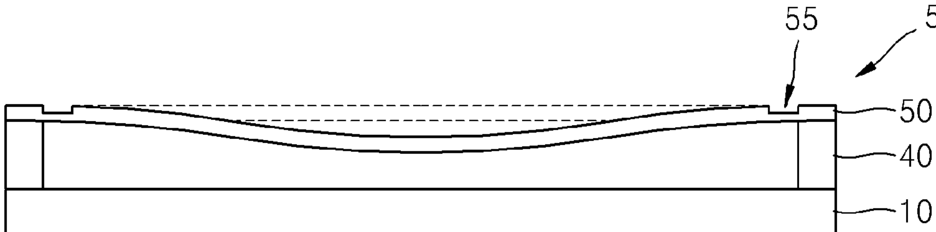


FIG. 2C

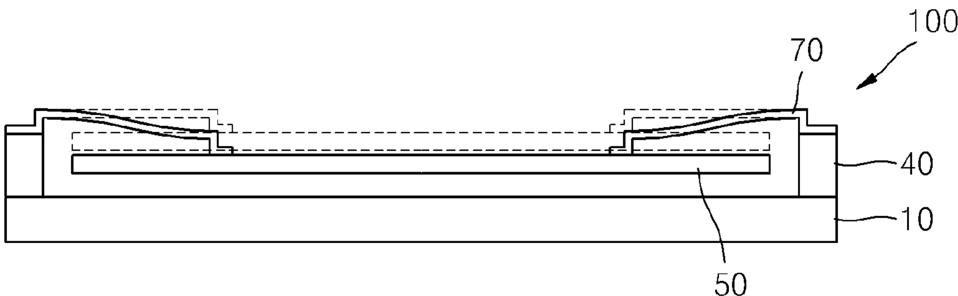


FIG. 3

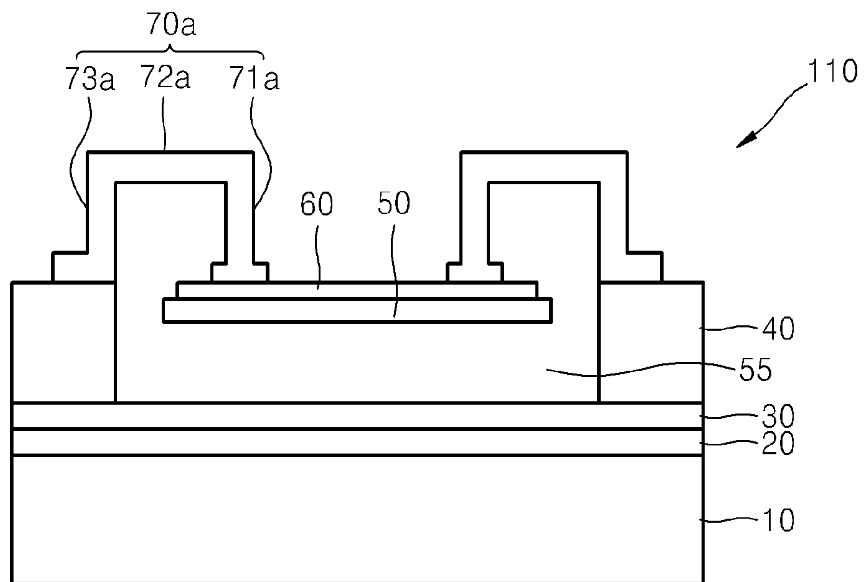


FIG. 4

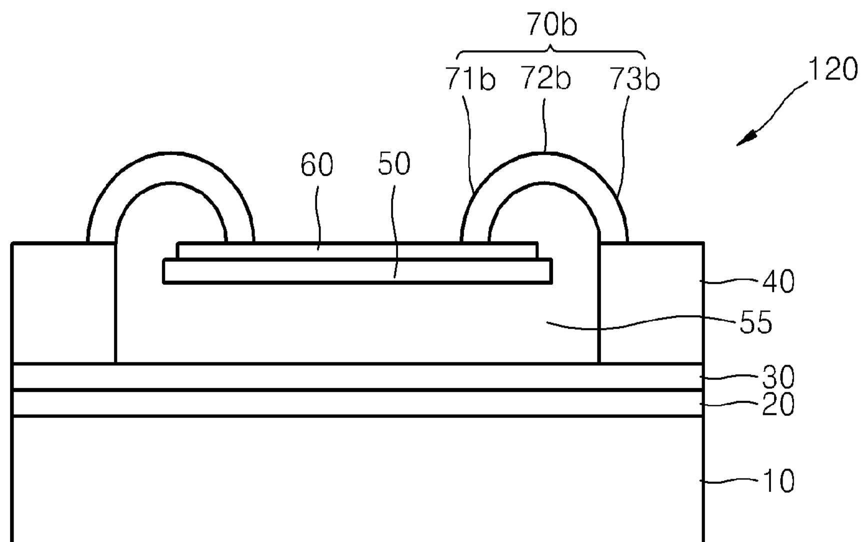


FIG. 5

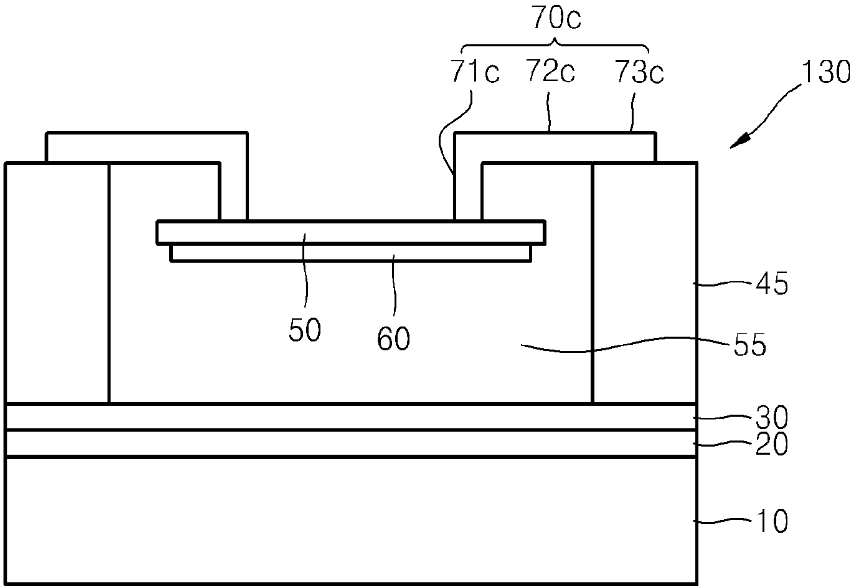


FIG. 6A

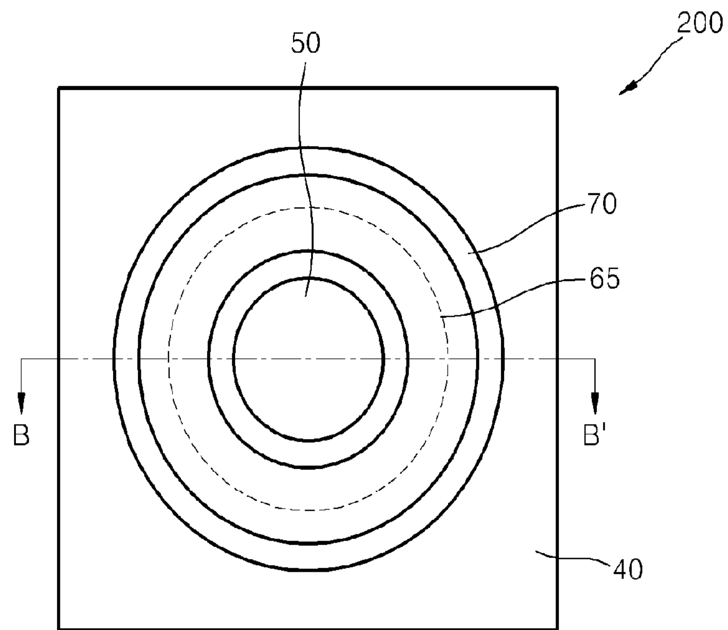


FIG. 6B

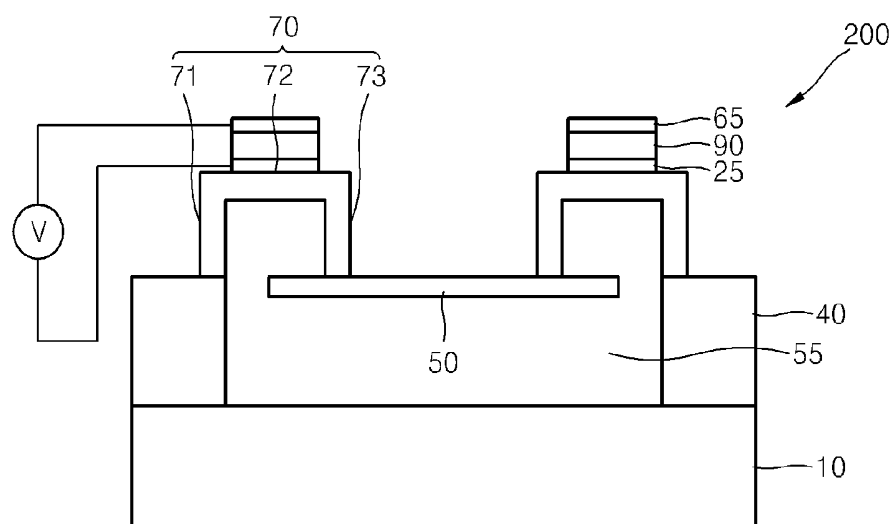


FIG. 7

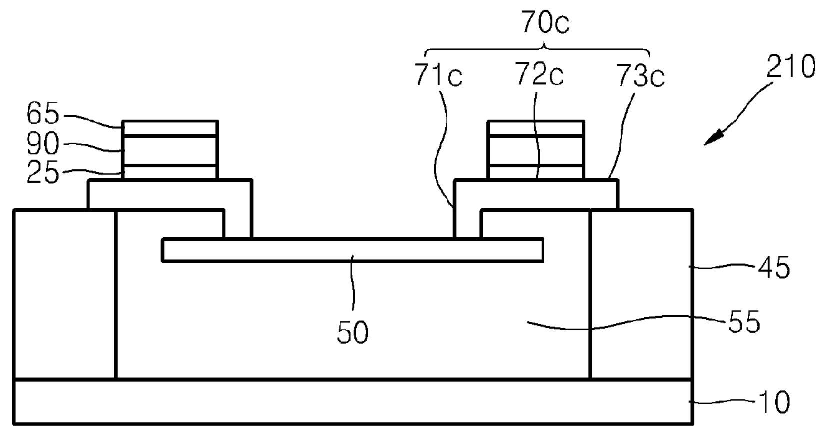


FIG. 8A

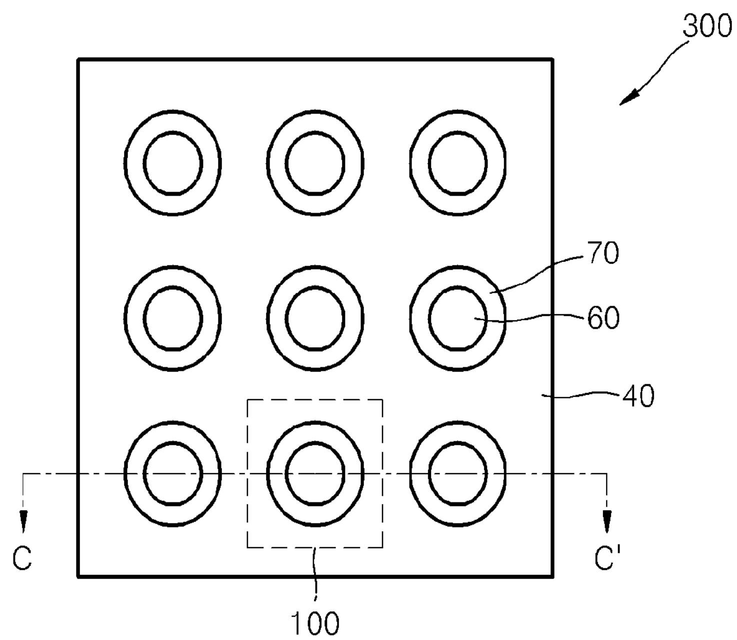


FIG. 8B

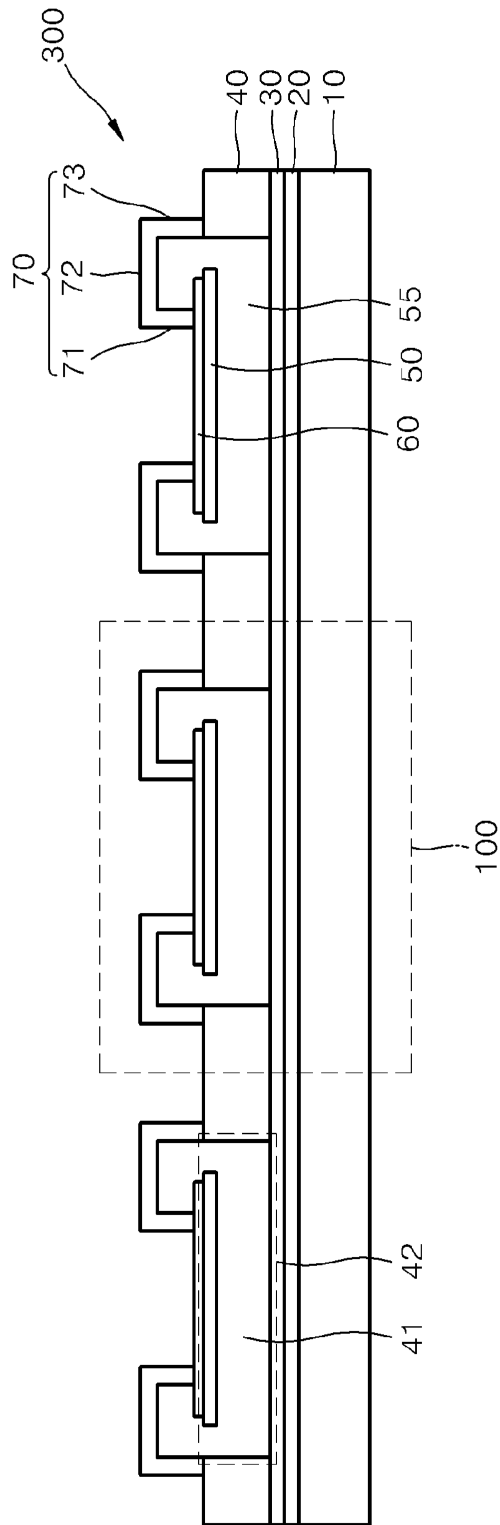
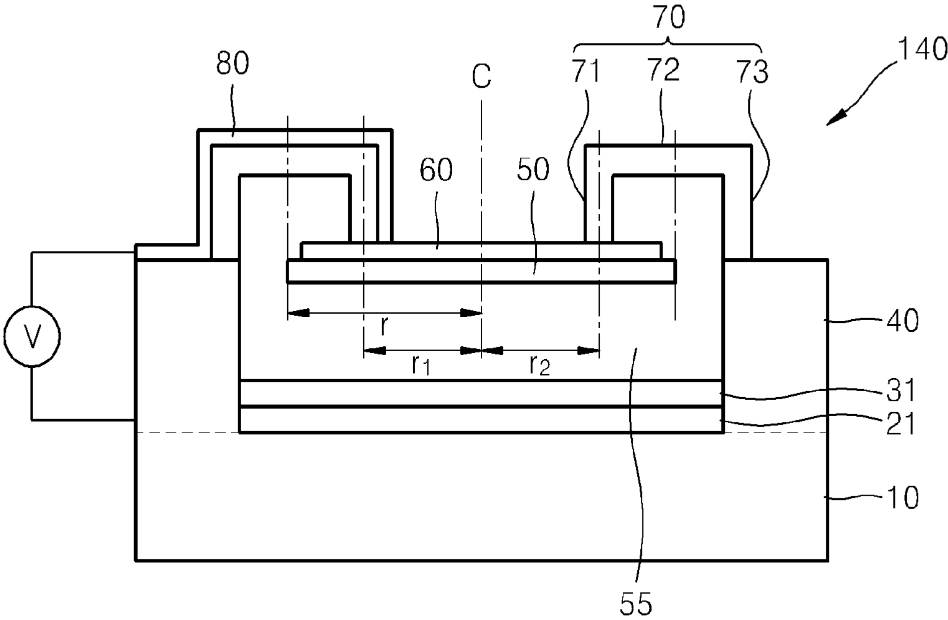


FIG. 9



CELL AND CHANNEL OF ULTRASONIC TRANSDUCER, AND ULTRASONIC TRANSDUCER INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority from Korean Patent Application No. 10-2010-0127871, filed on Dec. 14, 2010, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

Apparatuses consistent with the present disclosure relate to a cell and a channel of an ultrasonic transducer, and the ultrasonic transducer including the same.

2. Description of the Related Art

Micromachined ultrasonic transducers (MUTs) are apparatuses that convert an electrical signal into an ultrasonic signal or convert an ultrasonic signal into an electrical signal. Ultrasonic transducers are used in, for example, medical image diagnosis apparatuses, and may obtain photos and images of body tissues or body organs non-invasively. An ultrasonic transducer may include a piezoelectric micromachined ultrasonic transducer (pMUT), a capacitive micromachined ultrasonic transducer (cMUT), a magnetic micromachined ultrasonic transducer (mMUT), or the like, according to its transduction method.

SUMMARY

One or more embodiments provide a cell and a channel of an ultrasonic transducer, and the ultrasonic transducer including the same.

According to an aspect of an exemplary embodiment, a cell of an ultrasonic transducer includes: a substrate; a supporting portion disposed on the substrate; a thin film spaced apart from the substrate and the supporting portion; and a connection portion which connects the supporting portion and the thin film.

The connection portion may include a support contact portion connected to the supporting portion, a thin film contact portion connected to the thin film, and a deformation portion which connects the support contact portion and the thin film contact portion and which is elastically deformable.

An elastic deformation of the deformation portion causes the thin film to vibrate.

The cell may further include a first electrode disposed on the substrate.

The cell may further include an insulating layer disposed on the first electrode.

The cell may further include a second electrode disposed on the thin film.

The cell may further include a feeder which is disposed on the connection portion and which is electrically connected to the second electrode.

The thin film may be a conductive thin film.

The cell may further include a piezoelectric layer disposed on the connection portion.

The cell may further a first electrode disposed under the piezoelectric layer and a second electrode disposed on the piezoelectric layer.

The cell may include a cavity defined by the substrate, the supporting portion, the thin film, and the connection portion.

According to an aspect of another exemplary embodiment, a channel of an ultrasonic transducer includes a plurality of cells, wherein the cells are arranged in an m×n array, wherein m and n are natural numbers greater than 1.

According to an aspect of another exemplary embodiment, a channel of an ultrasonic transducer includes a substrate including a plurality of recesses and supporting portions; a plurality of thin films spaced apart from the recesses; and a plurality of connection portions, wherein each of the connection portions connects one of the thin films and a supporting portion.

The connection portion may include a support contact portion connected to the supporting portion, a thin film contact portion connected to the thin film, and a deformation portion which connects the support contact portion and the thin film contact portion and which is elastically deformable.

An elastic deformation of the deformation portion may cause the thin film to vibrate in a direction perpendicular to the substrate.

The channel may further include a first electrode disposed in each of the recesses.

The channel may further include an insulating layer disposed on each of the first electrodes.

The channel may further include a second electrode disposed on each of the thin films.

The channel may further include a feeder disposed on each of the connection portions and which is electrically connected to the second electrode.

The thin film may be a conductive thin film.

The channel may further include a piezoelectric layer disposed on each of the connection portions.

The channel may further include a first electrode disposed under the piezoelectric layer and a second electrode disposed on the piezoelectric layer.

A cavity may be defined by the substrate, one of the supporting portions, one of the plurality of thin films, and one of the plurality of connection portions.

According to an aspect of another exemplary embodiment, an ultrasonic transducer includes a plurality of the channels, wherein the channels are arranged in an m×n array, where m and n are natural numbers greater than 1.

BRIEF DESCRIPTION OF THE DRAWINGS

These and/or other aspects will become apparent and more readily appreciated from the following description of exemplary embodiments, taken in conjunction with the accompanying drawings of which:

FIG. **1**A is a schematic plane view illustrating a cell of an ultrasonic transducer, according to an exemplary embodiment of the present invention;

FIG. **1**B is a schematic cross-sectional view illustrating the cell of the ultrasonic transducer of FIG. **1**A;

FIG. **1**C is a schematic cross-sectional view illustrating the cell of the ultrasonic transducer of FIG. **1**A;

FIGS. **2**A and **2**B are schematic cross-sectional views each illustrating a cell of an ultrasonic transducer, according to a comparative example;

FIG. **2**C is a schematic cross-sectional view illustrating the cell of the ultrasonic transducer of FIG. **1**A;

FIG. **3** is a schematic cross-sectional view illustrating a cell of an ultrasonic transducer, according to another exemplary embodiment;

FIG. **4** is a schematic cross-sectional view illustrating a cell of an ultrasonic transducer, according to another exemplary embodiment;

FIG. **5** is a schematic cross-sectional view illustrating a cell of an ultrasonic transducer, according to another exemplary embodiment;

FIG. **6**A is a schematic plane view illustrating a cell of an ultrasonic transducer, according to another exemplary embodiment;

FIG. **6**B is a schematic cross-sectional view of the cell of FIG. **6**A;

FIG. **7** is a schematic cross-sectional view illustrating a cell of an ultrasonic transducer, according to another exemplary embodiment;

FIG. **8**A is a schematic plane view illustrating a channel of an ultrasonic transducer, according to an exemplary embodiment; and

FIG. **8**B is a schematic cross-sectional view of the channel of FIG. **8**A.

FIG. **9** is a schematic cross-sectional view illustrating a cell of an ultrasonic transducer, according to an exemplary embodiment.

DETAILED DESCRIPTION

Various exemplary embodiments will now be described more fully with reference to the accompanying drawings.

Detailed illustrative exemplary embodiments are disclosed herein. However, specific structural and functional details disclosed herein are merely representative for purposes of describing exemplary embodiments. This invention may, however, may be embodied in many alternate forms and should not be construed as limited to only the exemplary embodiments set forth herein.

Like numbers refer to like elements throughout the description of the figures.

It will be understood that, although the terms 'first', 'second', etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term "and/or," includes any and all combinations of one or more of the associated listed items.

It will be understood that when an element or layer is referred to as being "formed on," another element or layer, it can be directly or indirectly formed on the other element or layer. That is, for example, intervening elements or layers may be present. In contrast, when an element or layer is referred to as being "directly formed on," to another element, there are no intervening elements or layers present. Other words used to describe the relationship between elements or layers should be interpreted in a like fashion (e.g., "between," versus "directly between," "adjacent," versus "directly adjacent," etc.).

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of exemplary embodiments. As used herein, the singular forms "a," "an," and "the," are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes," and/or "including," when used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

In the drawings, the thicknesses of layers and regions are exaggerated for clarity.

FIG. **1**A is a schematic plane view illustrating a cell **100** of an ultrasonic transducer, according to an exemplary embodiment. FIG. **1**B is a schematic cross-sectional view illustrating the cell **100** of the ultrasonic transducer of FIG. **1**A. FIG. **1**C illustrates the cell **100** including a thin film **50** that vibrates.

Referring to FIGS. **1**A and **1**B, the cell **100** may include substrate **10**, a supporting portion **40** disposed on the substrate **10**, the thin film **50** spaced apart from the substrate **10** and the supporting portion **40**, and a connection portion **70** for connecting the supporting portion **40** and the thin film **50**. As shown in FIG. **9**, the supporting portion **40** may be disposed directly on the substrate **10** or may be integrally formed with the substrate **10**. The cell **100** of the ultrasonic transducer may further include a first electrode **20** that is disposed on the substrate **10**, an insulating layer **30** that is disposed on the first electrode **20**, a second electrode **60** disposed on the thin film **50**, and a feeder **80** that is connected to the second electrode **60**. The cell **100** may be a cell of a cMUT. That is, the first electrode **20** and the second electrode **60** may form a capacitor.

The substrate **10** may be formed of a material such as silicon (Si) or glass. The substrate **10** may be a silicon on insulator (SOI) wafer, or the like. The supporting portion **40** may be disposed on the substrate **10**, and the supporting portion **40** may be integrally formed with the substrate **10**. For example, the supporting portion **40** may be formed on the substrate **10** by etching the substrate **10**.

The first electrode **20** may be formed on the substrate **10** and may be disposed on an area on the substrate **10** corresponding to the location of the thin film **50** or the second electrode **60**. The first electrode **20** may be formed of a conductive material, for example, Cu, Al, Au, Cr, Mo, Ti, Pt, or the like.

The insulating layer **30** may be disposed on the first electrode **20**, and may electrically insulate the first electrode **20** and the second electrode **60** from each other. Also, when the thin film **50** is formed of a conductive material, the insulating layer **30** may insulate the first electrode **20** and the conductive thin film **50** from each other.

The thin film **50** may be spaced apart from the substrate **10** and the supporting portion **40**. That is, the thin film **50** may be disposed in a recess **41** (see FIG. **8**B) formed by the substrate **10** and the supporting portion **40** so as to be spaced apart from the substrate **10** and the supporting portion **40**. The thin film **50** may be formed of, for example, Si, silicon-nitride (Si_xN_y), parylene, or the like. The thin film **50** may have a circular shape or a polygonal shape, but is not limited thereto. In addition, the thin film **50**, the substrate **10**, the supporting portion **40**, and the connection portion **70** may define a cavity **55**, which may be in a vacuum state.

The connection portion **70** may connect the supporting portion **40** and the thin film **50**, and may be formed of, for example, Si, Si_xN_y, parylene, or the like. The connection portion **70** may have the shape of a tube cut in half in the horizontal direction, and a cross-section of the connection portion **70** may be bridge-shaped. The connection portion **70** includes a thin film contact portion **71**, a support contact portion **73**, and a deformation portion **72**.

The thin film contact portion **71** may be connected to an upper surface of the thin film **50** and may extend upward from the thin film **50** in a direction perpendicular to the thin film **50**. The thin film contact portion **71** may be symmetrically disposed about the center C of the thin film **50**. That is, as shown in FIG. **1**B, a distance r_1 between one thin film contact portion **71** and the center C of the thin film **50** may be equal to a

distance r_2 between the other thin film contact portion **71** and the center C of the thin film **50**. The distances r_1 and r_2 may be equal to or less than a radius r of the thin film **50**, for example, may be a half of the radius r of the thin film **50** ($r_1=r_2=0.5r$). As shown in FIG. **1**A, the thin film may surround a circumference of the thin film **50**, so the thin film contact portion may form a circular wall extending upward from the thin film **50**. If the second electrode **60** is formed on the upper surface of the thin film **50**, the thin film contact portion **71** may be connected to an upper surface of the second electrode **60**, rather than to the thin film directly. The support contact portion **73** is connected to an upper surface of the supporting portion **40**, and may extend in a direction perpendicular to the supporting portion **40**.

The deformation portion **72** is disposed between the thin film contact portion **71** and the support contact portion **73** and is elastically deformable. The deformation portion **72** connects the thin film contact portion **71** and the support contact portion **73**, and may be parallel to the substrate **10** or the thin film **50** when in a neutral position as shown in FIG. **1**B. In addition, the deformation portion **72** may be formed of an elastic material or may be elastically deformable due to its thinness. The thin film **50** may vibrate in a direction perpendicular to the substrate **10** due to the elastic deformation of the deformation portion **72**. That is, the thin film **50** may move in a vertical direction, like a piston, with respect to the substrate **10**. Accordingly, in the cell **100** of the ultrasonic transducer, an average electrostatic force between the first electrode **20** and the second electrode **60** and an amount of change in the volume of the cavity **55** due to the vibration of the thin film **50** may be increased, as compared to that in a related art ultrasonic transducer. The increase in the average electrostatic force and the amount of change in the volume of the cavity **55** may improve the transmission output and the reception sensitivity of the cell **100** of the ultrasonic transducer.

The second electrode **60** may be disposed on the upper surface of the thin film **50** or on the lower surface of the thin film **50**. The second electrode **60** may be formed of a conductive material, for example, Cu, Al, Au, Cr, Mo, Ti, Pt, or the like. The feeder **80** may be disposed on the supporting portion **40** and the connection portion **70**, and may extend to the second electrode **60**. The feeder **80** transmits an electrical signal from an external power source V to the second electrode **60**. Also, the feeder **80** may transmit a variation in the electrical signal between the first and second electrodes **20** and **60** to an external element, for example, may transmit a variation in the electrical signal due to a change in the capacitance. According to this embodiment, the external power source V may generate a direct current (DC) voltage or an alternating current (AC) voltage. The thin film **50** may be formed of a conductive material such as a doped Si, and the second electrode **60** may be omitted. In this case, the first electrode **20** and the conductive thin film **50** may form a capacitor, and the feeder **80** may transmit an electrical signal to the conductive thin film **50** or may transmit a variation in the electrical signal due to a change in the capacitance between the first electrode **20** and the conductive thin film **50**.

Next, referring to FIG. **1**C, an operation of the cell **100** of the ultrasonic transducer will be described. First, an operation of the transmission properties of the cell **100** will be described. When a DC voltage (not shown) is applied to the first and second electrodes **20** and **60**, the thin film **50** may be disposed in a neutral position in which an electrostatic force between the first and second electrodes **20** and **60** is balanced by the force of gravity on the thin film **50**. When the DC voltage (not shown) is applied to the first and second electrodes **20** and **60**, and an AC voltage is also applied to the first and second electrodes **20** and **60**, the thin film **50** vibrates due to the resultant variation in the electrostatic force between the first and second electrodes **20** and **60**. The thin film **50** of the cell **100** of the ultrasonic transducer does not vibrate due to the elastic deformation of the thin film **50** alone, but vibrates due to the deformation of the deformation portion **72**. Since an edge of the thin film **50** is not directly fixed to the supporting portion **40**, the degree of freedom of the movement of the thin film **50** increases as compared to a cell in which edges of a thin film are directly fixed to the supporting portion **40**. Accordingly, the thin film **50** does not arch, but rather moves in a direction perpendicular to the substrate **10** so as to be remain parallel to the substrate **10** during vibration. That is, the thin film **50** may move in a vertical direction, like a piston, with respect to the substrate **10**. Accordingly, the amount of change in the volume of the cavity **55** of the cell **100** may be increased as compared with a transducer in which the thin film is directly attached to the supporting portion **40**.

In the cell **100** of the ultrasonic transducer according to this embodiment, when the thin film **50** vibrates, a distance d_1 between a center of the thin film **50** and the insulating layer **30** may remain equal to a distance d_2 between an outer portion of the thin film **50** and the insulating layer **30**. Accordingly, an electrostatic force between centers of the first and second electrodes **20** and **60** may remain equal to an electrostatic force between outer portions of the first and second electrodes **20** and **60**. That is, the electrostatic force between the first and second electrodes **20** and **60**, may be uniformly distributed. Accordingly, an average electrostatic force between the first and second electrodes **20** and **60** may be increased as compared to a cell in which the thin film is directly attached to the supporting portion, and therefore does not remain parallel to the substrate when vibrating. Thus, the amount of change in the volume of the cavity **55** of the cell **100** of the ultrasonic transducer according to the present embodiment and the average electrostatic force between the first and second electrodes **20** and **60** are increased, thereby improving the transmission output of the cell **100** of the ultrasonic transducer.

An operation of the reception properties of the cell **100** of the ultrasonic transducer according to the present embodiment is as follows. Similarly to the function of the cell **100** during transmission, during reception, when a DC voltage (not shown) is applied to the first and second electrodes **20** and **60**, the thin film **50** may be disposed in a neutral position in which the electrostatic force between the first and second electrodes **20** and **60** is balanced by the force of gravity on the thin film **50**. When the DC voltage (not shown) is being applied to the first and second electrodes **20** and **60**, and a physical signal, e.g., ultrasonic waves, is applied to the thin film **50** from an external source, a resultant movement of the thin film **50** causes the electrostatic force between the first and second electrodes **20** and **60** to change. The cell **100** may receive ultrasonic waves from the outside, and the ultrasonic waves may be sensed based on the change in the electrostatic force. As discussed above with respect to the function of the cell **100** during transmission, during reception, the thin film **50** of the cell **100** may move in a direction perpendicular to the substrate **10** so as to remain parallel to the substrate **10**. Thus, an amount of change in the volume of the cavity **55** of the cell **100** and the average electrostatic force between the first and second electrodes **20** and **60** are increased, thereby increasing the reception sensitivity of the cell **100** of the ultrasonic transducer.

FIGS. **2**A and **2**B schematically illustrate respective cross-sections of cells **1** and **5** of ultrasonic transducers, according to comparative examples. FIG. **2**C schematically illustrates a cross-section of a cell **100** of an ultrasonic transducer accord-

ing to an exemplary embodiment. The thickness of the thin film **50** in each of FIGS. **2**A, **2**B, and **2**C is the same, and the thickness of the portion of the thin film under the trench **55** in FIG. **2**B is half the thickness of the thin film **50** in other regions of the cell **5** of FIG. **2**B. The thickness of the connection portion **70** of the cell **100** in FIG. **2**C is half the thickness of the thin film **50**.

Referring to FIG. **2**A, in the cell **1** of the ultrasonic transducer according to the comparative example of FIG. **2**A, an edge of the thin film **50** is fixed to a supporting portion **40**, and thus the cell **1** has a clamped shape. Referring to FIG. **2**B, in the cell **5** of the ultrasonic transducer according to the comparative example of FIG. **2**B, an edge of the thin film **50** is also fixed to a supporting portion **40**, and thus the cell **5** has a clamped shape. The cell **5** of FIG. **2**B also includes a trench **55** formed at the edge of the thin film **50**. The trench **55** mitigates constraints on the movement of the thin film **50** of the cell **5** of the ultrasonic transducer. Simulations show that an amount of change in the volume of the cavity of the cell **5** of the ultrasonic transducer of FIG. **2**B is increased as compared to that of the cell **1** of the ultrasonic transducer of FIG. **2**A. Further, the average electrostatic force generated by the cell **5** of the ultrasonic transducer of FIG. **2**B is increased as compared to that of the cell **1** of the ultrasonic transducer of FIG. **2**A.

As shown in FIG. **2**C, in the cell **100** of an ultrasonic transducer according to an exemplary embodiment, the thin film **50** of the cell **100** is not directly fixed to the supporting portion **40**, but rather is fixed to the supporting portion **40** via the connection portion **70**. Accordingly, constraints on the movement of the thin film **50** may be further mitigated as compared to that of the thin films **50** of cells **1** and **5** according to the comparative examples of FIGS. **2**A and **2**B. The thin film **50** of FIG. **2**C may move in a vertical direction, like a piston, with respect to the substrate **10**. Simulations show that in the cell **100** of the ultrasonic transducer, of FIG. **2**C, the amount of change in the volume of the cavity and the average electrostatic force generated are further increased as compared to the cells **1** and **5** of the ultrasonic transducers as shown in FIGS. **2**A and **2**B. Accordingly, the cell **100** of the ultrasonic transducer according to an exemplary embodiment as shown in FIG. **2**C may have an increased transmission output and an increased reception sensitivity as compared to the cells **1** and **5** of the ultrasonic transducers as shown in FIGS. **2**A and **2**B.

FIG. **3** is a schematic cross-sectional view illustrating a cell **110** of an ultrasonic transducer, according to another exemplary embodiment. Hereinafter, differences between the cell **100** of FIG. **1**B and the cell **110** of FIG. **3** will be described.

Referring to FIG. **3**, the cell **110** may include a substrate **10**, a supporting portion **40** disposed on the substrate **10**, a thin film **50** spaced apart from the substrate **10** and the supporting portion **40**, and a connection portion **70***a* for connecting the supporting portion **40** and the thin film **50**. The cell **110** may further include a first electrode **20** disposed on the substrate **10**, an insulating layer **30** disposed on the first electrode **20**, and a second electrode **60** disposed on the thin film **50**.

The connection portion **70***a* may connect the supporting portion **40** and the thin film **50**, and may be formed of, for example, Si, Si_xN_y, parylene, or the like. The connection portion **70***a* may have the shape of a tube that is cut in half in a horizontal direction, and the cross-section of the connection portion **70***a* may be bridge-shaped. The connection portion **70***a* may include a thin film contact portion **71***a*, a support contact portion **73***a*, and a deformation portion **72***a*. The thin film contact portion **71***a* is connected to an upper surface of the thin film **50** or to an upper surface of the second electrode **60**, and extends in a direction perpendicular to the thin film **50**. Ends of the thin film contact portion **71***a* may be configured to increase contact areas between the ends of the thin film contact portion **71***a* and the thin film **50**. For example, the ends of the thin film contact portion **71***a* may be shaped such that the ends extend bilaterally. Accordingly, the thin film **50** may be firmly coupled to the thin film contact portion **71***a*. The support contact portion **73***a* may be connected to an upper surface of the supporting portion **40**, and may extend in a direction perpendicular to the supporting portion **40**. Also, the support contact portion **73***a* may be disposed over a wide area on the upper surface of the supporting portion **40** in order to withstand the weight applied to the connection portion **70***a*. Accordingly, the weight applied to the connection portion **70***a* may be distributed over a wide area of the supporting portion **40** via the support contact portion **73***a*.

FIG. **4** is a schematic cross-sectional view illustrating a cell **120** of an ultrasonic transducer, according to another exemplary embodiment. Hereinafter, differences between the cells **100** and **110** respectively of FIGS. **1**B and **3** and the cell **120** of FIG. **4** will be described.

Referring to FIG. **4**, the cell **120** may include a substrate **10**, a supporting portion **40** disposed on the substrate **10**, a thin film **50** spaced apart from the substrate **10** and the supporting portion **40**, and a connection portion **70***b* for connecting the supporting portion **40** and the thin film **50**. The cell **120** may further include a first electrode **20** disposed on the substrate **10**, an insulating layer **30** disposed on the first electrode **20**, and a second electrode **60** disposed on the thin film **50**.

The connection portion **70***b* may have the shape of a tube that is cut in half in a horizontal direction, and the cross-section of the connection portion **70***b* be arch-shaped, as illustrated in FIG. **4**. The arch-shaped connection portion **70***b* may include a thin film contact portion **71***b*, a support contact portion **73***b*, and a deformation portion **72***b*. The thin film contact portion **71***b* may be connected to an upper surface of the thin film **50** or to an upper surface of the second electrode **60**, and may have a curved-shape. Ends of the thin film contact portion **71***b* may be configured to increase contact areas between the ends of the thin film contact portion **71***b* and the thin film **50**. For example, the ends of the thin film contact portion **71***b* may extend bilaterally, similar to the thin film contact portion **71***a* of FIG. **3**. Accordingly, the thin film **50** may be firmly coupled to the thin film contact portion **71***b*.

The support contact portion **73***b* may be connected to an upper surface of the supporting portion **40**, and may have a curved-shape. Also, the support contact portion **73***b* may be disposed over a wide area on the upper surface of the supporting portion **40** in order to withstand the weight applied to the connection portion **70**, similar to the support contact portion **71***a* of FIG. **3**. Accordingly, the weight applied to the connection portion **70** may be distributed over a wide area of the supporting portion **40** via the support contact portion **73***b*. The deformation portion **72***b* may have a curved-shape connecting the thin film contact portion **71***b* and the support contact portion **73***b*, and may function as described above.

FIG. **5** is a schematic cross-sectional view illustrating a cell **130** of an ultrasonic transducer, according to another exemplary embodiment. Hereinafter, differences between the cells **100**, **110**, and **120** respectively of FIGS. **1**B, **3**, and **4** and the cell **130** of FIG. **5** will be described.

Referring to FIG. **5**, the cell **130** may include a substrate **10**, a supporting portion **45** disposed on the substrate **10**, a thin film **50** spaced apart from the substrate **10** and the supporting portion **45**, and a connection portion **70***c* for connecting the supporting portion **45** and the thin film **50**. The cell **130** may further include a first electrode **20** disposed on the substrate

10, an insulating layer **30** disposed on the first electrode **20**, and a second electrode **60** disposed under the thin film **50**.

The connection portion **70c** may connect the supporting portion **45** and the thin film **50**, and may be formed of, for example, Si, Si_xN_y, parylene, or the like. A cross-section of the connection portion **70c** may be L-shaped, as illustrated in FIG. **5**. The connection portion **70c** may include a thin film contact portion **71c**, a support contact portion **73c**, and a deformation portion **72c**. The thin film contact portion **71c** may be connected to an upper surface of the thin film **50** and may extend in a direction perpendicular to the thin film **50**. Ends of the thin film contact portion **71c** may be configured to increase contact areas between the ends of the thin film contact portion **71c** and the thin film **50**. For example, the ends of the thin film contact portion **71c** may extend bilaterally, similar to the thin film contact portion **71a** of FIG. **3**. Accordingly, the thin film **50** may be firmly coupled to the thin film contact portion **71c**.

The support contact portion **73c** may be connected to an upper surface of the supporting portion **45**, and may extend parallel to the upper surface of the supporting portion **45**. To enable this structure, the supporting portion **45** disposed above the substrate **10** may extend higher than the previously-described supporting portions **40** of FIGS. **1A-1C**, **3**, and **4**. The support contact portion **73c** may be formed over a wide area on the upper surface of the supporting portion **45** in order to withstand the weight applied to the connection portion **70** by the thin film **50**, as similarly described above with respect to the support contact portion **71a** of FIG. **3**. Accordingly, the weight applied to the connection portion **70** may be distributed over a wide area of the supporting portion **45** via the support contact portion **73c**. The deformation portion **72c** may connect the thin film contact portion **71c** extending in a direction perpendicular to the thin film **50** and the support contact portion **73c** extending parallel to the upper surface of the supporting portion **45**. The function of the deformation portion **72c** is as described above.

FIG. **6**A is a schematic plane view illustrating a cell **200** of an ultrasonic transducer, according to another exemplary embodiment. FIG. **6**B is a schematic cross-sectional view taken along a line B-B' of FIG. **6**A. Hereinafter, differences between the above-described cells **100**, **110**, **120**, and **130** and the cell **200** respectively of FIGS. **6**A and **6**B will be described.

Referring to FIGS. **6**A and **6**B, the cell **200** may include a substrate **10**, a supporting portion **40** disposed on the substrate **10**, a thin film **50** spaced apart from the substrate **10** and the supporting portion **40**, and a connection portion **70** for connecting the supporting portion **40** and the thin film **50**. The cell **200** may further include a first electrode **25** disposed on the connection portion **70**, a piezoelectric layer **90** disposed on the first electrode **25**, and a second electrode **65** disposed on the piezoelectric layer **90**. According to this embodiment, the cell **200** may be a cell of a pMUT. That is, the first electrode **25** and the second electrode **65** may form a piezoelectric capacitor.

The first electrode **25** may be disposed on the deformation portion **72** of the connection portion **70**. The second electrode **65** may be disposed on the piezoelectric layer **90**. The first and second electrodes **25** and **65** may be formed of a conductive material, for example, Cu, Al, Au, Cr, Mo, Ti, Pt, or the like. An electrical signal, for example, an AC voltage, may be transmitted from an external power source V to the first and second electrodes **25** and **65**.

The piezoelectric layer **90** may be disposed on the first electrode **25**, and may be formed of a piezoelectric material, for example, ZnO, AlN, lead zirconate titanate (PZT), $PbTiO_3$, La-modified $PbTiO_3$ (PLT), or the like.

When the cell **200** of the ultrasonic transducer transmits a physical signal, the piezoelectric layer **90** expands or contract in a plane direction. That is, the piezoelectric layer **90** expands or contracts in a direction parallel to the substrate **10** based on an electrical signal applied to the electrodes by an external element. An expansion force and a contraction force of the piezoelectric layer **90** causes the deformation portion **72** disposed below the piezoelectric layer **90** to be elastically deformed. When the deformation portion **72** is deformed, the thin film **50** vibrates in a direction perpendicular to the substrate **10**. Accordingly, a physical signal, for example, ultrasonic waves, may be output from the cell **200** of the ultrasonic transducer.

When the cell **200** of the ultrasonic transducer according to the current embodiment receives a physical signal, the physical signal, for example, ultrasonic waves, applied by an external force may cause the thin film **50** to vibrate. When the thin film **50** vibrates, the deformation portion **72** is deformed causing the piezoelectric layer **90**, disposed above the deformation portion **72**, to expand or contract due to the elastic deformation of the deformation portion **72**. Accordingly, the piezoelectric layer **90** may expand or contract due to an external force, and thus may generate an electrical signal due to the piezoelectric effect.

In the cell **200** of the ultrasonic transducer according to the current embodiment, the thin film **50** vibrates in a vertical direction, like a piston, with respect to the substrate **10**, thereby increasing an amount of change in the volume of the cavity of the cell **200**. The increase in the amount of change in a volume of the cavity may improve a transmission output and a reception sensitivity of the cell **200** of the ultrasonic transducer.

FIG. **7** is a schematic cross-sectional view illustrating a cell **210** of an ultrasonic transducer, according to another exemplary embodiment. Hereinafter, differences between the above-described cells **100**, **110**, **120**, **130**, and **200** and the cell **210** of FIG. **7** will be described.

Referring to FIG. **7**, the cell **210** may include a substrate **10**, a supporting portion **45** disposed on the substrate **10**, a thin film **50** spaced apart from the substrate **10** and the supporting portion **45**, and a connection portion **70c** for connecting the supporting portion **45** and the thin film **50**. The cell **210** may further include a first electrode **25** disposed on the connection portion **70c**, a piezoelectric layer **90** disposed on the first electrode **25**, and a second electrode **65** disposed on the piezoelectric layer **90**.

The connection portion **70c** may connect the supporting portion **45** and the thin film **50**, and may be formed of, for example, Si, Si_xN_y, parylene, or the like. A cross-section of the connection portion **70c** may be L-shaped, as illustrated in FIG. **7**. The connection portion **70c** may include a thin film contact portion **71c**, a support contact portion **73c**, and a deformation portion **72c**. The thin film contact portion **71c** is connected to an upper surface of the thin film **50**, and extends in a direction perpendicular to the thin film **50**. Ends of the thin film contact portion **71c** may be configured to increase contact areas between the ends of the thin film contact portion **71c** and the thin film **50**. For example, the ends of the thin film contact portion **71c** may extend bilaterally, similarly to the ends of the thin film contact portion **71a** of FIG. **3**. Accordingly, the thin film **50** may be firmly coupled to the thin film contact portion **71c**.

The support contact portion **73c** may be connected to an upper surface of the supporting portion **45**, and may extend to be parallel to the upper surface of the supporting portion **45**.

According to this embodiment, the supporting portion **45** disposed above the substrate **10** may extend higher than the previously-described supporting portions **40** of FIGS. **1**A-**1**C, **3**, and **4**. The support contact portion **73***c* may be formed over a wide area on the upper surface of the supporting portion **45** in order to withstand the weight applied to the connection portion **70***c* by the thin film **50**, as similarly described above with respect to the support contact portion **71***a* of FIG. **3**. Accordingly, any weight applied to the connection portion **70***c* may be evenly distributed over a wide area of the supporting portion **45** via the support contact portion **73***c*. The deformation portion **72***c* may connect the thin film contact portion **71***c*, extending in a direction perpendicular to the thin film **50**, and the support contact portion **73***c* extending parallel to the upper surface of the supporting portion **45**. The a function of the deformation portion **72***c* is as described above.

Hereinafter, a channel of an ultrasonic transducer including a plurality of cells will be described in detail.

FIG. **8**A is a schematic plane view illustrating a channel **300** of an ultrasonic transducer, according to an exemplary embodiment. FIG. **8**B is a schematic cross-sectional view taken along a line C-C' of FIG. **8**A.

Referring to FIGS. **8**A and **8**B, the channel **300** includes a plurality of cells as described above. The cells **100** may be arranged in an m×n array, wherein m and n are natural numbers greater than 1. In FIG. **8**A, the cells **100** are arranged in a 3×3 array. The cells **100** of the channel **300** may include one or more cells as described above with respect to cells **110**, **120**, **130**, **200**, and **210**.

The channel **300** may include a substrate **10** in which recesses **41** are formed. In FIG. **8**B, one of the recesses **41** is schematically shown surrounded by a dashed line **42**, for illustrative purposes. A plurality of thin films **50** is disposed spaced apart from a bottom of each of the recesses **41**, and a plurality of connection portions **70** each connecting one of the plurality of thin films **50** to a supporting portion **40** is formed around the corresponding recess **41**. The channel **300** may further include a first electrode **20** disposed on the substrate **10** and an insulating layer **30** disposed on the first electrode **20**. Each of the cells **100** may further include a second electrode **60** disposed on the thin film **50** and a feeder (not shown) connected to the second electrode **60**. Each of the plurality of thin films **50**, forms a cavity **55** in conjunction with a connection portion **70**, the substrate **10**, and the supporting portion **40**. The channel **300** of the ultrasonic transducer according to the current embodiment may be a channel of a cMUT. That is, the first electrode **20** and the second electrode **60** may form a capacitor.

In the channel **300** of the ultrasonic transducer according to the current embodiment, the thin film **50** of each of the cells of the channel **300** may move in a direction perpendicular to the substrate **10**, and thus an average electrostatic force and an amount of change in a volume of the cavity of each of the cells **100** (see FIG. **8**B) of the ultrasonic transducer may be increased. Accordingly, a transmission output and a reception sensitivity of the channel **300** may be improved.

Alternately, instead of the first and second electrodes **20** and **60**, as illustrated in FIG. **6**B, one or more cells of the channel **300** may include a first electrode **25** disposed on the connection portion **70**, a piezoelectric layer **90** disposed on the first electrode **25**, and a second electrode **65** disposed on the piezoelectric layer **90**, as described above with respect to FIG. **6**B or **7**. Thus, the channel **300** of the ultrasonic transducer may be a channel of a pMUT. That is, the first electrode **25** and the second electrode **65** may form a piezoelectric capacitor.

An ultrasonic transducer (not shown) according to an exemplary embodiment may include a plurality of the channels **300**. A plurality of channels **300**, as shown in FIG. **8**B, may be arranged in an m×n array, wherein m and n are natural numbers greater than 1. As described above, the thin films **50** of the ultrasonic transducer may move in a direction perpendicular to the substrate **10**, and thus an average electrostatic force and an amount of change in a volume of the cavities of the cells **100** may be increased, thereby improving a transmission output and a reception sensitivity of the ultrasonic transducer.

While exemplary embodiments have been particularly shown and described, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the inventive concept as defined by the following claims.

What is claimed is:

1. A cell of an ultrasonic transducer, the cell comprising:
- a substrate;
- a supporting portion disposed on the substrate;
- a thin film spaced apart from the substrate and the supporting portion; and
- a connection portion which connects the supporting portion to the thin film,
- wherein the thin film extends underneath the connection portion toward the supporting portion so that an edge portion of the thin film is disposed beyond a contact point of the thin film and the connection portion.

2. The cell of claim **1**, wherein the connection portion comprises:
- a support contact portion connected to the supporting portion,
- a thin film contact portion connected to the thin film at the contact point, and
- a deformation portion which connects the support contact portion and the thin film contact portion and which is elastically deformable.

3. The cell of claim **2**, wherein an elastic deformation of the deformation portion causes the thin film to move in a direction perpendicular to the substrate.

4. The cell of claim **1**, further comprising a first electrode disposed on the substrate.

5. The cell of claim **4**, further comprising an insulating layer disposed on the first electrode.

6. The cell of claim **1**, further comprising a second electrode disposed on the thin film.

7. The cell of claim **6**, further comprising a feeder which is disposed on the connection portion and which is electrically connected to the second electrode.

8. The cell of claim **1**, wherein the thin film comprises a conductive thin film.

9. The cell of claim **1**, further comprising a piezoelectric layer disposed on the connection portion.

10. The cell of claim **9**, further comprising a first electrode disposed under the piezoelectric layer and a second electrode disposed on the piezoelectric layer.

11. The cell of claim **1**, further comprising a cavity defined by the substrate, the supporting portion, the thin film, and the connection portion.

12. A channel of an ultrasonic transducer, the channel comprising:
- a plurality of the cells of claim **1**,
- wherein the plurality of cells are arranged in an m x n array, wherein m and n are natural numbers greater than 1.

13. The cell of claim **1**, wherein the edge portion of the thin film comprises an edge which is disposed in a cavity underneath the connection portion and proximate the supporting portion.

14. A channel of an ultrasonic transducer, the channel comprising:

a substrate comprising recesses and supporting portions;

a plurality of thin films spaced apart from a bottom of each of the recesses; and

a plurality of connection portions, wherein each of the connection portions connects one of the thin films to a corresponding supporting portion,

wherein each of the plurality of thin films extends underneath a corresponding connection portion toward the corresponding supporting portion so that an edge portion of the thin film is disposed beyond a contact point of the thin film and the corresponding connection portion.

15. The channel of claim **14**, wherein each of the connection portions comprises:

a support contact portion connected to the supporting portion,

a thin film contact portion connected to the thin film at the contact point, and

a deformation portion which connects the support contact portion and the thin film contact portion and which is elastically deformable.

16. The channel of claim **15**, wherein an elastic deformation of the deformation portion causes the thin film to move in a direction perpendicular to the substrate.

17. The channel of claim **14**, further comprising a plurality of first electrodes, wherein each of the first electrodes is disposed in the bottom of one of the recesses.

18. The channel of claim **17**, further comprising an insulating layer disposed on each of the first electrodes.

19. The channel of claim **14**, further comprising a plurality of second electrodes,

wherein each of the second electrodes is disposed on one of the thin films.

20. The channel of claim **19**, further comprising a plurality of feeders,

wherein each of the feeders is disposed on one of the connection portions and is electrically connected to one of the second electrodes.

21. The channel of claim **14**, wherein at least one of the plurality of thin films comprises a conductive thin film.

22. The channel of claim **14**, further comprising a plurality of piezoelectric layers,

wherein each of the piezoelectric layers is disposed on one of the connection portions.

23. The channel of claim **22**, further comprising a plurality of first electrodes and a plurality of second electrodes,

wherein each of the first electrodes is disposed under the piezoelectric layers and each of the second electrodes is disposed on one of the piezoelectric layers.

24. The channel of claim **14**, further comprising a plurality of cavities, each of the cavities formed in the recess and defined by the substrate, one of the supporting portions, one of the thin films, and one of the connection portions.

25. An ultrasonic transducer comprising a plurality of the channels of claim **14**, wherein the channels are arranged in an m×n array, where m and n are natural numbers greater than 1.

* * * * *

patsnap

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摘要(译)

提供了一种超声换能器的单元。电池包括基板;支撑部分设置在基板上;与基板和支撑部分间隔开的薄膜;连接部分连接支撑部分和薄膜。连接部分可包括可弹性变形的变形部分。超声换能器的通道包括以阵列布置的多个单元。超声换能器包括以阵列布置的多个通道。