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(54) **ULTRASONIC PROBE AND METHOD OF MANUFACTURING THE SAME**

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(57) **ABSTRACT**

Provided are an ultrasonic probe and a method of manufacturing the same. The method includes: forming a plurality of grooves by removing regions of a first insulating layer and a first silicon wafer from a first substrate including the first silicon wafer and the first insulating layer; bonding a second substrate including a second silicon wafer, a second insulating layer, and a silicon thin layer to the first substrate, such that the plurality of grooves turn into a plurality of cavities; removing the second silicon wafer from the second substrate; forming transducer cells on regions of the second insulating layer corresponding to the plurality of cavities; and forming a plurality of unit substrates by cutting the first substrate, the silicon thin layer, and the second insulating layer.

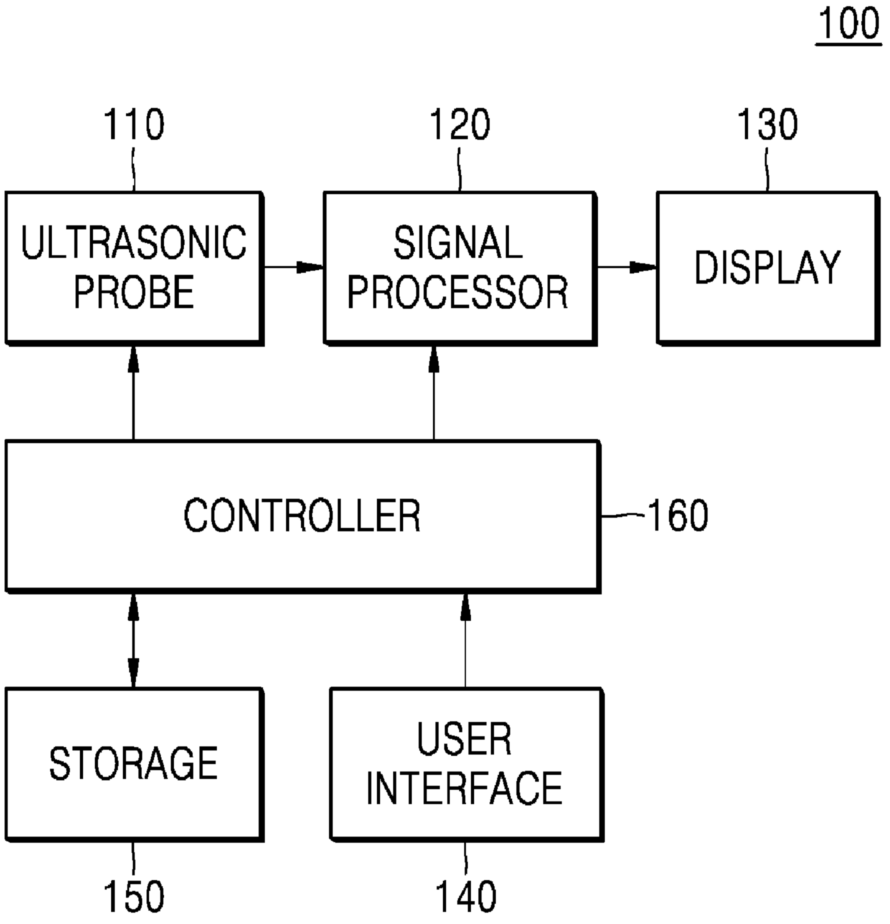


FIG. 1

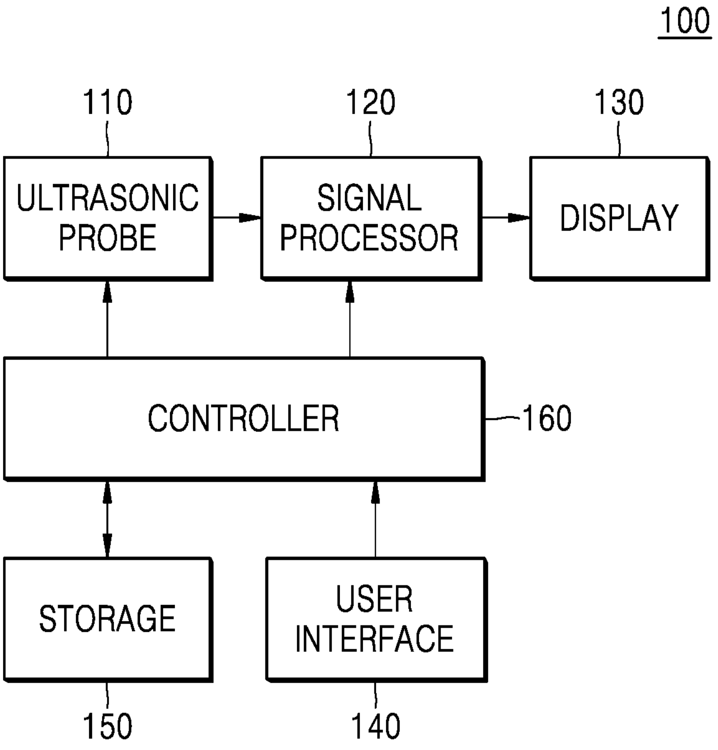

100
110
120
130
ULTRASONIC PROBE
SIGNAL PROCESSOR
DISPLAY
CONTROLLER
160
STORAGE
USER INTERFACE
150
140

FIG. 2

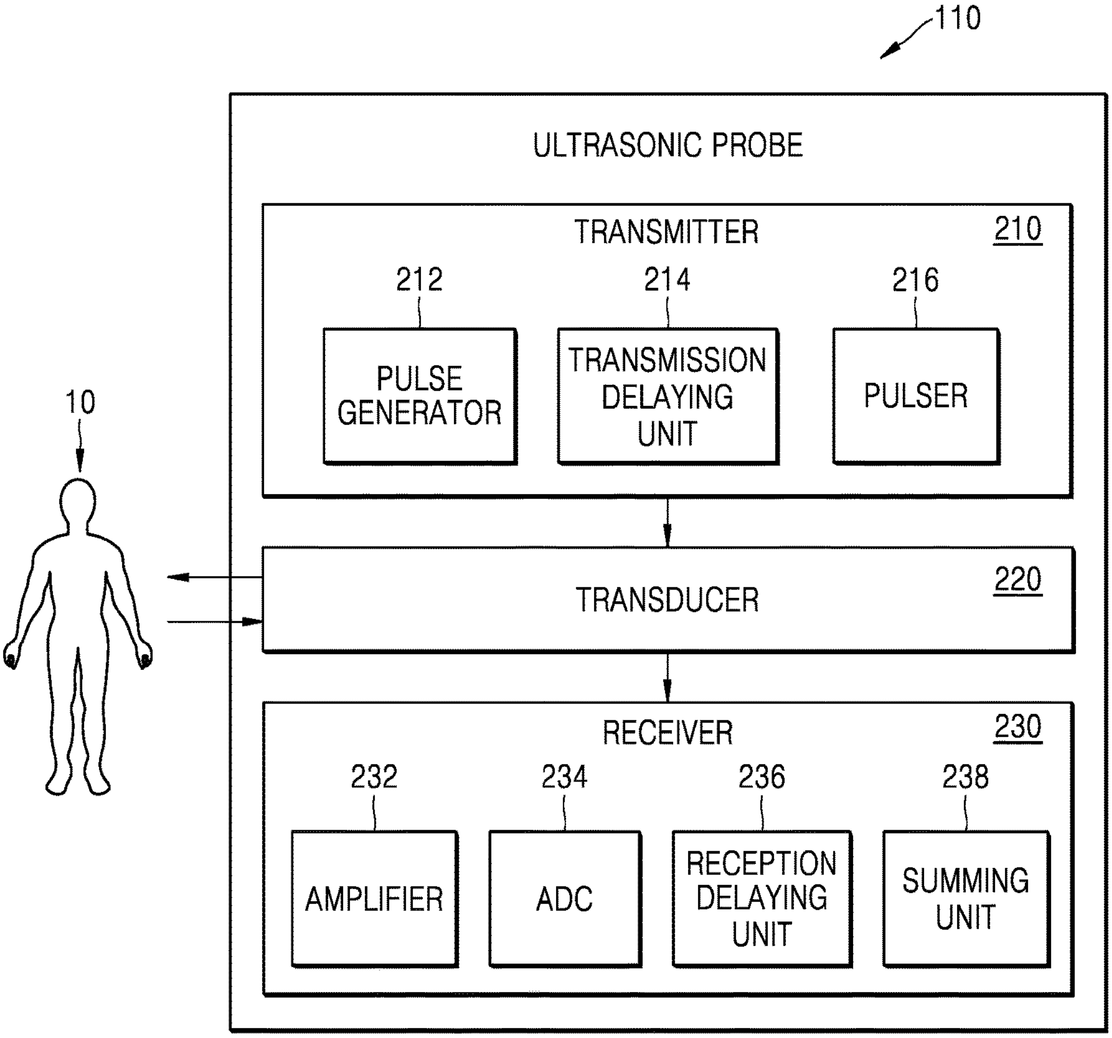

110
ULTRASONIC PROBE
TRANSMITTER
210
212
214
216
PULSE GENERATOR
TRANSMISSION DELAYING UNIT
PULSER
10
TRANSDUCER
220
RECEIVER
230
232
234
236
238
AMPLIFIER
ADC
RECEPTION DELAYING UNIT
SUMMING UNIT

FIG. 3

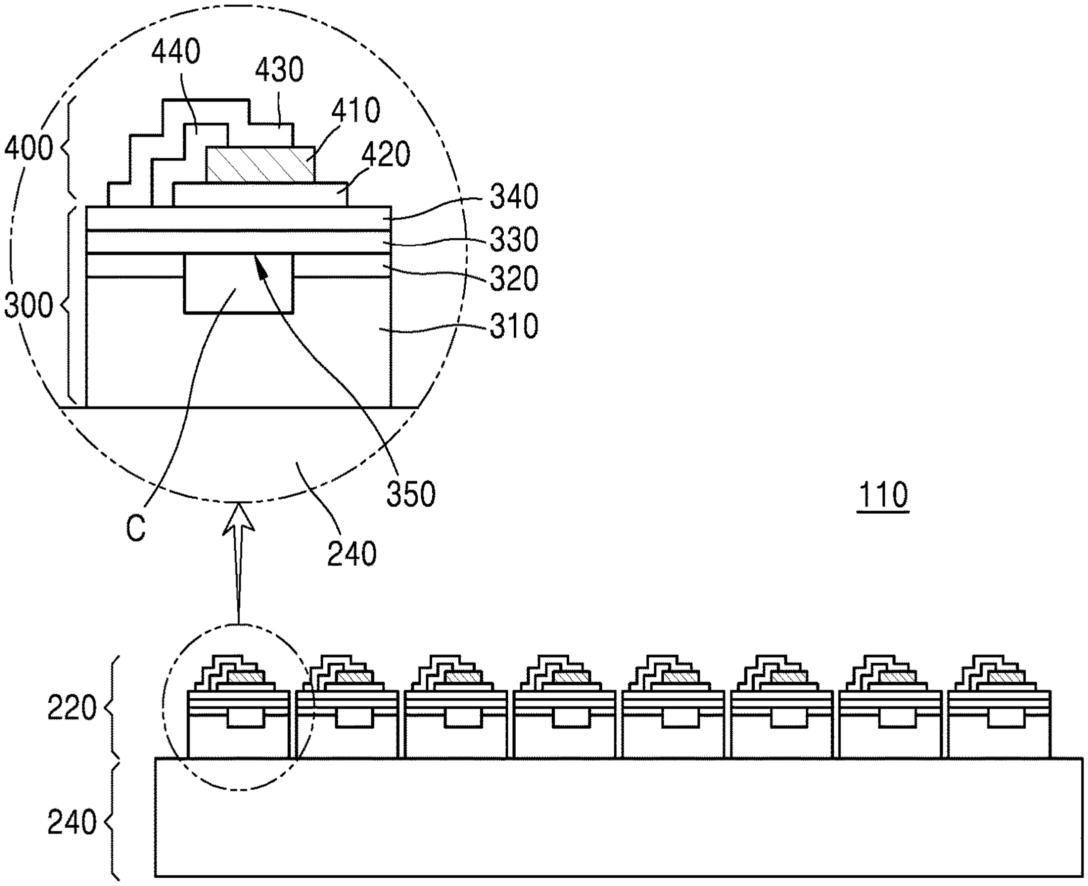


FIG. 4A

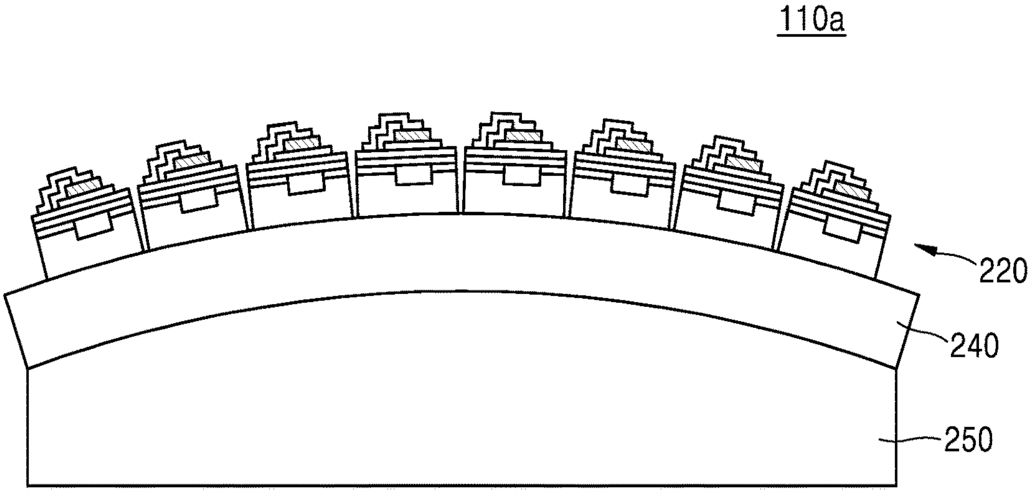


FIG. 4B

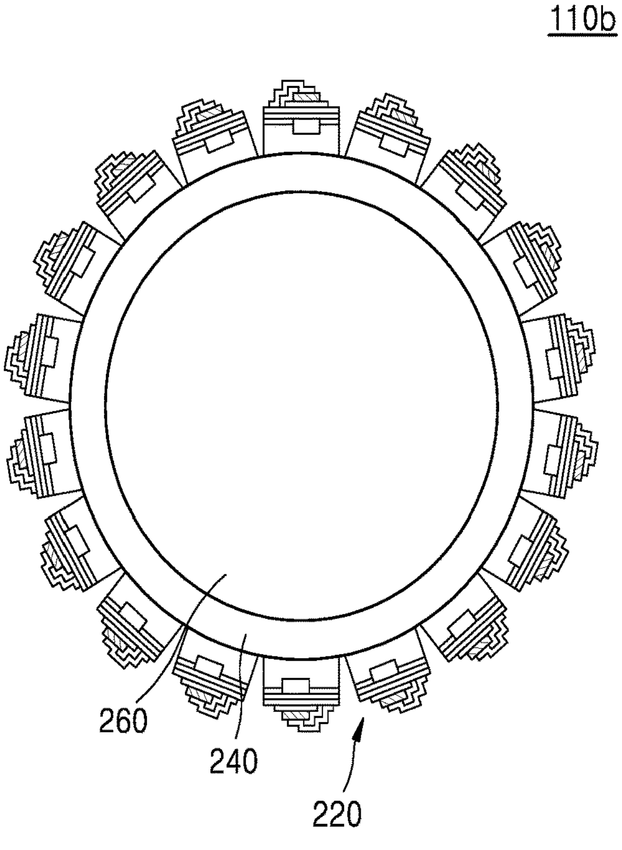


FIG. 5

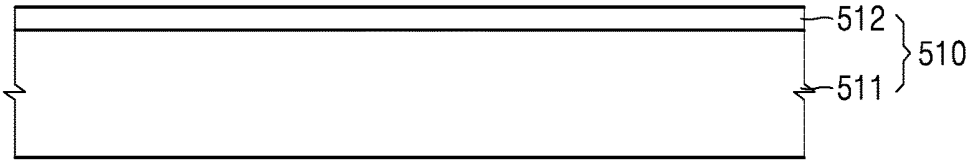


FIG. 6

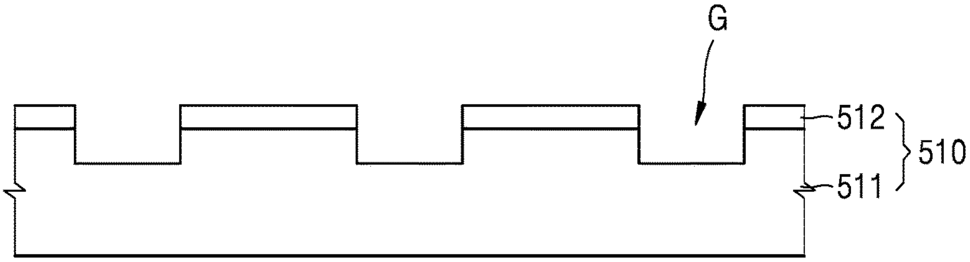


FIG. 7

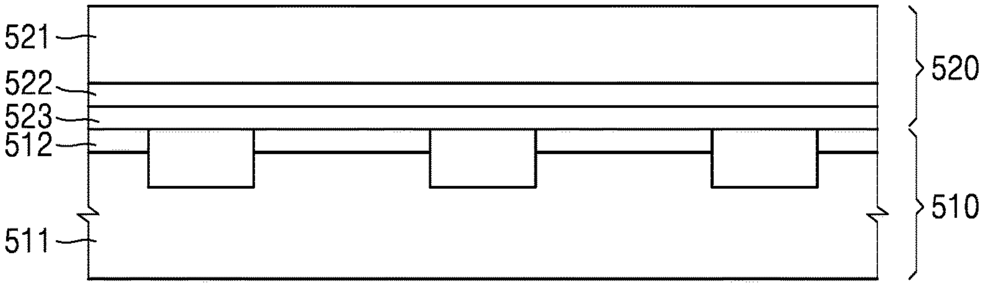


FIG. 8

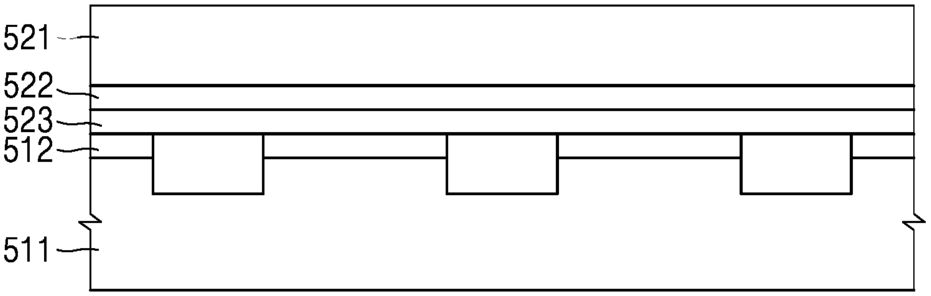


FIG. 9

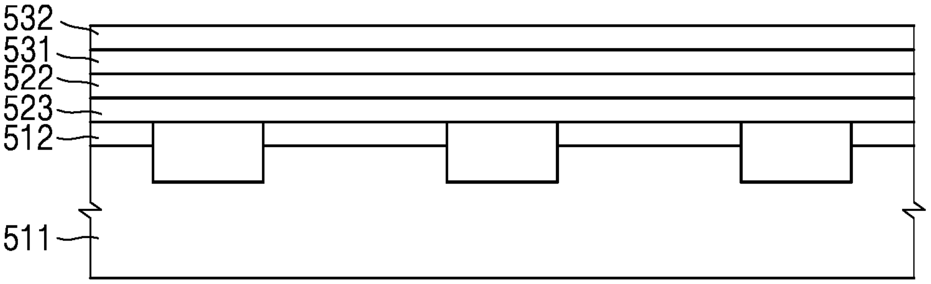


FIG. 10

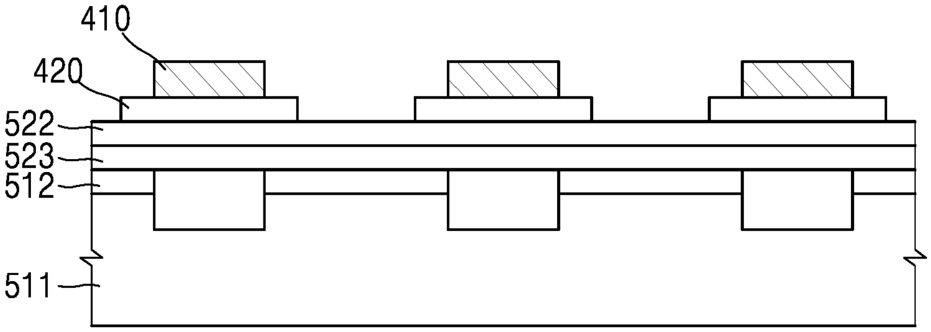


FIG. 11

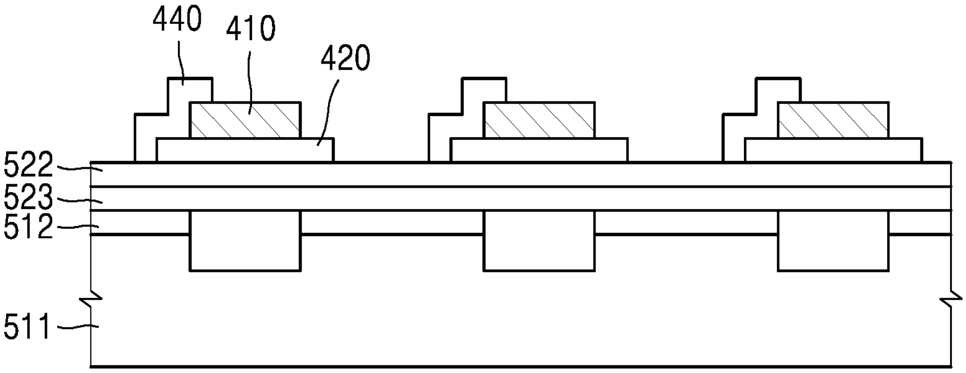


FIG. 12

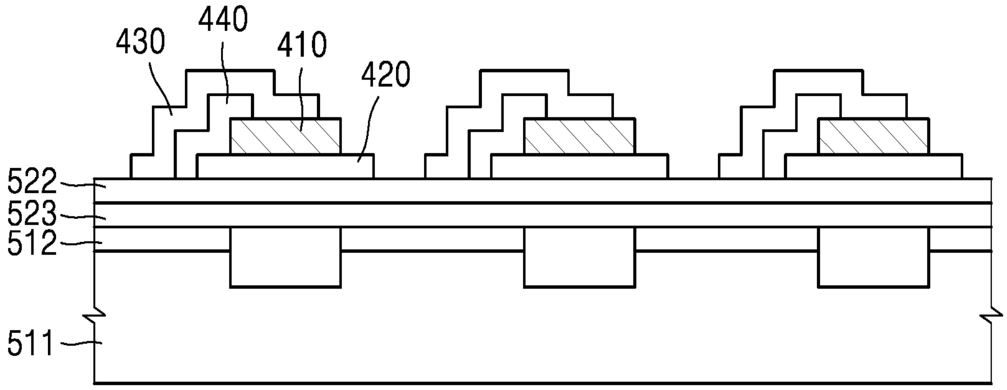


FIG. 13

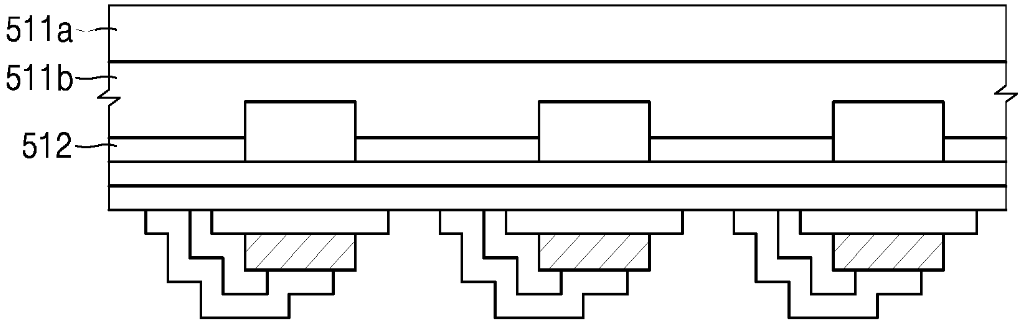


FIG. 14

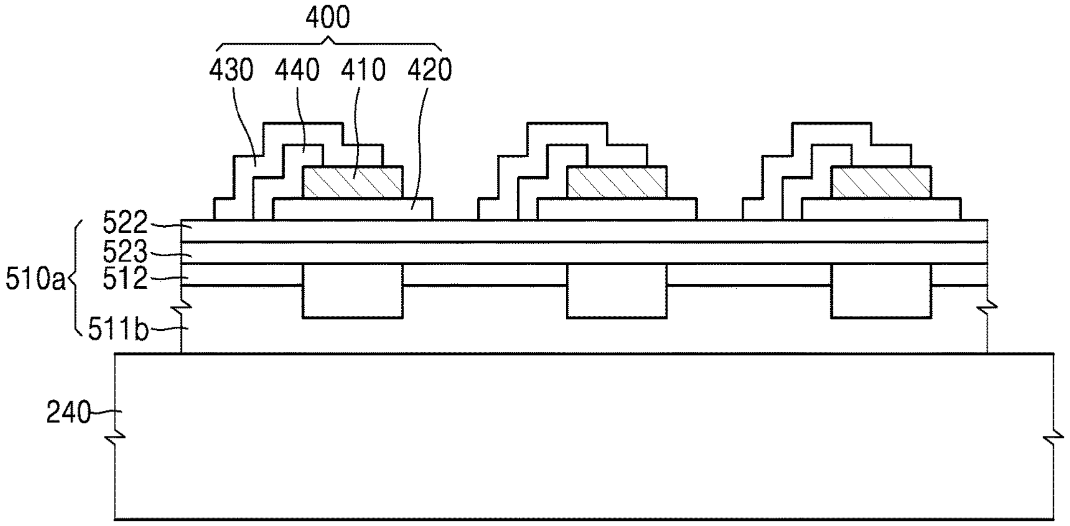
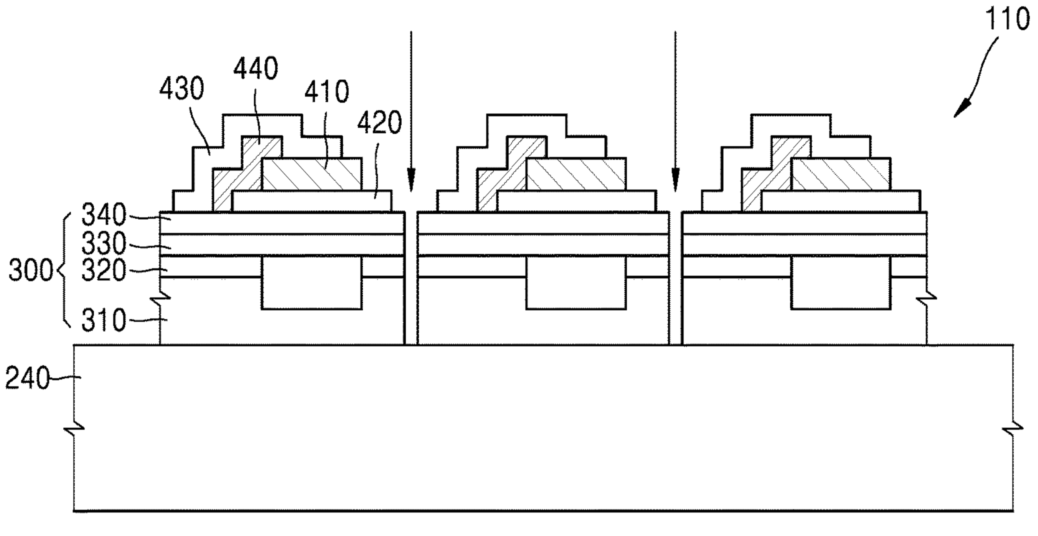

400
430
440
410
420
522
523
510a
512
511b
240

FIG. 15


110
430
440
410
420
340
330
300
320
310
240

ULTRASONIC PROBE AND METHOD OF MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Korean Patent Application No. 10-2017-0004166, filed on Jan. 11, 2017, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

[0002] The present disclosure relates to ultrasonic probes and methods of manufacturing the same.

2. Description of the Related Art

[0003] Generally, an ultrasonic diagnostic apparatus transmits ultrasound waves to an object, such as a person or an animal, displays an image of a cross-section of tissue in the object by detecting echo signals reflected from the object, and provides information necessary for diagnosing a disease of the object. The ultrasonic diagnostic apparatus includes an ultrasonic probe for transmitting ultrasound waves to and receiving echo signals from the object.

[0004] An ultrasonic probe may include transducers that convert electrical signals into ultrasound signals or vice versa. Micromachined ultrasonic transducers (MUTs) that are an example of ultrasonic transducers may be classified into piezoelectric MUTs (pMUTs), capacitive MUTs (cMUTs), and magnetic MUTs (mMUTs) according to the conversion methods they use.

SUMMARY

[0005] Provided are ultrasonic probes and methods of manufacturing the same, capable of realizing various probe shapes.

[0006] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

[0007] According to an aspect of an embodiment, a method of manufacturing an ultrasonic probe includes: forming a plurality of grooves by removing regions of a first insulating layer and a first silicon wafer from a first substrate including the first silicon wafer and the first insulating layer; bonding a second substrate including a second silicon wafer, a second insulating layer, and a silicon thin layer to the first substrate, such that the plurality of grooves turn into a plurality of cavities; removing the second silicon wafer from the second substrate; forming transducer cells on regions of the second insulating layer corresponding to the plurality of cavities; and forming a plurality of unit substrates by cutting the first substrate, the silicon thin layer, and the second insulating layer.

[0008] The method may further include reducing a thickness of the first silicon wafer by removing a part of the first silicon wafer.

[0009] The first silicon wafer may have a thickness of 30 to 150 μm after removing the part of the first silicon wafer.

[0010] The forming of the transducer cells may include: sequentially forming an electrically conductive material and a piezoelectric material on the second insulating layer; forming a first electrode and a piezoelectric layer by respectively patterning the electrically conductive material and the piezoelectric material; and forming a second electrode on the piezoelectric layer.

[0011] The piezoelectric layer may have a thickness of less than or equal to 10 μm.

[0012] Before forming the second electrode, the method may further include forming a third insulating layer covering the piezoelectric layer and the first electrode.

[0013] The plurality of unit substrates may be formed by deep reactive ion etching.

[0014] The forming of the plurality of unit substrates may include forming the plurality of unit substrates so that one or more transducer cells are provided for each of the plurality of unit substrates.

[0015] The forming of the plurality of unit substrates may include forming the plurality of unit substrates by removing regions of the first substrate, the silicon thin layer, and the second insulating layer that do not overlap the transducer cells.

[0016] The method may further include bonding the first substrate to a circuit substrate before forming the plurality of unit substrates.

[0017] The circuit substrate may be flexible.

[0018] The method may further include bonding the circuit substrate to a curved frame.

[0019] The frame may have a spherical shape.

[0020] According to an aspect of another embodiment, an ultrasonic probe includes: a plurality of unit substrates, each including a cavity formed therein and a silicon on insulator (SOI) structure; and a plurality of transducer cells arranged on the plurality of unit substrates and each including a piezoelectric layer.

[0021] The SOI structure may include a silicon wafer, a first insulating layer, and a silicon thin layer, and the silicon wafer of the SOI structure may have a thickness of 30 to 150 μm.

[0022] The cavity may be formed by a groove in the silicon wafer and an opening in the first insulating layer.

[0023] Each of the plurality of transducer cells may further include first and second electrodes separated from each other so that the piezoelectric layer is interposed therebetween.

[0024] The piezoelectric layer may have a thickness of less than or equal to 10 μm.

[0025] The ultrasonic probe may further include a circuit substrate provided on a bottom surface of the plurality of unit substrates.

[0026] The circuit substrate may be flexible.

[0027] The ultrasonic probe may further include a curved support member provided on a bottom surface of the circuit substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings in which:

[0029] FIG. **1** is a block diagram of an ultrasonic diagnostic apparatus according to an embodiment;

[0030] FIG. **2** is a block diagram of an ultrasonic probe included in the ultrasonic diagnostic apparatus of FIG. **1**;

[0031] FIG. **3** is a schematic diagram of a physical configuration of the ultrasonic probe of FIG. **1**;

[0032] FIGS. **4**A and **4**B illustrate curved ultrasonic probes according to embodiments; and

[0033] FIGS. **5** through **15** are reference diagrams for explaining a method of manufacturing an ultrasonic probe, according to an embodiment.

DETAILED DESCRIPTION

[0034] Exemplary embodiments will be described more fully hereinafter with reference to the accompanying drawings, in which the same or corresponding elements are denoted by the same reference numerals. Descriptions of the same or corresponding elements will not be repeated below.

[0035] It will be understood that the terms “comprises,” “comprising,” “includes” and/or “including,” if used herein, should not be construed as necessarily including various elements, components, steps, and/or operations stated in the specification, and do not preclude the exclusion of some of the stated elements, components, steps, and/or operations or addition of one or more other elements, components, steps and/or operations.

[0036] It will also be understood that when a layer or element is referred to as being “on” another layer or substrate, it can be directly on/beneath/on the left side of/on the right side of the other layer or substrate, or intervening layers may also be present therebetween. Accordingly, the embodiments are merely described below, by referring to the figures, to explain aspects.

[0037] It will be understood that, although the terms “first”, “second”, etc. may be used herein to describe various elements and/or components, these elements and/or components should not be limited by these terms. These terms are only used to distinguish one element or component from another element or component. Expressions such as “at least one of,” when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0038] In the present specification, an “object” may include a person or an animal, or a part of a person or an animal. For example, the object may include an organ such as the liver, the heart, the womb, the brain, a breast or the abdomen, or a blood vessel. Furthermore, a “user” refers to a medical professional, such as a doctor, a nurse, a medical laboratory technologist, an medical imaging expert, and an engineer who repairs a medical apparatus, but the user is not limited thereto.

[0039] FIG. **1** is a block diagram of an ultrasonic diagnostic apparatus **100** according to an embodiment. Referring to FIG. **1**, the ultrasonic diagnostic apparatus **100** includes an ultrasonic probe **110** for transmitting or receiving ultrasound waves, a signal processor **120** for processing a signal applied by the ultrasonic probe **110** to thereby generate an image, a display **130** for displaying an image, a user interface **140** for receiving a user command, a storage **150** for storing various types of information, and a controller **160** for controlling all operations of the ultrasonic diagnostic apparatus **100**.

[0040] The ultrasonic probe **110** transmits ultrasound waves to an object and receives echo signals corresponding to the ultrasound waves reflected from the object, as described in more detail below.

[0041] The signal processor **120** may process ultrasound data generated by the ultrasonic probe **110** to generate an ultrasound image. An ultrasound image may be at least one of a brightness (B) mode image representing a magnitude of an ultrasound echo signal reflected from an object as brightness, a Doppler (D) mode image showing an image of a moving object in the form of a spectrum by using a Doppler effect, a motion (M) mode image representing movement of an object at a specific position over time, an elastic mode image visualizing a difference between responses when compression is or is not applied to an object as an image, and a color (C) mode image representing a velocity of a moving object in colors by using a Doppler effect. Since an ultrasound image is generated by using currently available methods of generating an ultrasound image, a detailed description thereof will be omitted here. Accordingly, an ultrasound image according to an embodiment may include any of images taken in dimensional modes, such as a one-dimensional (1D) mode, a two-dimensional (2D) mode, a three-dimensional (3D) mode, and a four-dimensional (4D) mode.

[0042] The display **130** displays information processed by the ultrasonic diagnostic apparatus **100**. For example, the display **130** may display an ultrasound image generated by the signal processor **120** as well as a graphical user interface (GUI) for requesting a user input.

[0043] The display **230** may include at least one of a liquid crystal display (LCD), a thin film transistor-LCD (TFT-LCD), an organic light-emitting diode (OLED), a flexible display, a 3D display, and an electrophoretic display. The ultrasonic diagnostic apparatus **100** may include two or more displays **130** according to its implementation configuration.

[0044] The user interface **140** refers to a means via which a user inputs data for controlling the ultrasonic diagnostic apparatus **100**. The user interface **140** may include a keypad, a mouse, a touch panel, a track ball, etc. The user interface **140** is not limited thereto, and may further include various other input elements such as a jog wheel and a jog switch.

[0045] The touch panel may detect both a real touch where a pointer actually touches a screen and a proximity touch where the pointer approaches the screen while being separated from the screen by less than a predetermined distance. In the present specification, the term ‘pointer’ means a tool for touching a particular portion on or near the touch panel. Examples of the pointer may include a stylus pen and a body part such as a finger.

[0046] Furthermore, the touch panel may be formed as a touch screen that forms a layer structure with the display **130**. The touch screen may be implemented as various types such as capacitive overlay, resistive overlay, infrared beam, surface acoustic wave, integral strain gauge, and piezoelectric touch screens. The touch screen is very useful because it functions as both the display **130** and the user interface **140**.

[0047] Although not shown in FIG. **1**, various sensors may be disposed within or near the touch panel so as to sense a touch. A tactile sensor is an example of the sensors designed for the touch panel to sense a touch. The tactile sensor is used to sense a touch of a particular object to a same or greater degree than the degree to which a human can sense the touch. The tactile sensor may detect various pieces of information including the toughness of a contact surface, the hardness of an object to be touched, and the temperature of a point to be touched.

[0048] A proximity sensor is another example of the sensors designed for the touch panel to sense a touch. The proximity sensor is a sensor that detects the presence of an object that is approaching or is located near a predetermined detection surface by using the force of an electromagnetic field or infrared light without any mechanical contact. Examples of the proximity sensor include a transmissive photoelectric sensor, a direct reflective photoelectric sensor, a mirror reflective photoelectric sensor, a high-frequency oscillation proximity sensor, a capacitive proximity sensor, a magnetic proximity sensor, and an infrared proximity sensor.

[0049] The storage **150** stores various types of information that are processed by the ultrasonic diagnostic apparatus **100**. For example, the storage **150** may store medical data related to diagnosis of the object, such as images, and algorithms or programs that are executed in the ultrasonic diagnostic apparatus **100**.

[0050] The storage **150** may include at least one storage medium from among a flash memory-type storage medium, a hard disk-type storage medium, a multimedia card micro-type storage medium, card-type memories (e.g., an SD card, an XD memory, and the like), a Random Access Memory (RAM), a Static Random Access Memory (SRAM), a Read-Only Memory (ROM), an Electrically Erasable Programmable ROM (EEPROM), a PROM, a magnetic memory, a magnetic disc, and an optical disc. Furthermore, the ultrasonic diagnostic apparatus **100** may utilize web storage or a cloud server that functions as the storage **150** online.

[0051] The controller **160** controls all operations of the ultrasonic diagnostic apparatus **100**. In other words, the controller **160** may control operations of the ultrasonic probe **110**, the signal processor **120**, the display **130**, and other components described with reference to FIG. **1**. For example, the controller **160** may control the signal processor **120** to generate an image by using a user command received via the user interface **140** or programs stored in the storage **150**. The controller **160** may also control the display **130** to display the image generated by the signal processor **220**.

[0052] FIG. **2** is a block diagram of an ultrasonic probe included in the ultrasonic diagnostic apparatus of FIG. **1**. Referring to FIG. **2**, the ultrasonic probe **110** may transmit ultrasound waves to an object **10** and receive echo signals reflected from the object to thereby generate ultrasound data, and include a transmitter **210**, a transducer **220**, and a receiver **230**.

[0053] The transmitter **210** supplies a driving signal to the transducer **220**. The transmitter **210** includes a pulse generator **212**, a transmission delaying unit **214**, and a pulser **216**.

[0054] The pulse generator **212** generates rate pulses for forming transmission ultrasound waves based on a predetermined pulse repetition frequency (PRF), and the transmission delaying unit **214** delays the rate pulses by delay times necessary for determining transmission directionality. The rate pulses which have been delayed respectively correspond to a plurality of transducer cells (**400** of FIG. **3**) included in the transducer **220**. The pulser **216** applies a driving signal (or a driving pulse) to the transducer **210** based on timing corresponding to each of the rate pulses which have been delayed.

[0055] The transducer **220** transmits ultrasound waves to the object **10** in response to the driving signal applied by the transmitter **210** and receives echo signals corresponding to the ultrasound waves reflected by the object **10**. The transducer **220** may include the plurality of transducer cells **400** that convert electrical signals into acoustic energy (or vice versa).

[0056] The receiver **230** generates ultrasound data by processing signals received from the transducer **220** and may include an amplifier **232**, an analog-to-digital converter (ADC) **234**, a reception delaying unit **236**, and a summing unit **238**.

[0057] The amplifier **232** amplifies received from the transducer **220**, and the ADC **234** performs analog-to-digital conversion with respect to the amplified signals. The reception delaying unit **236** delays digital signals output by the ADC **234** by delay times necessary for determining reception directionality, and the summing unit **238** generates ultrasound data by summing signals processed by the reception delaying unit **236**. A reflection component from a direction determined by the reception directionality may be emphasized by a summing process performed by the summing unit **238**.

[0058] The transmitter **210** and the receiver **230** of the ultrasonic probe **110** may be formed as at least one chip on a single substrate. Here, the single substrate may be formed of silicon (Si), ceramic, or a polymer-based material. Each block or at least two blocks in the transmitter **210** and the receiver **230** may be formed as a single chip, or blocks in the transmitter **210** and the receiver **230** corresponding to each transducer cell may be formed as a single chip. Thus, a substrate including at least one of the transmitter **210** and the receiver **230** is referred to as a circuit substrate. The circuit substrate may mean a substrate including all or some of the chips included in the ultrasonic probe **110**.

[0059] In addition, the ultrasound probe **110** may further include some components included in the signal processor **120**, the display **130**, and the input interface **140**.

[0060] FIG. **3** is a schematic diagram of a physical configuration of the ultrasonic probe **110** of FIG. **2**. Referring to FIG. **3**, the ultrasonic probe **110** may include the transducer **220** for converting electrical signals into ultrasound waves or ultrasound echoes back into electrical signals and a circuit substrate **240** for providing or receiving electrical signals to or from the transducer **220**. In this case, ultrasound echoes are ultrasound waves reflected from the object, and are also referred to as ultrasound waves. The transducer **220** shown in FIG. **3** may be a piezoelectric micromachined ultrasonic transducer (pMUT).

[0061] The transducer **220** may include a plurality of unit substrates **300**, each having a cavity C formed therein, and a plurality of transducer cells **400** respectively arranged on the unit substrates **300** and each including a piezoelectric layer **410**. A plurality of cavities C respectively included in the plurality of unit substrates **300** may correspond one-to-one to the transducer cells **400**. Although FIG. **3** shows that each of the plurality of unit substrates **300** may include one cavity C which corresponds to each transducer cell **400**, embodiments are not limited thereto. For example, each of the plurality of unit substrates **300** may include one cavity C corresponding to some of the plurality of transducer cells **400**.

[0062] The plurality of unit substrates **300** may be spaced apart from one another, and be arranged in a 2D or 1D array. Alternatively, the plurality of unit substrates **300** may be arranged in various other shapes such as a circle or polygon.

[0063] Each of the plurality of unit substrates **300** may include a silicon on insulator (SOI) structure. In this case, the SOI structure may be a structure in which a first silicon wafer **310**, a first insulating layer **320**, and a silicon thin layer **330** are sequentially stacked. For example, the first insulating layer **320** may include oxide or nitride, and may be formed of silicon oxide. The first silicon wafer **310** may have a thickness of about 30 μm to about 150 μm. The silicon thin layer **330** may have a thickness less than or equal to 10 μm. Since the first silicon wafer **310** is thin, it is possible to realize a thin film transducer. Each of the plurality of unit substrates **300** may further include a second insulating layer **340** on the silicon thin layer **330**. Like the first insulating layer **320**, the second insulating layer **340** may include oxide or nitride and may be formed of silicon oxide.

[0064] Each of the plurality of unit substrates **300** may include the cavity C formed by a groove in the first silicon wafer **310** and an opening in the first insulating layer **320**. In other words, the first silicon layer **310** having the groove, the first insulating layer **320** having the opening, and the silicon thin layer **330** are combined to form the cavity C. The cavity C may be in a vacuum state, but is not limited thereto.

[0065] The cavity C may serve to absorb shock during vibration of the transducer cell **400**. In other words, since the silicon thin layer **330** and the second insulating layer **340** overlying the cavity C are thin, they may vibrate in a direction perpendicular to the unit substrate **300** as the transducer cell **400** vibrates. Thus, a region of the silicon thin layer **330** overlying the cavity C may be referred to as a vibrating member **350**. The vibrating member **350** may have a cross-sectional shape corresponding to that of the cavity C. For example, the vibrating member **350** may have a circular or polygonal shape, but is not limited thereto.

[0066] The transducer **220** may include the plurality of transducer cells **400** that convert electrical signals into ultrasound waves and vice versa. The plurality of transducer cells **400** may be spaced apart from one another. Each of the plurality of transducer cells **400** may include the piezoelectric layer **410** and first and second electrodes **420** and **430** separated from each other so that the piezoelectric layer **410** is disposed therebetween. The piezoelectric layer **410** may be formed of a material that may induce a piezoelectric effect. The material may include at least one of zinc oxide (ZnO), aluminum nitrate (AlN), lead zirconate titanate (Pb(Zr, Ti)O_3 or PZT), lead lanthanum zirconate titanate ((Pb, La)(Zr,—Ti)O_3 or PLZT), barium titanate ($BaTiO_3$ or BT), lead titanate ($PbTiO_3$ or PT), lead magnesium niobate (Pb($Mg_{1/3}Nb_{2/3}$)O_3 or PMN)-PT, lead niobium zirconate titanate (Pb(Nb, Zr, Ti)O_3 or PNZT), etc. The piezoelectric layer **410** may have a thickness of less than or equal to about 10 μm. The first and second electrodes **420** and **430** may be formed of an electrically conductive material. The first and second electrodes **420** and **430** may be each formed of a metal such as gold (Au), copper (Cu), tin (Sn), silver (Ag), aluminum (Al), platinum (Pt), titanium (Ti), nickel (Ni), chromium (Cr), molybdenum (Mo), iridium (Ir), or combinations thereof.

[0067] Each of the plurality of transducer cells **400** may further include a third insulating layer **440** that is interposed between the first and second electrodes **420** and **430** and prevents conduction of an electric current between the first and second electrodes **420** and **430**. For example, the third insulating layer **440** may cover at least some regions of the piezoelectric layer **410** and the first electrode **420**. Furthermore, the second electrode **430** may extend over the third insulating layer **440** while being connected to the piezoelectric layer **410**.

[0068] The ultrasonic probe **110** may further include a circuit substrate **240** for transmitting or receiving an electrical signal to or from the transducer **220**. As described above, the circuit substrate **240** means a substrate including at least one chip for processing an electrical signal. For example, at least one chip for performing operations of the receiver **230** and the transmitter **210** may be formed on the circuit substrate **240**. The circuit substrate **240** may be a flexible printed circuit board (FPCB). The ultrasonic probe **110** may further include a backing layer (not shown) underlying the circuit substrate **240**. The backing layer may be provided on a rear surface of the circuit substrate **240** to support the circuit substrate **240**. The backing layer and the circuit substrate **240** are separate components, but embodiments are not limited thereto. A substrate of the circuit substrate **240** may be formed of a backing material, and thus, the circuit substrate **240** may serve as a backing layer. According to the present embodiment, since the transducer **220** is a pMUT, the transducer **220** may not include a backing layer. The transducer **220** and the circuit substrate **240** may be electrically connected to each other via an electrically conductive material such as an electrically conductive bump and an electrically conductive pad.

[0069] According to an embodiment, since the ultrasonic probe **110** includes the transducer cells **400** having a small size and the circuit substrate **240** that is the FPCB, the transducer **220** and the circuit substrate **240** may be provided on a support member of various shapes FIGS. **4**A and **4**B illustrate curved ultrasonic probes according to embodiments. Referring to FIG. **4**B, the ultrasonic probe **110**a may further include a support member **250** having a curved surface. For example, the circuit substrate **240** onto which the transducer **220** is fixed may be bonded to the curved surface of the support member **250**. Since the circuit substrate **240** is flexible, and each of the transducer cells **400** has a small size, an adhesive force between the circuit substrate **240**/the transducer **220** and the curved surface may be high. Alternatively, referring to FIG. **4**B, the circuit substrate **240** and the transducer **220** may be fixed onto a spherical support member **260**, and thus, a compact ultrasonic probe **110***b* may be achieved. Furthermore, utilization of the ultrasonic probe **110***b* in a spherical form may be increased due to a large radiation angle of ultrasound waves.

[0070] FIGS. **5** through **15** are reference diagrams for explaining a method of manufacturing the ultrasonic probe **110** of FIG. **3**, according to an embodiment.

[0071] As shown in FIG. **5**, a first substrate **510** may be prepared by forming a first insulating layer **512** over a first silicon wafer **511**. The first insulating layer **512** may be formed of silicon oxide.

[0072] As shown in FIG. **6**, a plurality of grooves G may be formed in the first substrate **510** by etching some regions of the first insulating layer **512** and the first silicon wafer **511**. For example, the first insulating layer **512** and the first silicon wafer **511** may be patterned using a photolithographic technique. Alternatively, etching techniques may be used during patterning. For example, etching may be performed on the first insulating layer **512** to form openings that pass through the first insulating layer **512**, and deep reactive ion etching (DRIE) may be performed on the first silicon wafer **511** to form grooves extending down from the openings.

[0073] As shown in FIG. **7**, the first substrate **510** may be bonded to a second substrate **520** having an SOI structure.

The second substrate **520** may include a second silicon wafer **521**, a third insulating layer **522**, and a silicon thin layer **523**. The first substrate **510** may be bonded to the second substrate **520** by using a silicon direct bonding (SDB) technique. The grooves G in the first substrate **510** may be respectively turned into a plurality of cavities C by bonding the second substrate **520** to the first substrate **510**.

[0074] As shown in FIG. **8**, the second silicon wafer **521** may be removed from the second substrate **520** so that the second insulating layer **522** and the silicon thin layer **523** may remain on the second substrate **520**. For example, the second silicon wafer **521** may be removed using lapping, polishing, and wet etching techniques.

[0075] After removing the second silicon wafer **521** from the second substrate **520**, a plurality of transducer cells may be formed on the second insulating layer **522**. The plurality of transducer cells may respectively correspond to the plurality of cavities C. However, embodiments are not limited thereto, and the plurality of transducer cells may correspond to one of the plurality of cavities C.

[0076] In detail, referring to FIG. **9**, an electrically conductive material **531** and a piezoelectric material **532** may be sequentially formed over the second insulating layer **522**. The electrically conductive material **531** may be formed using a deposition technique. The piezoelectric material **532** may be formed using at least one of coating and growth techniques. The electrically conductive material **531** may be a metal such as Au, Cu, Sn, Ag, Al, Pt, Ti, Ni, Cr, Mo, Ir, or combinations thereof. The piezoelectric material **532** may include at least one of ZnO, AlN, PZT, PLZT, BT, PT, PMN-PT, PNZT, etc., and may have a thickness of less than or equal to about 10 μm.

[0077] Subsequently, as shown in FIG. **10**, the electrically conductive material **531** and the piezoelectric material **532** may be patterned to form a first electrode **420** and a piezoelectric layer **410**, respectively. For example, the first electrode **420** and the piezoelectric layer **410** may be formed using a photolithographic technique.

[0078] Then, as shown in FIG. **11**, a third insulating layer **440** may be formed to cover regions of the first electrode **420** and the piezoelectric layer **410**, and as shown in FIG. **12**, a second electrode **430** may be formed to extend over the third insulating layer **440** while contacting a region of the piezoelectric layer **410**. An insulating material may be formed on the first electrode **420** and the piezoelectric layer **410** and then patterned to form the third insulating layer **440**. Furthermore, an electrically conductive material may be formed on the piezoelectric layer **410** and the third insulating layer **440** and then patterned to form the second electrode **430**. The transducer **220** of FIG. **3** thus fabricated is a thin-film transducer that is highly flexible.

[0079] In addition, as shown in FIG. **13**, a thickness of the first silicon wafer **511** in the first substrate **510** may be reduced. A structure shown in FIG. **13** is an inverted version of the structure shown in FIG. **12**. In other words, a part **511***a* of the first silicon wafer **511** may be removed after turning the structure shown in FIG. **12** upside down. The thickness of the first silicon wafer **512** may be reduced by using grinding or chemical mechanical polishing (CMP). For example, a first silicon wafer having a thickness of 100 to 400 μm may be processed to form a first silicon wafer **511***b* having a thickness of 30 to 150 μm. Use of the first silicon wafer **511***b* having a reduced thickness may result in the transducer **220** being thinner. Due to the reduced thickness of the first silicon wafer **511**, flexibility of the ultrasonic probe may be increased.

[0080] After flipping the structure of FIG. **13** back to its original position, as shown in FIG. **14**, a first substrate **510***a* having transducer cells **400** formed thereon may be bonded to a circuit substrate **240**. —For example, a bottom surface of the first substrate **510***a* may be bonded to a top surface of the circuit substrate **240** via an electrically conductive pad, an electrically conductive bump, etc. The circuit substrate **240** may be a FPCB.

[0081] Thereafter, as shown in FIG. **15**, a plurality of unit substrates **300** may be formed by respectively cutting the first substrate **510***a*, the silicon thin layer **523**, and the second insulating layer **522**. By removing regions of the first substrate **510***a* and the silicon thin layer **523** that do not overlap the transducer cells **400**, the plurality of unit substrates **300** may be formed from the first substrate **510***a*, the silicon thin layer **523**, and the second insulating layer **522**. The plurality of unit substrates **300** may be formed by performing DRIE. Each of the plurality of unit substrates **300** may include an SOI structure composed of a first silicon wafer **310**, a first insulating layer **320**, and a silicon thin layer **330** and further include a second insulating layer **340**. Since a kerf between the transducer cells **400** is formed using DRIE, the kerf may be less than gaps formed using other methods such as a cutting technique.

[0082] The ultrasonic probe **110** shown in FIG. **15** may be formed to have various shapes by attaching the ultrasonic probe **200** to a component such as a support member. The support member may have a flat or curved surface. Alternatively, by bonding the ultrasonic probe **110** to a spherical support member, the ultrasonic probe **110** may be formed as a spherical ultrasonic probe.

[0083] Since a transducer is formed on a silicon wafer as described above, it is possible to configure an ultrasonic probe into various shapes. Furthermore, an ultrasonic probe employing a pMUT according to an embodiment may be inserted into an object for diagnosis since the ultrasonic probe may operate at a low electrical power.

[0084] While ultrasonic probes and methods of manufacturing the ultrasonic probes according to one or more embodiments of the present disclosure have been described with reference to the appended figures, it will be understood by those of ordinary skill in the art that the present disclosure is not limited to the above-described embodiments but is intended to cover various changes in form and details and other embodiments such as equivalent arrangements within the scope of the appended claims. Accordingly, the true scope of the present disclosure should be determined based on the appended claims.

What is claimed is:

1. A method of manufacturing an ultrasonic probe, the method comprising:

forming a plurality of grooves by removing regions of a first insulating layer and a first silicon wafer from a first substrate including the first silicon wafer and the first insulating layer;

bonding a second substrate including a second silicon wafer, a second insulating layer, and a silicon thin layer to the first substrate, such that the plurality of grooves turn into a plurality of cavities;

removing the second silicon wafer from the second substrate;

forming transducer cells on regions of the second insulating layer corresponding to the plurality of cavities; and

forming a plurality of unit substrates by cutting the first substrate, the silicon thin layer, and the second insulating layer.

2. The method of claim **1**, further comprising reducing a thickness of the first silicon wafer by removing a part of the first silicon wafer.

3. The method of claim **2**, wherein the first silicon wafer has a thickness of 30 to 150 μm after removing the part of the first silicon wafer.

4. The method of claim **1**, wherein the forming of the transducer cells comprises:

sequentially forming an electrically conductive material and a piezoelectric material on the second insulating layer;

forming a first electrode and a piezoelectric layer by respectively patterning the electrically conductive material and the piezoelectric material; and

forming a second electrode on the piezoelectric layer.

5. The method of claim **1**, wherein the piezoelectric layer has a thickness of less than or equal to 10 μm.

6. The method of claim **1**, further comprising, before forming the second electrode, forming a third insulating layer covering the piezoelectric layer and the first electrode.

7. The method of claim **1**, wherein the plurality of unit substrates are formed by deep reactive ion etching.

8. The method of claim **1**, wherein the forming of the plurality of unit substrates comprises forming the plurality of unit substrates so that one or more transducer cells are provided for each of the plurality of unit substrates.

9. The method of claim **1**, wherein the forming of the plurality of unit substrates comprises forming the plurality of unit substrates by removing regions of the first substrate, the silicon thin layer, and the second insulating layer that do not overlap the transducer cells.

10. The method of claim **1**, further comprising bonding the first substrate to a circuit substrate before forming the plurality of unit substrates.

11. The method of claim **10**, wherein the circuit substrate is flexible.

12. The method of claim **11**, further comprising bonding the circuit substrate to a curved frame.

13. The method of claim **12**, wherein the frame has a spherical shape.

14. An ultrasonic probe comprising:

a plurality of unit substrates, each including a cavity formed therein and a silicon on insulator (SOI) structure; and

a plurality of transducer cells arranged on the plurality of unit substrates and each including a piezoelectric layer.

15. The ultrasonic probe of claim **14**, wherein the SOI structure comprises a silicon wafer, a first insulating layer, and a silicon thin layer, and

wherein the silicon wafer of the SOI structure has a thickness of 30 to 150 μm.

16. The ultrasonic probe of claim **15**, wherein the cavity is formed by a groove in the silicon wafer and an opening in the first insulating layer.

17. The ultrasonic probe of claim **14**, wherein each of the plurality of transducer cells further comprises first and second electrodes separated from each other so that the piezoelectric layer is interposed therebetween.

18. The ultrasonic probe of claim **14**, wherein the piezoelectric layer has a thickness of less than or equal to 10 μm.

19. The ultrasonic probe of claim **14**, further comprising a circuit substrate provided on a bottom surface of the plurality of unit substrates.

20. The ultrasonic probe of claim **18**, further comprising a curved support member provided on a bottom surface of the circuit substrate.

* * * * *

专利名称(译)	超声波探头及其制造方法		
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[标]申请(专利权)人(译)	三星麦迪森株式会社		
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摘要(译)

提供一种超声波探头及其制造方法。该方法包括：通过从包括第一硅晶片和第一绝缘层的第一基板去除第一绝缘层和第一硅晶片的区域来形成多个凹槽;将包括第二硅晶片，第二绝缘层和硅薄层的第二基板接合到第一基板，使得多个凹槽变成多个腔;从第二基板上移除第二硅晶片;在与所述多个腔对应的第二绝缘层的区域上形成换能器单元;通过切割第一基板，硅薄层和第二绝缘层形成多个单元基板。