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(54) **ULTRASONIC TRANSDUCER ELEMENT CHIP AND PROBE, AND ELECTRONIC DEVICE AND ULTRASOUND DIAGNOSTIC EQUIPMENT**

CHIP UND SONDE FÜR ULTRASCHALLWANDLERTEIL SOWIE ELEKTRONISCHE VORRICHTUNG UND ULTRASCHALLDIAGNOSEVORRICHTUNG

PUCE ET SONDE D'ÉLÉMENT TRANSDUCTEUR ULTRASONORE ET DISPOSITIF ÉLECTRONIQUE ET ÉQUIPEMENT DE DIAGNOSTIC ULTRASONORE

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(73) Proprietor: **Seiko Epson Corporation**
Shinjuku-ku
Tokyo 163-0811 (JP)

(72) Inventors:
- **NAKAMURA, Tomoaki**
  Suwa-shi
  Nagano 392-8502 (JP)
- **TSURUNO, Jiro**
  Suwa-shi
  Nagano 392-8502 (JP)
- **KIYOSE, Kanechika**
  Suwa-shi
  Nagano 392-8502 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

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Description

Technical Field

[0001] The present invention relates to an ultrasonic transducer element chip, a probe that comprises the ultrasonic transducer element chip, and an electronic instrument and an ultrasonic diagnostic device that comprise the probe.

Background Art

[0002] As described in PTL 1, for example, an ultrasonic transducer element chip is provided with a substrate. A plurality of openings are formed in the substrate. An ultrasonic transducer element is provided in each of the openings. The ultrasonic transducer element is provided with a vibrating film. The vibrating film covers the openings from a surface of the substrate. PLT 3 describes a ultrasonic sensor with a substrate unit where a thin-walled portion is arranged and a piezoelectric oscillator which is formed at the substrate unit. The thin-walled portion and the piezoelectric oscillator construct a membrane structure which will resonate at a predetermined frequency. PLT 3 discloses the preamble of claim 1. PLT 4 discloses an ultrasonic transducer element chip having a substrate with an array of openings on which ultrasonic transducer elements are disposed. A vent connects the opening with an external space for pressure equalization.

[0003] PLT 5 discloses a liquid eject apparatus, wherein a plurality of piezoelectric actuators are disposed on liquid flow passages having iquid eject ports.

[0004] PLT 6 discloses an ultrasonic transducer element chip having a plurality of ultrasonic transducer elements disposed above cavities which can be vacuum or filled with air or inert gas in order to alter the acoustic impedance.

Prior Art Literature

Patent Literature

[0005]

PTL 1: JP-A-2011-82624
PTL 2: JP-A-2011-77918
PLT 3: US 2007/251324 A1
PLT 4: US 2010/327695 A1
PLT 5: EP 1793 431 A1
PLT 6: US 2003/024317 A1

Summary of Invention

Technical Problem

[0006] When the openings are formed in the substrate, the strength of the substrate is deteriorated. The strength is insufficient with respect to force in a thickness direction of the substrate. Therefore, when the ultrasonic transducer element chip is pressed against a target to be tested, the ultrasonic transducer element chip was sometimes damaged.

[0007] According to at least one embodiment of the invention, an ultrasonic transducer element chip that is thin and has sufficient strength in resistance to pressing force in a thickness direction of a substrate can be provided.

Solution to Problem

[0008]

(1) According to one aspect of the invention, an ultrasonic transducer element chip comprises the features of claim 1.

[0009] In this kind of ultrasonic transducer element chip, the ultrasonic transducer elements can be formed to be thin. The ultrasonic transducer elements can be formed in a thin substrate. Even in a case where the reinforcing member is fixed to a substrate, the ultrasonic transducer element chip can be formed to be thin. In addition, since the reinforcing member is fixed on the second surface of the substrate, it is possible for the strength of the substrate to be reinforced in the substrate thickness direction. The internal spaces of the openings are enclosed by the substrate, the ultrasonic transducer element, and the reinforcing member. The linear grooves connect the internal spaces of the openings and the external space of the substrate to each other. In this way, it is possible to ensure ventilation between the internal space of each opening and outside of the internal space. Since the linear grooves are arranged at intervals smaller than the width of the opening in the first direction, even if relative positional displacement occurs between the substrate and the reinforcing member, it is possible to have at least one linear groove connected to the opening. It is possible to absolutely ensure ventilation to the outside the opening for each opening. The internal spaces of the openings are not sealed tight. The internal spaces of the openings can easily follow ambient pressure fluctuations. In this way, it is possible to reliably avoid damage to the ultrasonic transducer element. If by chance the internal spaces of the openings are sealed airtight, there will be concern for damage to the ultrasonic transducer element due to pressure fluctuations.

(2) The reinforcing member may be bonded to a partition wall section of the substrate between the openings arranged in an array pattern in at least one bonding region. When the partition wall section is bonded to the reinforcing member, the movement of the partition wall section is restricted by the reinforcing member. Thus, vibration of the partition wall section can be prevented. As a result, crosstalk between the ultrasonic transducer elements can be prevented.

Further, when the movement of the partition wall section is restricted in this way, it is possible to avoid having the vibration of the partition wall section act on the ultrasonic vibration of the ultrasonic transducer elements. Then, ultrasonic vibration in a clear vibration mode can be obtained in the ultrasonic transducer elements. Consequently, when vibration of the partition wall section is avoided in this way, it is also possible to inhibit a decrease in the amplitude of ultrasonic vibration.

(3) With the ultrasonic transducer element chip, in the plan view seen along the substrate thickness direction, each of the linear grooves may continuously extend across each of the openings in a corresponding one of columns of the array pattern so that the internal spaces of adjacent ones of the openings in the corresponding one of the columns of the array pattern are in communication with each other and the internal space of the one of the openings disposed at an end of the corresponding one of the columns is in communication with the external space disposed outside of an outline of the substrate. In this way, it is possible to ensure ventilation for all the openings of one column.

(4) With the ultrasonic transducer element chip, instead of the one linear groove part, in a plan view seen along a substrate thickness direction, a combination of the linear grooves may extend across each of the openings in a corresponding one of columns of the array pattern so that the internal spaces of adjacent ones of the openings in the corresponding one of the columns of the array pattern are in communication with each other and the internal space of one of the openings disposed at an end of the corresponding one of the columns is in communication with the external space disposed outside of an outline of the substrate. In this way, it is possible to ensure ventilation for all the openings of one column.

(5) The interval in the first direction at which the linear grooves may be arranged is 1/3 or greater than and smaller than 1/2 of the width of each the openings in the first direction. If the linear grooves are aligned at this kind of interval, two linear grooves can extend across the outlines of the openings. Therefore, even if clogging occurs with one linear groove, for example, it is possible to ensure ventilation between the outside of the openings with the other linear grooves.

(6) In a plan view seen along a substrate thickness direction, the openings may have rectangular outlines, and the linear grooves extend across the openings along a short side direction of the rectangle outlines. When the intervals between the linear grooves are set in the long side direction of the rectangle in this way, it is possible to ensure a larger interval between parallel lines compared to when the intervals between the linear grooves are set in the short side direction of the rectangle. Therefore, it is possible to form a smaller number of linear grooves. This makes it possible to achieve more efficient processing.

(7) In a plan view seen along a substrate thickness direction, the openings may have rectangular outlines, and the linear grooves extend across the openings along a long side direction of the rectangle outlines. The wall of the outline of the opening does not deform easily due to the aspect ratio with the short side of the rectangle. Even if the superimposition scope becomes narrow based on the shape of the linear grooves, it is possible maintain a relatively high rigidity for the wall. Therefore, it is possible to inhibit vibration of the wall.

(8) In a plan view seen along a substrate thickness direction, the openings may be arranged at a constant pitch in the first direction, and the linear grooves are arranged at a regular pitch in the first direction. When forming the linear grooves, as long as a regular pitch between the linear grooves is ensured, it is possible to freely set the relative position of the linear grooves and the reinforcing member. For processing of the reinforcing member, it is possible to ease the alignment precision of the reinforcing member. This makes it possible to make the reinforcing member processing easier.

(9) The ultrasonic transducer element chip may be incorporated in a probe. The probe may be provided with the ultrasonic transducer element chip, and a case supporting the ultrasonic transducer element chip.

(10) The probe may be incorporated in an electronic instrument. The electronic instrument may be provided with a probe, and a processing circuit connected to the probe and configured to process output signals of the ultrasonic transducer elements.

(11) Similarly, the probe may be incorporated in an ultrasonic diagnostic device. The ultrasonic diagnostic device may be provided with a probe, a processing circuit connected to the probe, and configured to process output signals of the ultrasonic transducer elements to generate an image, and a display device configured to display the image.

(12) The ultrasonic transducer element chip may be incorporated in a probe head. The probe head may be provided with an ultrasonic transducer element chip, and a case supporting the ultrasonic transducer element chip, and configured to be coupled to a probe main body of a probe.

(13) According to another aspect of the invention, a method for manufacturing an ultrasonic transducer element chip comprises the steps of claim 13.

[0010] When the interval of the linear grooves are set in this way, even when relative positional displacement occurs between the substrate and the reinforcing member, it is possible for at least one linear groove to be in communication with the openings. In addition, even in a case when the substrate and the reinforcing member are superimposed with each other in air or in another gas atmosphere, it is possible to achieve superimposing relatively easily. On the other hand, when the second surface of the substrate is superimposed on an even plane, gas is pressed into each opening interior by the plane of the reinforcing member. At atmospheric pressure, gas of greater volume than the volume of the space within the opening tries to remain inside the openings. If extra gas does not escape from the gap between the substrate and the reinforcing member at the same time as sealing off of the openings, it is not possible to achieve binding together of the substrate and the reinforcing member.

Brief Description of Drawings

[0011]

[Fig. 1] Fig. 1 is a perspective view schematically showing a concrete example of an electronic instrument, that is, an ultrasonic diagnostic device according to one embodiment of the invention.
[Fig. 2] Fig. 2 is an enlarged front view of an ultrasonic probe.
[Fig. 3] Fig. 3 is an enlarged plan view of an ultrasonic transducer element chip.
[Fig. 4] Fig. 4 is a sectional view along line 4-4 of Fig. 3.
[Fig. 5] Fig. 5 is a plan view of a reinforcing plate showing grooves.
[Fig. 6] Fig. 6 is an enlarged partial plan view of Fig. 5.
[Fig. 7] Fig. 7 is a block diagram schematically showing a circuit configuration of the ultrasonic diagnostic device.
[Fig. 8] Fig. 8 is a partial enlarged vertical sectional view schematically showing a flexible film and a lower electrode formed on a silicon wafer.
[Fig. 9] Fig. 9 is a partial enlarged vertical sectional view schematically showing a piezoelectric film and an upper electrode formed on the lower electrode.
[Fig. 10] Fig. 10 is a partial enlarged vertical sectional view schematically showing a conductive film that covers the silicon wafer.
[Fig. 11] Fig. 11 is a partial enlarged vertical sectional view schematically showing an opening formed in the silicon wafer, and a reinforcing plate wafer.
[Fig. 12] Fig. 12 is a partial enlarged plan view schematically showing the positional relationship of the openings and grooves when the silicon wafer and the reinforcing plate wafer are superimposed.
[Fig. 13] Fig. 13 is a partial enlarged plan view schematically showing the ultrasonic transducer element chip of another embodiment.
[Fig. 14] Fig. 14 is a partial enlarged view schematically showing the ultrasonic transducer element chip of yet another embodiment.

Description of Embodiments

[0012] Next, one embodiment of the invention will be explained with reference to the attached drawings. The embodiments explained below shall not be construed as unreasonably limiting the subject matter of the invention as defined by the claims.

(1) Overall Configuration of Ultrasonic Diagnostic Device

[0013] Fig. 1 schematically shows a configuration of an ultrasonic diagnostic device 11 as a concrete example of an electronic instrument according to an embodiment of the invention. The ultrasonic diagnostic device 11 is provided with a device terminal 12 and an ultrasonic probe (probe) 13. The device terminal 12 and the ultrasonic probe 13 are connected to each other through a cable 14. The device terminal 12 and the ultrasonic probe 13 communicate an electric signal through the cable 14. A display panel (display device) 15 is incorporated in the device terminal 12. A screen of the display panel 15 is exposed on a surface of the device terminal 12. As described later, in the device terminal 12, an image is generated based on ultrasonic waves detected with the ultrasonic probe 13. Imaged detection results are displayed on the screen of the display panel 15.

[0014] As shown in Fig. 2, the ultrasonic probe 13 has a case 16. An ultrasonic transducer element chip (hereinafter referred to as "element chip") 17 is accommodated in the case 16. A surface of the element chip 17 may be exposed on a surface of the case 16. The element chip 17 outputs ultrasonic waves from the surface thereof, and receives reflected waves of ultrasonic waves. Also, the ultrasonic probe 13 may be provided with a probe head 13b removably coupled with a probe main body 13a. In such an instance, the element chip 17 may be incorporated in the case 16 of the probe head 13b.

[0015] Fig. 3 schematically shows a plan view of the element chip 17. The element chip 17 is provided with a substrate 21. An element array 22 is formed on the substrate 21. The element array 22 is constructed with an arrangement of ultrasonic transducer elements (hereinafter referred to as "elements") 23. The arrangement is formed in a matrix having a plurality of rows and a plurality of columns. Each element 23 has a piezoelectric element section. The piezoelectric element section is constructed of a lower electrode 24, an upper electrode 25, and a piezoelectric film 26. The piezoelectric film 26 is sandwiched between the lower electrode 24 and the upper electrode 25 in each element 23.

[0016] The lower electrode 24 has a plurality of first conductive bodies 24a. The first conductive bodies 24a extend in a column direction of the arrangement in parallel to each other. One first conductive body 24a is assigned to each column of the elements 23. One first conductive body 24a is provided in common with respect to the piezoelectric films 26 of the elements 23 aligned in the column direction of the arrangement. Both ends of the first conductive body 24a are connected to a pair of extraction wirings 27, respectively. The extraction wirings 27 extend in a row direction of the arrangement in parallel to each other. Therefore, all the first conductive bodies 24a have the same length. In this manner, the lower electrode 24 is provided in common with respect to the elements 23 of the entire matrix.

[0017] The upper electrode 25 has a plurality of second conductive bodies 25a. The second conductive bodies 25a extend in a row direction of the arrangement in parallel to each other. One second conductive body 25a is assigned to each row of the elements 23. One second conductive body 25a is provided in common with respect to the piezoelectric films 26 of the elements 23 aligned in the row direction of the arrangement. Power distribution to the elements 23 is switched for each row. Line scanning or sector scanning is achieved corresponding to such switching of power distribution. Since the elements 23 in one row output ultrasonic waves at the same time, the number of the elements 23 in one row, that is, the number of columns of the arrangement can be determined based on the output level of ultrasonic waves. For example, the number of columns may be set to be around 10-15. In the drawing, five columns are illustrated for simplicity. The number of rows of the arrangement can be determined based on the extent of an area to be scanned. For example, the number of rows may be set to be 128 or 256. In the drawing, eight rows are illustrated for simplicity. Regarding the arrangement, a zigzag pattern may be used. In the zigzag pattern, a group of the elements 23 in an even row may be displaced with respect to a group of the elements 23 in an odd row by one-half of the column pitch. The number of the elements in one of an odd row and an even row may be smaller than the number of the elements in the other of an odd row and an even row by one. Furthermore, the role of the lower electrode 24 and the role of the upper electrode 25 may be switched. Specifically, the upper electrode may be connected in common to the elements 23 of the entire matrix, and the lower electrode may be connected in common to the elements 23 in each row of the arrangement.

[0018] The outline of the substrate 21 has a first side 21a and a second side 21b that are opposed and partitioned by a pair of straight lines 29 parallel to each other. In a peripheral region 31 that extends between the outline of the element array 22 and the outer edge of the substrate 21, a first terminal array 32a of one line is arranged between the first side 21a and the outline of the element array 22, and a second terminal array 32b of one line is arranged between the second side 21b and the outline of the element array 22. One line of the first terminal array 32a can be formed parallel to the first side 21a. One line of the second terminal array 32b can be formed parallel to the second side 21b. The first terminal array 32a is constructed of a pair of lower electrode terminals 33 and a plurality of upper electrode terminals 34. Similarly, the second terminal array 32b is constructed of a pair of lower electrode terminals 35 and a plurality of upper electrode terminals 36. The lower electrode terminals 33 and 35 are connected to both ends of each of the extraction wiring 27, respectively. It is sufficient for the extraction wirings 27 and the lower electrode terminals 33 and 35 to be formed plane-symmetrically with respect to a vertical plane that bisects the element array 22. The upper electrode terminals 34 and 36 are connected to both ends of each of the second conductive bodies 25a, respectively. It is sufficient for the second conductive bodies 25a, the upper electrode terminals 34 and 36 to be formed plane-symmetrically with respect to the vertical plane that bisects the element array 22. Here, the outline of the substrate 21 is formed in a rectangle. The outline of the substrate 21 may also be square or trapezoidal.

[0019] A first flexible printed substrate (hereinafter referred to as "first flexible") 37 is coupled with the substrate 21. The first flexible 37 covers the first terminal array 32a. Conductive lines, that is, first signal lines 38 are formed at one end of the first flexible 37 corresponding to the lower electrode terminals 33 and the upper electrode terminals 34, respectively. The first signal lines 38 are respectively opposed to the lower electrode terminals 33 and the upper electrode terminals 34, and respectively bonded thereto. Similarly, a second flexible printed substrate (hereinafter referred to as "second flexible") 41 covers the substrate 21. The second flexible 41 covers the second terminal array 32b. Conductive lines, that is, second signal lines 42 are formed at a first end 41a of the second flexible 41 corresponding to the lower electrode terminals 35 and the upper electrode terminals 36, respectively. The second signal lines 42 are respectively opposed to the lower electrode terminals 35 and the upper electrode terminals 36, and respectively bonded thereto.

[0020] As shown in Fig. 4, each of the elements 23 has a vibrating film 43. When constructing the vibrating film 43, an opening 45 is formed in each of the elements 23 on a substrate base 44 of the substrate 21. The openings 45 are arranged in an array pattern with respect to the substrate base 44. A flexible film 46 is formed on the entire surface of the substrate base 44. The flexible film 46 is constructed of a silicon oxide (SiO_2) layer 47 layered on the surface of the substrate base 44, and a zirconium oxide (ZrO_2) layer 48 layered on a surface of the silicon oxide layer 47. The flexible film 46 contacts the openings 45. In this manner, a part of the flexible film 46 serves as the vibrating film 43 corresponding to the outline of the opening 45. The film thickness of the silicon oxide layer 47 can be determined based on the resonance frequency.

[0021] The lower electrode 24, the piezoelectric film 26, and the upper electrode 25 are layered on a surface of the vibrating film 43 in this order. For the lower electrode 24, a layered film of titanium (Ti), iridium (Ir), platinum (Pt), and titanium (Ti) can be used, for example. The piezoelectric film 26 may be formed of piezoelectric zirconate titanate (PZT), for example. The upper electrode 25 may be formed of iridium (Ir), for example. Another conductive material may be used for the lower electrode 24 and the upper electrode 25, and another piezoelectric material may be used for the piezoelectric film 26. Here, the piezoelectric film 26 completely covers the lower electrode 24 under the upper electrode 25. The function of the piezoelectric film 26 prevents short circuits between the upper electrode 25 and the lower electrode 24.

[0022] A protective film 49 is layered on the surface of the substrate 21. The protective film 49 covers, for example, the entire surface of the substrate 21. As a result, the protective film 49 covers the element array 22, the first terminal array 32a, the second terminal array 32b, and the first flexible printed circuit 37 and the second flexible printed circuit 41. For example, a silicone resin film may be used for the protective film 49. The protective film 49 protects the configuration of the element array 22, the bonding of the first terminal array 32a and the first flexible printed circuit 37, and the bonding of the second terminal array 32b and the second flexible printed circuit 41.

[0023] Partition walls 51 are laid out between the adjacent openings 45. The openings 45 are partitioned by the partition walls 51. The wall thickness "t" of the partition wall 51 corresponds to the interval between the hollow spaces of the openings 45. The partition wall 51 defines two wall surfaces in planes extending in parallel to each other. The wall thickness "t" of the partition wall 51 corresponds to the interval between the wall surfaces. Specifically, the wall thickness "t" can be defined by the length of a vertical line that is orthogonal to the wall surfaces and sandwiched between the wall surfaces. The wall height "H" of the partition wall 51 corresponds to the depth of the opening 45. The depth of the opening 45 corresponds to the thickness of the substrate base 44. Therefore, the wall height "H" of the partition wall 51 can be defined as the length of the wall surface defined in the thickness direction of the substrate base 44. Since the substrate base 44 has a uniform thickness, the partition wall 51 can have a uniform wall height "H" over the entire length. When the wall thickness "t" of the partition wall 51 is decreased, the arrangement density of the vibrating film 43 can be increased. This can contribute to downsizing of the element chip 17. When the wall height "H" of the partition wall 51 is larger than the wall thickness "t", the bending rigidity of the element chip 17 can be increased. Consequently, the interval between the openings 45 is set to be smaller than the depth of the opening 45.

[0024] A reinforcing plate (reinforcing member) 52 is fixed to a reverse surface of the substrate base 44. The reverse surface of the substrate base 44 is overlaid on a surface of the reinforcing plate 52. The reinforcing plate 52 closes the openings 45 in a reverse surface of the element chip 17. The reinforcing plate 52 may have a rigid base material. For example, the reinforcing plate 52 may be formed of a silicon substrate. The plate thickness of the substrate base 44 is set to be around 100 μm, and the plate thickness of the reinforcing plate 52 is set to be around 100 - 150 μm. Here, the partition walls 51 are bonded to the reinforcing plate 52. The reinforcing plate 52 is bonded to each of the partition walls 51 in at least one bonding region. An adhesive can be used for bonding.

[0025] Linear grooves 53 are formed on the surface of the reinforcing plate 52. The grooves 53 divide the surface of the reinforcing plate 52 into a plurality of planes 54. The plurality of planes 54 expand within one hypothetical plane HP. The reverse surface of the substrate base 44 expands within that hypothetical plane HP. The partition wall 51 is bonded to the plane 54. The grooves 53 sink from the hypothetical plane HP. The cross section shape of the groove 53 can be a quadrangle, a triangle, a semi-circle or another shape.

[0026] As shown in Fig. 5, the openings 45 form a line in a first direction D1. The centroids 45c of the outline shapes of the openings 45 are arranged at an equal pitch on a straight line 56 in the first direction D1. Since the outlines 45a of the openings 45 are formed by copying a single shape, the openings 45 of the same shape are arranged repeatedly at a uniform pitch. For example, an outline 45a of the opening 45 is defined as a quadrangle. Specifically, it is formed in a rectangle. The long side of the rectangle is made to coincide with the first direction D1. Since the opening 45 has a rectangular outline 45a in this way, the partition wall 51 can have a uniform wall thickness "t" over the entire length. In such an instance, the bonding region of the partition walls 51 may be a region that includes a center position of the long side. In particular, the bonding region of the partition walls 51 may be a region that includes the entire length of the long side. The partition walls 51 may be surface-bonded to the reinforcing plate 52 with respect to the entire surface between the openings 45 over the entire length of the long side. Also, the bonding region of the partition walls 51 may be located in at least one position of each side of the quadrangle. The bonding region of the partition walls 51 may continuously surround the quadrangle. The partition walls 51 may be surface-bonded to the reinforcing plate 52 with respect to the entire surface between the openings 45 over the entire periphery of the quadrangle.

[0027] The grooves 53 are aligned in the first direction D1 mutually parallel at a fixed interval L. The grooves 53 extend in a second direction D2 that intersects with the first direction D1. Both ends of the grooves 53 open at the end surfaces 57a and 57b of the reinforcing plate 52. One groove 53 cuts across one line (here it is one column) of outlines 45a of the openings 45 in sequence. Each of the openings 45 has at least one groove 53 connected. Here, the second direction D2 is orthogonal to the first direction D1. Therefore, the grooves 53 cut across the outlines 45a of the openings 45 in the short side direction of the rectangle.

[0028] As shown in Fig. 6, between the planes 54, the grooves 53 form passages 58a and 58b between the substrate base 44 and the reinforcing plate 52. In this way, the space within the groove 53 is made to communicate with the internal space of the opening 45. The passages 58a and 58b ensure ventilation between the internal spaces of the openings 45 and the external space of the substrate 21. In a plan view seen from the direction orthogonal to the surface of the substrate 21, specifically, the thickness direction of the substrate 21, one groove 53 cuts across one line (here it is one column) of the outlines 45a of the openings 45 in sequence, so the openings 45 are connected successively by the passage 58a. Both ends of the groove 53 are open at the end surfaces 57a and 57b of the reinforcing plate 52. In this way, the passage 58b opens from the opening 45 of the line end to outside the outline of the substrate 21.

[0029] The interval L of the grooves 53 is set to be smaller than the opening width S of the opening 45. The opening width S is defined by the maximum length among the cross cutting lines of the openings 45 in the direction in which the grooves 53 are aligned, specifically, the first direction D1. In other words, the opening width S corresponds to the interval between the parallel lines 59 circumscribing the outlines 45a of the openings 45. The parallel lines 59 circumscribing the outlines 45a of the openings 45 are specified for each opening 45. The parallel lines 59 extend in the second direction D2. In cases when the opening widths S are mutually different for each opening 45, the grooves 53 are aligned at intervals L that are smaller than the minimum value of the opening widths S. Here, the interval L of the grooves 53 is set to be 1/3 or greater and less than 1/2 the opening width S of the opening 45.

(2) Circuit Configuration of Ultrasonic Diagnostic Device

[0030] As shown in Fig. 7, an integrated circuit has a multiplexer 61, and a transmitting and receiving circuit 62. The multiplexer 61 has a group of ports 61a on the element chip 17 side, and a group of ports 61b on the transmitting and receiving circuit 62 side. The first signal lines 38 and the second signal lines 42 are connected to the group of ports 61a on the element chip 17 side via first wirings 54. In this manner, the group of ports 61a are connected to the element array 22. Here, a prescribed number of signal lines 63 within the integrated circuit chip 55 are connected to the group of ports 61b on the transmitting and receiving circuit 62 side. The prescribed number corresponds to the number of rows of the elements 23 output simultaneously when scanning. The multiplexer 61 controls interconnection between the ports on the cable 14 side and the ports on the element chip 17 side.

[0031] The transmitting and receiving circuit 62 has a prescribed number of changing switches 64. The changing switches 64 are connected to the corresponding signal lines 63, respectively. The transmitting and receiving circuit 62 has a transmission channel 65 and a reception channel 66 for each of the changing switches 64. The transmission channel 65 and the reception channel 66 are connected to the changing switch 64 in parallel. The changing switch 64 selectively connects the transmission channel 65 and the reception channel 66 to the multiplexer 61. A pulser 67 is incorporated in the transmission channel 65. The pulser 67 outputs a pulse signal at a frequency corresponding to the resonance frequency of the vibrating film 52. An amplifier 68, a low-pass filter (LPF) 69, and an analog-digital converter (ADC) 71 are incorporated in the reception channel 66. A detection signal of each of the elements 23 is amplified, and converted into a digital signal.

[0032] The transmitting and receiving circuit 62 has a driving/receiving circuit 72. The transmission channel 65 and the reception channel 66 are connected to the driving/receiving circuit 72. The driving/receiving circuit 72 controls the pulser 67 simultaneously depending on the state of scanning. The driving/receiving circuit 72 receives a digital signal of a detection signal depending on the state of scanning. The driving/receiving circuit 72 is connected to the multiplexer 61 through a control line 73. The multiplexer 61 conducts control of interconnection based on a control signal supplied from the driving/receiving circuit 72.

[0033] A processing circuit 74 is incorporated in the device terminal 12. The processing circuit 74 can be provided with a central processing unit (CPU) and a memory, for example. The entire operation of the ultrasonic diagnostic device 11 is controlled in accordance with processing of the processing circuit 74. The processing circuit 74 controls the driving/receiving circuit 72 in accordance with instructions input by a user. The processing circuit 74 generates an image in accordance with a detection signal of the element 23. The image is specified by drawing data.

[0034] A drawing circuit 75 is incorporated in the device terminal 12. The drawing circuit 75 is connected to the processing circuit 74. The display panel 15 is connected to the drawing circuit 75. The drawing circuit 75 generates a driving signal in accordance with drawing data generated in the processing circuit 74. The driving signal is sent to the display panel 15. As a result, an image is displayed on the display panel 15.

(3) Operation of Ultrasonic Diagnostic Device

[0035] Next, the operation of the ultrasonic diagnostic device 11 will be explained briefly. The processing circuit 74 gives the driving/receiving circuit 72 instructions to transmit and receive ultrasonic waves. The driving/receiving circuit 72 supplies a control signal to the multiplexer 61, and supplies a driving signal to each of the pulsers 67. The pulser 67 outputs a pulse signal in response to the supply of the driving signal. The multiplexer 61 connects the port of the group of ports 61a to the port of the group of ports 61b in response to the instructions of the control signal. The pulse signal is supplied to the elements 23 for each row through the lower electrode terminals 33, 35 and the upper electrode terminals 34, 36 in response to the selection of the port. The vibrating film 43 vibrates in response to the supply of the pulse signal. As a result, desired ultrasonic waves are emitted toward a target (for example, the inside of a human body).

[0036] After ultrasonic waves are transmitted, the changing switch 64 is switched. The multiplexer 61 maintains the connection relation of the ports. The changing switch 64 establishes a connection between the reception channel 66 and the signal line 63 instead of a connection between the transmission channel 65 and the signal line 63. Reflected waves of ultrasonic waves vibrate the vibrating film 43. As a result, a detection signal is output from the element 23. The detection signal is converted into a digital signal, and sent into the driving/receiving circuit 72.

[0037] Transmission and reception of ultrasonic waves are repeated. For repeating transmission and reception of ultrasonic waves, the multiplexer 61 changes the connection relation of the ports. As a result, line scanning or sector scanning is achieved. When scanning is finished, the processing circuit 74 generates an image based on the digital signal of the detection signal. The generated image is displayed on the screen of the display panel 15.

[0038] In the element chip 17, the element 23 can be formed to be thin. The element 23 can be formed on the thin substrate 21. Even in a case where the reinforcing plate 52 is fixed to the substrate 21, the element chip 17 can be formed to be thin. At the same time, the reinforcing plate 52 reinforces the strength of the substrate 21. In particular, since the wall thickness "t" is smaller than the wall height "H" in the partition wall 51, sufficient rigidity of the partition wall 51 can be obtained in the thickness direction of the substrate 21 due to the section modulus. Force in the thickness direction of the substrate 21 is transmitted through the partition wall 51 and supported by the reinforcing plate 52. In this manner, the element chip 17 has sufficient strength in the thickness direction of the substrate 21. Even when the plate thickness of the substrate 21 is set to be around 100 μm, for example, the reinforcing plate 52 can prevent the substrate 21 from being damaged. On the other hand, in a case where the element array is constructed of a bulk-type ultrasonic transducer element, the plate thickness of the substrate is set to be around several millimeters. Even when the reinforcing plate 52 is bonded, for example, the thickness of the element chip 17 can be reduced securely compared to the case where the element array is constructed of a bulk-type ultrasonic transducer element. In addition, since the acoustic impedance of the vibrating film 43 is close to that of a human body compared to a bulk-type ultrasonic transducer element, an acoustic impedance matching layer can be omitted in the element chip 17 unlike in the case of a bulk-type ultrasonic transducer element. Omission of the matching layer can further contribute to making the element chip 17 thinner.

[0039] The reinforcing plate 52 is bonded to each of the partition walls 51 in at least one bonding region. When the partition walls 51 are bonded to the reinforcing plate 52, the movement of the partition walls 51 is restricted by the reinforcing plate 52. Thus, vibration of the partition walls 51 can be prevented. As a result, crosstalk between the elements 23 can be prevented. Further, when the movement of the partition walls 51 is restricted, vibration of the partition walls 51 can be prevented from acting on ultrasonic vibration of the elements 23. Then, ultrasonic vibration in a clear vibration mode can be obtained in the elements 23. When vibration of the partition walls 51 is avoided in this way, the amplitude of ultrasonic vibration can be prevented from being decreased. On the other hand, when the partition wall 51 moves, a distorted vibration mode having a lower frequency than the vertical vibration mode of the vibrating film 43 occurs. Furthermore, the kinetic energy of the vibrating film 43 decreases by the movement amount of the partition wall 51, and the amplitude of the vibration decreases.

[0040] The spaces within the openings 45 are enclosed by the substrate 21, the flexible film 46 (vibrating film 43) and the reinforcing plate 52. In a plan view seen from the substrate 21 thickness direction, the grooves 53 cut across the outlines 45a of the openings 45. In this way, it is possible to ensure ventilation between the internal space of each opening 45 and the external space of the substrate 21. As a result, the internal spaces of the openings 45 are connected to the atmospheric space. This makes it possible to avoid a rise in pressure in the internal spaces of the openings 45. That makes it possible to prevent damage to the vibrating film 43. Here, the external space is the space separated from the internal space by the substrate 21, the flexible film 46, and the reinforcing plate 52, meaning that this is a significantly larger space than the internal space.

[0041] The interval L of the grooves 53 are set to be smaller than the opening width S of the openings 45 with the element chip 17. Therefore, even when a relative position displacement occurs between the substrate 21 and the reinforcing plate 52, at least one groove 53 can be connected to the outlines 45a of the openings 45. It is possible to absolutely ensure ventilation to outside of the opening 45 for each of the openings 45. In addition, the interval L of the grooves 53 are set to be 1/3 or greater and less than 1/2 of the opening width S, so it is possible for at least two grooves 53 to be connected to the outlines 45a of the openings 45 for each opening 45. Therefore, with each opening 45, even if clogging occurs with one of the grooves 53, for example, it is possible to ensure ventilation between the other grooves 53 and outside of the openings 45. In fact, since cutting across more than four outlines 45a by the grooves 53 is avoided, it is possible to inhibit a decrease in bonding strength of the partition walls 51. Here, it is desirable for the width of the grooves 53 to be set smaller than the wall thickness "t" of the partition wall 51. By working in this way, even if the groove 53 is arranged between adjacent openings 45 in the first direction D1, it is possible to ensure a bonded surface of a sufficient size between the partition wall

51 and the reinforcing plate 52. This makes it possible to inhibit a decrease in the bonding strength of the partition walls 51.

[0042] The bonding region of the partition walls 51 can be a region that includes a center position of the long side. Therefore, a part of the partition walls 51 in which the amplitude of vibration is large is bonded to the reinforcing plate 52. As a result, vibration of the partition walls 51 can be effectively prevented. Also, the bonding region of the partition walls 51 can be a region that includes the entire length of the long side. When the partition walls 51 are bonded to the reinforcing plate 52 over the entire length of the long side, vibration of the partition walls 51 can be securely prevented. Further, the partition walls 51 can be surface-bonded with respect to the entire surface between the openings 45 over the entire length of the long side. When the partition walls 51 are surface-bonded to the reinforcing plate 52 with respect to the entire surface between the openings 45 over the entire length of the long side in this way, vibration of the partition walls 51 can be securely prevented.

[0043] It is sufficient that the bonding region of the partition walls 51 be located in at least one position of each side of the quadrangle. When the partition walls 51 are bonded to the reinforcing plate 52 in each side of the quadrangle in this way, vibration of the partition walls 51 can be securely prevented. Also, the bonding region of the partition walls 51 can continuously surround the quadrangle. When the partition walls 51 are bonded to the reinforcing plate 52 with respect to the entire region of the quadrangle in this way, vibration of the partition walls 51 can be securely prevented. Further, the partition walls 51 can be surface-bonded with respect to the entire surface between the openings 45 over the entire periphery of the quadrangle. When the partition walls 51 are surface-bonded to the reinforcing plate 52 with respect to the entire surface between the openings 45 over the entire periphery of the quadrangle in this way, vibration of the partition walls 51 can be securely prevented.

[0044] With the element chip 17, between adjacent openings 45 in the column direction, the spaces inside the openings 45 are in mutual communication by the passage 55a. Also, the passage 55b is open from the opening 45 of the column end to outside the outline of the substrate 21. The passages 55a and 55b are formed with one groove 53. In this way, it is possible to ensure ventilation for all of one column of openings 45 with one groove 53.

[0045] Further, the grooves 53 cut across the openings 45 in the short side direction of the rectangle in a plan view from the substrate 21 thickness direction. When the interval L between grooves 53 is set in this way in the long side direction of the rectangle, it is possible to ensure a larger interval between the parallel lines 56 compared to when the interval between the grooves 53 is set in the short side direction of the rectangle. Therefore, it is sufficient to form a smaller number of the grooves 53. This makes it possible to achieve more efficient processing.

[0046] In addition, the grooves 53 are aligned at an equal pitch in the first direction D1. When forming the grooves 53, as long as an equal pitch is ensured, it is possible to freely set the relative position of the groove 53 and the reinforcing plate 52. When processing the reinforcing plate 52, it is possible to ease the alignment precision of the reinforcing plate 52. This allows the processing of the reinforcing plate 52 to be made easier.

(4) Method for Manufacturing Ultrasonic Transducer Element Chip

[0047] As shown in Fig. 8, the lower electrode 24, the extraction wiring 27, and the lower electrode terminals 33, 35 (not shown in the drawings subsequent to Fig. 7) are formed on a surface of a silicon wafer (substrate) 78 for each element chip 17. Prior to forming the lower electrode 24, the extraction wiring 27, and the lower electrode terminals 33, 35, a silicon oxide film 79 and a zirconium oxide film 81 are formed on the surface of the silicon wafer 78 successively. A conductive film is formed on a surface of the zirconium oxide film 81. The conductive film is constructed as a layered film of titanium, iridium, platinum, and titanium. The lower electrode 24, the extraction wiring 27, and the lower electrode terminals 33, 35 are formed from the conductive film by a photolithographic technique.

[0048] As shown in Fig. 9, the piezoelectric film 26 and the upper electrode 25 are formed on a surface of the lower electrode 24 for each element 23. Prior to forming the piezoelectric film 26 and the upper electrode 25, a piezoelectric material film and a conductive film are formed on the surface of the silicon wafer 78. The piezoelectric material film is constructed of a PZT film. The conductive film is constructed of an iridium film. The piezoelectric film 26 and the upper electrode 25 are formed from the piezoelectric material film and the conductive film for each element 23 by a photolithographic technique.

[0049] Next, as shown in Fig. 10, a conductive film 82 is formed on the surface of the silicon wafer 78. The conductive film 82 connects the upper electrodes 25 with respect to each other for each row in each element chip 17. Also, the upper electrode 25 and the upper electrode terminals 34, 36 are formed from the conductive film 82 by a photolithographic technique.

[0050] Next, as shown in Fig. 11, the openings 45 of an array pattern are formed from the reverse surface of the silicon wafer 78. For forming the openings 45, an etching treatment is conducted. The silicon oxide film 79 serves as an etching stop layer. The vibrating film 43 is divided into the silicon oxide film 79 and the zirconium oxide film 81. After the openings 45 are formed, a surface of a reinforcing plate wafer 83 (reinforcing member) is superimposed on the reverse surface of the silicon wafer 78. Before superimposing, the wafer 83 is held on a handling mechanism or a stage. For example, a rigid insulating substrate can be used for the wafer 83. A silicon wafer can be used for the insulating substrate. An adhesive can be used for bonding, for example. After bonding, each of the element chips 17 is cut out of the silicon wafer 78.

[0051] Before bonding, linear grooves 84 are formed on the surface of the reinforcing plate wafer 83. The grooves 84 extend in parallel to each other at equal intervals. At least one end of the grooves 84 is open at the end surface of the wafer 83. The grooves 84 are aligned at intervals L which are smaller than the opening width S of the openings 45. When the interval L of the grooves 84 is set in this way, even when a relative positional displacement occurs between the silicon wafer 78 and the reinforcing plate wafer 83, it is possible for at least one groove 84 to cut across the outlines 45a of the openings 45. For example as shown in Fig. 12, even when the groove 84a is positioned between the openings 45 with the reinforcing plate wafer 83 displaced in the first direction D1 in relation to the silicon wafer 78, it is possible for at least one groove 84b to be arranged at two openings 45. When each of the element chips 17 is cut out from the silicon wafer 78, the grooves 84 provide the grooves 53 of the reinforcing plate 52.

[0052] When grooves 84 are formed in this way, even when the silicon wafer 78 and the wafer 83 are superimposed with each other in air or in another gas atmosphere, superimposing can be achieved relatively easily. On the other hand, when the reverse surface of the silicon wafer 78 is superimposed on an even plane, the gas is pushed into each opening 45 interior by the plane of the reinforcing plate wafer. At atmospheric pressure, gas of greater volume than the volume of the space within the opening 45 tries to remain inside the openings 45. When extra gas does not escape from the interval between the silicon wafer 78 and the reinforcing plate wafer at the same time as sealing off of the openings 45, it is not possible to achieve binding together of the silicon wafer 78 and the reinforcing plate wafer.

(5) Ultrasonic Transducer Element Chip of Other Embodiments

[0053] Fig. 13 schematically shows the ultrasonic transducer element chip 17a of another embodiment. With this element chip 17a, each individual groove 85 extends locally in the second direction D2. These local grooves 85 form passages 55a and 55b between a number of the openings 45. With a combination of a plurality of the grooves 85, in a plan view from the substrate 21 thickness direction, a series of passages 55a and 55b that cut across one line of openings 45 in sequence and connect openings 45 successively are formed. In this way, it is possible to ensure ventilation for all of one column of openings 45 using a combination of the passages 55a and 55b. The grooves 85 can be constituted in the same manner as the grooves 53. The remainder of the constitution can be constituted in the same manner as the element chip 17. In the drawing, equivalent constitutions and structures to those of the element chip 17 are given the same reference code numbers.

[0054] Fig. 14 schematically shows the ultrasonic transducer element chip 17b of yet another embodiment. With this element chip 17b, the grooves 86 extend in the first direction D1, specifically, the long side direction of the rectangle. Therefore, in a plan view from the substrate 21 thickness direction, the grooves 86 cut across the outlines 45a of the openings 45 at the short side of the rectangle. At the short side of the rectangle, due to the section modulus, the wall of the outline 45a of the opening 45, specifically the partition wall 51, does not deform easily. Even if the bonding range becomes narrower based on the formation of the grooves 86, it is possible to maintain relatively high rigidity for the partition wall 51. Therefore, it is possible to inhibit vibration (residual vibration) of the partition wall 51. The remainder of the constitution can be constituted in the same manner as the element chip 17. In the drawing, equivalent constitutions and structures to those of the element chip 17 are given the same reference code numbers.

[0055] In addition, for any of the embodiments, it is also possible to use a zigzag pattern for the arrangement of the openings 45. With a zigzag pattern, a group of the elements 23 in an even row may be displaced with respect to a group of the elements 23 in an odd row by one-half of the column pitch. The number of the elements in one of an odd row and an even row may be smaller than the number of the elements in the other of an odd row and an even row by one. In addition, the grooves 53, 85, and 86 can be inclined at a designated inclined angle in relation to the first direction D1 and the second direction D2.

[0056] While the present embodiment has been explained in detail as above, it will be apparent to those skilled in the art that various modifications can be made herein without departing from the scope of the invention defined by the claims. Therefore, all such modifications are included in the scope of the invention. Also, the configurations and operations of the ultrasonic diagnostic device 11, the ultrasonic probe 13, the probe head 13b, the element chips 17, 17a, and 17b, the element 23 and the like are not limited to the present embodiment, and various modifications are possible.

Reference Signs List

[0057]

11:	electronic device (ultrasonic diagnostic device)
13	probe (ultrasonic probe)
13b	probe head
15	display device (display panel)
16	case
17	ultrasonic transducer element chip
17a	ultrasonic transducer element chip
17b	ultrasonic transducer element chip
21	substrate

23	ultrasonic transducer element
45	opening
45a	outline
52	reinforcing member (reinforcing plate)
53	linear groove
55a	passage
55b	passage
56	parallel line
74	processing circuit
83	reinforcing member (reinforcing plate wafer)
84	linear groove
85	linear groove
86	linear groove
D1	first direction
D2	second direction
L	interval (of linear grove)
S	opening width

Claims

1. An ultrasonic transducer element chip (17, 17a, 17b) comprising:

   a substrate (21) including openings (45) arranged in an array pattern;
   ultrasonic transducer elements (23) respectively disposed at the openings (45) on a first surface of the substrate;
   a reinforcing member (52) fixed on a second surface of the substrate (21) opposite to the first surface of the substrate (21) to reinforce the substrate (21), the reinforcing member (52) including linear grooves (53, 84, 85, 86) formed on a surface of the reinforcing member (52) fixed on the second surface of the substrate (21) so that internal spaces of the openings (45) and an external space of the substrate (21) are in communication with each other via the linear grooves (53, 84, 85, 86) to ensure ventilation, the linear grooves (53, 84, 85, 86) extending along a plane of the surface of the reinforcing member (52), and the linear grooves (53, 84, 85, 86) being arranged at an interval (L) in a first direction (D1) smaller than a width (S) of each of the openings (45) on the second surface of the substrate (21) in the first direction (D1), **characterized in that** in a plan view seen along a substrate thickness direction, either each of the linear grooves (53, 84, 85, 86) continuously extends, or a combination of a plurality of the linear grooves (53, 84, 85, 86) extends, across each of the openings (45) in a corresponding one of the columns of the array pattern so that the internal spaces of adjacent ones of the openings (45) in the corresponding one of the columns of the array pattern are in communication with each other and the internal space of the one of the openings (45) disposed at an end of the corresponding one of the columns is in communication with the external space disposed outside of an outline of the substrate (21).

2. The ultrasonic transducer element chip (17, 17a, 17b) according to claim 1, wherein
   the reinforcing member (52) is bonded to a partition wall section (51)of the substrate (21) between the openings (45) arranged in an array pattern in at least one bonding region.

3. The ultrasonic transducer element chip according to claim 1 or 2, wherein
   in the plan view seen along the substrate thickness direction, each of the linear grooves (53, 84, 85, 86) continuously extends across each of the openings (45) in a corresponding one of columns of the array pattern so that the internal spaces of adjacent ones of the openings (45) in the corresponding one of the columns of the array pattern are in communication with each other and the internal space of the one of the openings (45) disposed at an end of the corresponding one of the columns is in communication with the external space disposed outside of an outline of the substrate (21).

4. The ultrasonic transducer element chip (17, 17a, 17b) according to claim 1 or 2, wherein
   in the plan view seen along a substrate thickness direction, a combination of a plurality of the linear grooves (53, 84, 85, 86) extends across each of the openings (45) in a corresponding one of columns of the array pattern so that the internal spaces of adjacent ones of the openings (45) in the corresponding one of the columns of the array pattern are in communication with each other and the internal space of one of the openings (45) disposed at an end of the corresponding one of the columns is in communication with the external space disposed outside of an outline of the substrate (21).

5. The ultrasonic transducer element chip (17, 17a, 17b) according to any one of claims 1 to 4, wherein the interval (L) in the first direction (D1) at which the linear grooves (53, 84, 85, 86) are arranged is 1/3 or greater than and smaller than 1/2 of the width of each the openings (45) in the first direction (D1).

6. The ultrasonic transducer element chip (17, 17a, 17b) according to any one of claims 1 to 5, wherein in the plan view seen along a substrate thickness direction, the openings (45) have rectangular outlines (45a), and
   the linear grooves (53, 84, 85, 86) extend across the openings (45) along a short side direction of the rectangular outlines (45a).

7. The ultrasonic transducer element chip (17, 17a, 17b) according to any one of claims to 5, wherein in the plan view seen along a substrate thickness direction, the openings (45) have rectangular outlines (45a), and
the linear grooves (53, 84, 85, 86) extend across the openings (45) along a long side direction of the rectangular outlines (45a).

8. The ultrasonic transducer element chip (17, 17a, 17b) according to any one of claims 1 to 6, wherein in the plan view seen along a substrate thickness direction, the openings (45) are arranged at a constant pitch in the first direction (D1), and
the linear grooves (53, 84, 85, 86) are arranged at a regular pitch in the first direction (D1).

9. A probe (13) **characterized by** comprising:

the ultrasonic transducer element chip (17, 17a, 17b) according to any one of claims 1 to 8; and
a case (16) supporting the ultrasonic transducer element chip (17, 17a, 17b).

10. An electronic instrument **characterized by** comprising:

the probe (13) according to claim 9; and
a processing circuit (74) connected to the probe (13), and configured to process output signals of the ultrasonic transducer elements (23).

11. An ultrasonic diagnostic device **characterized by** comprising:

the probe (13) according to claim 9;
a processing circuit (74) connected to the probe (13), and configured to process output signals of the ultrasonic transducer elements (23) to generate an image; and
a display device (15) configured to display the image.

12. A probe head (13b) **characterized by** comprising:

the ultrasonic transducer element chip (17, 17a, 17b) according to any one of claims 1 to 8; and
a case (16) supporting the ultrasonic transducer element chip (17, 17a, 17b).

13. A method for manufacturing an ultrasonic transducer element chip (17, 17a, 17b) **characterized by** comprising:

a step of holding a reinforcing member (52) including linear grooves (53, 84, 85, 86) formed on a surface of the reinforcing member (52) and arranged at an interval (L) in a first direction (D1) smaller than a width of each of openings (45) in the first direction (D1), the openings (45) being arranged in an array pattern on a substrate (21); and
a step of superimposing the surface of the reinforcing member (52) and a second surface of the substrate (21) opposite to a first surface of the substrate on which ultrasonic transducer elements (23) are respectively disposed at the openings (45), such that in a plan view seen along a substrate thickness direction, either each of the linear grooves (53, 84, 85, 86) continuously extends, or a combination of a plurality of the linear grooves (53, 84, 85, 86) extends, across each of the openings (45) in a corresponding one of the columns of the array pattern so that the internal spaces of adjacent ones of the openings (45) in the corresponding one of the columns of the array pattern are in communication with each other and the internal space of the one of the openings (45) disposed at an end of the corresponding one of the columns is in communication with the external space disposed outside of an outline of the substrate (21) to ensure ventilation.

Patentansprüche

1. Ultraschall-Transducer-Element-Chip (17, 17a, 17b), umfassend: ein Substrat (21), das Öffnungen (45) beinhaltet, die in einem Array-Muster angeordnet sind; Ultraschall-Transducer-Elemente (23), die jeweils an den Öffnungen (45) auf einer ersten Fläche des Substrats angeordnet sind;
ein Verstärkungselement (52), das auf einer zweiten Fläche des Substrats (21) gegenüber der ersten Fläche des Substrats (21) befestigt ist, um das Substrat (21) zu verstärken, wobei das Verstärkungselement (52) lineare Rillen (53, 84, 85, 86) beinhaltet, die auf einer Fläche des Verstärkungselements (52) gebildet sind, die an der zweiten Fläche des Substrats (21) befestigt ist, so dass innere Räume der Öffnungen (45) und ein äußerer Raum des Substrats (21) miteinander über die linearen Rillen (53, 84, 85, 86) in Kommunikation sind, um eine Belüftung zu gewährleisten, wobei die linearen Rillen (53, 84, 85, 86) entlang einer Ebene der Fläche des Verstärkungselements (52) verlaufen, und wobei die linearen Rillen (53, 84, 85, 86) in einem Abstand (L) in einer ersten Richtung (D1) angeordnet sind, der kleiner ist als eine Breite (S) von jeder der Öffnungen (45) auf der zweiten Fläche des Substrats (21) in der ersten Richtung (D1), **dadurch gekennzeichnet, dass**
in einer Draufsicht bei Betrachtung entlang einer Substrat-Dickenrichtung entweder jede der linearen Rillen (53, 84, 85, 86) kontinuierlich verläuft oder ei-

ne Kombination einer Mehrzahl der linearen Rillen (53, 84, 85, 86) über jede der Öffnungen (45) hinweg in einer entsprechenden der Spalten des Array-Musters verläuft, so dass die inneren Räume von aneinandergrenzenden Öffnungen (45) in der entsprechenden der Spalten des Array-Musters in Kommunikation miteinander sind und der innere Raum der einen der Öffnungen (45), die am Ende der entsprechenden der Spalten angeordnet ist, in Kommunikation mit dem äußeren Raum ist, der außerhalb eines Umrisses des Substrats (21) angeordnet ist.

2. Ultraschall-Transducer-Element-Chip (17, 17a, 17b) nach Anspruch 1, wobei
das Verstärkungselement (52) an einen Trennungswandabschnitt (51) des Substrats (21) zwischen den Öffnungen (45) angeordnet in einem Array-Muster in zumindest einem Bonding-Bereich gebondet ist.

3. Ultraschall-Transducer-Element-Chip nach Anspruch 1 oder 2, wobei
in der Draufsicht entlang der Substrat-Dickenrichtung jede der linearen Rillen (53, 84, 85, 86) kontinuierlich über die Öffnungen (45) hinweg in einer entsprechenden der Spalten des Array-Musters verläuft, so dass die inneren Räume von aneinandergrenzenden Öffnungen (45) in der entsprechenden der Spalten des Array-Musters in Kommunikation miteinander sind und der innere Raum der einen der Öffnungen (45), die an einem Ende der entsprechenden der Spalten angeordnet ist, in Kommunikation mit dem äußeren Raum ist, der außerhalb eines Umrisses des Substrats (21) angeordnet ist.

4. Ultraschall-Transducer-Element-Chip (17, 17a, 17b) nach Anspruch 1 oder 2, wobei
in der Draufsicht bei Betrachtung entlang einer Substrat-Dickenrichtung eine Kombination einer Mehrzahl der linearen Rillen (53, 84, 85, 86) über jede der Öffnungen (45) hinweg in einer entsprechenden der Spalten des Array-Musters verläuft, so dass die inneren Räume von aneinandergrenzenden Öffnungen (45) in der entsprechenden der Spalten des Array-Musters in Kommunikation miteinander sind und der innere Raum der einen der Öffnungen (45), die an einem Ende der entsprechenden der Spalten angeordnet ist, in Kommunikation mit dem äußeren Raum ist, der außerhalb eines Umrisses des Substrats (21) angeordnet ist.

5. Ultraschall-Transducer-Element-Chip (17, 17a, 17b) nach einem der Ansprüche 1 bis 4, wobei
der Abstand (L) in der ersten Richtung (D1), unter welchem die linearen Rillen (53, 84, 85, 86) angeordnet sind, 1/3 oder größer als und kleiner als 1/2 der Breite von jeder der Öffnungen (45) in der ersten Richtung (D1) ist.

6. Ultraschall-Transducer-Element-Chip (17, 17a, 17b) nach einem der Ansprüche 1 bis 5, wobei
in der Draufsicht bei Betrachtung entlang einer Substrat-Dickenrichtung die Öffnungen (45) rechteckige Umrisse (45a) haben, und
die linearen Rillen (53, 84, 85, 86) über die Öffnungen (45) entlang einer Kurzseitenrichtung der rechteckigen Umrisse (45a) hinweg verlaufen.

7. Ultraschall-Transducer-Element-Chip (17, 17a, 17b) nach einem der Ansprüche 1 bis 5, wobei
in der Draufsicht bei Betrachtung entlang einer Substrat-Dickenrichtung die Öffnungen (45) rechteckige Umrisse (45a) haben, und
die linearen Rillen (53, 84, 85, 86) über die Öffnungen (45) entlang einer Langseitenrichtung der rechteckigen Umrisse (45a) hinweg verlaufen.

8. Ultraschall-Transducer-Element-Chip (17, 17a, 17b) nach einem der Ansprüche 1 bis 6, wobei
in der Draufsicht bei Betrachtung entlang einer Substrat-Dickenrichtung die Öffnungen (45) mit einem konstanten Abstandsmaß in der ersten Richtung (D1) angeordnet sind, und
die linearen Rillen (53, 84, 85, 86) mit einem regelmäßigen Abstandsmaß in der ersten Richtung (D1) angeordnet sind.

9. Sonde (13), **dadurch gekennzeichnet, dass** sie umfasst:

den Ultraschall-Transducer-Element-Chip (17, 17a, 17b) nach einem der Ansprüche 1 bis 8; und
ein Gehäuse (16), das den Ultraschall-Transducer-Element-Chip (17, 17a, 17b) stützt.

10. Elektronisches Instrument, **dadurch gekennzeichnet, dass** es umfasst:

die Sonde (13) nach Anspruch 9; und
eine Verarbeitungsschaltung (74), die mit der Sonde (13) verbunden ist und dazu konfiguriert ist, Ausgangssignale der Ultraschall-Transducer-Elemente (23) zu verarbeiten.

11. Ultraschall-Diagnostikeinrichtung, **dadurch gekennzeichnet, dass** sie umfasst:

die Sonde (13) nach Anspruch 9;
eine Verarbeitungsschaltung (74), die mit der Sonde (13) verbunden ist und dazu konfiguriert ist, Ausgangssignale der Ultraschall-Transducer-Elemente (23) zu verarbeiten, um ein Bild zu erzeugen; und
eine Anzeigeeinrichtung (15), die dazu konfiguriert ist, das Bild anzuzeigen.

12. Sondenkopf (13b), **dadurch gekennzeichnet, dass**

er umfasst:

den Ultraschall-Transducer-Element-Chip (17, 17a, 17b) nach einem der Ansprüche 1 bis 8; und ein Gehäuse (16), das den Ultraschall-Transducer-Element-Chip (17, 17a, 17b) stützt.

13. Verfahren zum Herstellen eines Ultraschall-Transducer-Element-Chips (17, 17a, 17b), **dadurch gekennzeichnet, dass** es umfasst:

einen Schritt, in welchem ein Verstärkungselement (52) gehalten wird, das lineare Rillen (53, 84, 85, 86) beinhaltet, die auf einer Fläche des Verstärkungselements (52) gebildet sind und in einem Abstand (L) in einer ersten Richtung (D1) angeordnet sind, der kleiner ist als eine Breite von jeder der Öffnungen (45) in der ersten Richtung (D1), wobei die Öffnungen (45) in einem Array-Muster auf einem Substrat (21) angeordnet sind; und
einen Schritt, in welchem die Fläche des Verstärkungselements (52) und eine zweiten Fläche des Substrats (21) gegenüber einer ersten Fläche des Substrats überlagert wird, auf welcher Ultraschall-Transducer-Elemente (23) jeweils an den Öffnungen (45) angeordnet sind, so dass in einer Draufsicht bei Betrachtung entlang einer Substrat-Dickenrichtung entweder jede der linearen Rillen (53, 84, 85, 86) kontinuierlich verläuft oder eine Kombination einer Mehrzahl der linearen Rillen (53, 84, 85, 86) über jede der Öffnungen (45) hinweg in einer entsprechenden der Spalten des Array-Musters verläuft, so dass die inneren Räume von aneinandergrenzenden Öffnungen (45) in der entsprechenden der Spalten des Array-Musters in Kommunikation miteinander sind und der innere Raum der einen der Öffnungen (45), die am Ende der entsprechenden der Spalten angeordnet ist, in Kommunikation mit dem äußeren Raum ist, der außerhalb eines Umrisses des Substrats (21) angeordnet ist, um eine Belüftung zu gewährleisten.

Revendications

1. Puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b) comprenant :

un substrat (21) comprenant des ouvertures (45) arrangées en un motif matriciel ;
des éléments faisant office de transducteurs à ultrasons (23) respectivement disposés aux ouvertures (45) sur une première surface du substrat ;
un membre de renforcement (52) fixé sur une seconde surface du substrat (21) opposée à la première surface du substrat (21) pour renforcer le substrat (21), le membre de renforcement (52) comprenant des rainures linéaires (53, 84, 85, 86) formées sur une surface du membre de renforcement (52) fixé sur la seconde surface du substrat (21) d'une manière telle que des espaces internes des ouvertures (45) et un espace externe du substrat (21) entrent en communication les uns avec les autres via les rainures linéaires (53, 84, 85, 86) afin de garantir une ventilation, les rainures linéaires (53, 84, 85, 86) s'étendant le long d'un plan de la surface du membre de renforcement (52), et les rainures linéaires (53, 84, 85, 86) étant arrangées à un intervalle (L) dans une première direction (D1) inférieur à une largeur (S) de chacune des ouvertures (45) sur la seconde surface du substrat (21) dans la première direction (D1) ;
caractérisée en ce que, dans une vue en plan prise dans une direction de l'épaisseur du substrat, soit chacune des rainures linéaires (53, 84, 85, 86) s'étend en continu, soit une combinaison d'une pluralité des rainures linéaires (53, 84, 85, 86) s'étend, à travers chacune des ouvertures (45) dans une colonne correspondante parmi les colonnes du motif matriciel, d'une manière telle que les espaces internes d'ouvertures adjacentes (45) dans la colonne correspondante parmi les colonnes du motif matriciel entrent en communication les uns avec les autres et que l'espace interne d'une des ouvertures (45) disposée à une extrémité de la colonne correspondante parmi les colonnes entre en communication avec l'espace externe disposé à l'extérieur d'un contour du substrat (21).

2. Puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b) selon la revendication 1, dans laquelle le membre de renforcement (52) est lié à un tronçon de paroi de séparation (51) du substrat (21) entre les ouvertures (45) arrangées en un motif matriciel dans au moins une zone de liaison.

3. Puce sous la forme d'un élément faisant office de transducteur à ultrasons selon la revendication 1 ou 2, dans laquelle, dans la vue en plan prise dans la direction de l'épaisseur du substrat, chacune des rainures linéaires (53, 84, 85, 86) s'étend en continu à travers chacune des ouvertures (45) dans une colonne correspondante parmi les colonnes du motif matriciel, d'une manière telle que les espaces internes d'ouvertures adjacentes (45) dans la colonne correspondante parmi les colonnes du motif matriciel entrent en communication les uns avec les autres et que l'espace interne d'une des ouvertures (45) disposée à une extrémité de la colonne correspondante parmi les colonnes entre en communication avec l'espace externe disposé à l'extérieur d'un contour du substrat (21).

4. Puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b) selon la revendication 1 ou 2, dans laquelle, dans la vue en plan prise dans une direction de l'épaisseur du substrat, une combinaison d'une pluralité des rainures linéaires (53, 84, 85, 86) s'étend à travers chacune des ouvertures (45) dans une colonne correspondante parmi les colonnes du motif matriciel, d'une manière telle que les espaces internes d'ouvertures adjacentes (45) dans la colonne correspondante parmi les colonnes du motif matriciel entrent en communication les uns avec les autres et que l'espace interne d'une des ouvertures (45) disposée à une extrémité de la colonne correspondante parmi les colonnes entre en communication avec l'espace externe disposé à l'extérieur d'un contour du substrat (21).

5. Puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b) selon l'une quelconque des revendications 1 à 4, dans laquelle l'intervalle (L) dans la première direction (D1) auquel les rainures linéaires (53, 84, 85, 86) sont arrangées est supérieur à raison de 1/3 ou plus et inférieur à raison de 1/2 de la largeur de chacune des ouvertures (45) dans la première direction (D1).

6. Puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b) selon l'une quelconque des revendications 1 à 5, dans laquelle dans la vue en plan prise dans une direction de l'épaisseur du substrat, les ouvertures (45) possèdent des contours rectangulaires (45a) ; et
les rainures linéaires (53, 84, 85, 86) s'étendent à travers les ouvertures (45) le long d'une petite direction latérale des contours rectangulaires (45a).

7. Puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b) selon l'une quelconque des revendications 1 à 5, dans laquelle dans la vue en plan prise dans une direction de l'épaisseur du substrat, les ouvertures (45) possèdent des contours rectangulaires (45a) ; et
les rainures linéaires (53, 84, 85, 86) s'étendent à travers les ouvertures (45) le long d'une grande direction latérale des contours rectangulaires (45a).

8. Puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b) selon l'une quelconque des revendications 1 à 6, dans laquelle dans la vue en plan prise dans une direction de l'épaisseur du substrat, les ouvertures (45) sont arrangées à un pas constant dans la première direction (D1) ; et
les rainures linéaires (53, 84, 85, 86) sont arrangées à un pas régulier dans la première direction (D1).

9. Sonde (13) **caractérisée par le fait qu'**elle comprend :

la puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b) selon l'une quelconque des revendications 1 à 8 ; et
un boîtier (16) supportant la puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b).

10. Instrument électronique **caractérisé par le fait qu'**il comprend :

la sonde (13) selon la revendication 9 ; et
un circuit de traitement (74) relié à la sonde (13) et configuré pour traiter des signaux de sortie des éléments faisant office de transducteur à ultrasons (23).

11. Dispositif diagnostique à ultrasons **caractérisé par le fait qu'**il comprend :

la sonde (13) selon la revendication 9 ;
un circuit de traitement (74) relié à la sonde (13) et configuré pour traiter des signaux de sortie des éléments faisant office de transducteur à ultrasons (23) dans le but de générer une image ; et
un dispositif d'affichage (15) configuré pour afficher l'image.

12. Tête de sonde (13a) **caractérisée par le fait qu'**elle comprend :

la puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b) selon l'une quelconque des revendications 1 à 8 ; et
un boîtier (16) supportant la puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b).

13. Procédé pour la fabrication d'une puce sous la forme d'un élément faisant office de transducteur à ultrasons (17, 17a, 17b), **caractérisé par le fait qu'**il comprend :

une étape de maintien d'un membre de renforcement (52) comprenant des rainures linéaires (53, 84, 85, 86) formées sur une surface du membre de renforcement (52) et arrangées à un intervalle (L) dans une première direction (D1) inférieur à une largeur (S) de chacune des ouvertures (45) dans la première direction (D1), les ouvertures (45) étant arrangées en un motif matriciel sur un substrat (21) : et une étape de superposition de la surface du membre de renforcement (52) et d'une seconde surface du substrat (21) opposée à une première surface du substrat sur laquelle des éléments faisant office de transducteurs à ultrason (23) sont respectivement disposés aux ouvertures (45), d'une manière telle que dans une vue en plan prise dans une direction de l'épaisseur du substrat, soit chacune des rainures linéaires (53, 84, 85, 86) s'étend en continu, soit une combinaison d'une pluralité des rainures linéaires (53, 84, 85, 86) s'étend, à travers chacune des ouvertures (45) dans une colonne correspondante parmi les colonnes du motif matriciel, d'une manière telle que les espaces internes d'ouvertures adjacentes (45) dans la colonne correspondante parmi les colonnes du motif matriciel entrent en communication les uns avec les autres et que l'espace interne d'une des ouvertures (45) disposée à une extrémité de la colonne correspondante parmi les colonnes entre en communication avec l'espace externe disposé à l'extérieur d'un contour du substrat (21) afin de garantir une ventilation.

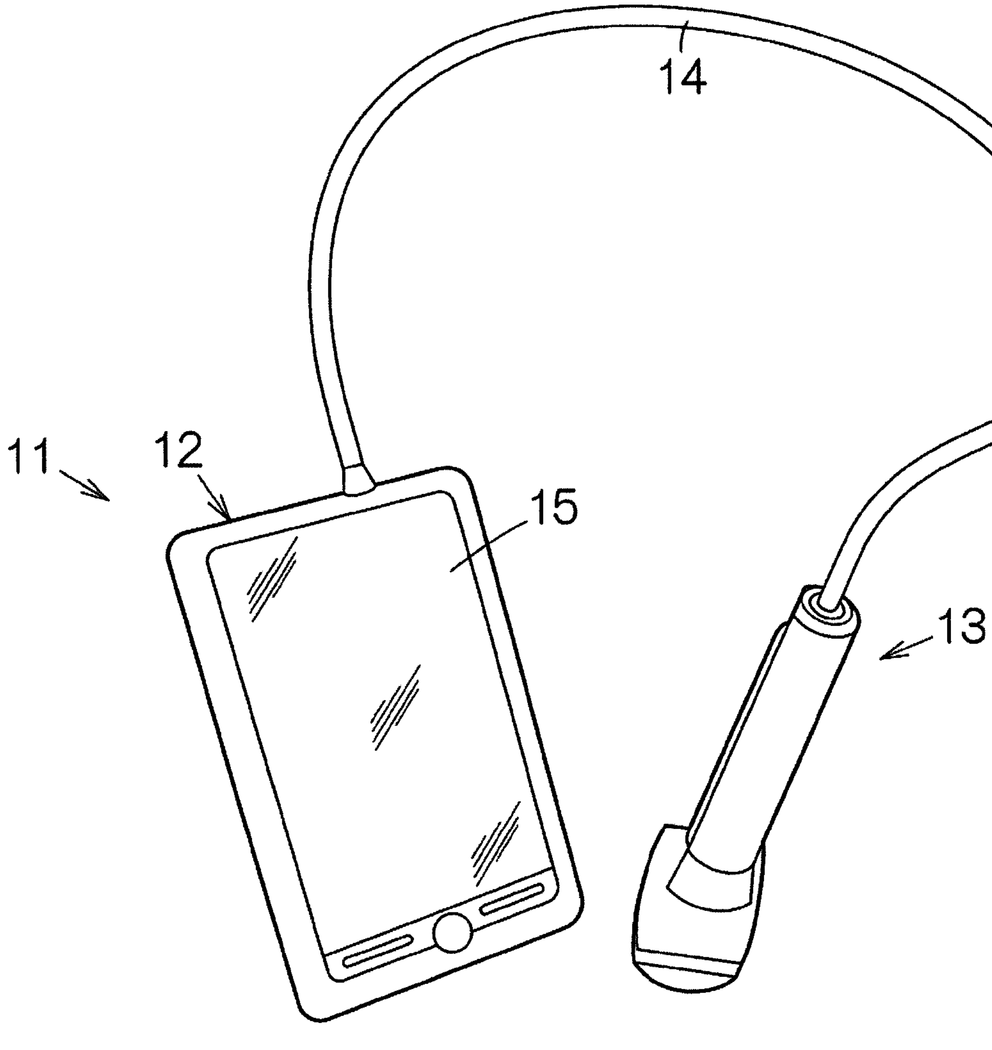


Fig. 1

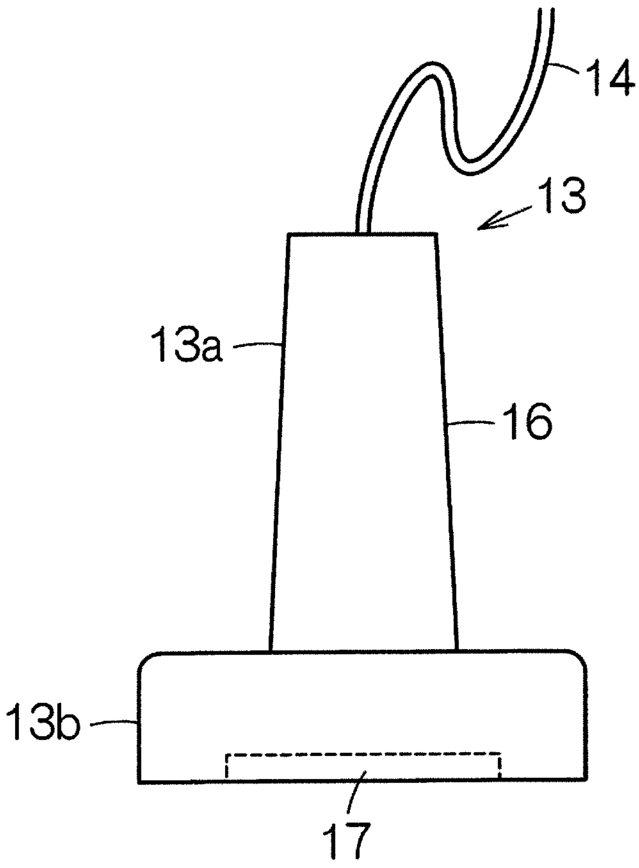
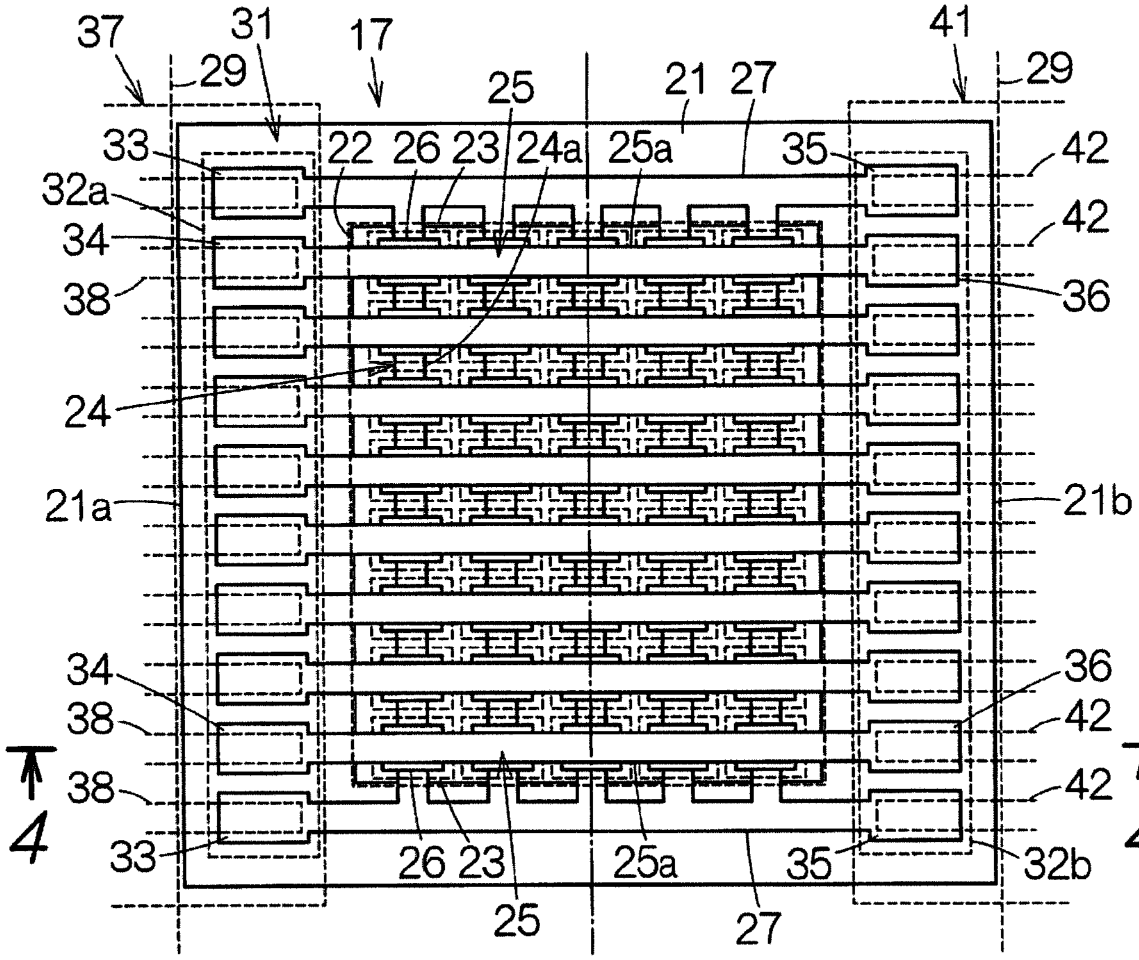


Fig. 2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32b
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Fig. 3

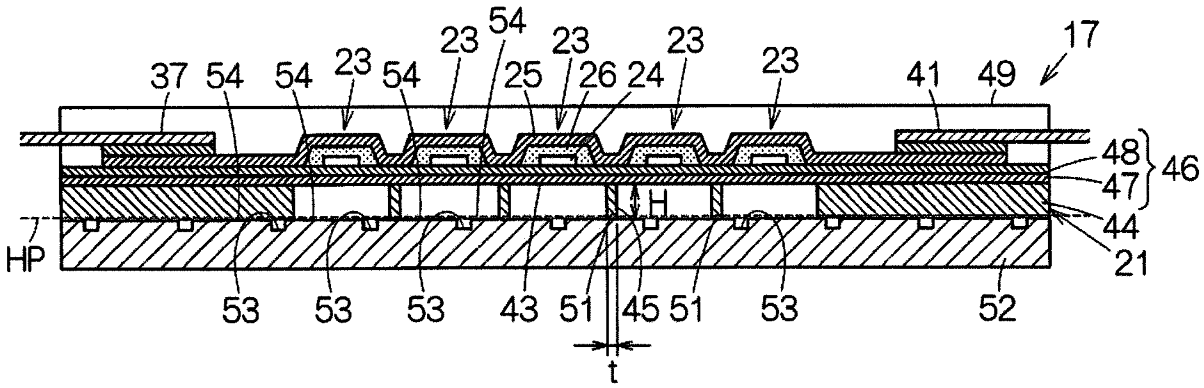
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Fig. 4

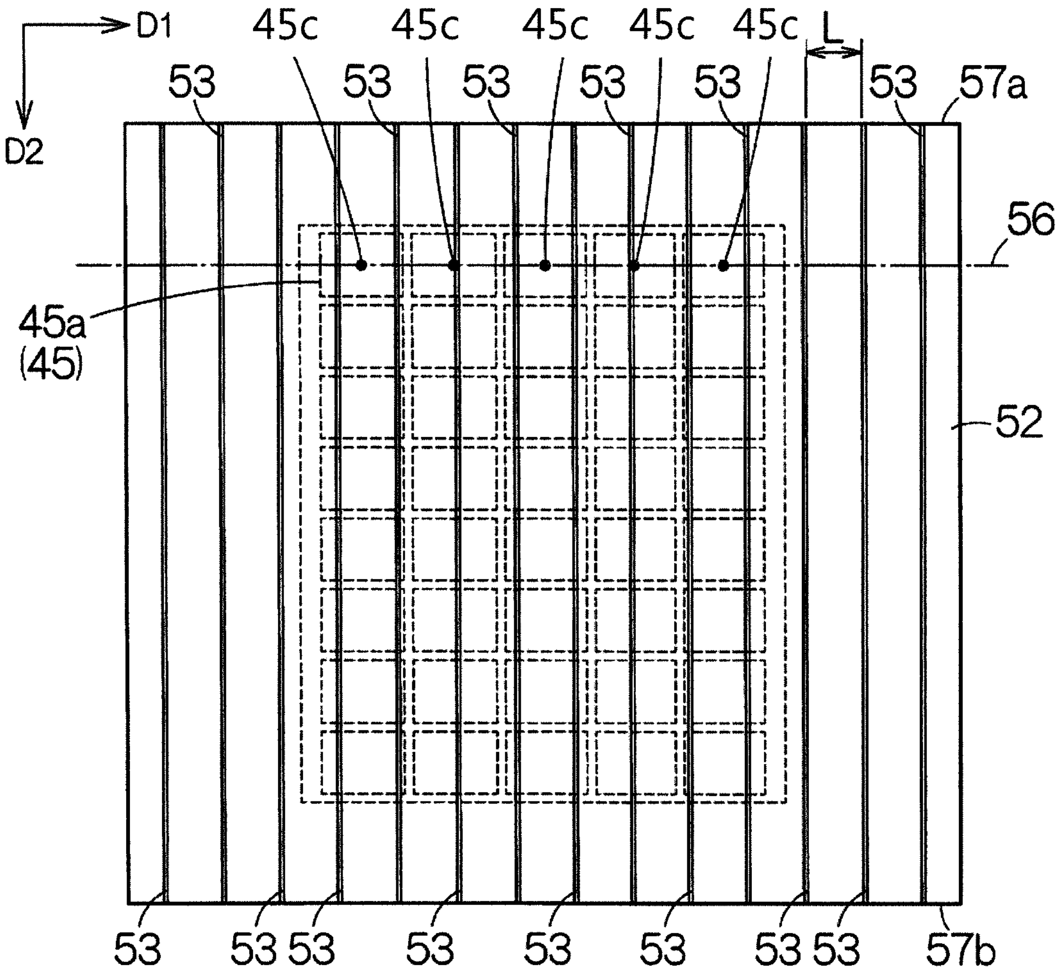
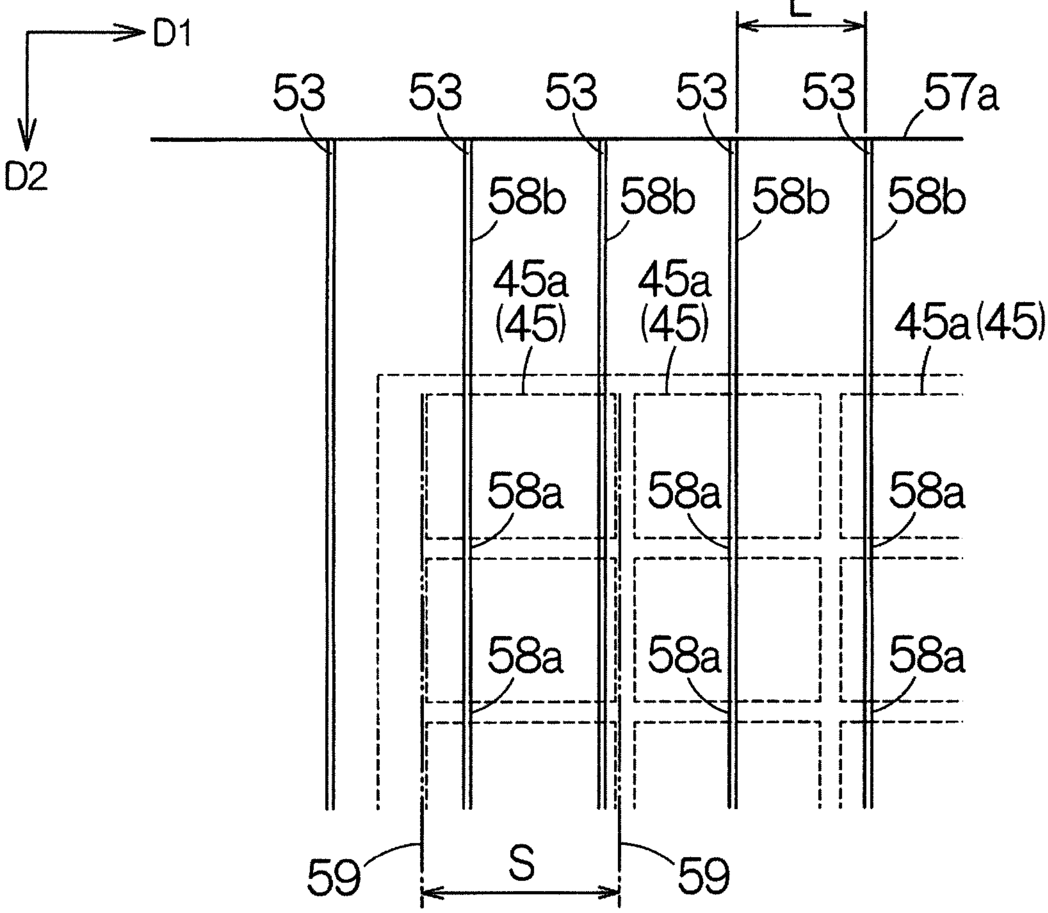


Fig. 5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D2
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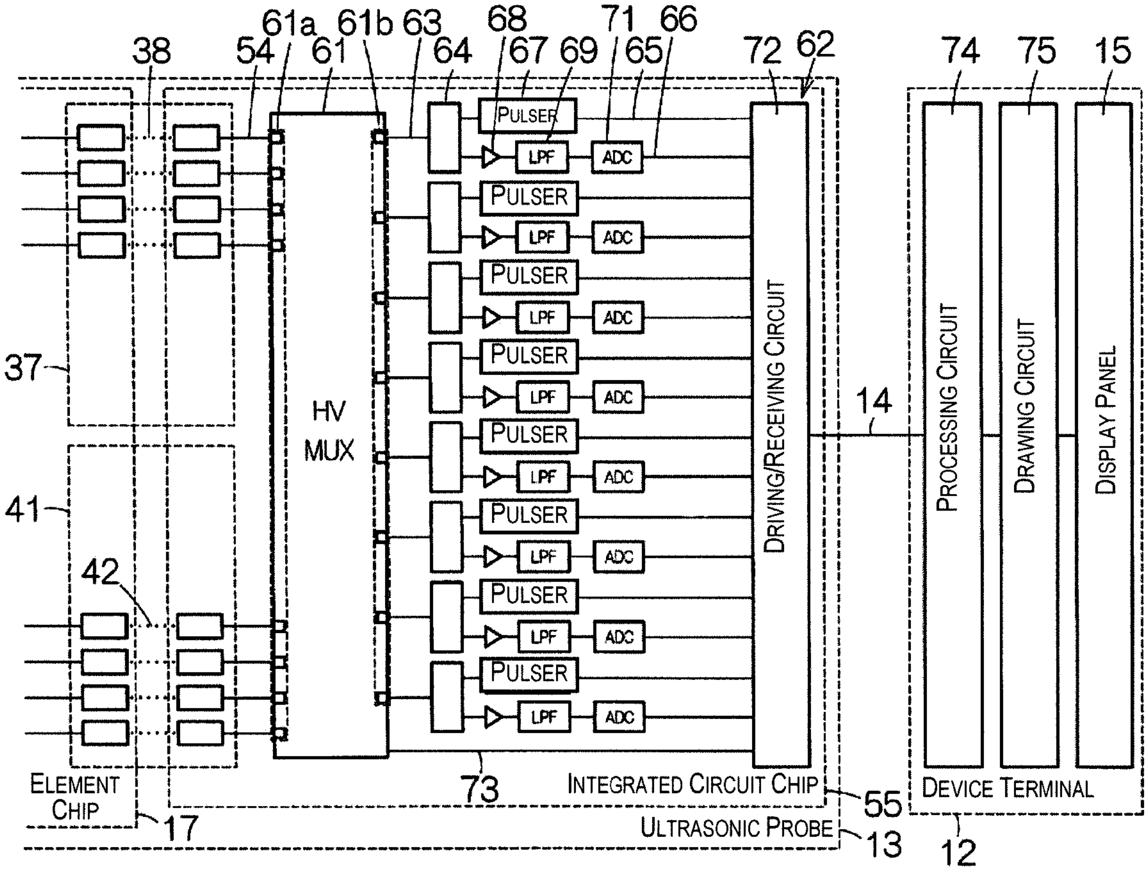
Fig. 6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LPF
ADC
37
HV
MUX
DRIVING/RECEIVING CIRCUIT
14
PROCESSING CIRCUIT
DRAWING CIRCUIT
DISPLAY PANEL
41
42
ELEMENT
CHIP
17
73
INTEGRATED CIRCUIT CHIP
55
ULTRASONIC PROBE
13
DEVICE TERMINAL
12

Fig. 7

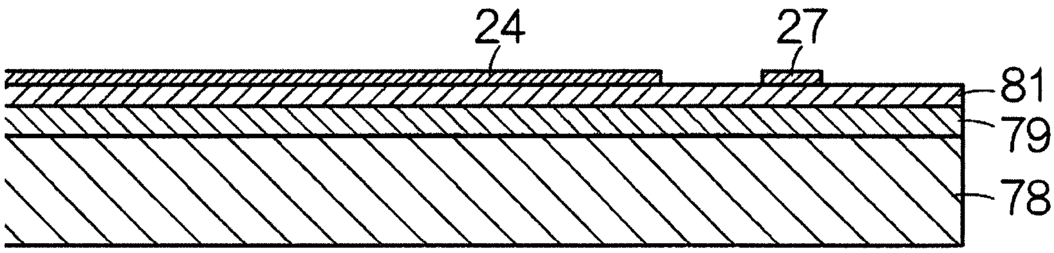

Fig. 8

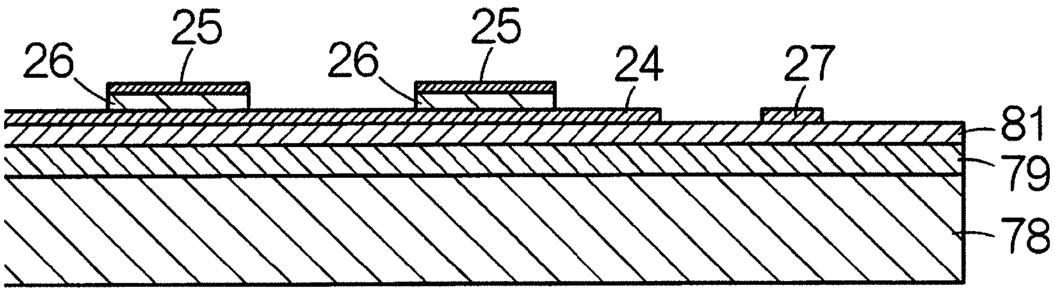

Fig. 9

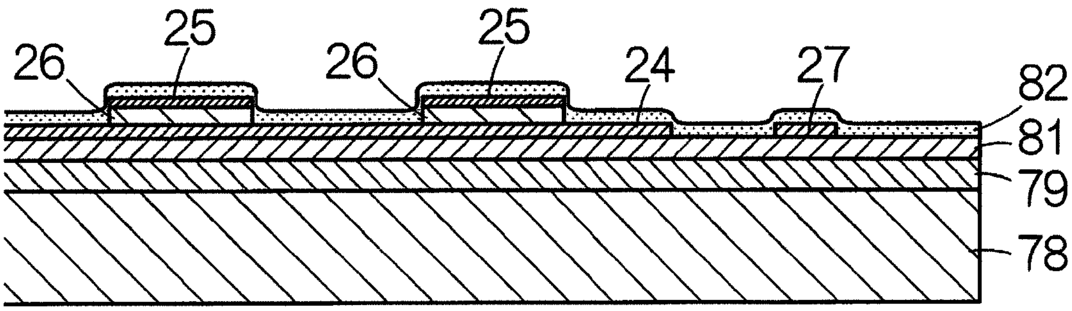

Fig. 10

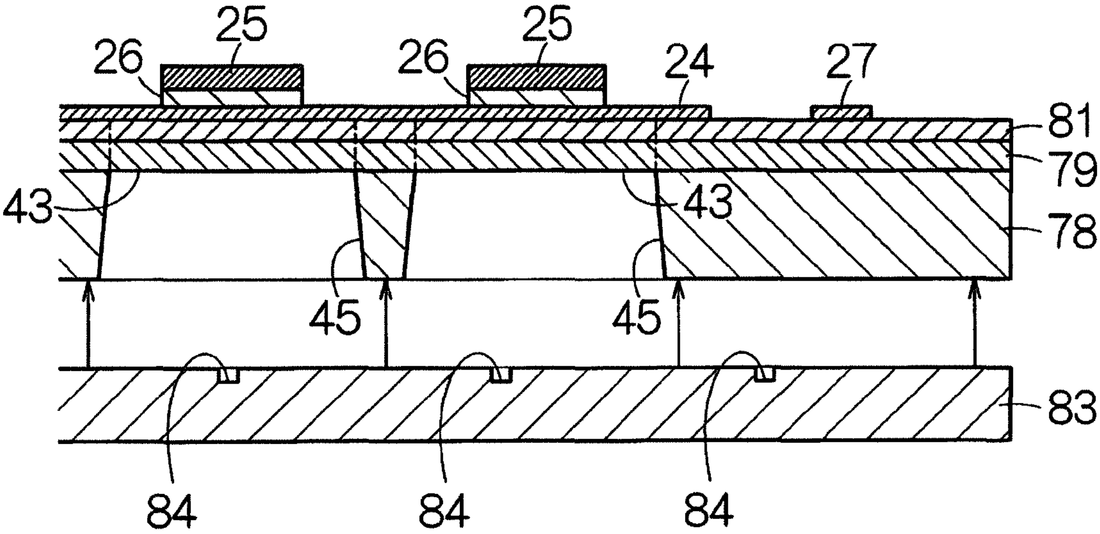
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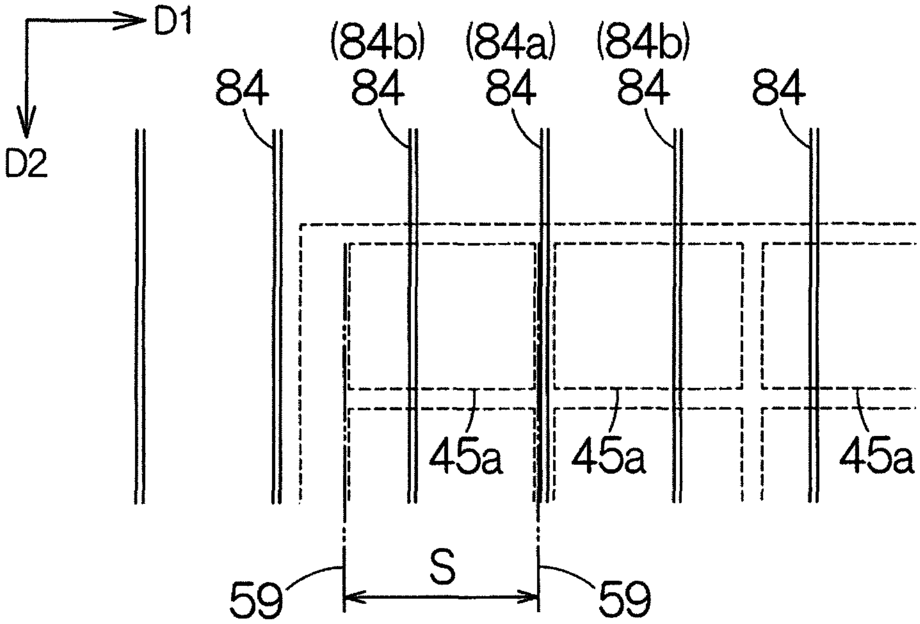
Fig. 11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(84a)
(84b)
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45a
S
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Fig. 12

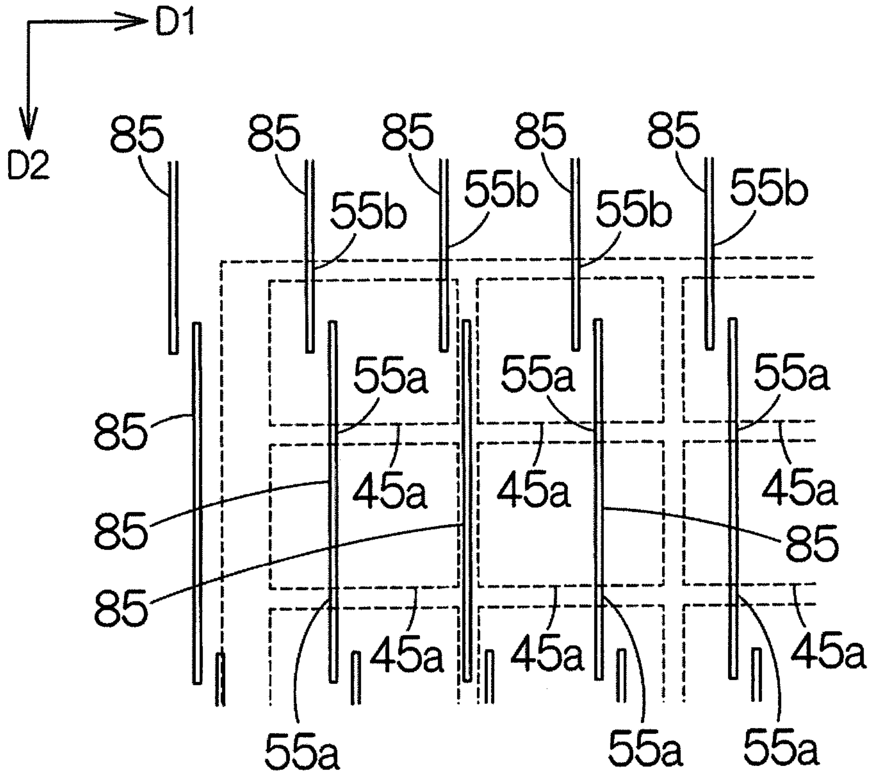
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Fig. 13

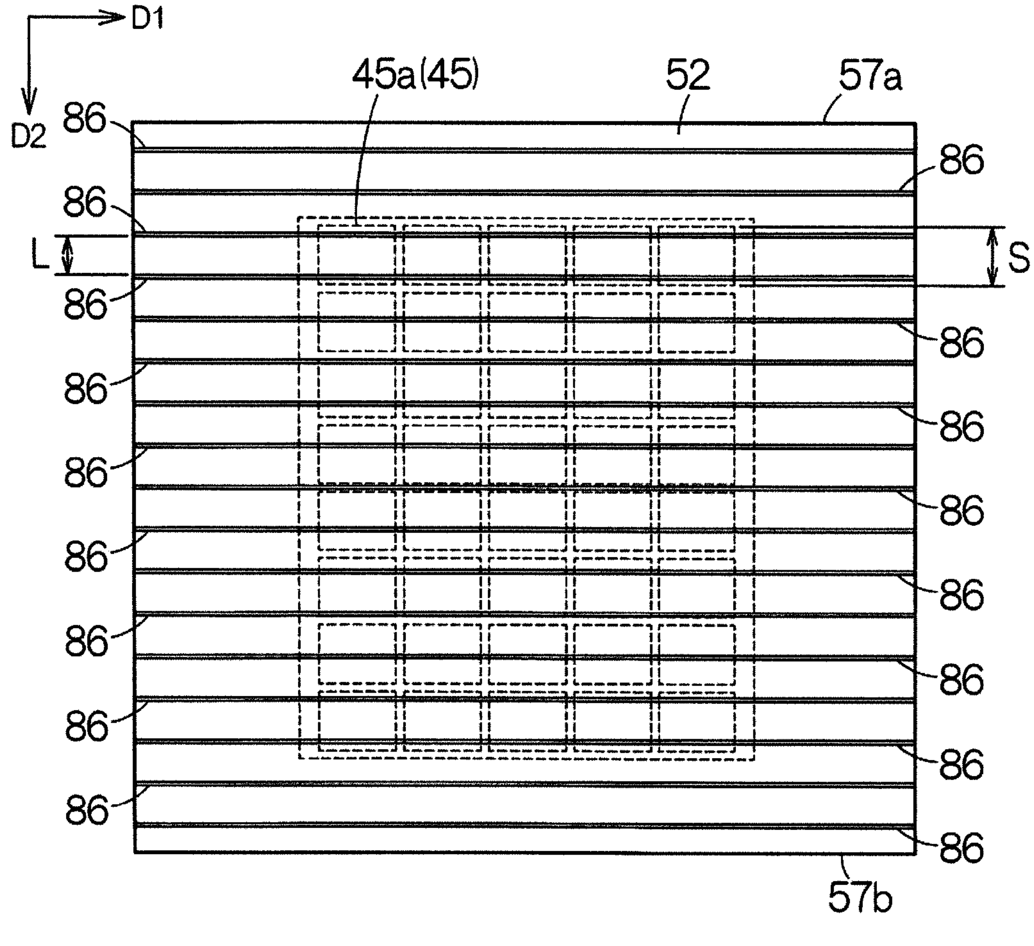
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Fig. 14

REFERENCES CITED IN THE DESCRIPTION

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patsnap

专利名称(译)	超声换能器元件芯片和探头，以及电子设备和超声诊断设备		
公开(公告)号	EP2833649B1	公开(公告)日	2018-02-14
申请号	EP2013768807	申请日	2013-03-28
[标]申请(专利权)人(译)	精工爱普生株式会社		
申请(专利权)人(译)	SEIKO EPSON CORPORATION		
当前申请(专利权)人(译)	SEIKO EPSON CORPORATION		
[标]发明人	NAKAMURA TOMOAKI TSURUNO JIRO KIYOSE KANECHIKA		
发明人	NAKAMURA, TOMOAKI TSURUNO, JIRO KIYOSE, KANECHIKA		
IPC分类号	H04R17/00 A61B8/00 H01L41/08 H01L41/09 B06B1/06		
CPC分类号	B06B1/0207 A61B8/4494 B06B1/0622 G01S7/5208 G01S7/56 G01S15/8925 H04R1/20 H04R31/00 Y10T29/49005		
优先权	2012078673 2012-03-30 JP		
其他公开文献	EP2833649A4 EP2833649A1		

摘要(译)

一种超声换能器元件芯片，其特征在于包括：基板，包括以阵列图案布置的开口;超声换能器元件，分别设置在基板的第一表面上的开口处;以及加强构件，固定在基板的与第一表面相对的第二表面上所述基板的表面加强所述基板，所述加强构件包括形成在所述加强构件的表面上的线性凹槽部分，所述加强构件的表面固定在所述基板的第二表面上，使得所述开口的内部空间与所述基板的外部空间连通。通过线性凹槽部分彼此相对，沿着加强构件的表面的平面延伸的线性凹槽部分，并且线性凹槽部分以小于第二方向上的每个开口的宽度的第一方向的间隔布置第一方向上的基板表面。

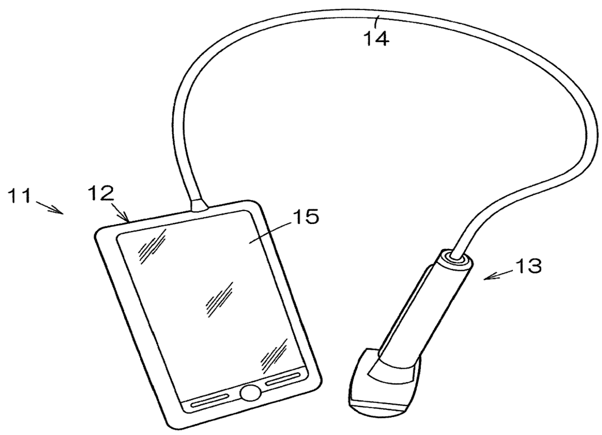

Fig. 1