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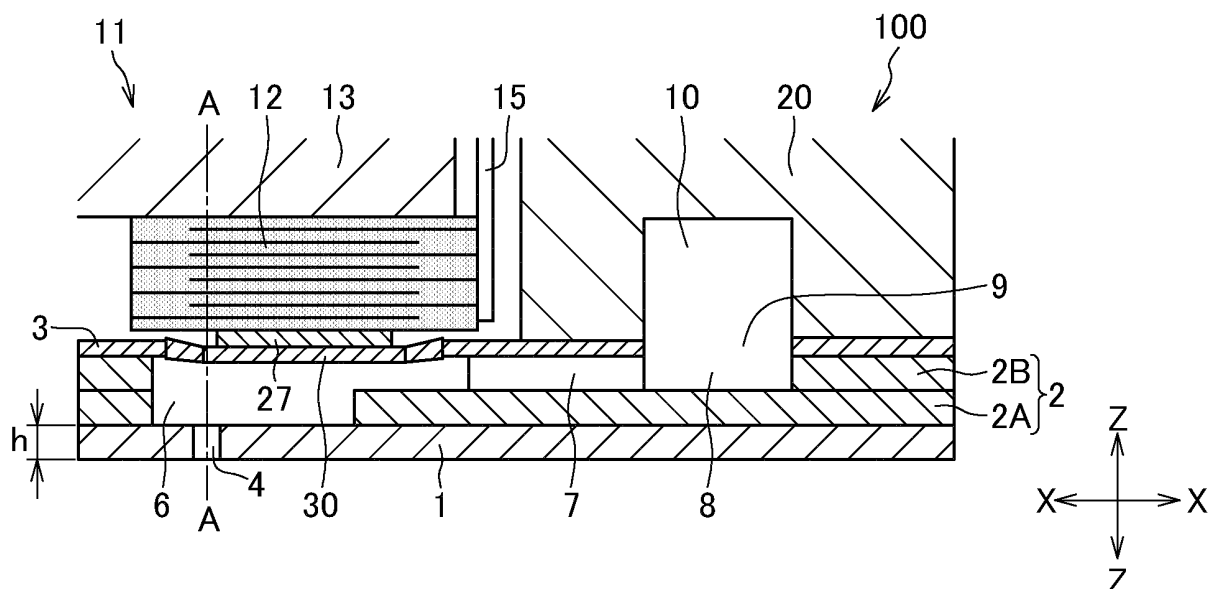
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(54) **LIQUID DISCHARGE HEAD AND LIQUID DISCHARGE APPARATUS**

(57) A liquid discharge head (100) includes a pressure chamber (6) to store a liquid to be discharged from a nozzle (4) and a deformable portion (30) defining a part of a first wall (6f1) in a longitudinal direction. The nozzle (4) is disposed at a leading end (6e1) or in a vicinity of the leading end (6e1). The first wall (6f1) is opposed to a second wall (6f2). The deformable portion (30) has a first

end (30a) closer to the nozzle (4) and a second end (30b) farther from the nozzle (4) than the first end (30a). A first distance (Z1; X1) between the deformable portion (30) and the second wall (6f2) at the first end (30a) or in a vicinity of the first end (30a) is larger than a second distance (Z2; X2) between the deformable portion (30) and the second wall (6f2) at the second end (30b).

FIG. 2



Description**BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS****BACKGROUND****Technical Field**

[0001] Embodiments of the present disclosure relate to a liquid discharge head and a liquid discharge apparatus including the liquid discharge head.

Related Art

[0002] An inkjet image forming apparatus includes a liquid discharge head that discharges ink as liquid from a nozzle hole to form an image. In such a liquid discharge head, the nozzle hole of the liquid discharge head is likely to be clogged with ink dried and thickened in the nozzle hole and the vicinity thereof. In particular, when a fast-drying ink is used as the ink, the nozzle hole is more likely to be clogged with the ink.

[0003] To solve such a situation, for example, in an ink head disclosed in Japanese Unexamined Patent Application Publication No. 2018-103616, a part of ink supplied to an individual liquid chamber is returned to a circulation common liquid chamber via a circulation flow path so that the ink is circulated in the ink head. The circulation type ink head disclosed in Japanese Unexamined Patent Application Publication No. 2018-103616 prevents the nozzle hole from being clogged with the dried and thickened ink. However, the ink head including components for circulating the ink may upsize the apparatus and may increase manufacturing costs.

SUMMARY

[0004] An object of the present disclosure is to provide a liquid discharge head having a simple configuration that prevents a nozzle from being clogged.

[0005] To solve the above-described situation, an improved liquid discharge head includes a pressure chamber to store a liquid to be discharged from a nozzle and a deformable portion defining a part of a first wall of the pressure chamber in a longitudinal direction of the pressure chamber. The first wall is opposed to a second wall of the pressure chamber. The nozzle is disposed at a leading end or in a vicinity of the leading end of the pressure chamber. The deformable portion has a first end closer to the nozzle and a second end farther from the nozzle than the first end in the longitudinal direction. A first distance between the deformable portion and the second wall at the first end or in a vicinity of the first end is larger than a second distance between the deformable portion and the second wall at the second end.

[0006] As a result, according to the present disclosure, the liquid discharge head having a simple configuration can be provided that prevents the nozzle from being clogged.

[0007] A more complete appreciation of the disclosure and many of the attendant advantages and features thereof can be readily obtained and understood from the following detailed description with reference to the accompanying drawings, wherein:

FIG. 1 is an external perspective view of a liquid discharge head according to an embodiment of the present disclosure;

FIG. 2 is a cross-sectional view of the liquid discharge head illustrated in FIG. 1 in a direction perpendicular to a nozzle array direction;

FIG. 3 is a cross-sectional view of the liquid discharge head along line A-A in FIG. 2;

FIGS. 4A to 4D are bottom views of the liquid discharge head;

FIG. 5 is a perspective view of a pressure chamber of the liquid discharge head;

FIG. 6 is a cross-sectional view of the pressure chamber in the direction perpendicular to the nozzle array direction;

FIG. 7 is a plan view of the pressure chamber;

FIG. 8 is a cross-sectional view of another pressure chamber different from the pressure chamber illustrated in FIG. 6 in the direction perpendicular to the nozzle array direction;

FIG. 9 is a schematic view of plates constructing the pressure chamber;

FIG. 10 is a schematic view of other plates constructing yet another pressure chamber, which are different from the plates illustrated in FIG. 9;

FIG. 11 is a cross-sectional view of still another pressure chamber different from the pressure chambers illustrated in FIGS. 6 and 8 in the direction perpendicular to the nozzle array direction;

FIG. 12 is a perspective view of a pressure chamber whose longitudinal direction is different from the longitudinal direction of the pressure chambers in the above drawings;

FIG. 13 is a cross-sectional view of the pressure chamber illustrated in FIG. 12 in the direction perpendicular to the nozzle array direction;

FIG. 14 is a cross-sectional view of another pressure chamber different from the pressure chamber illustrated in FIG. 13 in the direction perpendicular to the nozzle array direction;

FIG. 15 is a perspective view of still another pressure chamber;

FIG. 16 is a schematic view illustrating a first cross section and a second cross section of the pressure chamber illustrated in FIG. 15;

FIG. 17 is a schematic view illustrating a configuration of an image forming apparatus according to an embodiment of the present disclosure;

FIG. 18 is a functional block diagram of the image

forming apparatus in FIG. 17;

FIG. 19 is a plan view of a part of a printer according to another embodiment of the present disclosure;

FIG. 20 is a side view of the part of the printer in FIG. 19;

FIG. 21 is a plan view of a part of a liquid discharge device according to yet another embodiment of the present disclosure; and

FIG. 22 is a front view of a part of a liquid discharge device according to still another embodiment of the present disclosure.

[0008] The accompanying drawings are intended to depict embodiments of the present invention and should not be interpreted to limit the scope thereof. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted. Also, identical or similar reference numerals designate identical or similar components throughout the several views.

DETAILED DESCRIPTION

[0009] In describing embodiments illustrated in the drawings, specific terminology is employed for the sake of clarity. However, the disclosure of this specification is not intended to be limited to the specific terminology so selected and it is to be understood that each specific element includes all technical equivalents that have a similar function, operate in a similar manner, and achieve a similar result.

[0010] Referring now to the drawings, embodiments of the present disclosure are described below. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0011] Embodiments of the present disclosure are described below with reference to the accompanying drawings. A description is given of an embodiment of the present disclosure with reference to FIGS. 1 and 3. FIG. 1 is an external perspective view of a liquid discharge head 100 according to the present embodiment. FIG. 2 is a cross-sectional view of the liquid discharge head 100 according to the present embodiment in a direction X (i.e., a longitudinal direction of a pressure chamber 6 of the liquid discharge head 100). FIG. 3 is a cross-sectional view of the liquid discharge head 100 in a direction Y (i.e., a nozzle array direction). In the present embodiment, the direction X in FIGS. 1 and 2 is the longitudinal direction of the pressure chamber 6. Hereinafter, the direction X is also referred to as the "longitudinal direction X." Multiple nozzles 4 are arranged in the direction Y as illustrated in FIG. 3. The direction Y is also referred to as the "nozzle array direction Y." The nozzle 4 is open in a direction Z (i.e., an opening direction of the nozzle 4). The direction Z is also a height direction of the pressure chamber 6, and liquid is discharged in the direction Z from the nozzle 4 (i.e., a liquid discharge direction). The direction Z is also a vertical direction. The direction Z

(i.e., the vertical direction) refers to a direction of gravity and a direction opposite to gravity when the liquid discharge head 100 is used, that is, when the liquid discharge head is installed in an apparatus such as a liquid discharge apparatus. The direction X, the direction Y, and the direction Z illustrated in FIG. 1 are perpendicular to each other. The direction X is different from the nozzle array direction and the vertical direction among the directions perpendicular to each other. The direction X which is the longitudinal direction of the pressure chamber 6, the direction Y which is the nozzle array direction, and the direction Z which is the liquid discharge direction may not be strictly perpendicular to each other, and may deviate from the perpendicular with a slight error.

[0012] As illustrated in FIG. 1, the liquid discharge head 100 according to the present embodiment includes a nozzle plate 1, a channel plate 2 defining an individual channel, a diaphragm 3 serving as a wall of the pressure chamber 6, a piezoelectric actuator 11 (see FIG. 2), a common-chamber substrate 20, and a head cover 29. The nozzle plate 1, the channel plate 2, and the diaphragm 3 are stacked one on another and joined to each other. The piezoelectric actuator 11 displaces a deformable portion 30 of the diaphragm 3. The head cover 29 also serves as a frame of the liquid discharge head 100.

[0013] A piezoelectric element 12 and the like are disposed inside the common-chamber substrate 20. As illustrated in FIG. 1, the head cover 29 is attached to an upper portion of the common-chamber substrate 20 and covers the piezoelectric elements 12 and the like. Ink as liquid is supplied to a common supply channel in the common-chamber substrate 20 through a supply port 28. As illustrated in FIGS. 2 and 3, the nozzle plate 1 includes the multiple nozzles 4 from which ink is discharged.

[0014] The channel plate 2 and the diaphragm 3 define a fluid restrictor 7 and an intermediate supply channel 8. The nozzle plate 1, the channel plate 2, and the diaphragm 3 define the multiple pressure chambers 6. The multiple pressure chambers 6 communicate with the multiple nozzles 4, respectively. The fluid restrictor 7 is the individual channel communicating with each pressure chamber 6. The intermediate supply channel 8 is a liquid introduction portion communicating with one or multiple fluid restrictors 7 (one fluid restrictor 7 in the present embodiment).

[0015] The diaphragm 3 includes multiple plates stacked in layers, in the present embodiment, two metal plates. The diaphragm 3 includes the deformable portion 30 facing the piezoelectric actuator 11.

[0016] The deformable portion 30 defines a part of a first wall 6f1 (see FIG. 6) of the pressure chamber 6 and is elastically deformed by the piezoelectric actuator 11. The piezoelectric actuator 11 includes an electromechanical transducer element serving as a driving device (e.g., an actuator or a pressure generator). The deformable portion 30 according to the present embodiment includes fewer plates than the other portions of the diaphragm 3 and is thinner than the other portions. Specif-

ically, the deformable portion 30 includes one metal plate. Alternatively, the diaphragm 3 may be cut out to be partially deformable, and a part of the deformable cutout portion defining the wall of the pressure chamber 6 may be used as the deformable portion 30.

[0017] In the piezoelectric actuator 11, a piezoelectric material bonded on a base 13 is grooved by half-cut dicing, to form a desired number of columnar piezoelectric elements 12 at predetermined intervals in a comb shape in the nozzle array direction as illustrated in FIG. 3. A support 27 that supports the deformable portion 30 is disposed on the deformable portion 30. The piezoelectric element 12 is bonded to the support 27. The piezoelectric element 12 includes piezoelectric layers and internal electrodes alternately laminated on each other. In the piezoelectric element 12, each internal electrode is led out to an end face and connected to an external electrode (end face electrode). The external electrode is connected to a flexible wiring 15.

[0018] The common-chamber substrate 20 defines a common liquid chamber 10 communicating with the multiple pressure chambers 6. The common liquid chamber 10 communicates with the intermediate supply channel 8 via an opening 9 of the diaphragm 3 and further communicates with the fluid restrictor 7 via the intermediate supply channel 8. Ink in the common liquid chamber 10 is supplied to the pressure chamber 6 via the intermediate supply channel 8 and the fluid restrictor 7. The pressure chamber 6 stores the ink to be discharged from the nozzle 4. The ink in the pressure chamber 6 is discharged from the nozzle 4 to the outside of the liquid discharge head 100. In the pressure chamber 6, the ink is supplied in the direction X from the fluid restrictor 7 toward the nozzle 4.

[0019] In the liquid discharge head 100, for example, when a voltage applied to the piezoelectric element 12 is lowered below a reference potential (intermediate potential), the piezoelectric element 12 contracts. As the piezoelectric element 12 contracts, the deformable portion 30 deforms toward the piezoelectric element 12. As a result, the volume of the pressure chamber 6 expands, and thus the ink flows into the pressure chamber 6.

[0020] As the voltage applied to the piezoelectric element 12 is increased, the piezoelectric element 12 expands in the direction of lamination. As a result, the deformable portion 30 deforms toward the nozzle 4, and thus the volume of the pressure chamber 6 contracts. Accordingly, the ink in the pressure chamber 6 is pressurized and discharged from the nozzle 4.

[0021] The liquid discharge head 100 according to the present embodiment is a non-circulation type liquid discharge head. In a circulation type liquid discharge head, ink that has flowed into the pressure chamber 6 is circulated via a circulation flow path and flows into the pressure chamber 6 again. On the other hand, ink is not circulated in the non-circulation type liquid discharge head 100 according to the present embodiment. The pressure chamber 6 of the liquid discharge head 100 has two openings, the nozzle 4 and a connection port (i.e., a supply

port 6c illustrated in FIG. 6 and the like) with the fluid restrictor 7. That is, the pressure chamber 6 stores ink supplied from the supply port 6c, and all the ink stored in the pressure chamber is to be discharged from the nozzle 4 in the non-circulation type liquid discharge head 100.

[0022] In the liquid discharge head 100, the nozzles 4 may be arranged in a single nozzle row as illustrated in FIG. 4A or may be arranged in a plurality of nozzle rows as illustrated in FIG. 4B. In addition to the arrangement in which the nozzle rows are arranged in parallel as illustrated in FIG. 4B, the nozzles 4 of the nozzle rows may be arranged in a staggered manner. A plurality of liquid discharge heads 100 may be arranged as illustrated in FIG. 4C to construct a head unit 103. Further, multiple pairs of adjacent liquid discharge heads 100 may be arranged in a staggered manner in the head unit 103 as illustrated in FIG. 4D. The arrangement of the nozzles 4 and the liquid discharge heads 100 is not limited to the above examples and can be selected appropriately.

[0023] In the non-circulation type liquid discharge head 100 according to the present embodiment, if ink is thickened or dried in the nozzle 4 or the vicinity thereof, the nozzle 4 may be clogged with the ink. In particular, in the present embodiment, the length in the longitudinal direction and the height of the pressure chamber 6 are set to be small so as to reduce a meniscus vibration cycle and discharge ink at high speed, which may cause the nozzle 4 to be clogged. In particular, when an aqueous pigment ink or a fast-drying ink is used as liquid for the liquid discharge head 100, the nozzle 4 is more likely to be clogged with the ink.

[0024] If the length of the entire pressure chamber in the height direction is set to be large, the ink in the nozzle 4 and the vicinity thereof is prevented from being thickened or dried. However, when the length of the entire pressure chamber in the height direction is increased, meniscus vibration cycle may be increased, thereby hindering high-speed discharge.

[0025] A configuration of the pressure chamber 6 according to the present embodiment is described below with reference to FIGS. 5 to 7. The pressure chamber 6 prevents the nozzle 4 from being clogged with the thickened or dried ink in the nozzle 4 and the vicinity thereof. FIG. 5 is a perspective view of the pressure chamber 6. FIG. 6 is a cross-sectional view of the pressure chamber 6 taken along a plane that is perpendicular to the nozzle array direction and passes through a center 4a of the nozzle 4 in the longitudinal direction X. FIG. 7 is a plan view of the pressure chamber 6.

[0026] As illustrated in FIGS. 5 and 6, the pressure chamber 6 according to the present embodiment is wider on one side where the nozzle 4 is disposed (i.e., a nozzle hole side) than on the other side opposite to the nozzle 4 in the longitudinal direction X (i.e., an opposite side). Specifically, the pressure chamber 6 has a stepped portion 6a in the middle thereof in the longitudinal direction X. The stepped portion 6a makes an area of cross section

perpendicular to the longitudinal direction X on the nozzle hole side larger than an area of cross section perpendicular to the longitudinal direction X on the opposite side. Since a height of the pressure chamber 6 is increased stepwise toward the nozzle 4 by the stepped portion 6a, the pressure chamber 6 having the stepped portion 6a prevents bubbles from accumulating in a portion of the pressure chamber 6. For example, bubbles are likely to accumulate in a recessed portion of a pressure chamber according to a comparative example. In the present embodiment, as illustrated in FIG. 5, a first cross section E1 that is closest to the center 4a of the nozzle 4 in the longitudinal direction is larger than a second cross section E2 that is the farthest from the center 4a. The first cross section E1 and the second cross section E2 are perpendicular to the longitudinal direction X of pressure chamber 6 and includes the deformable portion 30.

[0027] As illustrated in FIG. 6, in a range where the deformable portion 30 is disposed in the longitudinal direction X, a position that is closest to the center 4a of the nozzle 4 in the longitudinal direction X is defined as a first longitudinal position Xa, and a position that is the farthest from the center 4a in the longitudinal direction X is defined as a second longitudinal position Xb. A first distance Z1 of the pressure chamber 6 in the direction Z at the first longitudinal position Xa is larger than a second distance Z2 of the pressure chamber 6 in the direction Z at the second longitudinal position Xb. In the present embodiment, the term "position that is closest to the center 4a" of the nozzle 4 in the longitudinal direction X may be the same position as the center 4a in longitudinal direction X.

[0028] In other words, the nozzle 4 is disposed in a vicinity of a leading end 6e1 of the pressure chamber 6, the first wall 6f1 is opposed to a second wall 6f2 of the pressure chamber 6, the second wall 6f2 has the nozzle 4, and the deformable portion 30 has a first end 30a closer to the nozzle 4 and a second end 30b farther from the nozzle 4 than the first end 30a in the longitudinal direction of the pressure chamber 6. The first distance Z1 between the deformable portion 30 and the second wall 6f2 in the vicinity of the first end 30a (i.e., at the center 4a of the nozzle 4) is larger than the second distance Z2 between the deformable portion 30 and the second wall 6f2 at the second end 30b.

[0029] The first distance Z1 is included in the first cross section E1 and the second distance Z2 is included in the second cross section E2 as illustrated in FIG. 5. Since the interval between the nozzles 4 is restricted by the resolution of an image to be formed, the maximum length of the pressure chamber 6 in the nozzle array direction Y is limited by the restricted interval. In the present embodiment, the area of the first cross section E1 increases with an increase in the first distance Z1 of the pressure chamber 6. Accordingly, the area of the pressure chamber 6 on the nozzle hole side can be increased without adversely affecting the function of the liquid discharge head 100.

[0030] The large area of the pressure chamber 6 on the nozzle hole side, in particular, the large area above the nozzle 4 prevents the ink in the nozzle 4 and the vicinity thereof from being thickened and dried. That is, a wider space on the nozzle hole side prevents the ink in the nozzle 4 and the vicinity thereof from being thickened and dried because a large amount of moisture can be supplied to the ink in the pressure chamber 6 on the nozzle hole side. Accordingly, the nozzle 4 is prevented from being clogged. The pressure chamber 6 having the area on the nozzle hole side larger than the area on the opposite side prevents the ink in the nozzle 4 and the vicinity thereof from being thickened and dried as compared with a comparative pressure chamber that has substantially the same length in the longitudinal direction X and substantially the same volume as the pressure chamber 6 according to the present embodiment, and has substantially the same area on the nozzle hole side and the opposite side. Therefore, according to the present embodiment, the pressure chamber 6 having the above-described shape efficiently prevents the ink in the nozzle 4 and the vicinity thereof from being thickened and dried. Specifically, when the area of the first cross section E1 is set to larger than the area of the second cross section E2, the above-described effect can be obtained. In particular, when the first distance Z1 is set to larger than the second distance Z2, the above effect can be obtained.

[0031] As illustrated in FIG. 6, the stepped portion 6a divides the second wall 6f2 of the pressure chamber 6 into multiple steps (e.g., a first step 6d1 and a second step 6d2) in longitudinal direction X. One of the multiple steps in which the nozzle 4 is disposed (i.e., the first step 6d1) has a third length X3 in the longitudinal direction X at the position of the center 4a of the nozzle 4 in the nozzle array direction Y. The first distance Z1 is set to be shorter than the third length X3.

[0032] In other words, the pressure chamber 6 includes a first chamber 6g1 having the first distance Z1 and a second chamber 6g2 having the second distance Z1 between which the stepped portion 6a is disposed. A length of the first chamber 6g1 (i.e., the third length X3) is larger than the first distance Z1. The pressure chamber 6 having such a configuration efficiently prevents the ink from being thickened and dried in the nozzle 4 and the vicinity thereof.

[0033] The nozzle plate 1 in which the multiple nozzles 4 are formed preferably has a thickness h of 20 μm or more and 40 μm or less (see FIG. 2). In FIG. 6, the nozzle plate 1 defines the second wall 6f2 of the pressure chamber 6, and the multiple nozzles 4 are arrayed in the nozzle plate 1 in the nozzle array direction orthogonal to the longitudinal direction of the pressure chamber 6. With such a thickness, the length of the nozzle 4 in the direction Z can be reduced, and the natural frequency of the pressure chamber 6 can be reduced. Accordingly, the liquid discharge head 100 discharges ink at high speed. Since the natural frequency may increase with an increase in

the height of the pressure chamber 6 as described above, the thickness h of the nozzle plate 1 is preferably set as described above in the configuration according to the present embodiment.

[0034] The pressure chamber 6 according to the present embodiment has a volume of 35 nL (nanoliter) or less. Even when the pressure chamber 6 has such a small volume, the configuration of the liquid discharge head 100 described above prevents the ink in the nozzle 4 and the vicinity thereof from being thickened and dried, thereby preventing the nozzle 4 from being clogged. The pressure chambers 6 to be described with reference to FIGS. 11 and 12 also have the volume of 35 nL or less.

[0035] As illustrated in FIG. 7, the pressure chamber 6 has rounded corners. The pressure chamber 6 according to the present embodiment is disposed in a range F including the rounded corners illustrated in FIG. 7. The volume of the pressure chamber 6 enclosed by walls thereof and broken lines in FIG. 6, which are boundaries with nozzle 4 and the fluid restrictor 7, is calculated. That is, the broken line in FIG. 6 extended from the second wall 6f2 of the pressure chamber 6 around the nozzle 4 is the boundary between the pressure chamber 6 and the nozzle 4. The fluid restrictor 7 according to the present embodiment is a passage of ink communicating with the intermediate supply channel 8 and has a length shorter than the length of the pressure chamber 6 in the direction Y . Ink is supplied to the pressure chamber 6 from the fluid restrictor 7 via the supply port 6c. The supply port 6c is an opening formed in the pressure chamber 6, which is a boundary with the fluid restrictor 7. The supply port 6c is disposed at a rear end 6e2 of the pressure chamber 6 opposite to the leading end 6e1 as illustrated in FIG. 6 (or in a vicinity of the rear end 6e2 as illustrated in FIG. 13).

[0036] In the pressure chamber 6, the supply port 6c of the ink is disposed closer to the second end 30b of the deformable portion 30 than to the first end 30a of the deformable portion 30 in the longitudinal direction X as illustrated in FIG. 6. The second end 30b is an end of the deformable portion 30 that is farther from the nozzle 4 than the first end 30a. Thus, ink is supplied to the pressure chamber 6 from the far end from the nozzle 4, thereby preventing the ink from stagnating in the pressure chamber 6 and facilitating draining bubbles from the pressure chamber 6.

[0037] In the pressure chamber 6 illustrated in FIG. 6, the deformable portion 30 is disposed directly above the center 4a of the nozzle 4 in the longitudinal direction X , but the configuration of the liquid discharge head 100 is not limited thereto. For example, in the pressure chamber 6 illustrated in FIG. 8, the deformable portion 30 is not disposed directly above the center 4a of the nozzle 4 in the longitudinal direction X . In this case, the first longitudinal position X_a is the position of the first end 30a of the deformable portion 30, and the first distance Z_1 is the length of the pressure chamber 6 in the direction Z at the position of the first end 30a. That is, the first distance Z_1

between the deformable portion 30 and the second wall 6f2 at the first end 30a is larger than the second distance Z_2 between the deformable portion 30 and the second wall 6f2 at the second end 30b.

[0038] The stepped portion 6a of the pressure chamber 6 is formed by stacking multiple plates. For example, as illustrated in FIG. 9, channel plates 2A to 2C are stacked. The pressure chamber 6 indicated by dotted lines in FIG. 9 is defined by holes of the channel plates 2A to 2C. The channel plate 2A has a thickness of 30 μm , and each of the channel plates 2B and 2C has a thickness of 50 μm . Accordingly, the ratio of the second distance Z_2 to the first distance Z_1 is 1:1.3 in the pressure chamber 6 illustrated in FIG. 9. As illustrated in FIG. 10, multiple stepped portions 6a may be disposed in the pressure chamber 6. In FIG. 10, each of the channel plates 2A to 2C has a thickness of 35 μm , and the ratio of the second distance Z_2 to the first distance Z_1 is 1:3.

[0039] As the ratio of the first distance Z_1 to the second distance Z_2 increases, the pressure chamber 6 is wider on the nozzle hole side than on the other side, thereby preventing the ink in the nozzle 4 and the vicinity thereof from being thickened and dried. As the ratio of the first distance Z_1 to the second distance Z_2 is too large in the pressure chamber 6 having the volume of 35 nL or less according to the present embodiment, the pressure chamber 6 is too narrow on the other side opposite to the nozzle hole side. Since the plates (e.g., the channel plates 2A to 2C) are stacked as described above to form the pressure chamber 6, the shorter second distance Z_2 requires a thinner plate, causing deterioration in yield and manufacturing accuracy of the liquid discharge head 100. In consideration of the above, the ratio of the second distance Z_2 to the first distance Z_1 is preferably in a range of 1:1.25 to 1:4, more preferably in a range of 1:1.3 to 1:3.

[0040] In the above-described embodiments, the stepped portion 6a makes the pressure chamber 6 wider on the nozzle hole side than on the other side opposite to the nozzle 4 in the longitudinal direction X . However, the shape of the pressure chamber 6 is not limited thereto. For example, as illustrated in FIG. 11, the pressure chamber 6 has an inclined portion 6b that gradually increases the length of the pressure chamber 6 in the direction Z from the other side opposite to the nozzle 4 toward the nozzle hole side. The inclined portion 6b makes the pressure chamber 6 illustrated in FIG. 11 wider on the nozzle hole side than on the other side opposite to the nozzle 4. As compared with the configuration in which the inclined portion 6b is formed in the pressure chamber 6 as illustrated in FIG. 11, the configuration in which the stepped portion 6a is formed by stacking plates as illustrated in FIG. 9 is easily processed.

[0041] In the above-described embodiments, the longitudinal direction of the pressure chamber 6 is perpendicular to the vertical direction and the nozzle array direction, but the longitudinal direction of pressure chamber 6 is not limited thereto. For example, as illustrated in FIGS. 12 and 13, a longitudinal direction Z of the pressure

chamber 6 is the same as the vertical direction and the opening direction of the nozzle 4. The longitudinal direction Z is perpendicular to the nozzle array direction Y. Ink is supplied to the pressure chamber 6 from the supply port 6c that is disposed on the other side opposite to the nozzle 4. In other words, the pressure chamber includes a third wall 6f3 having the nozzle 4 in a transverse direction of the pressure chamber 6 orthogonal to the longitudinal direction. The supply port 6c is disposed in the vicinity of the rear end 6e2 as illustrated in FIG. 13.

[0042] The pressure chamber 6 according to the present embodiment has the stepped portion 6a. The stepped portion 6a makes the pressure chamber 6 wider on the nozzle hole side than on the other side opposite to the nozzle 4 in the longitudinal direction Z. As illustrated in FIG. 14, the pressure chamber 6 may have the inclined portion 6b.

[0043] The stepped portion 6a or the inclined portion 6b makes the pressure chamber 6 wider on the nozzle hole side than on the other side opposite to the nozzle 4 in the longitudinal direction Z. More specifically, in the pressure chambers 6 illustrated in FIGS. 13 and 14, the first cross section E1 (see FIG. 12) that is closest to the center 4a of the nozzle 4 in the longitudinal direction is larger than the second cross section E2 (see FIG. 12) that is the farthest from the center 4a. The first cross section E1 and the second cross section E2 are perpendicular to the longitudinal direction Z of pressure chamber 6 and includes the deformable portion 30. As illustrated in FIGS. 13 and 14, in a range including the deformable portion 30 in the longitudinal direction Z, a position closest to the center 4a of the nozzle hole 4 is defined as a first longitudinal position Za, and a position farthest from the center 4a is defined as a second longitudinal position Zb. A first distance X1 of the pressure chamber 6 in the direction X at the first longitudinal position Za is larger than a second distance X2 of the pressure chamber 6 in the direction X at the second longitudinal position Zb.

[0044] In other words, the first distance X1 between the deformable portion 30 and the second wall 6f2 at the first end 30a is larger than the second distance X2 between the deformable portion 30 and the second wall 6f2 at the second end 30b.

[0045] The large area of the pressure chamber 6 on the nozzle hole side prevents the ink in the nozzle 4 and the vicinity thereof from being thickened and dried. Specifically, when the area of the first cross section E1 is set to larger than the area of the second cross section E2, the above-described effect can be obtained. In particular, when the first distance X1 is set to longer than the second distance X2, the above effect can be obtained.

[0046] As illustrated in FIG. 13, the stepped portion 6a divides the pressure chamber 6 into multiple steps in longitudinal direction Z. One of the multiple steps in which the nozzle 4 is disposed has a third length Z3 in the longitudinal direction Z at the position of the center 4a of the nozzle 4 in the nozzle array direction Y. The first distance X1 is set to be shorter than the third length Z3.

[0047] In other words, the pressure chamber 6 includes the first chamber 6g1 having the first distance X1 and the second chamber 6g2 having the second distance X1 between which the stepped portion 6a is disposed. A length of the first chamber 6g1 (i.e., the third length Z3) is larger than the first distance X1. The pressure chamber 6 having such a configuration efficiently prevents the ink from being thickened and dried in the nozzle 4 and the vicinity thereof.

[0048] The pressure chamber 6 is not limited to a rectangle in cross section as in the pressure chamber 6 in the embodiment illustrated in FIG. 12. For example, the pressure chamber 6 illustrated in FIG. 15 has a parallelogram cross section perpendicular to the direction Z. Also in the present embodiment, as illustrated in FIGS. 15 and 16, the first cross section E1 that is closest to the center 4a of the nozzle 4 in the longitudinal direction is larger than the second cross section E2 that is the farthest from the center 4a. The first cross section E1 and the second cross section E2 are perpendicular to the longitudinal direction Z of pressure chamber 6 and includes the deformable portion 30. The pressure chamber 6 having such a configuration prevents the ink from being thickened and dried in the nozzle 4 and the vicinity thereof.

[0049] In the above description, the deformable portion 30 is disposed on one wall of the pressure chamber 6, but may be disposed on multiple walls of the pressure chamber 6.

[0050] In the liquid discharge head 100 according to the above-described embodiments, an aqueous pigment ink is preferably used. In addition, in the liquid discharge head 100 according to the above-described embodiments, a fast-drying ink is preferably used. These inks are likely to be thickened and dried, and the nozzle 4 is likely to be clogged with the inks. However, the pressure chamber 6 according to the above-described embodiments effectively prevents the nozzle 4 from being clogged. The aqueous pigment ink referred to herein includes at least water, an organic solvent, and a pigment.

[0051] The proportion of water in the ink is not particularly limited and can be suitably selected to suit to a particular application, but is preferably from 10% to 90% by mass, more preferably from 20% to 60% by mass, for drying property and discharge reliability of the ink.

[0052] There is no specific limitation on the type of the organic solvent contained in the ink. For example, water-soluble organic solvents are usable. Examples thereof include, but are not limited to, polyols, ethers such as polyol alkyl ethers and polyol aryl ethers, nitrogen-containing heterocyclic compounds, amides, amines, and sulfur-containing compounds.

[0053] Specific examples of the water-soluble organic solvents include, but are not limited to, polyols such as ethylene glycol, diethylene glycol, 1,2-propanediol, 1,3-propanediol, 1,2-butanediol, 1,3-butanediol, 1,4-butanediol, 2,3-butanediol, 3-methyl-1,3-butanediol, triethylene glycol, polyethylene glycol, polypropylene glycol, 1,2-pentanediol, 1,3-pentanediol, 1,4-pentanediol, 2,4-pen-

tanediol, 1,5-pentanediol, 1,2-hexanediol, 1,6-hexanediol, 1,3-hexanediol, 2,5-hexanediol, 1,5-hexanediol, glycerin, 1,2,6-hexanetriol, 2-ethyl-1,3-hexanediol, ethyl-1,2,4-butanetriol, 1,2,3-butanetriol, 2,2,4-trimethyl-1,3-pentanediol, and 3-methyl-1,3,5-pentanetriol; polyol alkyl ethers such as ethylene glycol monoethyl ether, ethylene glycol monobutyl ether, diethylene glycol monomethyl ether, diethylene glycol monoethyl ether, diethylene glycol monobutyl ether, tetraethylene glycol monomethyl ether, and propylene glycol monoethyl ether; polyol aryl ethers such as ethylene glycol monophenyl ether and ethylene glycol monobenzyl ether; nitrogen-containing heterocyclic compounds such as 2-pyrrolidone, N-methyl-2-pyrrolidone, N-hydroxyethyl-2-pyrrolidone, 1,3-dimethyl-2-imidazolidinone, ϵ -caprolactam, and γ -butyrolactone; amides such as formamide, N-methylformamide, N,N-dimethylformamide, 3-methoxy-N,N-dimethylpropionamide, and 3-butoxy-N,N-dimethylpropionamide; amines such as monoethanolamine, diethanolamine, and triethylamine; sulfur-containing compounds such as dimethyl sulfoxide, sulfolane, and thiodiethanol; propylene carbonate; and ethylene carbonate.

[0054] In particular, organic solvents having a boiling point of 250°C or less are preferable, since the organic solvents not only function as wetting agents but also provide good drying property.

[0055] The proportion of the organic solvent in the ink is not particularly limited and can be appropriately selected to suit to a particular application, but is preferably from 10% to 60% by mass, more preferably from 20% to 60% by mass, for drying property and discharge reliability of the ink.

[0056] Usable pigments to be contained in the ink include both inorganic pigments and organic pigments. Each of the pigments may be used alone or two or more of the pigments may be used in combination. Mixed crystals can also be used. Usable pigments include, but are not limited to, black pigments, yellow pigments, magenta pigments, cyan pigments, white pigments, green pigments, orange pigments, glossy color pigments (e.g., gold pigments and silver pigments), and metallic pigments.

[0057] Specific examples of the inorganic pigment include, but are not limited to, titanium oxide, iron oxide, calcium carbonate, barium sulfate, aluminum hydroxide, Barium Yellow, Cadmium Red, Chrome Yellow, and carbon black produced by a known method such as a contact method, a furnace method, and a thermal method.

[0058] Specific examples of the organic pigment include, but are not limited to, azo pigments, polycyclic pigments (e.g., phthalocyanine pigments, perylene pigments, perinone pigments, anthraquinone pigments, quinacridone pigments, dioxazine pigments, indigo pigments, thioindigo pigments, isoindolinone pigments, and quinophthalone pigments), dye chelates (e.g., basic dye chelates and acid dye chelates), nitro pigments, nitroso pigments, and aniline black. Among these pigments, the pigments having good affinity for solvents are preferable.

In addition, hollow resin particles and hollow inorganic particles can also be used.

[0059] Specific examples of the pigments used for black-and-white printing include, but are not limited to: carbon blacks (i.e., C.I. Pigment Black 7) such as furnace black, lamp black, acetylene black, and channel black; metals such as copper, iron (i.e., C.I. Pigment Black 11), and titanium oxide; and organic pigments such as aniline black (i.e., C.I. Pigment Black 1).

[0060] Specific examples of the pigments for color include, but are not limited to, C.I. Pigment Yellow 1, 3, 12, 13, 14, 17, 24, 34, 35, 37, 42 (yellow iron oxide), 53, 55, 74, 81, 83, 95, 97, 98, 100, 101, 104, 108, 109, 110, 117, 120, 138, 150, 153, 155, 180, 185, and 213; C.I. Pigment Orange 5, 13, 16, 17, 36, 43, and 51; C.I. Pigment Red 1, 2, 3, 5, 17, 22, 23, 31, 38, 48:2 (Permanent Red 2B (Ca)), 48:3, 48:4, 49:1, 52:2, 53:1, 57:1 (Brilliant Carmine 6B), 60:1, 63:1, 63:2, 64:1, 81, 83, 88, 101 (red iron oxide), 104, 105, 106, 108 (Cadmium Red), 112, 114, 122 (Quinacridone Magenta), 123, 146, 149, 166, 168, 170, 172, 177, 178, 179, 184, 185, 190, 193, 202, 207, 208, 209, 213, 219, 224, 254, and 264; C.I. Pigment Violet 1 (Rohdamine Lake), 3, 5:1, 16, 19, 23, and 38; C.I. Pigment Blue 1, 2, 15 (Phthalocyanine Blue), 15:1, 15:2, 15:3, 15:4, (Phthalocyanine Blue), 16, 17:1, 56, 60, and 63; C.I. Pigment Green 1, 4, 7, 8, 10, 17, 18, and 36.

[0061] The proportion of the pigments in the ink is preferably from 0.1% to 15% by mass, more preferably from 1% to 10% by mass, for improving image density, fixability, and discharge stability.

[0062] FIG. 17 is a schematic view of an image forming apparatus 200 which is an example of a liquid discharge apparatus including the liquid discharge head 100 according to the above-described embodiments. The image forming apparatus 200 includes a controller 102, the head unit 103, an image inspection device 104, an unwinder 105, a drying device 106, and a rewinder 107.

[0063] The image forming apparatus 200 discharges ink droplets onto a sheet P1 to form an image on the sheet P1. The sheet P1 is an example of a recording medium. The sheet P1 is, for example, rolled sheet in the present embodiment. The ink is an example of liquid. A direction J in FIG. 17 is perpendicular to a width direction of the sheet P1, and indicates a direction from the supply side to the ejection side of the sheet P1 in the image forming apparatus 200. The width direction is perpendicular to the surface of the paper on which FIG. 17 is drawn.

[0064] The controller 102 controls the entire operation of the image forming apparatus 200. The unwinder 105 and the rewinder 107 are synchronized by a control signal T1 output from the controller 102, and convey the sheet P1 at a predetermined speed. The unwinder 105, the rewinder 107, and a plurality of conveyance rollers 108 construct a conveyance mechanism 150.

[0065] The head unit 103 includes a line head 131, a line head 132, a line head 133, and a line head 134. Each of the line heads 131 to 134 is an example of a droplet

discharge head. The liquid discharge head 100 according to the above-described embodiments is mounted on each of the line heads 131 to 134.

[0066] When the sheet P1 conveyed by the unwinder 105 and the rewinder 107 passes directly below the head unit 103, each of the line heads 131, 132, 133, and 134 discharges ink based on image data and applies the ink onto the sheet P1 to form an image. For example, the line head 131 discharges black ink, the line head 132 discharges cyan ink, the line head 133 discharges magenta ink, and the line head 134 discharges yellow ink.

[0067] The drying device 106 is a heating drum that heats ink applied onto the sheet P1 by the head unit 103 while conveying the sheet P1. The drying device 106 heats ink to evaporate liquid components such as moisture in the ink. As a result, the ink is fixed on the sheet P1 to fix an image on the sheet P1.

[0068] The image inspection device 104 reads the image fixed on the sheet P1 and inspects the image. The controller 102 receives a reception signal T2 including image inspection data from the image inspection device 104, and performs various correction processing using the image inspection data.

[0069] In addition to the configuration illustrated in FIG. 17, other functional devices can be appropriately added to the image forming apparatus 200. For example, a pretreatment device that treats the sheet P1 before image formation may be added between the unwinder 105 and the head unit 103, or an aftertreatment device that treats the sheet P1 after the image formation may be added between the drying device 106 and the rewinder 107. The pretreatment device includes, but is not limited to, a device that applies a treatment liquid to the sheet P1. The treatment liquid reacts with ink to prevent the ink from bleeding, for example. The aftertreatment device includes, but is not limited to, a cooling device that cools the sheet P1.

[0070] A functional configuration of the controller 102 included in the image forming apparatus 200 is described with reference to FIG. 18. FIG. 18 is a block diagram illustrating an example of the functional configuration of the controller 102. As illustrated in FIG. 18, the controller 102 includes a temperature control unit 501, a conveyance speed control unit 502, a head discharge control unit 503, and an image inspection device control unit 504. In the controller 102, a central processing unit (CPU) loads a program stored in a read only memory (ROM) into a random access memory (RAM) and executes the program to implement functions of the above-described units.

[0071] The temperature control unit 501 controls the temperature of the drying device 106. The conveyance speed control unit 502 is an example of a moving unit that relatively moves the head unit 103 and the sheet P1 in a conveyance direction of the sheet P1. The conveyance speed control unit 502 controls a conveyance speed of the sheet P1 by the conveyance mechanism 150 including the unwinder 105, the rewinder 107, and the con-

veyance rollers 108. The head discharge control unit 503 outputs a drive voltage waveform to cause each of the line heads 131 to 134 to discharge ink. The image inspection device control unit 504 controls the image inspection device 104.

[0072] When the image formation is performed, the temperature control unit 501 starts temperature control to maintain the drying device 106 at a desired temperature. The conveyance speed control unit 502 starts conveying the sheet P1, timed to coincide with the preparation of the image formation in which the drying device 106 has reached the desired temperature. When the conveyance speed of the sheet P1 by the conveyance speed control unit 502 is a substantially constant speed and the temperature of the drying device 106 is within a desired temperature range, the head discharge control unit 503 outputs the drive voltage waveform to each of the line heads 131 to 134 of the head unit 103 to discharge ink. The image forming apparatus 200 can form an image on the sheet P1 with the ink discharged from each of the line heads 131 to 134.

[0073] Each of the line heads 131 to 134 discharges ink to form an image for adjustment, and the image inspection device 104 reads landing positions of the ink in the image. An ink discharge timing of each of the line heads 131 to 134 is optimized in advance based on the landing positions of the ink. The ink discharge timing can also be adjusted by image inspection during image formation.

[0074] Next, a printer 500 as the liquid discharge apparatus according to the present embodiment is described with reference to FIGS. 19 and 20. FIG. 19 is a plan view of a part of the printer 500. FIG. 20 is a side view of the part of the printer 500 in FIG. 19. The printer 500 is a serial type apparatus, and a main-scanning moving mechanism 493 reciprocally moves a carriage 403 in a main scanning direction K illustrated in FIG. 19. The main-scanning moving mechanism 493 includes a guide 401, a main-scanning motor 405, and a timing belt 408. The guide 401 is bridged between left and right side plates 491A and 491B to moveably hold the carriage 403. The main-scanning motor 405 reciprocates the carriage 403 in the main scanning direction K via the timing belt 408 looped around a drive pulley 406 and a driven pulley 407.

[0075] The carriage 403 carries a liquid discharge device 300 including the liquid discharge head 100 according to the present embodiment and a head tank 441 as a single integrated unit. The liquid discharge head 100 of the liquid discharge device 300 discharges color liquid of, for example, yellow (Y), cyan (C), magenta (M), or black (K). The liquid discharge head 100 is mounted on the liquid discharge device 300 such that a nozzle row including a plurality of nozzles 4 is arranged in a sub-scanning direction L perpendicular to the main scanning direction K. The liquid discharge head 100 discharges the color liquid downward. The main scanning direction K is the direction X in the liquid discharge head 100 de-

scribed above, and the sub-scanning direction L is the direction Y in the liquid discharge head 100 described above.

[0076] The printer 500 includes a conveyance mechanism 495 to convey a sheet 410. The conveyance mechanism 495 includes a conveyance belt 412 as a conveyor and a sub-scanning motor 416 to drive the conveyance belt 412. The conveyance belt 412 attracts the sheet 410 and conveys the sheet 410 at a position facing the liquid discharge head 100. The conveyance belt 412 is an endless belt stretched between a conveyance roller 413 and a tension roller 414. The sheet 410 can be attracted to the conveyance belt 412 by electrostatic attraction, air suction, or the like. The conveyance belt 412 circumferentially moves in the sub-scanning direction L as the conveyance roller 413 is rotationally driven by the sub-scanning motor 416 via a timing belt 417 and a timing pulley 418.

[0077] On one side of the carriage 403 in the main scanning direction K, a maintenance mechanism 420 that maintains and recovers the liquid discharge head 100 is disposed lateral to the conveyance belt 412. The maintenance mechanism 420 includes, for example, a cap 421 to cap a nozzle face (i.e., a face on which nozzles 4 are formed) of the liquid discharge head 100 and a wiper 422 to wipe the nozzle face. The main-scanning moving mechanism 493, the maintenance mechanism 420, and the conveyance mechanism 495 are mounted onto a housing including the side plates 491A and 491B and a back plate 491C.

[0078] In the printer 500 having the above-described configuration, the sheet 410 is fed and attracted onto the conveyance belt 412 and conveyed in the sub-scanning direction L by the circumferential movement of the conveyance belt 412. The liquid discharge head 100 is driven in response to an image signal while moving the carriage 403 in the main scanning direction K to discharge liquid onto the sheet 410 not in motion, thereby forming an image.

[0079] Next, another example of the liquid discharge device 300 according to the present embodiment is described with reference to FIG. 21. FIG. 21 is a plan view illustrating a part of the liquid discharge device 300. The liquid discharge device 300 includes the housing, the main-scanning moving mechanism 493, the carriage 403, and the liquid discharge head 100 among components of the printer 500 described above. The side plates 491A and 491B, and the back plate 491C construct the housing. Note that, in the liquid discharge device 300, the maintenance mechanism 420 described above may be mounted on, for example, the side plate 491B.

[0080] Next, still another example of the liquid discharge device 300 according to the present embodiment is described with reference to FIG. 22. FIG. 22 is a front view of the liquid discharge device 300. The liquid discharge device 300 includes the liquid discharge head 100 to which a channel component 444 is attached, and a tube 456 connected to the channel component 444.

The channel component 444 is disposed inside a cover 442. In some embodiments, the liquid discharge device 300 may include the head tank 441 (see FIG. 20) instead of the channel component 444. A connector 443 for electrically connecting to the head 100 is provided on an upper portion of the channel component 444.

[0081] The above-described liquid discharge head 100 can also be provided in the liquid discharge device 300 and the printer 500 described above. Accordingly, ink in the nozzle 4 and the vicinity thereof can be prevented from being thickened and dried.

[0082] In the present disclosure, the liquid to be discharged is not limited to a particular liquid as long as the liquid has a viscosity or surface tension to be discharged from a head (liquid discharge head). However, preferably, the viscosity of the liquid is not greater than 30 mPa·s under ordinary temperature and ordinary pressure or by heating or cooling. Examples of the liquid include a solution, a suspension, or an emulsion including, for example, a solvent, such as water or an organic solvent, a colorant, such as dye or pigment, a functional material, such as a polymerizable compound, a resin, or a surfactant, a biocompatible material, such as DNA, amino acid, protein, or calcium, and an edible material, such as a natural colorant. Such a solution, a suspension, or an emulsion can be used for, e.g., inkjet ink; surface treatment liquid; a liquid for forming an electronic element component, a light-emitting element component, or an electronic circuit resist pattern; or a material solution for three-dimensional fabrication.

[0083] Examples of an energy source for generating energy to discharge liquid include a piezoelectric actuator (a laminated piezoelectric element or a thin-film piezoelectric element), a thermal actuator that employs a thermoelectric conversion element, such as a thermal resistor, and an electrostatic actuator including a diaphragm and a counter electrode.

[0084] The "liquid discharge device" is an assembly of parts relating to liquid discharge. The term "liquid discharge device" represents a structure including the liquid discharge head and a functional part(s) or unit(s) combined with the liquid discharge head as a single unit. For example, the "liquid discharge device" includes a combination of the liquid discharge head with at least one of a head tank, a carriage, a supply mechanism, a maintenance mechanism, and a main-scanning moving mechanism.

[0085] Here, the integrated unit may be, for example, a combination in which the liquid discharge head and a functional part(s) are secured to each other through, e.g., fastening, bonding, or engaging, and a combination in which one of the liquid discharge head and a functional part(s) is movably held by another. The liquid discharge head may be detachably attached to the functional part(s) or unit(s) each other.

[0086] For example, the liquid discharge head and the head tank are integrated as the liquid discharge device. Alternatively, the liquid discharge head and the head tank

coupled (connected) to each other via a tube or the like may form the liquid discharge device as a single unit. Here, a unit including a filter may further be added to a portion between the head tank and the liquid discharge head.

[0087] In another example, the liquid discharge device may be an integrated unit in which a liquid discharge head is integrated with a carriage.

[0088] As yet another example, the liquid discharge device is a unit in which the liquid discharge head and the main-scanning moving mechanism are combined into a single unit. The liquid discharge head is movably held by a guide that is a part of the main-scanning moving mechanism. The liquid discharge device may include the liquid discharge head, the carriage, and the main-scanning moving mechanism that are integrated as a single unit.

[0089] In another example, the cap that forms a part of the maintenance mechanism is secured to the carriage mounting the liquid discharge head so that the liquid discharge head, the carriage, and the maintenance mechanism are integrated as a single unit to form the liquid discharge device.

[0090] Further, in still another example, the liquid discharge device includes a tube connected to the liquid discharge head mounting the head tank or the channel component so that the liquid discharge head and the supply mechanism are integrated as a single unit.

[0091] The main-scanning moving mechanism may be a guide only. The supply mechanism may be a tube(s) only or a loading device only.

[0092] The above-described embodiments are illustrative and do not limit the present disclosure. Thus, numerous additional modifications and variations are possible in light of the above teachings. For example, elements and/or features of different illustrative embodiments may be combined with each other and/or substituted for each other within the scope of the present disclosure.

[0093] In the present disclosure, the term "liquid discharge apparatus" includes a liquid discharge head or a liquid discharge device (unit) and drives the liquid discharge head to discharge liquid. The term "liquid discharge apparatus" used here includes, in addition to apparatuses to discharge liquid to materials onto which liquid can adhere, apparatuses to discharge the liquid into gas (air) or liquid.

[0094] The "liquid discharge apparatus" may further include devices relating to feeding, conveying, and ejecting of the material onto which liquid can adhere and also include a pretreatment device and an aftertreatment device.

[0095] The "liquid discharge apparatus" may be, for example, an image forming apparatus to form an image on a sheet by discharging ink, or a three-dimensional apparatus to discharge fabrication liquid to a powder layer in which powder material is formed in layers, so as to form a three-dimensional object.

[0096] The "liquid discharge apparatus" is not limited

to an apparatus that discharges liquid to visualize meaningful images such as letters or figures. For example, the liquid discharge apparatus may be an apparatus that forms meaningless images such as meaningless patterns or an apparatus that fabricates three-dimensional images.

[0097] The above-described term "material onto which liquid can adhere" represents a material on which liquid is at least temporarily adhered, a material on which liquid is adhered and fixed, or a material into which liquid is adhered to permeate. Specific examples of the "material onto which liquid can adhere" include, but are not limited to, a recording medium such as a paper sheet, recording paper, a recording sheet of paper, a film, or cloth, an electronic component such as an electronic substrate or a piezoelectric element, and a medium such as layered powder, an organ model, or a testing cell. The "material onto which liquid can adhere" includes any material to which liquid adheres, unless particularly limited.

[0098] Examples of the "material onto which liquid can adhere" include any materials to which liquid can adhere even temporarily, such as paper, thread, fiber, fabric, leather, metal, plastic, glass, wood, and ceramic.

[0099] The term "liquid discharge apparatus" may be an apparatus to relatively move the liquid discharge head and the material onto which liquid can adhere. However, the liquid discharge apparatus is not limited to such an apparatus. For example, the liquid discharge apparatus may be a serial head apparatus that moves the liquid discharge head or a line head apparatus that does not move the liquid discharge head.

[0100] Examples of the liquid discharge apparatus further include: a treatment liquid applying apparatus that discharges a treatment liquid onto a paper sheet to apply the treatment liquid to the surface of the paper sheet, for reforming the surface of the paper sheet; and an injection granulation apparatus that injects a composition liquid, in which a raw material is dispersed in a solution, through a nozzle to granulate fine particle of the raw material.

[0101] The terms "image formation," "recording," "printing," "image printing," and "fabricating" used in the present embodiments may be used synonymously with each other.

Claims

1. A liquid discharge head (100) comprising:

a pressure chamber (6) configured to store a liquid to be discharged from a nozzle (4), the nozzle (4) disposed at a leading end (6e1) or in a vicinity of the leading end (6e1) of the pressure chamber (6) in a longitudinal direction of the pressure chamber (6); and
a deformable portion (30) defining a part of a first wall (6f1) of the pressure chamber (6), the first wall (6f1) opposed to a second wall (6f2) of

- the pressure chamber (6), the deformable portion (30) having a first end (30a) closer to the nozzle (4) and a second end (30b) farther from the nozzle (4) than the first end (30a) in the longitudinal direction,
- wherein a first distance (Z1; X1) between the deformable portion (30) and the second wall (6f2) at the first end (30a) or in a vicinity of the first end (30a) is larger than a second distance (Z2; X2) between the deformable portion (30) and the second wall (6f2) at the second end (30b).
2. The liquid discharge head (100) according to claim 1,
- wherein the second wall (6f2) has the nozzle (4), and
- the first distance (Z1) between the deformable portion (30) and the second wall (6f2) at a center (4a) of the nozzle (4) or at the first end (30a) is larger than the second distance (Z2) between the deformable portion (30) and the second wall (6f2) at the second end (30b).
3. The liquid discharge head (100) according to claim 1,
- wherein the pressure chamber (6) includes a third wall (6f3) having the nozzle (4) in a transverse direction orthogonal to the longitudinal direction, and
- the first distance (X1) between the deformable portion (30) and the second wall (6f2) at the first end (30a) is larger than the second distance (X2) between the deformable portion (30) and the second wall (6f2) at the second end (30b).
4. The liquid discharge head (100) according to any one of claims 1 to 3,
- wherein a ratio of the second distance (Z2; X2) to the first distance (Z1; X1) is within a range of 1:1.25 to 1:1.4.
5. The liquid discharge head (100) according to any one of claims 1 to 4,
- wherein the second wall (6f2) has a stepped portion (6a),
- the pressure chamber (6) includes:
- a first chamber (6g1) having the first distance (Z1; X1); and
- a second chamber (6g2) having the second distance (Z2; X2), and
- the stepped portion (6a) is between the first chamber (6g1) and the second chamber (6g2).
6. The liquid discharge head according to claim 5,
- wherein a length (X3; Z3) of the first chamber (6g1) in the longitudinal direction is larger than the first distance (Z1; X1).
7. The liquid discharge head (100) according to any one of claims 1 to 6,
- wherein the pressure chamber (6) includes a supply port (6c) from which the liquid is supplied into the pressure chamber (6), and
- the supply port (6c) is disposed at a rear end (6e2) or a vicinity of the rear end (6e2) of the pressure chamber (6) opposite to the leading end (6e1), the supply port (6c) is closer to the second end (30b) than to the first end (30a) in the longitudinal direction.
8. The liquid discharge head (100) according to any one of claims 1 to 7,
- wherein all the liquid stored in the pressure chamber (6) is to be discharged from the nozzle (4).
9. The liquid discharge head (100) according to any one of claims 1 to 8,
- wherein the pressure chamber (6) has a volume of 35 nL or less.
10. The liquid discharge head (100) according to any one of claims 1 to 9,
- wherein the liquid is an ink including water, an organic solvent, and a pigment.
11. The liquid discharge head (100) according to any one of claims 1 to 10, further comprising a nozzle plate (1) defining the second wall (6f2) or the third wall (6f3),
- wherein the nozzle (4) has multiple nozzles (4) arrayed in the nozzle plate (1) in a nozzle array direction orthogonal to the longitudinal direction of the pressure chamber (6), and
- the nozzle plate (1) has a thickness of 20 μm or more and 40 μm or less.
12. A liquid discharge apparatus (200; 500) comprising the liquid discharge head (100) according to any one of claims 1 to 11.

FIG. 1

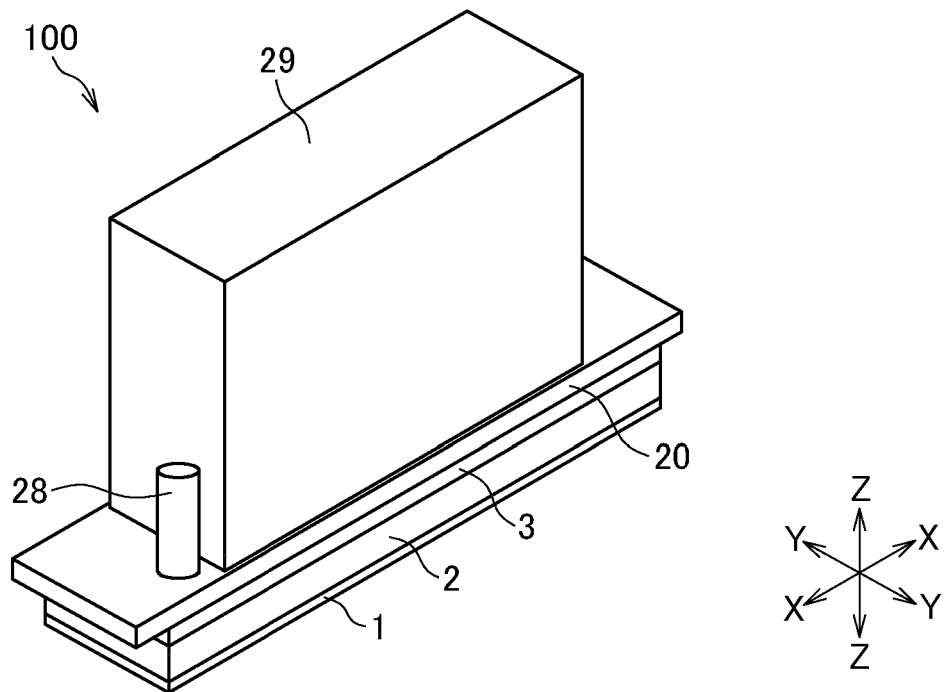


FIG. 2

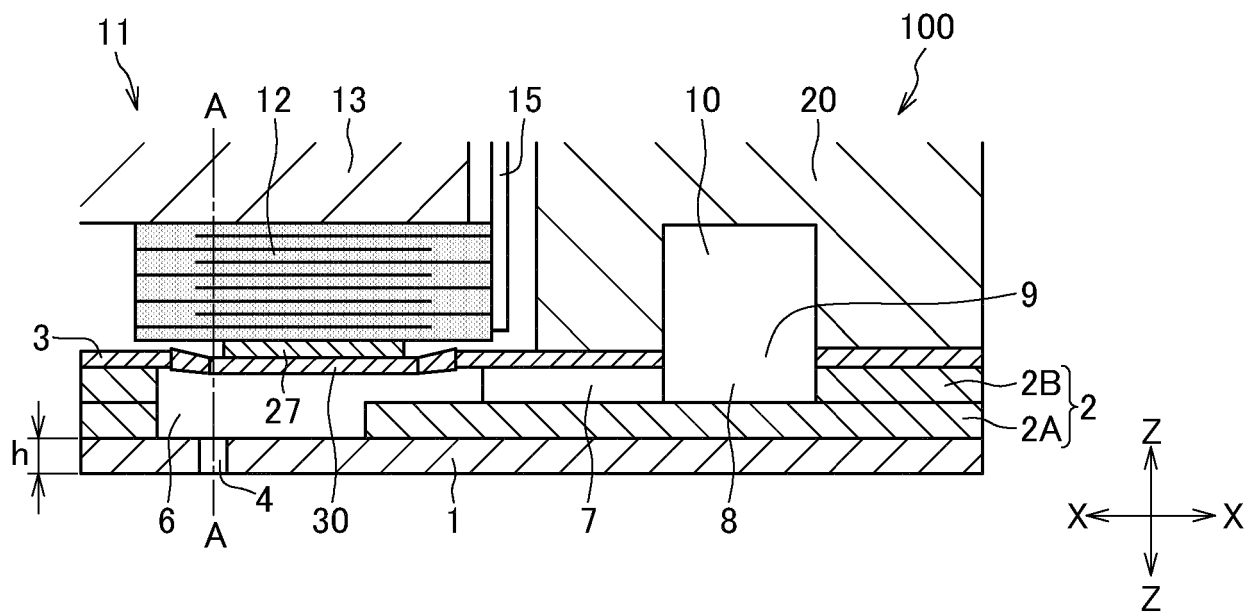


FIG. 3

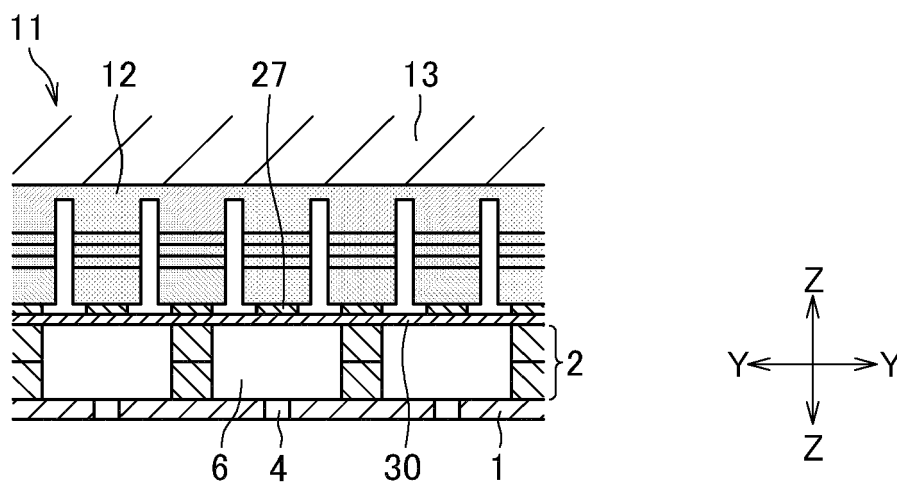


FIG. 4A

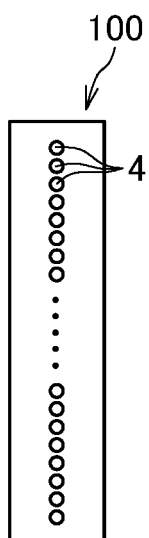


FIG. 4B

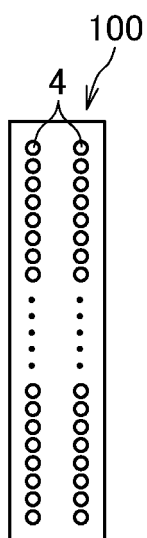


FIG. 4C

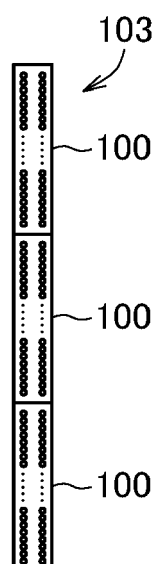


FIG. 4D

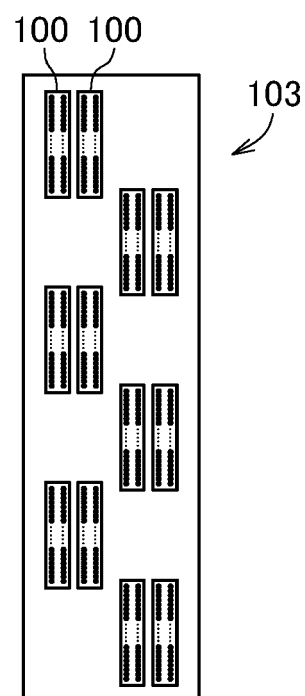


FIG. 5

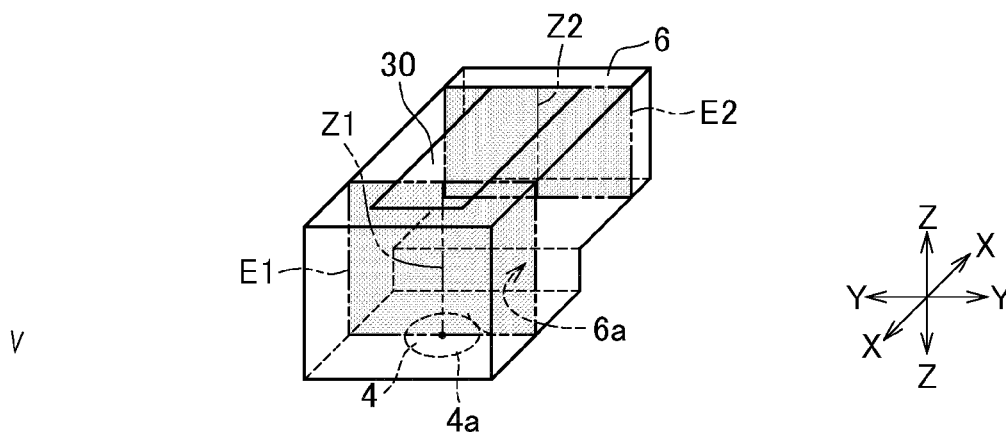


FIG. 6

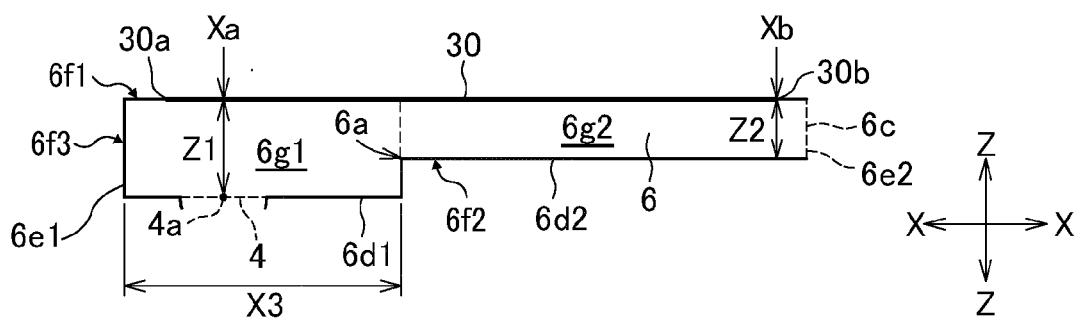


FIG. 7

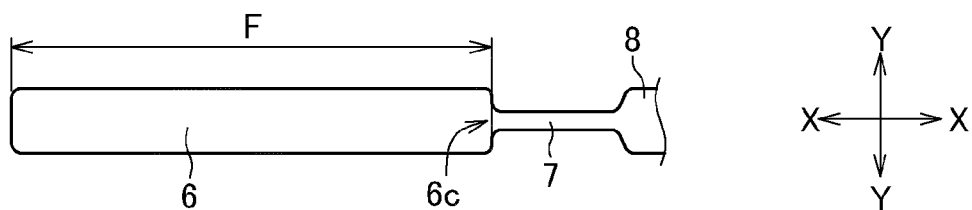


FIG. 8

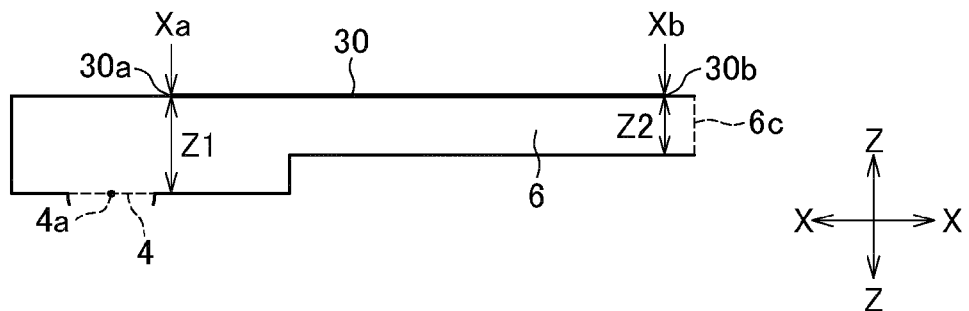


FIG. 9

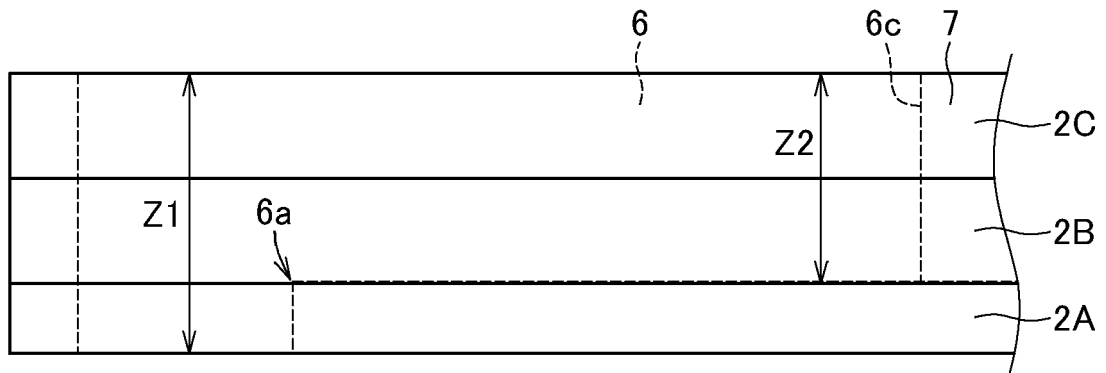


FIG. 10

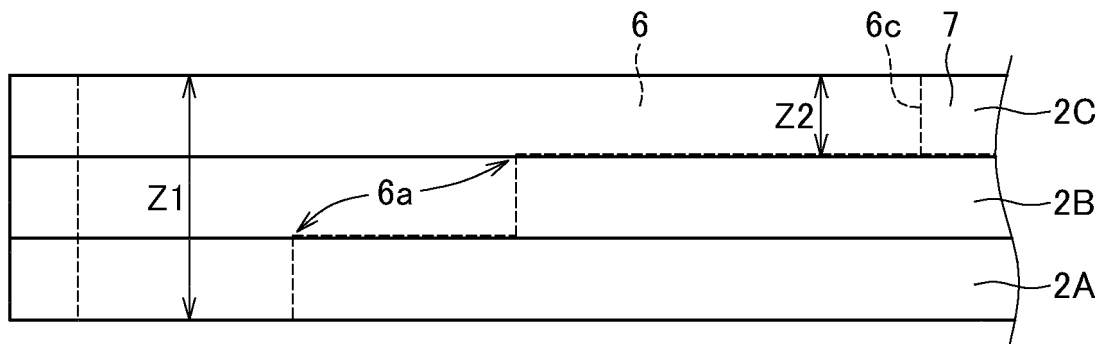


FIG. 11

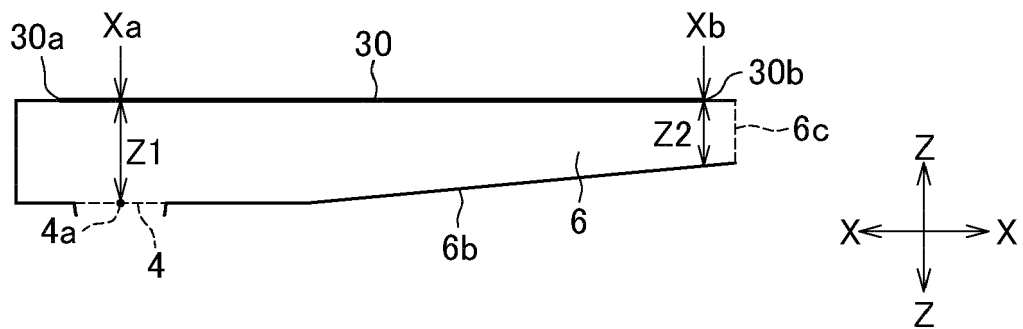


FIG. 12

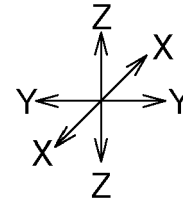
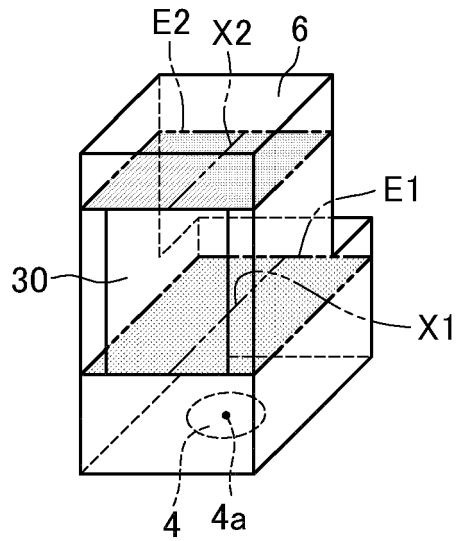


FIG. 13

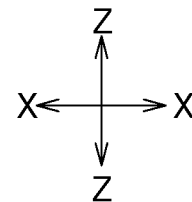
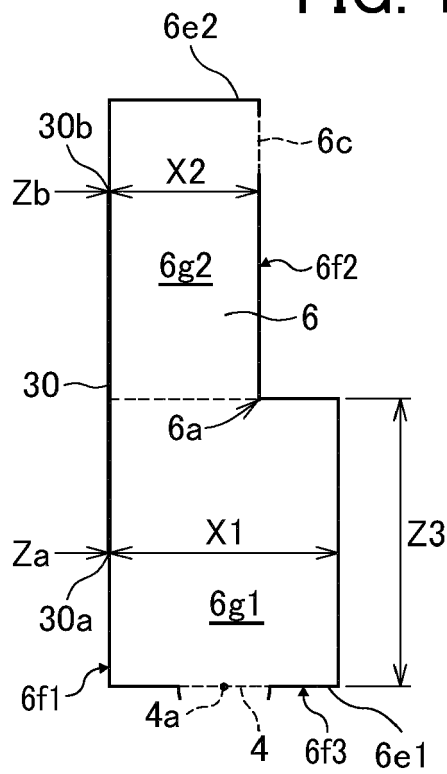


FIG. 14

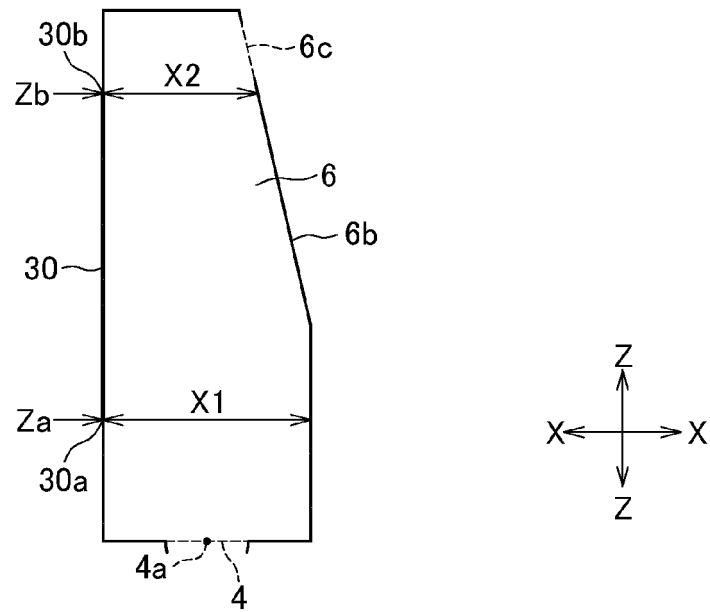


FIG. 15

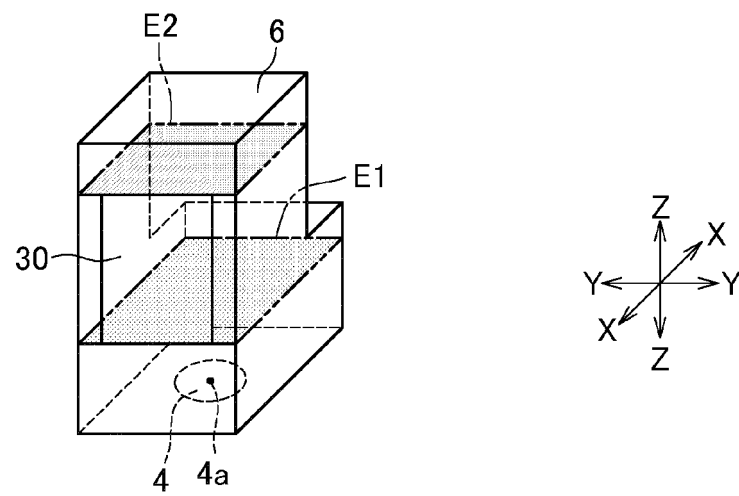


FIG. 16

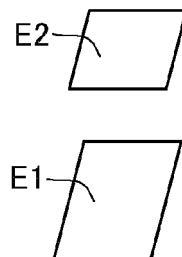


FIG. 17

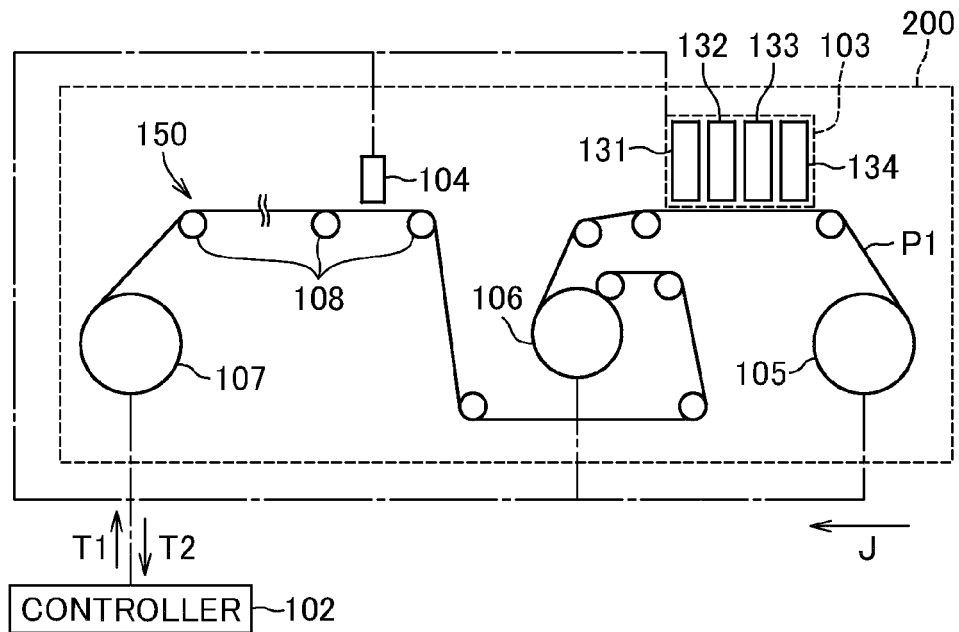


FIG. 18

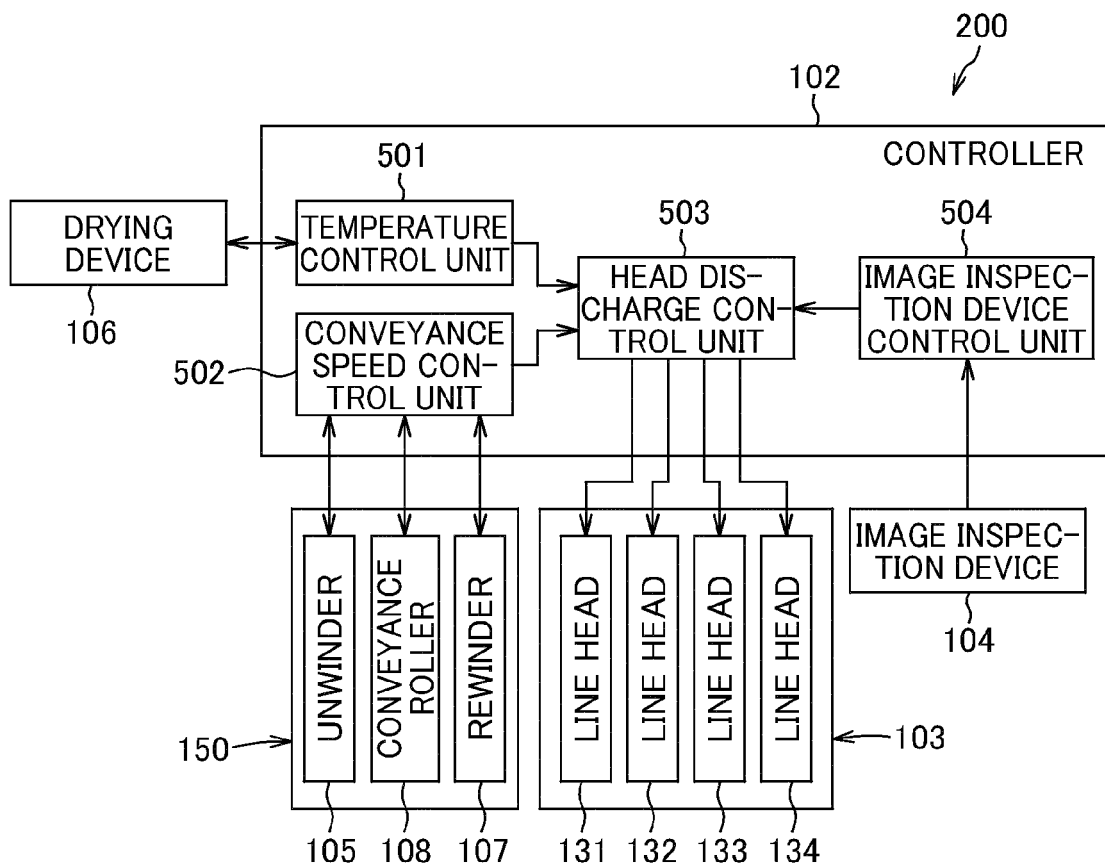


FIG. 19

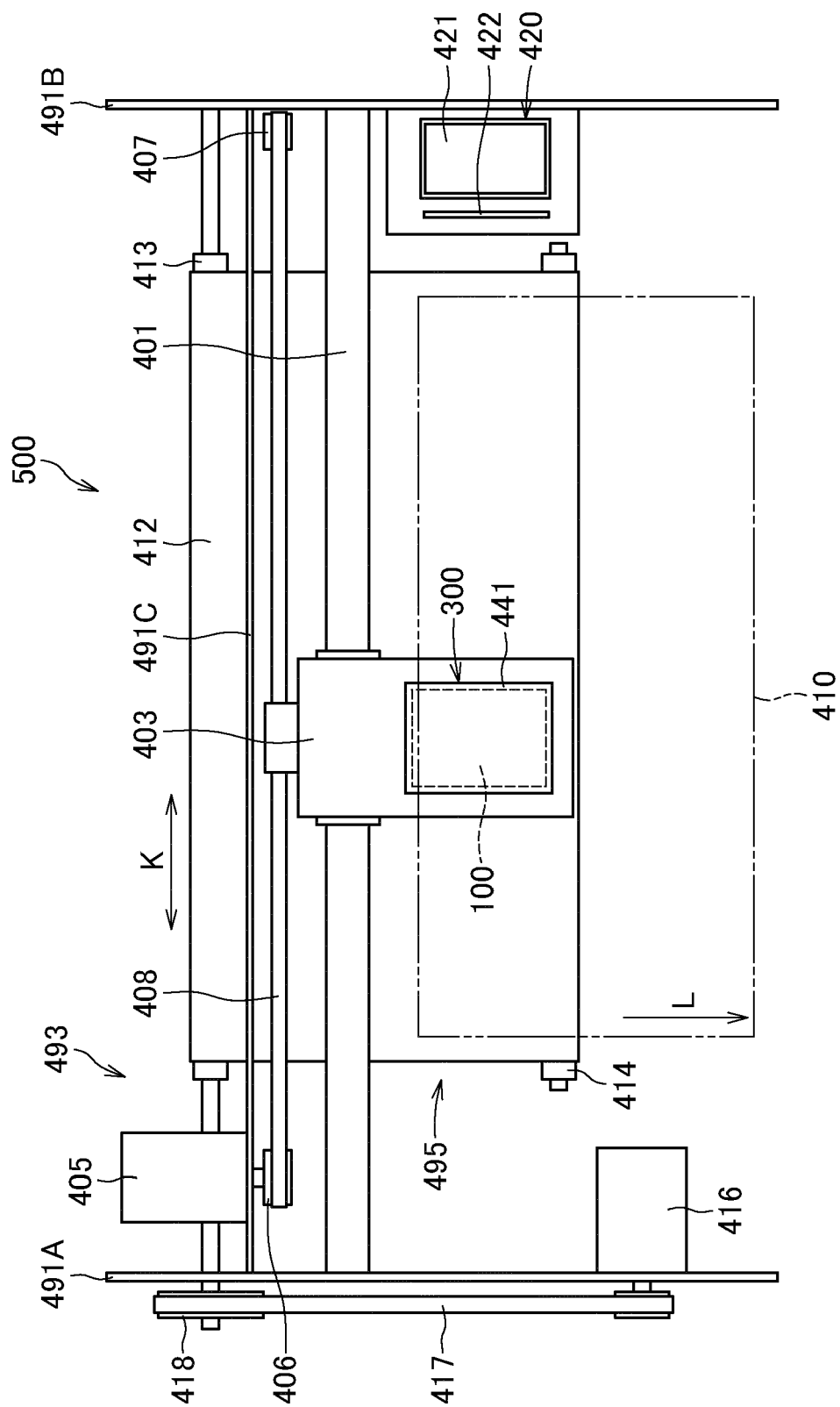


FIG. 20

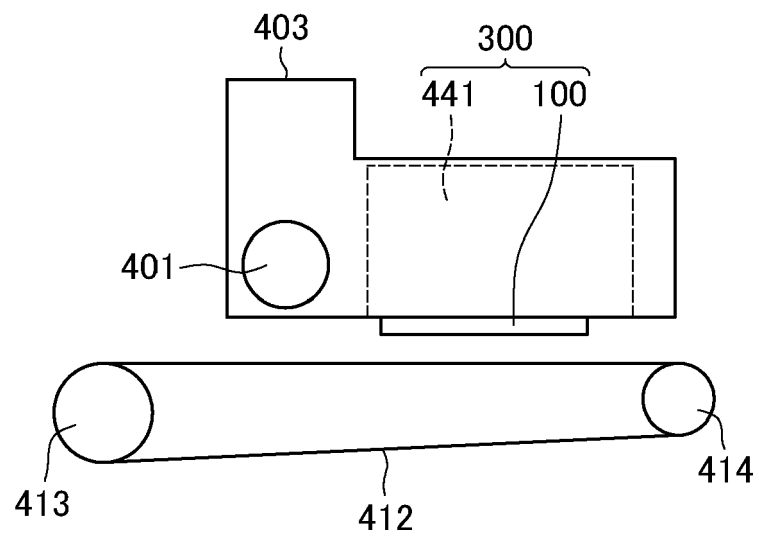


FIG. 21

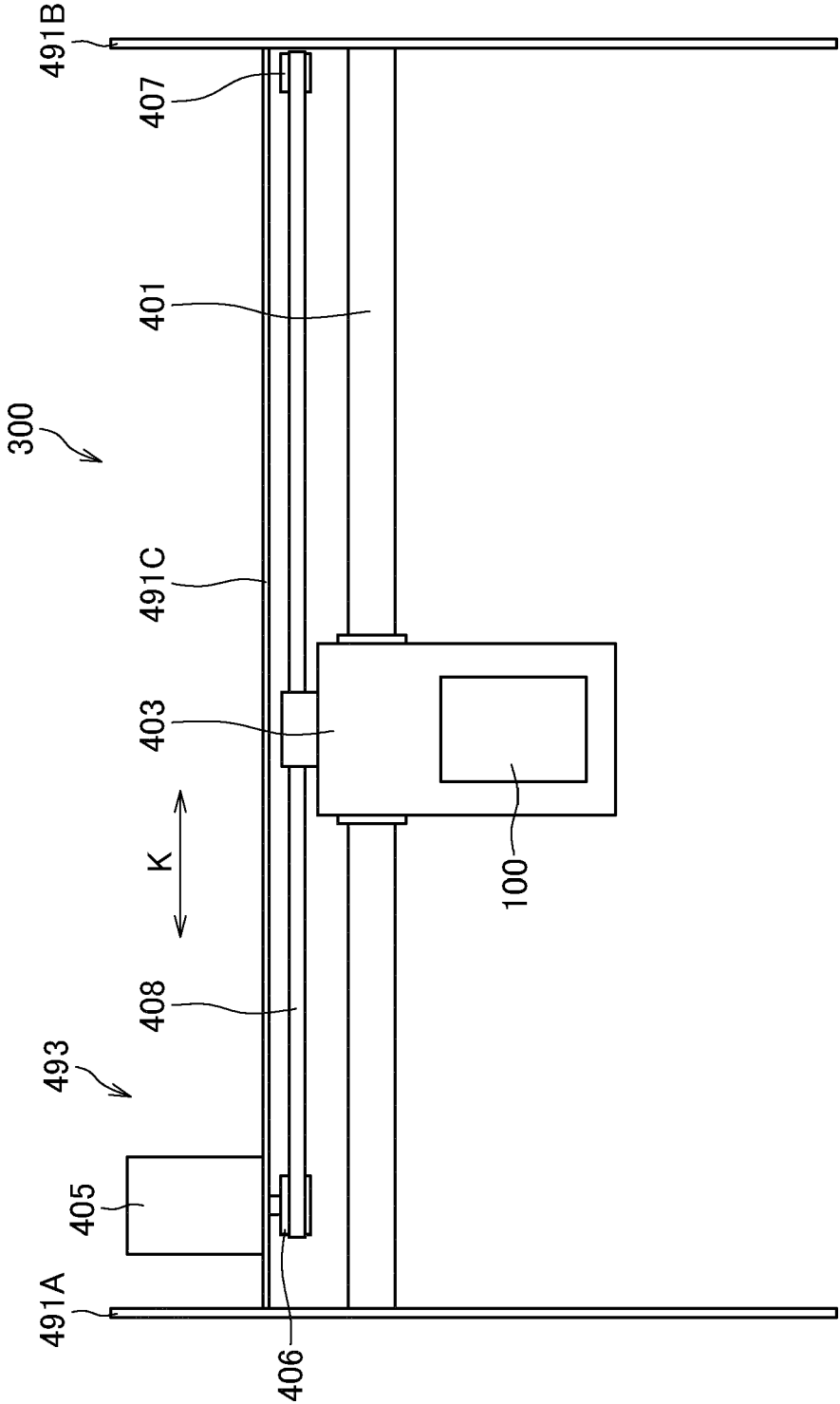
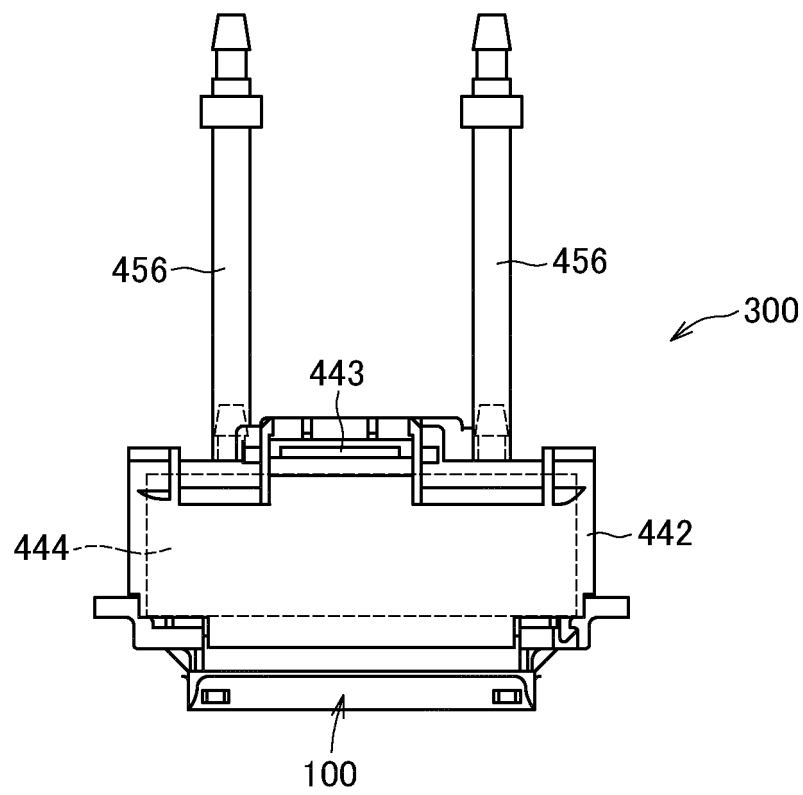


FIG. 22





EUROPEAN SEARCH REPORT

Application Number

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X	US 2017/120602 A1 (NAKAI TAKAYUKI [JP] ET AL) 4 May 2017 (2017-05-04) * the whole document * -----	1-12	
			TECHNICAL FIELDS SEARCHED (IPC)
			B41J
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 6 February 2023	Examiner Dewaele, Karl
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