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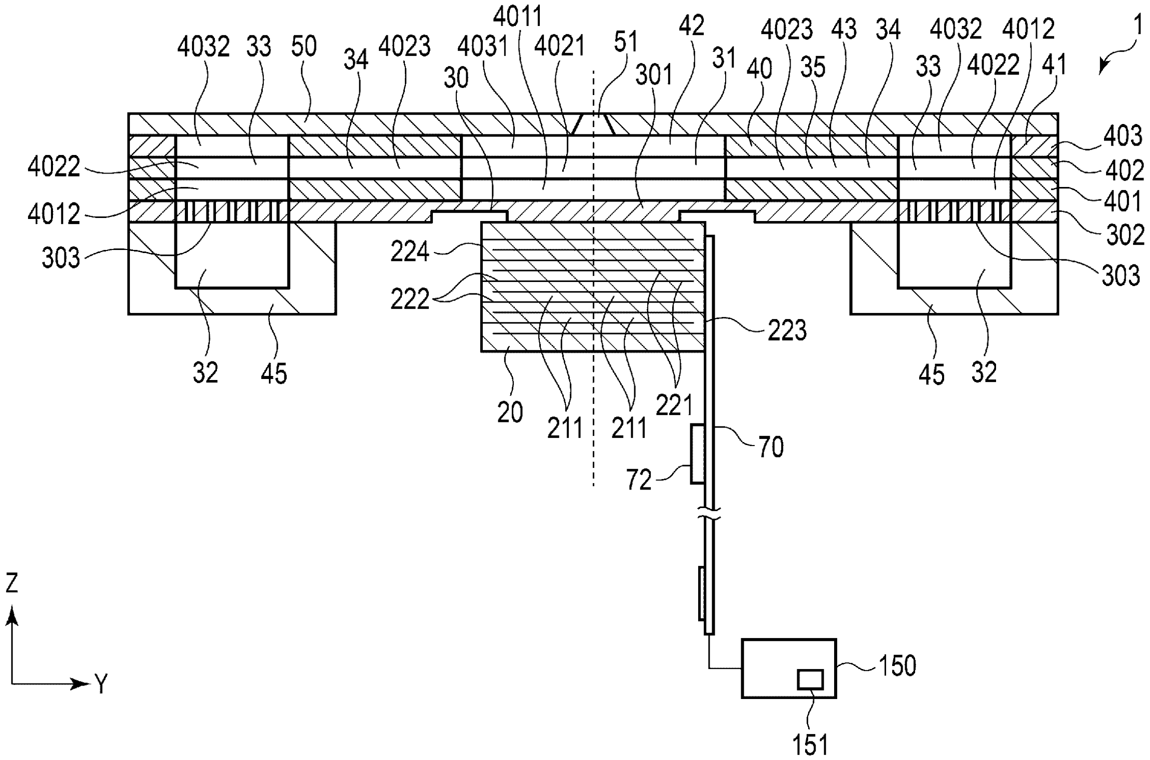
# (54) LIQUID EJECTION HEAD AND LIQUID EJECTION APPARATUS

(57) Provided are a liquid ejection head and a liquid ejection apparatus capable of improving accuracy of fluid resistance. According to one embodiment, the liquid ejection head includes a plurality of flow path substrates. The plurality of flow path substrates are each formed with an opening for forming a flow path and are stacked in a stacking direction. At least one of the flow path substrates includes a slit. A flow path formed by the slit has a flow path cross section in which a dimension in a longitudinal direction orthogonal to an extending direction of the slit and the stacking direction is three times or more a dimension in a short side direction along the stacking direction of the flow path substrates.

FIG. 1



## Description

### FIELD

**[0001]** Embodiments described herein relate generally to a liquid ejection head and a liquid ejection apparatus.

### BACKGROUND

**[0002]** In a liquid ejection head such as an inkjet head, a method is used in which a pressure chamber facing a vibration plate is deformed by deforming the vibration plate using an actuator formed of a piezoelectric body such as lead zirconate titanate (PZT), and ink is ejected from a nozzle that communicates with the pressure chamber. The liquid ejection head includes a plurality of actuators joined to the vibration plate, and a flow path portion where a plurality of pressure chambers facing the vibration plate are formed and a flow path that communicates with the pressure chambers and has a larger fluid resistance than that of the pressure chambers is formed. In the flow path portion of such an inkjet head, the flow path portion is formed by stacking a plurality of flow path plates having slits of a predetermined shape. Accuracy of a fluid resistance portion in the flow path portion greatly affects performance. In other words, when a cross-sectional area is large, vibration of a meniscus of a nozzle portion after ejection becomes large, and when the cross-sectional area is small, refilling becomes slow, either of which is a cause of hindering high-speed followability. In particular, in a circulation system in which ink circulates in a pressure chamber, when fluid resistance varies between upstream and downstream, negative pressure in the pressure chamber varies, which causes variation in ejection performance.

**[0003]** To this end, a liquid ejection head and a liquid ejection apparatus according to appended claims are provided.

### DESCRIPTION OF THE DRAWINGS

**[0004]**

FIG. 1 is a cross-sectional view illustrating a configuration of a part of an inkjet head according to a first embodiment;
FIG. 2 is a cross-sectional view illustrating a configuration of a part of the ink jet head;
FIG. 3 is a cross-sectional view illustrating a configuration of a part of a first flow path substrate;
FIG. 4 is a cross-sectional view illustrating a configuration of a part of a second flow path substrate;
FIG. 5 is a table illustrating a pipe friction coefficient ratio of a rectangular pipe;
FIG. 6 is a graph illustrating a relationship between the pipe friction coefficient ratio and an aspect ratio;
FIG. 7 is a graph illustrating correspondence between longitudinal and lateral dimensions of a flow path and a fluid resistance ratio; and
FIG. 8 is a diagram illustrating a schematic configuration of an inkjet recording apparatus.

### DETAILED DESCRIPTION

**[0005]** In order to solve the above problems, an object of an embodiment described herein is to provide a liquid ejection head and a liquid ejection apparatus capable of improving accuracy of fluid resistance.

**[0006]** In general, according to one embodiment, a liquid ejection head includes a plurality of flow path substrates. The plurality of flow path substrates are each formed with an opening for forming a flow path and are stacked in a stacking direction. At least one of the flow path substrates includes a slit. A flow path formed by the slit has a flow path cross section in which a dimension in a longitudinal direction orthogonal to an extending direction of the slit and the stacking direction is three times or more a dimension in a short side direction along the stacking direction of the flow path substrates.

**[0007]** Hereinafter, an inkjet head 1 that is a liquid ejection head and an inkjet recording apparatus 100 that is a liquid ejection apparatus according to a first embodiment will be described with reference to FIGS. 1 to 8. FIG. 1 is a cross-sectional view illustrating a configuration of a part of the inkjet head according to the first embodiment, and FIG. 2 is a cross-sectional view illustrating a configuration of a part of the inkjet head. FIG. 3 is a cross-sectional view illustrating a configuration of a part of flow path substrates 401 and 403 of the ink jet head, and FIG. 4 is a cross-sectional view illustrating a configuration of a part of a flow path substrate 402. FIG. 5 is a table illustrating a pipe friction coefficient ratio of a rectangular pipe, and FIG. 6 is a graph illustrating a relationship between the pipe friction coefficient ratio of the rectangular pipe and an aspect ratio. FIG. 7 is a graph illustrating correspondence between longitudinal and lateral dimensions of a flow path and a fluid resistance ratio in the inkjet head according to the first embodiment. FIG. 8 is a diagram illustrating a schematic configuration of an ink jet recording apparatus. Arrows X, Y, and Z in the drawings indicate three directions orthogonal to one another. In the present embodiment, X is a parallel direction of nozzles 51 or pressure chambers 31, Y is an extending direction, and Z is an axial direction of a nozzle. In the drawings, a configuration is illustrated enlarged, reduced, or omitted as appropriate for the purpose of description.

**[0008]** As illustrated in FIGS. 1 and 2, the ink jet head 1 includes an actuator portion 20, a vibration plate 30, a flow path portion 40 serving as a flow path portion including a plurality of the flow path substrates 401, 402, and 403, a nozzle plate 50 serving as a nozzle portion including a plurality of nozzles 51, a frame portion 45 serving as a structure portion, and a drive circuit 70. For example, in the ink jet head 1 according to the present embodiment, a stacking direction of piezoelectric layers 211, a vibration direction of a piezoelectric element 21, and a vibration direction of the vibration plate 30 are along a Z direction. In the present embodiment, on a back side of the nozzle plate 50, the vibration plate 30 and the flow path portion 40 constitute a flow path structure portion that forms an ink flow path 35 in the head 1. The inkjet head 1 is of a circulation type that causes liquid to circulate in a predetermined flow path.

**[0009]** The actuator portion 20 is formed of, for example, a piezoelectric member, and includes a plurality of drive piezoelectric elements 21 and a plurality of non-drive piezoelectric elements 22 as actuators alternately arranged along a row direction, and a piezoelectric structure portion 26 that integrally connects the plurality of piezoelectric elements 21 and 22. In the present embodiment, the nozzle 51 is provided at the center in an extending direction of the actuator portion 20, and the actuator portion 20 has a structure in which one side and the other side are symmetrical with respect to the nozzle 51. For example, the actuator portion 20 is joined to a rectangular base. In the actuator portion 20, the plurality of drive piezoelectric elements 21 and the non-drive piezoelectric elements 22 may not be formed continuous by the piezoelectric structure portion 26, and may be individually divided.

**[0010]** In the actuator portion 20, the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22 are arranged in parallel at regular intervals. For example, the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22 are formed in rectangular columnar shapes having the same outer shape. The actuator portion 20 is divided into a plurality sections by a plurality of groove portions 23, and the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22 are arranged in the row direction at the same pitch by, for example, the groove portions 23 having the same width. For example, the number of the drive piezoelectric elements 21 arranged in the row direction in the actuator portion 20 corresponds to the number of the nozzles 51 or the pressure chambers 31.

**[0011]** For example, the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22 are formed in a rectangular shape having a short side direction along the row direction of an element row and a longitudinal direction along an extending direction that is orthogonal to the row direction and the Z direction in a plan view as viewed from the Z direction which is an axial direction of the nozzle 51.

**[0012]** The drive piezoelectric elements 21 are arranged at positions facing a plurality of the pressure chambers 31 formed in the flow path portion 40 in the Z direction. For example, a center position of the drive piezoelectric element 21 in the row direction and the extending direction and a center position of the pressure chamber 31 in the row direction and the extending direction are aligned in the Z direction.

**[0013]** The non-drive piezoelectric elements 22 are arranged at positions facing partition wall portions 42 formed in the flow path portion 40 in the Z direction. For example, a center position of the non-drive piezoelectric element 22 in the row direction and the extending direction and a center position of the partition wall portion 42 in the row direction and the extending direction are aligned in the Z direction.

**[0014]** For example, stacked piezoelectric members constituting the actuator portion 20 are formed by stacking and sintering sheet-shaped piezoelectric materials. In the actuator portion 20, a plurality of piezoelectric elements formed in rectangular columnar shapes are formed at predetermined intervals by forming the groove portions 23 by die-working the stacked piezoelectric members from one end surface. Electrodes and the like are provided on a plurality of the formed columnar elements to form the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22 that are arranged alternately. The plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22 are alternately arranged in parallel in a manner of sandwiching the groove portions 23 in the row direction.

**[0015]** The piezoelectric members constituting the drive piezoelectric elements 21 and the non-drive piezoelectric elements 22 are, for example, stacked piezoelectric bodies. Each of the drive piezoelectric element 21 and the non-drive piezoelectric element 22 includes a plurality of stacked piezoelectric layers 211 and internal electrodes 221 and 222 formed on a main surface of each of the piezoelectric layers 211. For example, the drive piezoelectric elements 21 and the non-drive piezoelectric elements 22 have the same stacked structure. Each of the drive piezoelectric element 21 and the non-drive piezoelectric element 22 includes external electrodes 223 and 224 formed on surfaces thereof.

**[0016]** The piezoelectric layer 211 is formed of a piezoelectric material such as a lead zirconate titanate (PZT) based material or a lead-free sodium potassium niobate (KNN) based material. A plurality of piezoelectric layers 211 are stacked with a thickness direction being aligned along the stacking direction. For example, in the present embodiment, the thickness direction and the stacking direction of the piezoelectric layers 211 are along a vibration direction (the Z direction).

**[0017]** The internal electrodes 221 and 222 are conductive films formed in a predetermined shape and formed of a sinterable conductive material such as silver palladium. The internal electrodes 221 and 222 are formed in predetermined regions on main surfaces of the piezoelectric layers 211. The internal electrodes 221 and 222 have different poles. For example, the internal electrode 221 is formed in a region reaching one end portion of the piezoelectric layer 211 and not reaching the other end portion of the piezoelectric layer 211 in the extending direction (a Y direction) orthogonal to both the vibration direction (the Z direction) and the row direction (an X direction) which is an arrangement direction of the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22. The internal electrode 222 is formed in a region not reaching the one end portion of the piezoelectric layer 211 but reaching the other end portion of the piezoelectric layer 211 in the extending direction. The internal electrodes 221 and 222 are connected to the external electrodes 223 and 224 formed on side surfaces of the piezoelectric elements 21 and 22.

**[0018]** The stacked piezoelectric members constituting the drive piezoelectric elements 21 and the non-drive piezoelectric elements 22 may further include dummy layers on either one or both of a side close to the nozzle plate 50 and an opposite side. The dummy layer is formed of, for example, the same material as the piezoelectric layer 211, includes an electrode only on one side, and is not deformed because no electric field is applied thereto. For example, the dummy layer does not function as a piezoelectric body, but serves to fix the actuator portion 20 to a base, or serves as a polishing allowance for polishing to improve accuracy during and after assembly.

**[0019]** The external electrodes 223 and 224 are formed on surfaces of the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22, and are formed by collecting ends of the internal electrodes 221 and 222. For example, the external electrode 223 and the external electrode 224 are respectively formed on one end surface and the other end surface in the extending direction of the piezoelectric layer 211. The external electrodes 223 and 224 are formed by depositing a film of Ni, Cr, Au, or the like by a method such as plating or sputtering. The external electrode 223 and the external electrode 224 have different poles. The external electrode 223 and the external electrode 224 are disposed on different side surface portions of the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22. The external electrodes 223 and 224 may be disposed in different regions on the same side surface portions of the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22.

**[0020]** In the present embodiment, for example, the external electrodes 223 are individual electrodes, and the external electrodes 224 are common electrodes. Electrode layers of the external electrodes 223 serving as individual electrodes of the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22 are divided by the groove portions 23, and are disposed independently of one another. Electrode layers of the external electrodes 224 serving as common electrodes are connected to one another, for example, on a side surface of the piezoelectric structure portion 26, and, for example, are grounded. The external electrodes 223 and 224 are connected to the drive circuit 70 via, for example, wiring films. For example, each of the external electrodes 223 and 224 is connected to a control unit 150 via a drive IC 72 of the drive circuit 70, and can be driven and controlled. The arrangement of the common electrodes and the individual electrodes may be reversed.

**[0021]** A vibration direction of the piezoelectric elements 21 and 22 is along the stacking direction, and is displaced in a d33 direction when an electric field is applied. In each of the piezoelectric elements 21 and 22, the number of stacked layers of the piezoelectric layers 211 and the internal electrodes 221 and 222 is three or more. For example, the number of stacked layers in each of the piezoelectric elements 21 and 22 is three or more and 50 or less, a thickness of each layer is 10 $\mu$m or more and 40 $\mu$m or less, and a product of the thickness and the total number of stacked layers is less than 1000 $\mu$m.

**[0022]** In the ink jet head 1, the drive piezoelectric element 21 vibrates when a voltage is applied to the internal electrodes 221 and 222 via the external electrodes 223 and 224. In the present embodiment, the drive piezoelectric elements 21 perform longitudinal vibration along the stacking direction of the piezoelectric layers 211. The term "longitudinal vibration" referred to here is, for example, "vibration in a thickness direction defined by a piezoelectric constant d33". The drive piezoelectric element 21 displaces the vibration plate 30 and deforms the pressure chamber 31 by the longitudinal vibration.

**[0023]** The vibration plate 30 extends along a plane orthogonal to the Z direction which is a vibration direction, and is joined to one side in the vibration direction of the piezoelectric layers 211 of the plurality of piezoelectric elements 21 and 22, that is, a surface on a side close to the nozzle plate 50. The vibration plate 30 faces the plurality of nozzles 51 via the pressure chambers 31 in the Z direction which is the vibration direction. For example, the vibration plate 30 is configured to be deformable. The vibration plate 30 is joined to the drive piezoelectric elements 21 and the non-drive piezoelectric elements 22 of the actuator portion 20 and the frame portion 45. For example, the vibration plate 30 has a vibration region 301 facing the piezoelectric elements 21 and 22 and a support region 302 facing the frame portion 45. The vibration plate 30 is provided between the flow path substrate 401 and the actuator portion 20 in the vibration direction. The vibration plate 30 is disposed in a manner of overlapping the plurality of flow path substrates 401, 402, and 403, and constitutes a part of the ink flow path 35.

**[0024]** The vibration region 301 has, for example, a flat plate shape disposed such that a thickness direction is the vibration direction of the piezoelectric layer 211. A plane direction of the vibration plate 30 extends in an arrangement direction of the plurality of drive piezoelectric elements 21 and the plurality of non-drive piezoelectric elements 22. The vibration plate 30 is, for example, a metal plate. The vibration plate 30 has a plurality of vibration portions that face the respective pressure chambers 31 and can be displaced individually. The vibration plate 30 is formed by integrally connecting the plurality of vibration portions.

**[0025]** For example, the vibration plate 30 is formed of a nickel plate or an SUS plate, and a thickness dimension thereof along the vibration direction is about 5 μm to 15 μm. In the vibration region 301, a fold or a step may be formed at a portion adjacent to the vibration portion or between adjacent vibration portions so that the plurality of vibration portions are easily displaced. The vibration region 301 is deformed by displacing a portion that faces the drive piezoelectric element 21 due to expansion and compression of the drive piezoelectric element 21. For example, since the vibration plate 30 needs to have a very thin and complicated shape, the vibration plate 30 is formed by electroforming or the like. The vibration plate 30 is joined to an upper end surface of the actuator portion 20 by adhesion or the like.

**[0026]** The support region 302 is a plate-shaped member disposed between the frame portion 45 and the flow path substrate 401. The vibration plate 30 has a structure in which one side and the other side in the Y direction are symmetrical with respect to the nozzle 51.

**[0027]** The flow path portion 40 is joined to the one side of the vibration plate 30.

**[0028]** The flow path portion 40 includes a plurality of stacked flow path substrates 401, 402, and 403 having a flat plate shape. For example, the flow path portion 40 includes the flow path substrate 401 and the flow path substrate 403 serving as first flow path substrates having the same shape, and the flow path substrate 402 serving as a second flow path substrate, which are stacked. For example, the plurality of flow path substrates 401, 402, and 403, the nozzle plate 50, and the vibration plate 30 are combined and joined to form the desired ink flow path 35 according to ink viscosity, a volume of the ink to be ejected, and the like. The plurality of flow path substrates 401, 402, and 403 are stacked in the stacking direction, and openings or grooves formed in the flow path substrates 401, 402 and 403 form the predetermined ink flow path 35 including a plurality of pressure chambers 31 that communicate with the plurality of nozzles 51, a plurality of throttle flow paths 34 that are individual flow paths, and individual liquid chambers 33 that communicate with a common chamber 32.

**[0029]** The flow path portion 40 is disposed between the nozzle plate 50 and the vibration plate 30. The flow path portion 40 is formed by stacking and joining the plurality of flow path substrates 401, 402, and 403 to form the predetermined ink flow path 35 (a liquid chamber) including, therein, the plurality of pressure chambers 31, the plurality of individual liquid chambers 33 that communicate with the common chamber 32, and the plurality of throttle flow paths 34 serving as resistance flow paths extending from the individual liquid chambers 33 to the pressure chambers 31. In other words, the flow path portion 40 is formed by the plurality of stacked flow path substrates 401, 402, and 403, and includes a peripheral wall portion 41 that surrounds the ink flow path 35 (the liquid chamber) including the plurality of pressure chambers 31, the plurality of throttle flow paths 34, and the individual liquid chambers 33, and includes a plurality of the partition wall portions 42 that partition rows of the plurality of pressure chambers 31, and side wall portions 43 that partition the plurality of throttle flow paths 34.

**[0030]** As illustrated in FIGS. 1 to 4, the flow path substrate 401 serving as the first flow path substrate is joined to the vibration plate 30. The flow path substrate 401 is a plate-shaped member having the same shape as the vibration plate 30, and is made of, for example, a metal material containing SUS 430 or a resin material such as silicone. FIGS. 3 and 4 show a region of three rows of the ink flow paths 35 formed in a plurality of rows in a parallel direction.

**[0031]** The flow path substrate 401 has first openings 4011 that each form a part of the pressure chamber 31 and second openings 4012 that each form a part of the individual liquid chamber 33. For example, the first opening 4011 is disposed at the center in an extending direction in which the ink flow path 35 extends, and the second openings 4012 are disposed at both ends. In an arrangement direction, the openings 4011 and 4012 are each arranged in a plurality of rows corresponding to the number of rows of the nozzles 51, a beam portion 461 is formed between the openings 4011 adjacent in the arrangement direction, and a beam portion 462 is formed between the openings 4012 adjacent in the arrangement direction. The beam portions 461 and 462 have the same length as the respective openings 4011 and 4012.

**[0032]** The flow path substrate 402 serving as a second flow path substrate is stacked on the flow path substrate 401, and is joined to the flow path substrate 401. The flow path substrate 402 is a plate-shaped member having the same outer shape as the vibration plate 30, and is made of, for example, a metal material containing SUS 430 or a resin material such as silicone. The flow path substrate 402 has long hole portions 4024 that are long and thin, and each of the long hole portions 4024 integrally includes a first opening portion 4021 that forms a part of the pressure chamber 31, a second opening portion 4022 that forms a part of the individual liquid chamber 33, and a slit 4023 that communicates with the first opening portion 4021 and the second opening portion 4022 and forms the throttle flow path 34 which is an individual flow path. For example, the first opening portion 4021 is disposed at the center in the extending direction in which the ink flow path 35 extends, and the second opening portions 4022 are disposed at both ends. The first opening portion 4021 and the second opening portion 4022 are continuous by being connected by the slit 4023 to form the groove-shaped long hole portion 4024 that is thin and long.

**[0033]** The long hole portions 4024 are arranged in a plurality of rows in an arrangement direction, and a beam portion 463 is formed between the long hole portions 4024 adjacent to each other in the arrangement direction. The beam portion 463 has the same length as the long hole portion 4024.

**[0034]** That is, the flow path substrate 402 has the long hole portion 4024 having an opening with a length in the extending direction being longer than those of the flow path substrate 401 and the flow path substrate 403 which are other flow path substrates. For example, the long hole portion 4024 of the flow path substrate 402 is a slit extending over the entire length of the ink flow path 35 in one direction, and extends from one end to the other end of the ink flow path 35 in the extending direction (the Y direction).

**[0035]** A thickness dimension HA of the second flow path substrate 402 is 1/3 or less of a width direction dimension WA of the slit 4023 formed in the second flow path substrate 402. In the present embodiment, a flow path cross section of the throttle flow path 34 orthogonal to the extending direction which is a flow direction is configured such that a width direction of the slit 4023 is longer than a thickness direction. Therefore, a longitudinal direction of the flow path cross section of the throttle flow path 34 is the width direction of the slit 4023, and a short side direction of the flow path cross section is a thickness direction of the substrate 402. In the present embodiment, the width direction dimension WA of the slit 4023 that is the longitudinal direction of the flow path cross section of the slit 4023 which is a part of the opening formed in the second flow path substrate 402 is three times or more the thickness dimension HA of the flow path substrate 402 that is the short side direction of the flow path cross section.

**[0036]** For example, the second flow path substrate 402 has a thickness of 20 μm to 100 μm. For example, in the case of 300 dpi, an arrangement pitch of the pressure chambers 31 in the parallel direction is 169 μm, a width of the pressure chamber 31 is about 100 μm to 150 μm, and for example, a width of the beam portion 463 is about 20 μm to 70 μm.

**[0037]** The flow path substrate 403 serving as the first flow path substrate is joined to the flow path substrate 402. The flow path substrate 403 is a plate-shaped member having the same shape as the flow path substrate 401, and is made of, for example, a metal material containing SUS 430 or a resin material such as silicone. The flow path substrate 403 has first openings 4031 that each form a part of the pressure chamber 31 and second openings 4032 that each form a part of the individual liquid chamber 33. For example, the first opening 4031 is disposed at the center in the extending direction in which the ink flow path 35 extends, and the second openings 4032 are disposed at both ends. In the arrangement direction, a plurality of openings 4031 and a plurality of openings 4032 are arranged, the beam portion 461 is formed between the openings 4031 adjacent to each other in the arrangement direction, and the beam portion 462 is formed between the openings 4032 adjacent to each other in the arrangement direction. The beam portions 461 and 462 have the same length as the openings 4031 and 4032 in the longitudinal direction.

**[0038]** For example, the flow path substrates 401 and 403 serving as the first flow path substrates have a thickness of 20 μm to 100 μm. For example, in the case of 300 dpi, an arrangement pitch of the pressure chambers 31 in the parallel direction is 169 μm, a width of the pressure chamber 31 is about 100 μm to 150 μm, and a width of the beam portion 461 is about 20 μm to 70 μm.

**[0039]** For example, the flow path substrates 401, 402, and 403 are formed by etching a metal plate made of SUS or the like into a plate shape having a predetermined thickness to form openings at predetermined positions.

**[0040]** In the flow path portion 40, the plurality of pressure chambers 31 are formed by the first openings 4011, 4021, and 4031 in the plurality of flow path substrates 401, 402, and 403 that communicate with one another and are arranged in the stacking direction. The plurality of pressure chambers 31 are spaces formed on one side of the vibration region 301 of the vibration plate 30, and the pressure chamber 31 communicates with the nozzle 51 formed in the nozzle plate 50 (a nozzle member). The pressure chamber 31 is closed by the vibration plate 30 on a side opposite to the nozzle plate 50.

**[0041]** The plurality of pressure chambers 31 communicate with the common chamber 32 via the throttle flow paths 34 and the individual liquid chambers 33 and an opening 303. The pressure chamber 31 holds a liquid supplied from the common chamber 32, and the pressure chamber 31 is deformed by vibration of the vibration plate 30 that forms a part of the pressure chamber 31, thereby ejecting the liquid from the nozzle 51.

**[0042]** In the flow path portion 40, the individual liquid chambers 33 on both sides in the Y direction of the pressure chamber are formed by the second openings 4012, 4022, and 4032 in the plurality of flow path substrates 401, 402, and 403 that communicate with one another and are arranged in the stacking direction.

**[0043]** The individual liquid chambers 33 are flow paths that communicate with end portions in the flow direction of the plurality of throttle flow paths 34. The individual liquid chamber 33 is formed, for example, between the vibration plate 30 and the nozzle plate 50, and communicates with the common chamber 32 of the frame portion 45. Here, each of the flow path substrates 401, 402, and 403 has a structure in which one side and the other side in the Y direction are symmetrical with respect to the nozzle 51. Flow path lengths of the individual liquid chambers 33 arranged at both sides in the Y direction with the central pressure chamber 31 as a center are formed to be equal and flow path cross sections of the individual liquid chambers 33 in a direction orthogonal to the Y direction are formed to have the same shape.

**[0044]** In the flow path portion 40, the throttle flow paths 34 are formed by the slits 4023. The throttle flow paths 34 enable the pressure chambers 31 to communicate with the individual liquid chambers 33, and extend in the Y direction which is the flow direction. The throttle flow paths 34 on both sides are formed to have a smaller dimension in the width direction orthogonal to the extending direction which is the flow direction than the individual liquid chambers 33 and the pressure chambers 31, and flow path cross sections of the throttle flow paths 34 are formed to be narrower than the individual liquid chambers 33 and the pressure chambers 31. That is, the throttle flow path 34 is a narrow portion where a flow path is reduced in the width direction intersecting the stacking direction and the extending direction of the flow path.

**[0045]** Here, each of the flow path substrates 401, 402, and 403 has a structure in which one side and the other side in the Y direction are symmetrical with respect to the nozzle 51. Flow path lengths of the throttle flow paths 34 arranged at both sides in the Y direction with the central pressure chamber 31 as a center are formed to be equal and flow path cross sections of the throttle flow paths 34 in a direction orthogonal to the Y direction are formed to have the same shape. In the flow path portion 40, the partition wall portions 42 that partition the plurality of pressure chambers 31 are formed by the beam portions 461 of the stacked flow path substrates 401 and 403 and central portions of the beam portions 463 of the flow path substrate 402.

**[0046]** The partition wall portions 42 are wall members that partition the plurality of pressure chambers 31 in the arrangement direction. The partition wall portion 42 is disposed in a manner of facing the non-drive piezoelectric element 22 via the vibration plate 30, and is supported by the non-drive piezoelectric element 22. A plurality of the partition wall portions 42 are provided at a pitch the same as an arrangement pitch of the pressure chambers 31.

**[0047]** In the flow path portion 40, the side wall portions 43 that partition the plurality of throttle flow paths 34 are formed by portions between the slits 4023 and the beam portions 463 of the flow path substrate 402.

**[0048]** The side wall portions 43 are wall members that partition the plurality of throttle flow paths 34 in the arrangement direction. For example, the side wall portion 43 is provided at an inlet of the pressure chamber 31. The side wall portion 43 is configured such that flow path resistance of the throttle flow path 34 is larger than that inside the pressure chamber 31, and a flow path cross-sectional area of the throttle flow path 34 is smaller than that in the pressure chamber 31. A plurality of the side wall portions 43 are provided at a pitch the same as the arrangement pitch of the plurality of pressure chambers 31.

**[0049]** That is, in the flow path portion 40, the throttle flow path 34 along the extending direction is interposed between the flow path substrate 401 and the flow path substrate 403 in the stacking direction, and is a space interposed between the side wall portions 43, 43 in the width direction. In a flow path cross section of the throttle flow path 34 which is a cross section orthogonal to the extending direction, a dimension in the short side direction is the thickness dimension HA of the flow path substrate 402 which is a dimension of a space between the flow path substrate 401 and the flow path substrate 403, and a dimension in the longitudinal direction is a width direction dimension of the slit 4023.

**[0050]** Therefore, on both sides of the pressure chamber 31, the throttle flow path 34 along the extending direction has a rectangular flow path cross section in which the dimension in the longitudinal direction along the width direction of the slit 4023 is three times or more the dimension in the short side direction along the thickness direction of the flow path substrate 402.

**[0051]** FIG. 5 is a table illustrating a relationship between a pipe friction coefficient ratio k of a rectangular pipe and an aspect ratio (based on technical document "fluid resistance of pipe and duct" of The Japan Society of Mechanical Engineers). FIG. 6 is a graph illustrating the relationship between the pipe friction coefficient ratio k of the rectangular pipe and the aspect ratio, a horizontal axis represents an aspect ratio $\varepsilon$ and a vertical axis represents a pipe friction coefficient ratio k.

**[0052]** As illustrated in FIG. 5, in a flow path having a rectangular cross section, when Reynolds number is small and a pipe length L is sufficiently long (for example, longer than a side of the cross section by one or more order), flow path resistance R of the pipe having a cross-sectional area A (m^2), a wet edge length S (m), and a pipe length L (m) is expressed by the following Formula 1 with $\mu$(Pa·s) being ink viscosity.

$$R(Pa\cdot s/m^{\wedge}3) = 2k(S^{\wedge}2/A^{\wedge}3)\cdot L\cdot \mu \qquad \text{(Formula 1)}$$

**[0053]** In this case, k is the pipe friction coefficient ratio of the rectangular pipe, and as illustrated in FIGS. 5 and 6, when the aspect ratio is less than 0.3, k rapidly increases. The pipe length L is a length in an extending direction of a flow path.

**[0054]** FIG. 7 is a table in which a length of a long side of a flow path cross section orthogonal to the extending direction of the throttle flow path 34 that is a fluid resistance portion is set to 100 μm, and a length of a short side is set to 30 μm, and values of ± 10% of the long side and the short side are substituted to compare magnitudes of fluid resistance. In order to obtain a fluid resistance ratio, the unit was not meter but micrometer, and k was calculated based on an approximation formula of the graph. L and μ are the same.

**[0055]** According to FIG. 7, a change amount in a resistance value caused by a change of 3 μm in the short side is larger than a change amount in a resistance value caused by a change of 10 μm in the long side. That is, in FIG. 7, when comparing a case in which the length of the short side is fixed at 30 μm and the length of the long side is changed in increment and decrement of 10 μm in the top three rows of the table with a case in which the length of the long side is fixed and the length of the short side is changed in increment and decrement of 3 μm in the bottom two rows of the table, it can be seen that the change in fluid resistance is larger when the length of the short side is changed. Therefore, accuracy of the short side is dominant in determining the fluid resistance value, and it can be said that an increase in the accuracy of the short side leads to an increase in accuracy of the fluid resistance.

**[0056]** For example, the flow path substrate 402 is formed by forming an opening in a metal plate such as a thin SUS plate by etching or the like. Although depending on a method and cost, generally, plate thickness accuracy is higher than etching accuracy, and thus accuracy of the fluid resistance is improved by making a plate thickness as a short side and an etched opening as a long side. In particular, as ink viscosity decreases, factors other than the ink viscosity become dominant in determining the fluid resistance, and thus accuracy of a flow path shape becomes important.

**[0057]** The nozzle plate 50 is formed of a metal such as SUS and Ni, or a resin material such as polyimide, and has a rectangular plate shape with a thickness of about 10 μm to 100 μm. The nozzle plate 50 is disposed on one side of the flow path portion 40 in a manner of covering an opening on one side of the pressure chamber 31. The nozzle plate 50 has a plurality of nozzles 51 that eject liquid droplets. The plurality of nozzles 51 are holes that pass through the nozzle plate 50 in the thickness direction. The plurality of nozzles 51 are arranged in a first direction the same as the arrangement direction of the pressure chambers 31 to form a nozzle row. The nozzles 51 are provided at positions corresponding to the plurality of pressure chambers 31.

**[0058]** The frame portion 45 is a structure joined to the vibration plate 30 together with the piezoelectric elements 21 and 22. The frame portion 45 is provided on a side of the piezoelectric elements 21 and 22 and a side of the vibration plate 30 opposite to the flow path portion 40. For example, the frame portion 45 is adjacent to the actuator portion 20 in the present embodiment. The frame portion 45 constitutes an outer shell of the inkjet head 1. Further, the frame portion 45 may be formed with a liquid flow path therein. In the present embodiment, the frame portion 45 is joined to the other side of the vibration plate 30, and the common chamber 32 is formed between the frame portion 45 and the vibration plate 30.

**[0059]** The common chamber 32 is formed inside the frame portion 45 and communicates with the pressure chamber 31 through the opening 303 provided in the vibration plate 30, the individual liquid chamber 33, and the throttle flow path 34.

**[0060]** The drive circuit 70 includes a wiring film having one end connected to the external electrodes 223 and 224, a driver IC mounted on the wiring film, and a printed wiring board mounted on the other end of the wiring film.

**[0061]** The drive circuit 70 causes the driver IC to drive the piezoelectric element 21 by applying a drive voltage to the external electrodes 223 and 224 to increase or decrease a volume of the pressure chamber 31, and causes droplets to be ejected from the nozzle 51.

**[0062]** The wiring film is connected to the plurality of external electrodes 223 and 224. For example, the wiring film is an anisotropic conductive film (ACF) fixed to connection portions with the external electrodes 223 and 224 by thermo-compression bonding or the like. The wiring film is, for example, a chip on film (COF) on which the driver IC is mounted.

**[0063]** The driver IC is connected to the external electrodes 223 and 224 via the wiring film. Instead of the wiring film, the driver IC may be connected to the external electrodes 223 and 224 by other methods such as an anisotropic conductive paste (ACP), a non-conductive film (NCF), and a non-conductive paste (NCP).

**[0064]** The driver IC generates a control signal and a drive signal for operating each piezoelectric element 21. The driver IC generates a control signal for controlling a timing of ejecting ink, selection of the piezoelectric element 21 to eject ink, and so on, according to an image signal received from the control unit 150 of the inkjet recording apparatus 100. The driver IC generates a voltage to be applied to the piezoelectric element 21, that is, a drive signal (an electric signal), according to the control signal. When the driver IC applies the drive signal to the piezoelectric element 21, the piezoelectric element 21 is driven to displace the vibration plate 30 and change a volume of the pressure chamber 31. Accordingly, ink filled in the pressure chamber 31 are caused to perform pressure vibration. Due to the pressure vibration, the ink is ejected from the nozzle 51 provided in the pressure chamber 31. The ink jet head 1 may be configured to implement gradation expression by changing an amount of ink droplets that land on one pixel. The inkjet head 1 may be configured to change the amount of ink droplets that land on one pixel by changing the number of times of ink ejection. In this manner, the driver IC is an example of an application unit that applies a drive signal to the piezoelectric element 21.

**[0065]** For example, the driver IC includes a data buffer, a decoder, and a driver. The data buffer stores printing data in time series for each piezoelectric element 21. The decoder controls the driver based on the printing data stored in the data buffer for each piezoelectric element 21. The driver outputs a drive signal for operating each piezoelectric element 21 based on the control of the decoder. The drive signal is, for example, a voltage to be applied to each piezoelectric element 21.

**[0066]** The printed wiring board includes a printing wiring assembly (PWA) mounted with various electronic components and connectors. The printed wiring board is connected to the control unit 150 of the inkjet recording apparatus 100.

**[0067]** In the inkjet head 1 configured as described above, the nozzle plate 50, the frame portion 45, the flow path portion 40, and the vibration plate 30 form the ink flow path 35 including the plurality of pressure chambers 31 communicating with the nozzles 51, the individual flow paths implemented by the throttle flow paths 34 communicating with the plurality of pressure chambers 31, and the individual liquid chambers 33 and the common chamber 32 serving as a common flow path. For example, the common chamber 32 communicates with a cartridge, and the ink is supplied to the pressure chambers 31 through the common chamber 32. All of the piezoelectric elements 21 are connected by wiring so that a voltage can be applied thereto. In the inkjet head 1, when the control unit 150 causes the driver IC to apply a drive voltage to the electrodes 221 and 222, the piezoelectric element 21 to be driven vibrates in the stacking direction, that is, the thickness direction of the piezoelectric layers 211. That is, the piezoelectric element 21 vibrates longitudinally.

**[0068]** Specifically, the control unit 150 selectively drives the piezoelectric element 21 to be driven by applying a drive voltage to the internal electrodes 221 and 222 of the piezoelectric element 21 to be driven. Then, the vibration plate 30 is deformed and the volume of the pressure chamber 31 is changed by the piezoelectric element 21 to be driven by combining deformation in a tensile direction and deformation in a compression direction, thereby guiding the liquid from the common chamber 32 and ejecting the liquid from the nozzle 51.

**[0069]** Hereinafter, an example of the inkjet recording apparatus 100 including the ink jet head 1 will be described with reference to FIG. 8. The inkjet recording apparatus 100 includes a housing 111, a medium supply unit 112, an image forming unit 113, a medium discharge unit 114, a conveyance device 115, and the control unit 150.

**[0070]** The inkjet recording apparatus 100 is a liquid ejection apparatus that ejects a liquid such as ink while conveying a printing medium that is an ejection target such as a sheet P along a predetermined conveyance path RA from the medium supply unit 112 to the medium discharge unit 114 through the image forming unit 113, and thereby executes image forming processing on the sheet P.

**[0071]** The housing 111 constitutes an outer shell of the ink jet recording apparatus 100. A discharge port through which the sheet P is to be discharged to the outside is provided at a predetermined position of the housing 111.

**[0072]** The medium supply unit 112 includes a plurality of sheet feed cassettes, and can hold a plurality of sheets P of various sizes in a manner of stacking the sheets P.

**[0073]** The medium discharge unit 114 includes a sheet discharge tray that can hold the sheet P discharged from the discharge port.

**[0074]** The image forming unit 113 includes a support portion 117 that supports the sheet P, and a plurality of head units 130 that are disposed in a manner of facing the support portion 117 above the support portion 117.

**[0075]** The support portion 117 includes a conveyance belt 118 provided in a loop shape in a predetermined region where image formation is performed, a support plate 119 that supports the conveyance belt 118 from a back side, and a plurality of belt rollers 120 provided on the back side of the conveyance belt 118.

**[0076]** During image formation, the support portion 117 supports the sheet P on a holding surface that is an upper surface of the conveyance belt 118, and conveys the sheet P to a downstream side by sending the conveyance belt 118 at a predetermined timing by rotation of the belt rollers 120.

**[0077]** The head unit 130 includes a plurality of (four colors) ink jet heads 1, ink tanks 132 serving as liquid tanks respectively mounted on the inkjet heads 1, connection flow paths 133 that connect the inkjet heads 1 and the ink tanks 132, and supply pumps 134.

**[0078]** In the present embodiment, the head unit 130 includes the inkjet heads 1 of four colors of cyan, magenta, yellow, and black, and the ink tanks 132 that store ink of the respective colors. The ink tank 132 is connected to the inkjet head 1 by the connection flow path 133.

**[0079]** A negative pressure control device such as a pump (not illustrated) is connected to the ink tank 132. A negative pressure in the ink tank 132 is controlled by the negative pressure control device according to water head values of the inkjet head 1 and the ink tank 132, thereby forming the ink supplied to each nozzle 51 of the inkjet head 1 into a meniscus having a predetermined shape.

**[0080]** The supply pump 134 is, for example, a liquid sending pump formed of a piezoelectric pump. The supply pump 134 is provided in a supply flow path. The supply pump 134 is connected to a drive circuit of the control unit 150 by wiring, and is configured to be controllable under the control of a central processing unit (CPU). The supply pump 134 supplies a liquid to the inkjet head 1.

**[0081]** The conveyance device 115 conveys the sheet P along the conveyance path RA from the medium supply unit 112 to the medium discharge unit 114 through the image forming unit 113. The conveyance device 115 includes a plurality of guide plate pairs 121 disposed along the conveyance path RA and a plurality of conveyance rollers 122.

**[0082]** Each of the plurality of guide plate pairs 121 includes a pair of plate members disposed in a manner of facing each other across the sheet P to be conveyed, and guides the sheet P along the conveyance path RA.

**[0083]** The conveyance roller 122 is driven and rotated under the control of the control unit 150, thereby conveying the sheet P to a downstream side along the conveyance path RA. Sensors that detect a sheet conveyance state are disposed at various positions in the conveyance path RA.

**[0084]** The control unit 150 includes a control circuit 151 such as a CPU serving as a controller, a read only memory (ROM) that stores various programs, a random access memory (RAM) that temporarily stores various kinds of variable data, image data, and the like, and an interface unit that receives data from the outside and outputs data to the outside.

**[0085]** In the inkj et recording apparatus 100 configured as described above, for example, when the control unit 150 detects a print instruction by a user operating an operation input unit at an interface, the control unit 150 drives the inkjet head 1 by driving the conveyance device 115 to convey the sheet P and outputting a printing signal to the head unit 130 at a predetermined timing. As an ejection operation, the ink jet head 1 transmits a drive signal to the driver IC according to an image signal corresponding to image data, and applies a drive voltage to the internal electrodes 221 and 222 to selectively drive the piezoelectric element 21 of an ejection target to cause the piezoelectric element 21 to vibrate longitudinally in a stacking direction, thereby changing a volume of the pressure chamber 31 to eject the ink from the nozzle 51 and form an image on the sheet P held on the conveyance belt 118. As a liquid ejection operation, the control unit 150 drives the supply pump 134 to supply the ink from the ink tank 132 to the common chamber 32 of the inkjet head 1.

**[0086]** Here, a driving operation for driving the ink jet head 1 will be described. The inkjet head 1 according to the present embodiment includes the piezoelectric elements 21 disposed in a manner of facing the pressure chambers 31, and the piezoelectric elements 21 are connected by wiring so that a voltage can be applied thereto. The control unit 150 sends a drive signal to the driver IC according to the image signal corresponding to the image data, and applies a drive voltage to the internal electrodes 221 and 222 of the piezoelectric element 21 to be driven, thereby selectively deforming the piezoelectric element 21 to be driven. Then, deformation of the vibration plate 30 in a tensile direction and deformation of the vibration plate 30 in a compression direction are combined to change the volume of the pressure chamber 31 to eject a liquid.

**[0087]** For example, the control unit 150 alternately performs a pulling operation and a compressing operation. In the ink jet head 1, at the time of pulling for increasing the internal volume of the target pressure chamber 31, the piezoelectric element 21 to be driven is contracted, and a drive piezoelectric element other than a drive target is not deformed. In the ink jet head 1, at the time of compressing for reducing the internal volume of the target pressure chamber 31, the target drive piezoelectric element 21 is extended and the non-drive piezoelectric element 22 is not deformed.

**[0088]** The ink jet head 1 and the ink jet recording apparatus 100 according to the embodiment described above can improve accuracy of fluid resistance and prevent variation in ejection performance among nozzles of the inkjet head. In the inkjet head 1 according to the embodiment, each of the throttle flow paths 34 along the extending direction on both sides of the pressure chamber 31 has a flow path cross section in which a dimension in the longitudinal direction of the flow path cross section along a width direction of the slit 4023 is three times or more a dimension in the short side direction of the flow path cross section along the thickness direction of the flow path substrate 402. That is, when a thickness dimension is defined by processing a metal such as SUS as the flow path substrate 402 and an opening is formed by etching, in general, it is easier to ensure dimension accuracy by a method of processing plate thickness with high accuracy as compared with etching accuracy. Therefore, a plate thickness direction where it is easy to ensure dimension accuracy is set as a short side of the flow path cross section, an opening width direction where it is difficult to ensure dimension accuracy is set as a long side of the flow path cross section, and an aspect ratio is set to three times or more, so that it is easy to ensure dimension accuracy and it is possible to improve accuracy of fluid resistance. Therefore, it is possible to prevent variation in ejection performance among the nozzles of the ink jet head. In particular, as ink viscosity decreases, factors other than the ink viscosity become dominant in determining the fluid resistance, and accuracy of a flow path shape becomes important. According to the above embodiment, accuracy of the flow path shape can be ensured to improve ejection performance.

**[0089]** The present disclosure is not limited to the embodiment described above, and constituent elements can be modified and embodied in an implementation stage without departing from the gist of the disclosure.

**[0090]** For example, a specific configuration of the flow path portion 40 is not limited to the one described above. For example, although the flow path portion 40 is formed by the three flow path substrates 401, 402, and 403, the flow path portion 40 may be formed by two or four or more flow path substrates. In addition, shapes of openings in the flow path substrates 401, 402, and 403 are not limited to those in the above-described embodiment.

**[0091]** For example, although the second openings 4012, 4022, and 4032 are divided into a plurality of openings in the row direction, and the plurality of individual liquid chambers 33 connected to the common chamber 32 are formed in the above-described embodiment, the embodiment disclosed herein is not limited thereto. For example, the plurality of the second openings 4012, 4022, and 4032 may be continuous in an arrangement direction to form a common flow path. Further, positions of the first flow path substrates 401 and 403 and the second flow path substrate 402 in the stacking direction and shapes of the openings are not limited to those in the above-described embodiment, and can be appropriately changed. For example, the flow path substrates 401 and 403 which are the first flow path substrates may be on a side close to the nozzle plate 50, and the flow path substrate 402 which is the second flow path substrate may be on a side close to the actuator portion 20.

**[0092]** For example, although the piezoelectric element 21 formed by stacking a plurality of piezoelectric members is driven by longitudinal vibration (d33) in the stacking direction in the above-described embodiment, the embodiment disclosed herein is not limited thereto. For example, the piezoelectric element 21 may be applicable to an aspect of being formed of a single-layer piezoelectric member, and may be applicable to an aspect of being driven by lateral vibration (d31).

**[0093]** Specific configurations of the piezoelectric elements 21 and 22, shapes of flow paths, and configurations and positional relationships of various components including the flow path portion 40, the nozzle plate 50, and the frame portion 45 are not limited to examples described above, and can be appropriately changed. Further, the arrangement of the nozzles 51 and the arrangement of the pressure chambers 31 are not limited to those described above. For example, the nozzles 51 may be arranged in two or more rows. Dummy chambers may be formed between the plurality of pressure chambers 31.

**[0094]** The liquid to be ejected is not limited to ink for printing, and for example, the embodiment described herein may be applied to an apparatus that ejects a liquid containing conductive particles for forming a wiring pattern of a printed wiring board.

**[0095]** Although the inkjet head 1 is used in a liquid ejection apparatus such as an ink jet recording apparatus in the embodiment described above, the embodiment described herein is not limited thereto. For example, the inkjet head 1 may be used in a 3D printer, an industrial manufacturing machine, and a medical application, and the inkjet head 1 can be reduced in size, weight, and cost.

**[0096]** According to at least one embodiment described above, it is possible to improve the accuracy of the fluid resistance and prevent variation in the ejection performance among the nozzles of the inkjet head.

**[0097]** While several embodiments of the present disclosure have been described, the embodiments have been presented by way of example and are not intended to limit the scope of the disclosure. These novel embodiments can be implemented in various other forms, and various omissions, substitutions, and modifications can be made without departing from the gist of the disclosure. The embodiments and modifications thereof are included in the scope and the gist of the disclosure, and are included in the scope of the disclosure disclosed in the claims and equivalents thereof.

## Claims

**1.** A liquid ejection head comprising:

a plurality of flow path substrates (401-403) that are each formed with an opening for forming a flow path and that are stacked in a stacking direction, wherein
at least one of the flow path substrates includes a slit (4023), and a flow path formed by the slit has a flow path cross section in which a dimension in a longitudinal direction orthogonal to an extending direction of the slit and the stacking direction is three times or more a dimension in a short side direction along the stacking direction.

**2.** The head according to claim 1, wherein

a plurality of the openings formed in the plurality of flow path substrates communicate with one another to form a plurality of pressure chambers, a plurality of resistance flow paths that each communicate with a respective one of the plurality of pressure chambers and that each have a cross section orthogonal to one direction smaller than that of the pressure chambers, and a common chamber that communicates with the plurality of resistance flow paths, and
the slit constitutes the resistance flow path.

**3.** The head according to claim 1 or 2, wherein
the flow path substrate is made of metal.

**4.** The head according to any one of claims 1 to 3, wherein the flow path substrate (401) is a plate-shaped member made of a metal material containing SUS or a resin material.

**5.** The head according to claim 4, wherein the resin material is silicone.

**6.** The head according to any one of claims 1 to 5, wherein the plurality of flow path substrates comprises a first flow path substrate (401), a second flow path substrate (402) stacked on the first flow path substrate and a third flow path substrate stacked on the second flow path substrate.

**7.** The head according to claim 6, wherein the slit is formed in the second flow path substrate (402).

**8.** The head according to claim 6 or 7 wherein the first, second and third flow path substrates are made of the same material.

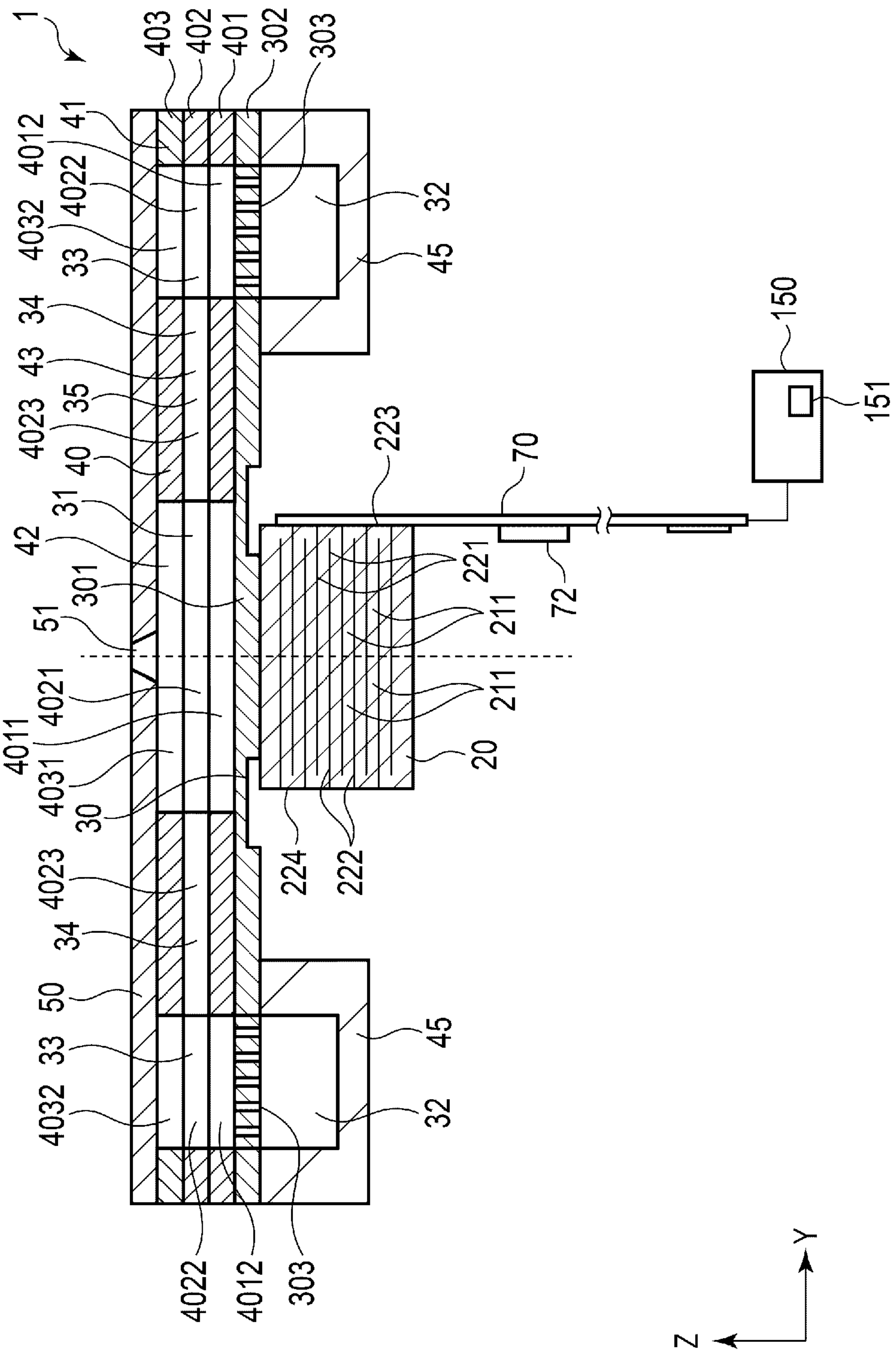
**9.** The head according to any one of claims 6 to 8, further comprising a vibration plate (30) joined to the first flow path substrate (401).

**10.** The head according to any one of claims 1 to 9, further comprising:

a nozzle member that includes a plurality of nozzles in an arrangement direction;
a flow path portion that faces one side of the nozzle member in the stacking direction, that is formed by stacking the plurality of flow path substrates, and that includes the plurality of pressure chambers and the plurality of resistance flow paths in the arrangement direction;
a plurality of vibration portions that face one sides of the pressure chambers in the stacking direction; and
an actuator portion that faces one sides of the vibration portions in the stacking direction and that includes a plurality of actuators.

**11.** A liquid ejection apparatus comprising: the liquid ejection head according to any one of claims 1 to 10.

FIG. 1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403
402
401
302
303
41
4012
4022
4032
33
34
43
35
4023
40
31
42
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51
4021
4011
4031
30
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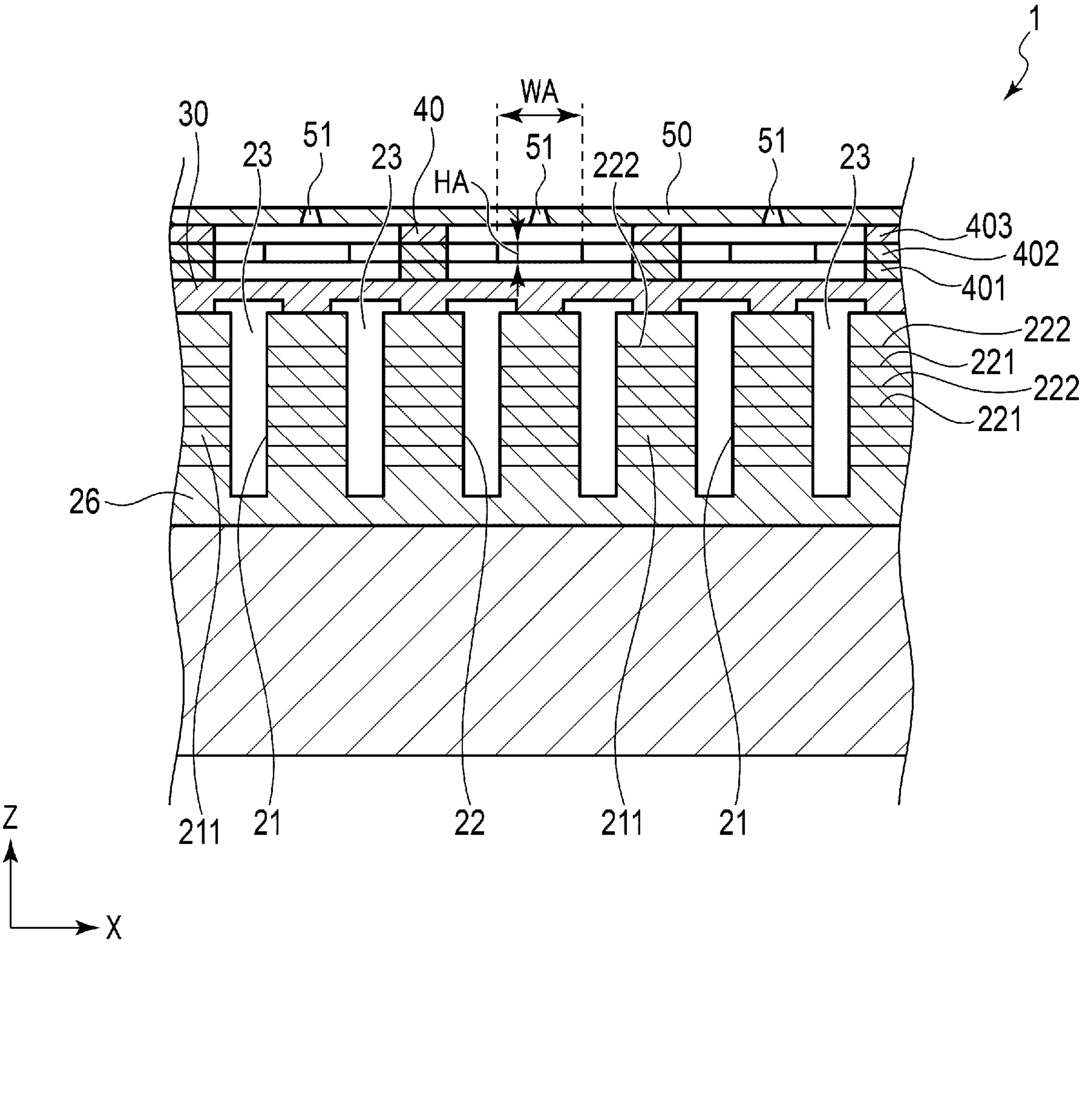
32
45
150
151
223
70
221
72
211
20
224
222
Y
Z

FIG. 2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40
51
50
51
23
23
HA
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401
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26
211
21
22
211
21
Z
X

FIG. 3

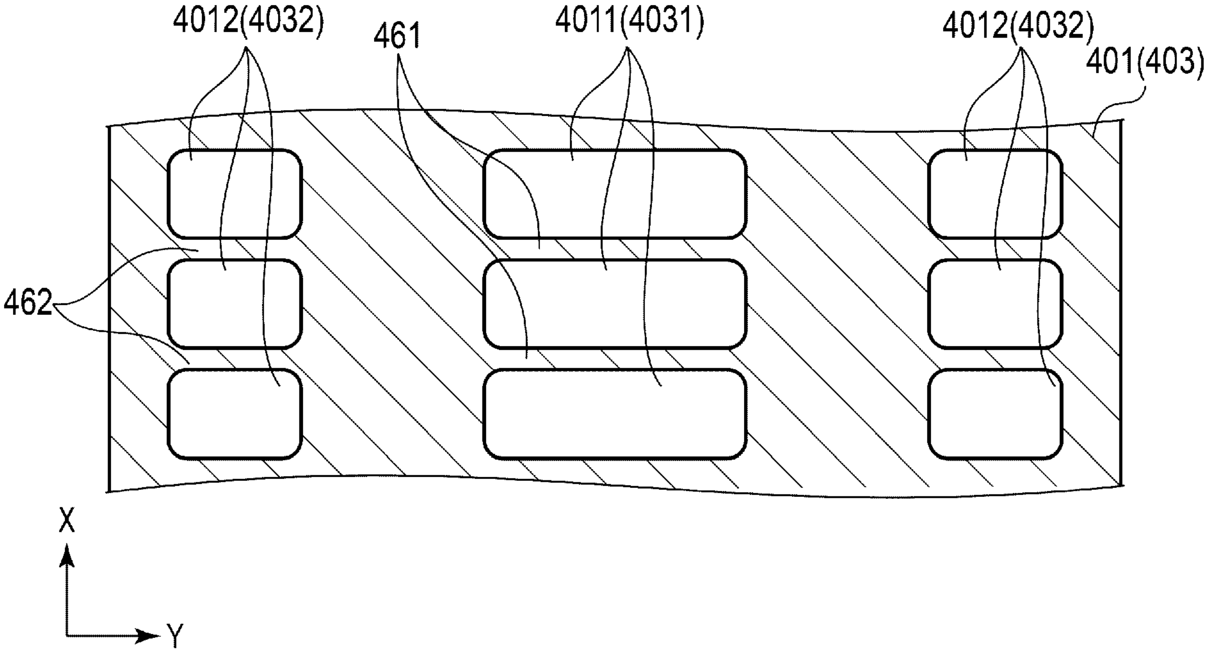

4012(4032)
461
4011(4031)
4012(4032)
401(403)
462
X
Y

FIG. 4

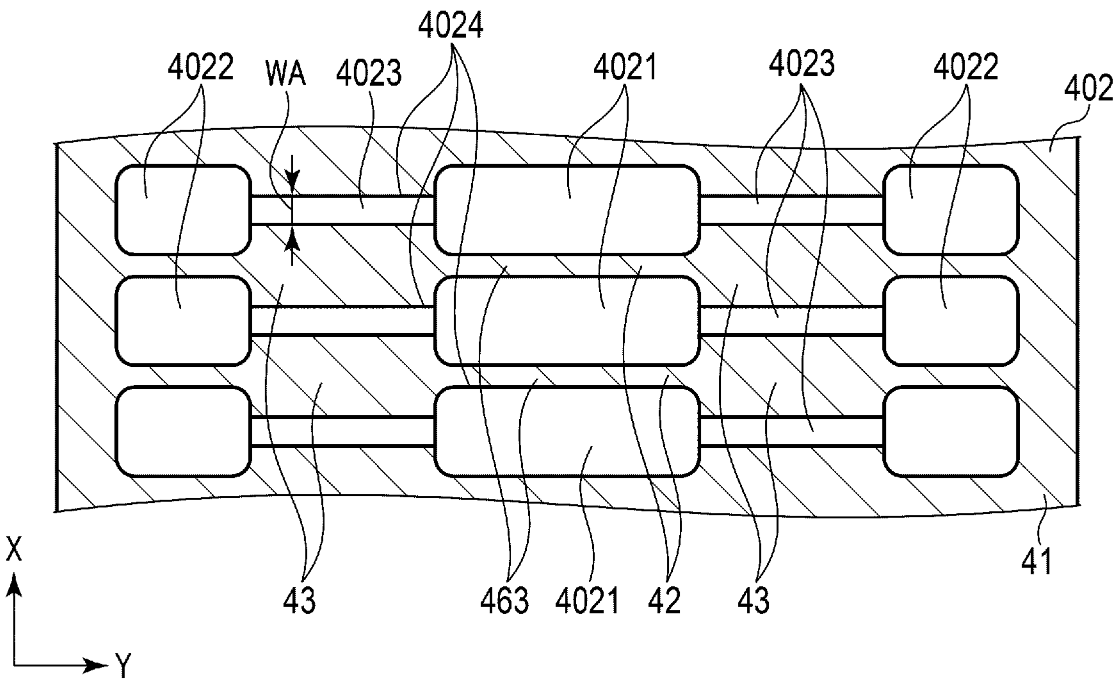

4024
4022
WA
4023
4021
4023
4022
402
43
463
4021
42
43
41
X
Y

*FIG. 5*

| PIPE FRICTION COEFFICIENT RATIO k OF RECTANGULAR PIPE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ASPECT RATIO $\varepsilon = b/a$ | 0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
| $k = \lambda / (64/R_e)$ | 1.500 | 1.323 | 1.192 | 1.094 | 1.023 | 0.971 6 | 0.936 0 | 0.912 6 | 0.898 3 | 0.890 9 | 0.888 7 |

FIG. 6

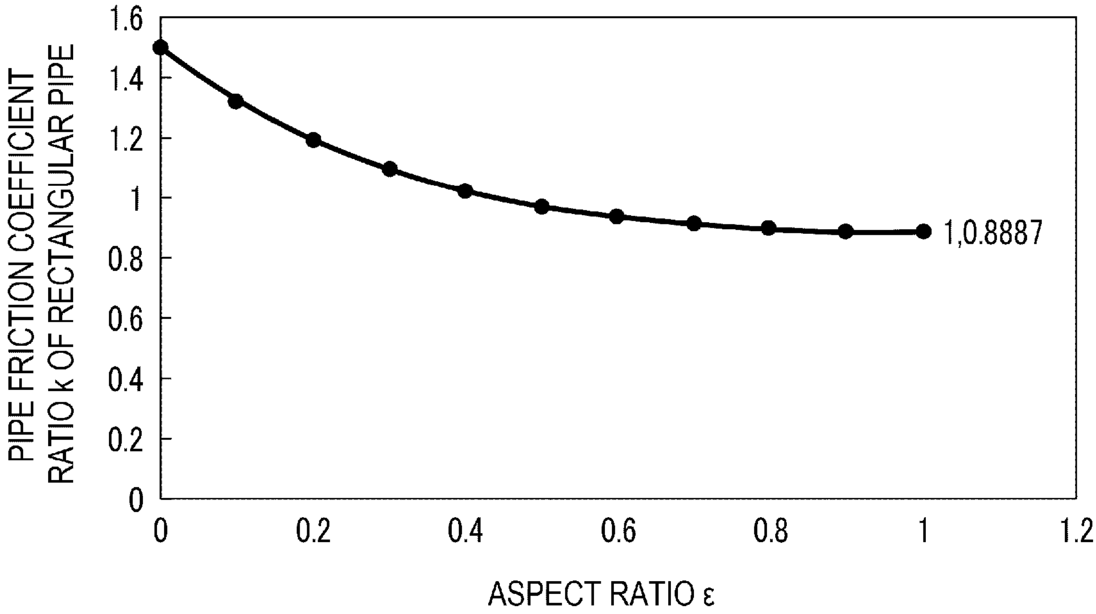
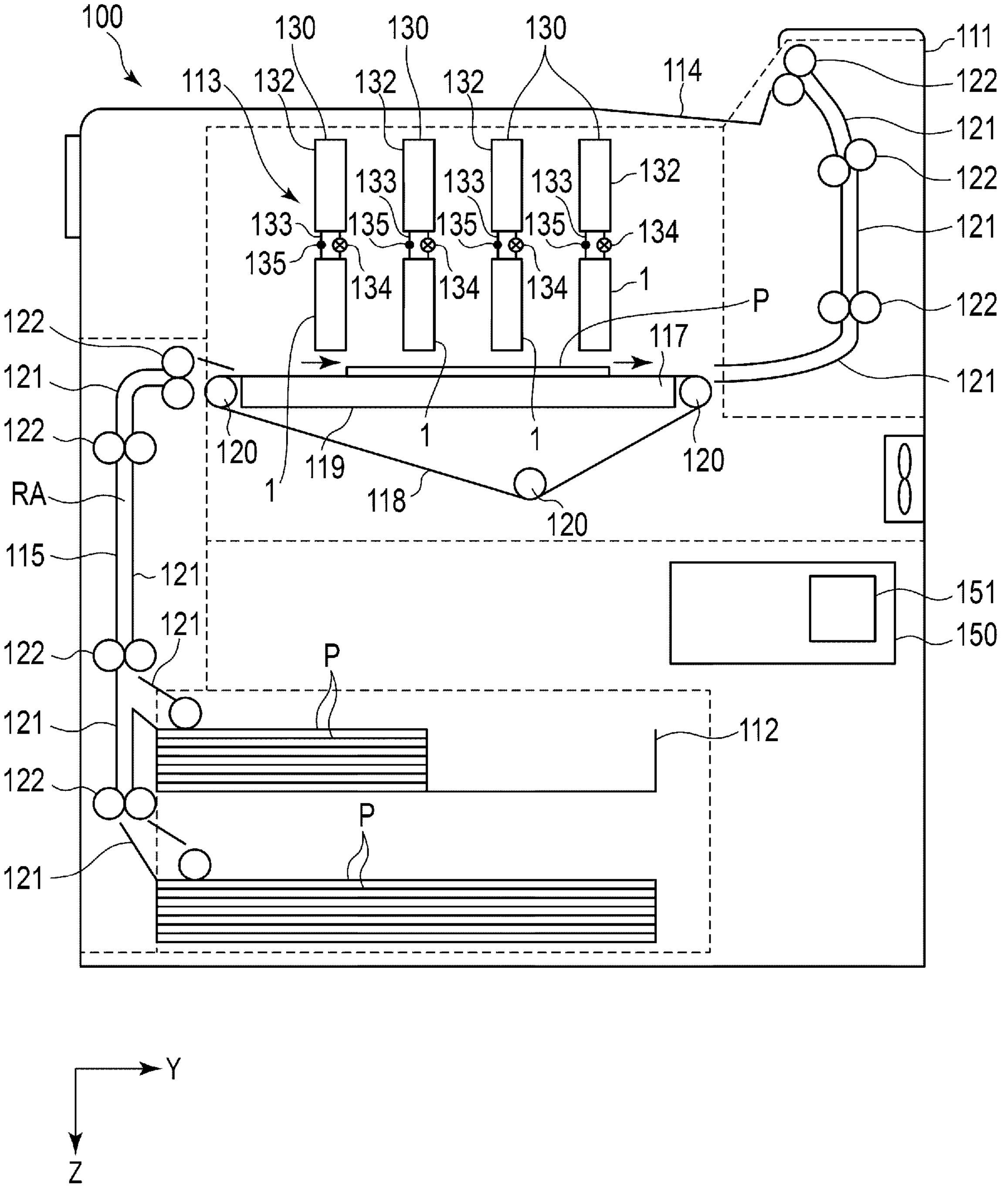



FIG. 7

| LONG SIDE (μm) | SHORT SIDE (μm) | R/L/ μ | FLUID RESISTANCE RATIO (%) |
|---|---|---|---|
| 100 | 30 | 5.4781E-06 | 100.0 |
| 110 | 30 | 4.8578E-06 | 88.7 |
| 90 | 30 | 6.6800E-05 | 121.9 |
| 100 | 33 | 4.5036E-06 | 82.2 |
| 100 | 27 | 7.3114E-06 | 132.5 |

*FIG. 8*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120
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RA
115
151
150
112
Y
Z

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# EUROPEAN SEARCH REPORT

Application Number
EP 24 22 2574

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The present search report has been drawn up for all claims

2

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 24 May 2025 | Öztürk, Serkan |

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24-05-2025

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