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

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B41J 2/14 (2006.01)
B41J 2/16 (2006.01)

(52) **U.S. Cl.**
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See application file for complete search history.

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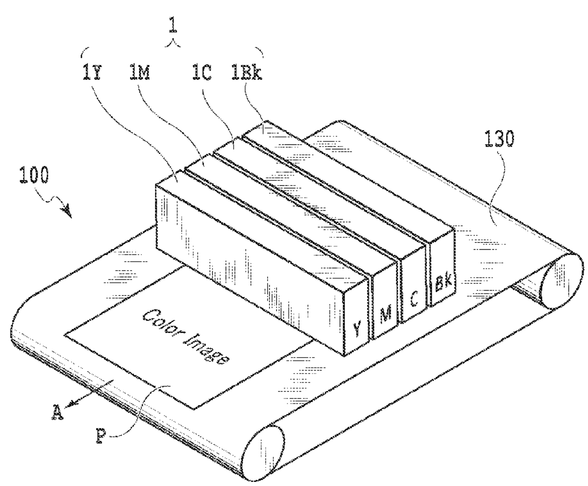
(57) **ABSTRACT**

A liquid ejection head includes a print element substrate including multiple ejection openings, pressure chambers, a common flow path, and pumps, the pumps being configured to circulate liquid between the common flow path and the pressure chamber; and a flow path member laminated to the print element substrate. The flow path member includes a supply flow path and a collection flow path, the supply flow path being configured to supply liquid to the print element substrate, and the collection flow path being configured to collect liquid that is not ejected. The supply flow path and the collection flow path have liquid connection with the same common flow path. A circulating pump generates a flow of liquid flowing in an order of the supply flow path, the common flow path, and the collection flow path, the circulating pump being provided at a position different from the print element substrate.

8 Claims, 6 Drawing Sheets



Related U.S. Application Data

division of application No. 16/710,367, filed on Dec. 11, 2019, now Pat. No. 11,065,878.

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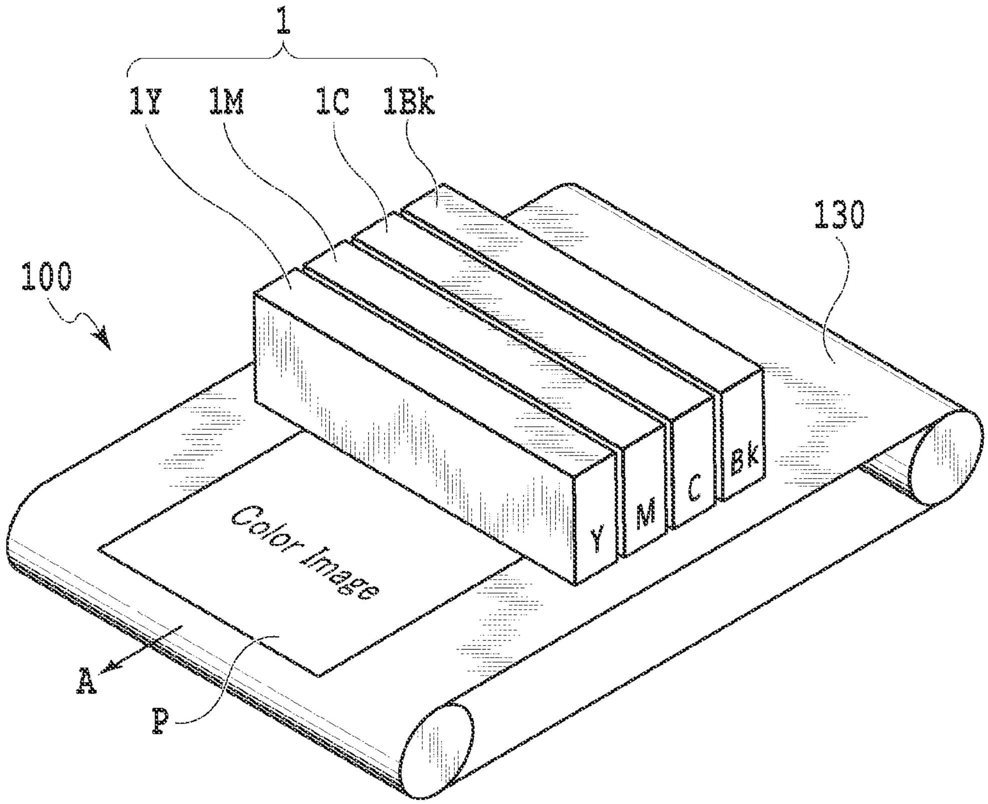

FIG.1

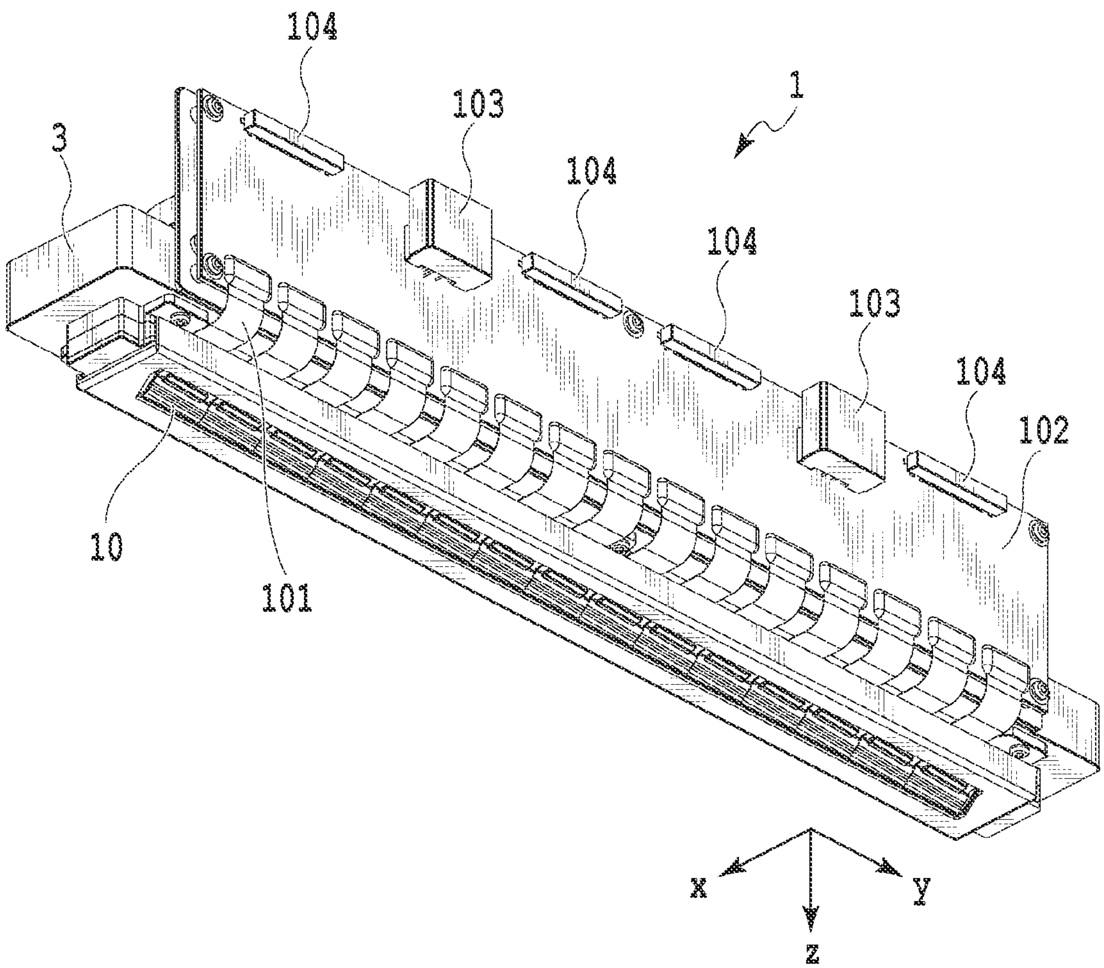

FIG.2

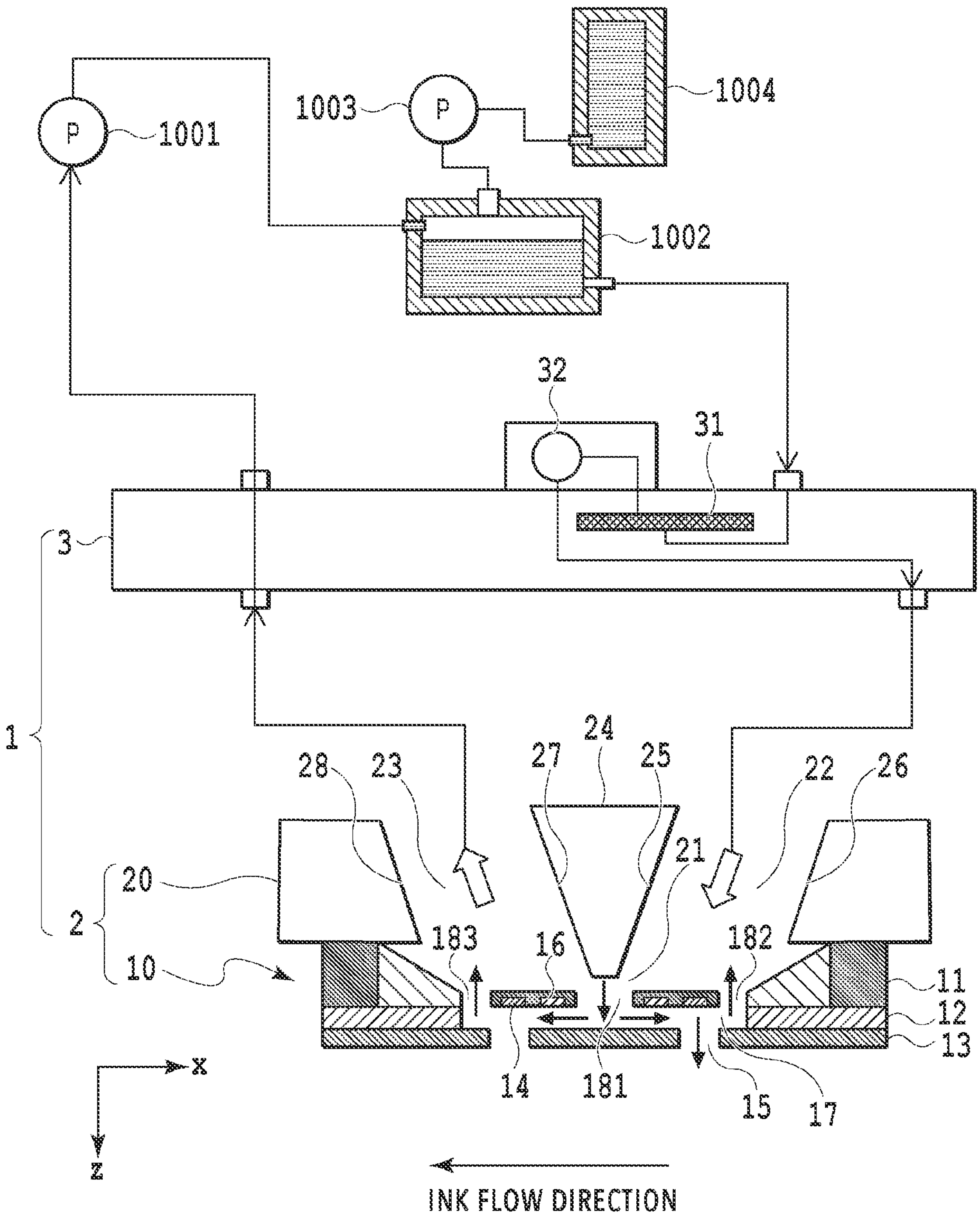
1004
1003
P
P
1001
1002
32
31
3
1
24
27
25
28
23
22
26
21
20
2
183
16
182
10
11
12
13
14
181
15
17
X
Z
INK FLOW DIRECTION

FIG.3

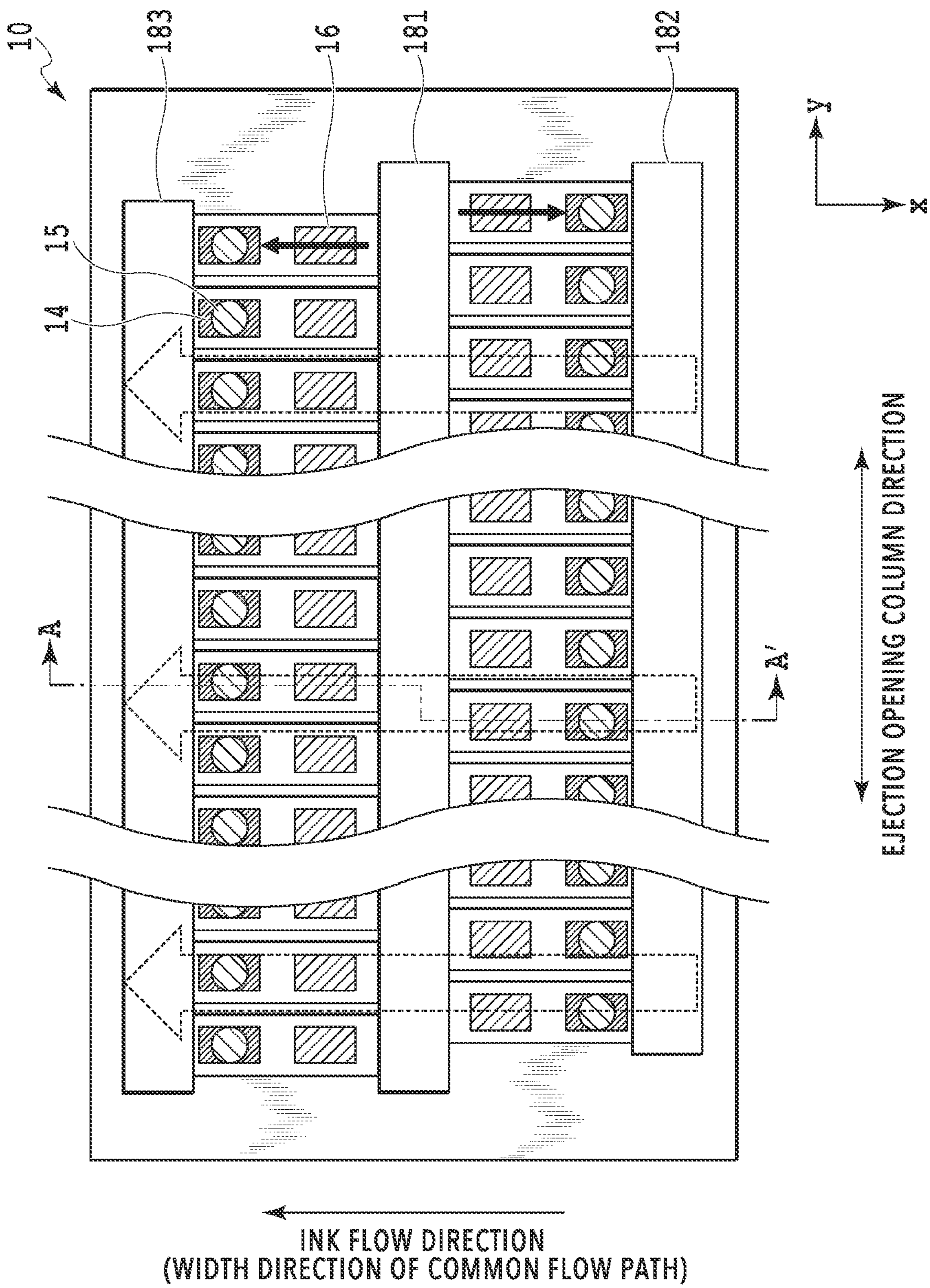
10
183
16
181
182
15
14
y
x
A
A'
EJECTION OPENING COLUMN DIRECTION
INK FLOW DIRECTION
(WIDTH DIRECTION OF COMMON FLOW PATH)

FIG.4

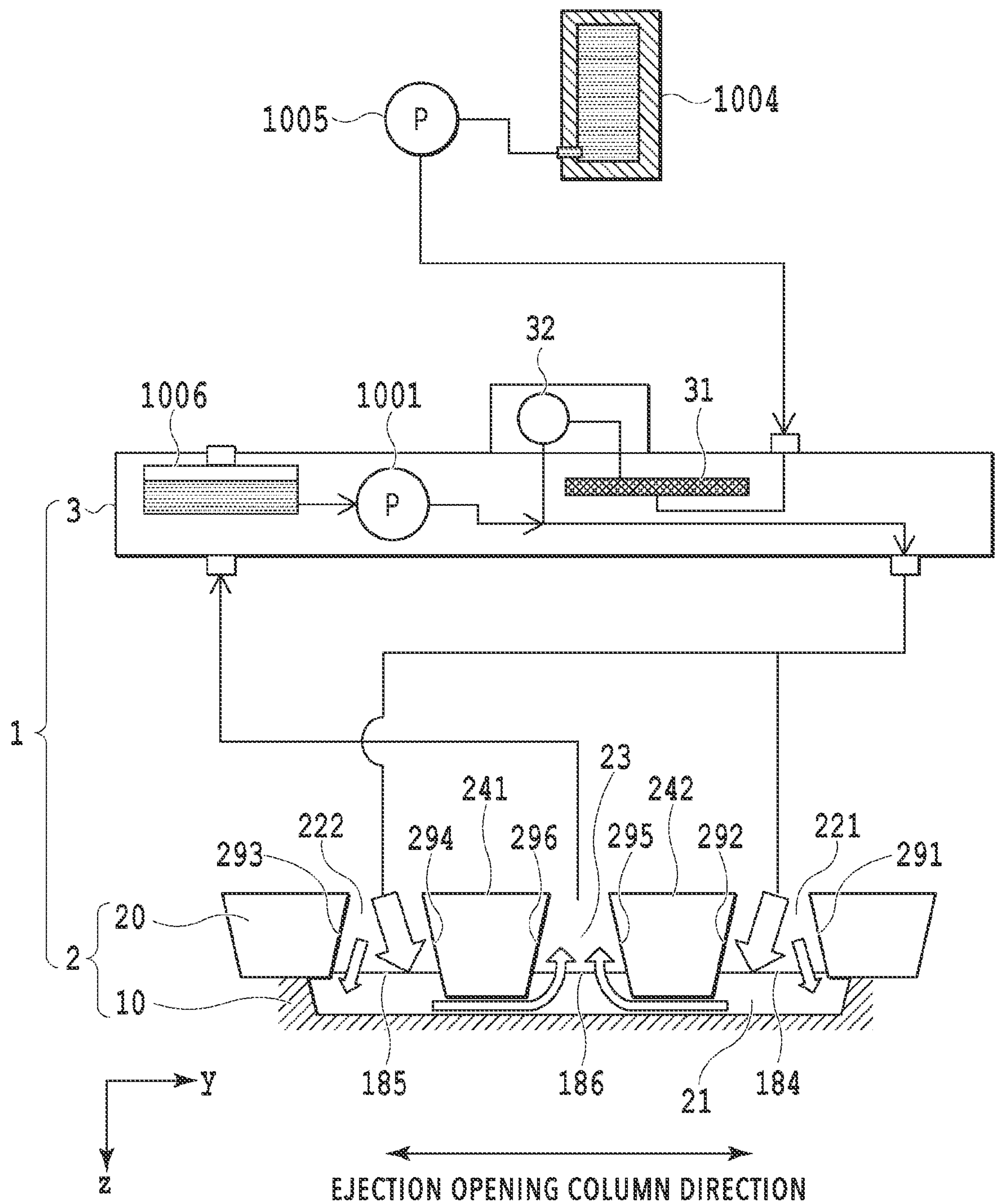
1004
1005
P
32
31
1006
1001
P
3
1
23
241
242
222
294
296
295
292
221
291
293
20
2
10
185
186
21
184
y
z
EJECTION OPENING COLUMN DIRECTION

FIG.5

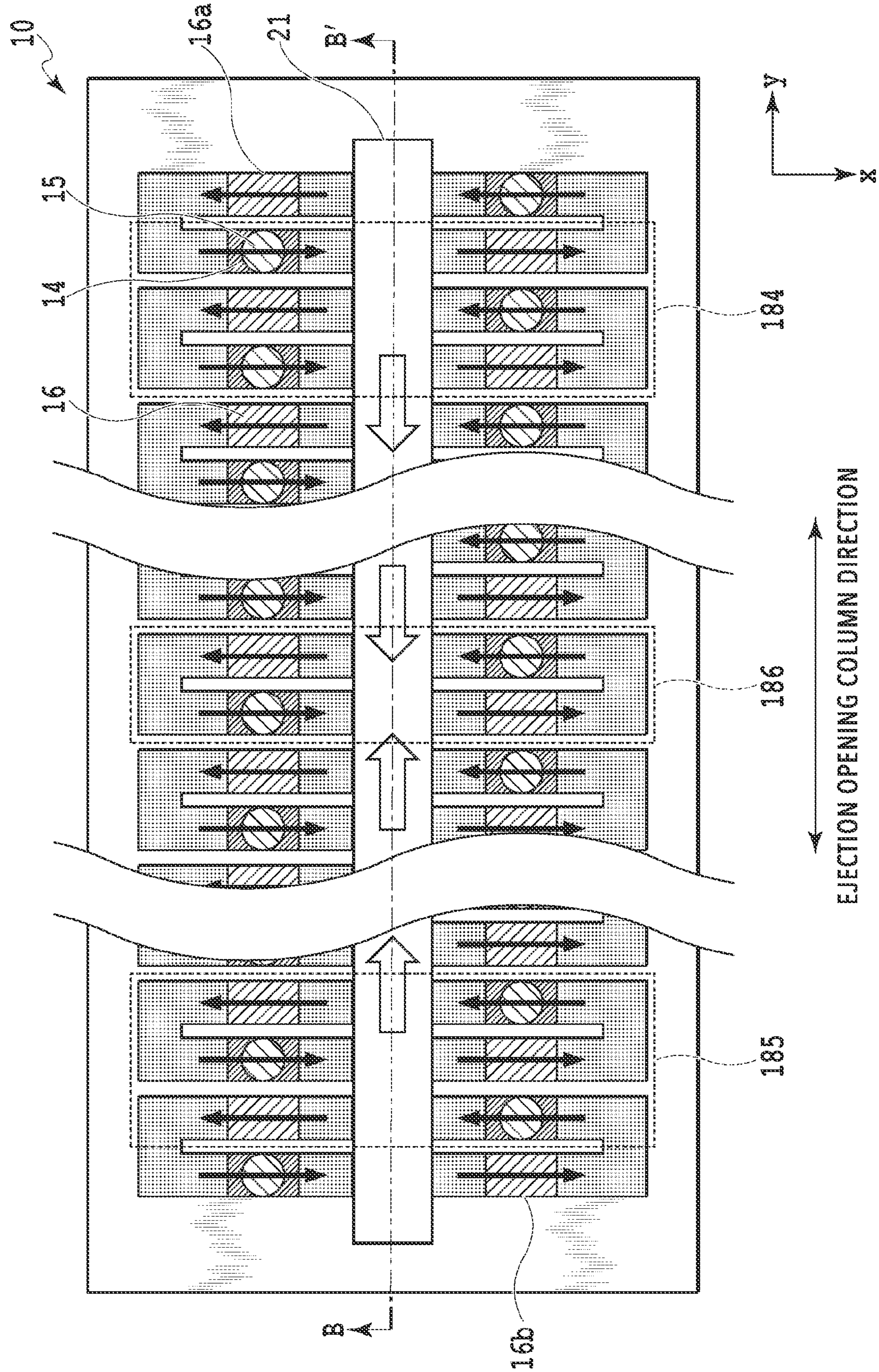
10
16a
21
B'
15
14
16
184
186
185
16b
B
y
x
EJECTION OPENING COLUMN DIRECTION

FIG.6

LIQUID EJECTION HEAD AND LIQUID EJECTION APPARATUS

BACKGROUND OF THE DISCLOSURE

Field of the Disclosure

The present disclosure relates to a liquid ejection head and a liquid ejection apparatus.

DESCRIPTION OF THE RELATED ART

In a liquid ejection head used in a liquid ejection apparatus that ejects liquid such as ink, there is a possibility that ejection failure or concentration change occurs due to liquid thickening or precipitation of solid components in the vicinity of an ejection opening. In addition, bubbles or foreign substances may remain in the vicinity of an ejection opening. As a measure to attend to such problems, as disclosed in International Laid Open Publication No. WO 2012/015397 (hereinafter referred to as Document 1), there is a proposition of a technique in which a micropump for flowing liquid is provided inside a print element substrate so as to flow ink into a pressure chamber of the print element substrate by use of the micropump. Document 1 discloses a technique in which a micropump is incorporated in a nozzle flow path of a print element substrate and, by driving the micropump, an ink circulatory flow passing through a pressure chamber is generated. Further, in Document 1, each nozzle flow path of the print element substrate has liquid connection with one flow path (liquid slot) formed in a flow path member, which is laminated to the print element substrate, so that liquid is supplied from the flow path to each nozzle flow path.

In such a liquid ejection head as disclosed in Document 1, in a case where a stopped state lasts for a long period of time, an ink concentration area proceeds to a flow path positioned in the upstream of a circulation flow path of the micropump due to moisture evaporation from an ejection opening. Even in a case where the micropump is driven in such a state, there is a problem that ink concentration at an ejection opening is not decreased and the effect by circulation cannot be obtained.

SUMMARY OF THE DISCLOSURE

A liquid ejection head according to an embodiment of the present disclosure includes: an element substrate including a plurality of ejection openings, pressure chambers, a common flow path, and first pumps, the plurality of ejection openings being configured to eject liquid, the pressure chamber being internally provided with an element configured to generate energy utilized for ejecting liquid from the ejection openings, the common flow path being configured to communicate with the plurality of ejection openings, the first pumps being configured to circulate liquid between the common flow path and the pressure chamber; and a flow path member laminated to the element substrate in a laminated direction, wherein the flow path member includes a supply flow path and a collection flow path, the supply flow path being configured to supply liquid to the element substrate, the collection flow path being configured to collect liquid that is not ejected, wherein the supply flow path and the collection flow path have liquid connection with a same common flow path, and wherein a second pump generates a flow of liquid flowing in an order of the supply flow path, the common flow path, and the collection flow path, the second pump being provided at a position different from the element substrate.

Further features of the present disclosure will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic perspective view for explaining a configuration example of a liquid ejection apparatus;

FIG. **2** is a perspective view of a liquid ejection head;

FIG. **3** is a schematic view illustrating a liquid ejection head and an ink circulation path;

FIG. **4** is a schematic view illustrating a print element substrate;

FIG. **5** is a schematic view illustrating a liquid ejection head and an ink circulation path; and

FIG. **6** is a schematic view illustrating a print element substrate.

DESCRIPTION OF THE EMBODIMENTS

Hereinafter, an explanation is given of a liquid ejection head and a liquid ejection apparatus according to an embodiment of the present disclosure with reference to the drawings. An example of the liquid ejection head is a liquid ejection head that ejects ink. An example of the liquid ejection apparatus is an inkjet printing apparatus. Examples of the liquid ejection head and the liquid ejection apparatus are not limited thereto. The liquid ejection head and the liquid ejection apparatus can be applied to an apparatus, such as a printer, a copying machine, a facsimile machine having a communication system, or a word processor having a printer unit, and to a complex industrial printing apparatus combined with various processing apparatuses. For example, the liquid ejection head and the liquid ejection apparatus can be utilized for biochip fabrication and printing of electronic circuits, etc.

First Embodiment

<Configurations of Liquid Ejection Apparatus and Liquid Ejection Head>

FIG. **1** is a schematic perspective view for explaining a configuration example of a liquid ejection apparatus **100** using a liquid ejection head **1**. The liquid ejection apparatus **100** is what is termed a full-line type in which a long liquid ejection head **1** extending over the whole area in the width direction of a print medium P is used. A print medium P is continuously conveyed in the direction of arrow A by a conveyance mechanism **130** in which a conveyance belt, or the like, is used. An image is printed on a print medium P by ejecting ink (liquid) from the liquid ejection head **1** while the print medium P is conveyed in the direction of arrow A. In the case of the present embodiment, it is possible to print a color image by using each of the liquid ejection heads **1**C, **1**M, **1**Y, and **1**Bk that eject inks of cyan (C), magenta (M), yellow (Y), and black (K), respectively, as a liquid ejection head **1**.

FIG. **2** is a perspective view of the liquid ejection head **1**. The liquid ejection head **1** is configured such that multiple print element substrates **10**, each of which includes multiple print elements aligned in y-direction, are further aligned in y-direction. Here, a full-line type liquid ejection head **1**, which is configured with print element substrates **10** aligned in y-direction for a distance corresponding to the width of A4 size, is illustrated.

Each of the print element substrates **10** is connected to the same electric wiring substrate **102** via a flexible wiring substrate **101**. The electric wiring substrate **102** is provided with a power supply terminal **103** for receiving power and a signal input terminal **104** for receiving an ejection signal. On the other hand, the ink supply unit **3** includes a circulation flow path formed for supplying ink, which is supplied from an ink tank (not illustrated in FIG. **2**), to each of the print element substrates **10** and for collecting ink that has not been consumed in printing.

Each of the print elements arranged on a print element substrate **10** ejects, in z-direction of FIG. **2**, ink supplied from the ink supply unit **3** using power supplied from the power supply terminal **103** based on an ejection signal input from the signal input terminal **104**.

<Explanation of Circulation Path>

FIG. **3** is a diagram for explaining an ink circulation path of an entire liquid ejection apparatus **100** including a liquid ejection head **1**. FIG. **3** is a schematic view illustrating an ink path (ink channel) corresponding to one color in the liquid ejection head **1**. The liquid ejection head **1** is connected to a circulating pump **1001** and a buffer tank **1002**. In FIG. **3**, an ink path for only one color is illustrated. However, in reality, circulation paths for the number of colors of the liquid ejection heads **1** are provided in the liquid ejection heads **1** and the liquid ejection apparatus **100**.

The buffer tank **1002** is a reservoir portion for reserving ink. The buffer tank **1002** includes an outside air communication hole (not illustrated in FIG. **3**), so that it is possible to discharge bubbles in the ink to the outside. The buffer tank **1002** is also connected to a replenishing pump **1003**. In a case where ink is consumed by the liquid ejection head **1** due to print operation and suction recovery, etc., the replenishing pump **1003** transfers the consumed amount of ink from the main tank **1004** to the buffer tank **1002**.

The circulating pump **1001** has a function of pulling ink from the liquid ejection head **1** to return the ink to the buffer tank **1002** as well as a function of applying a pressure reducing force (vacuuming force) to the negative pressure control unit **32** from the downstream side of the circulation path. As the circulating pump **1001** and the replenishing pump **1003**, a syringe pump, a tube pump, a diaphragm pump, a gear pump, or the like, can be used, for example.

The liquid ejection head **1** includes a liquid ejection unit **2** and an ink supply unit **3**. Ink is supplied to the ink supply unit **3** from a liquid connection portion, which is connected to the buffer tank **1002**. The ink supply unit **3** supplies ink to the liquid ejection unit **2** after letting the ink pass through in the order of the filter **31** and the inside of the negative pressure control unit **32**. The negative pressure control unit **32** is a regulator mechanism in general and has a function of maintaining the inside of the downstream side thereof (that is, the liquid ejection unit side) to a preset constant negative pressure even in a case where the ink supply flow rate fluctuates in accordance with change in printing duty. Furthermore, the ink supply unit **3** once collects ink from the outlet of the liquid ejection unit **2** and then discharges the ink to the suction side of the circulating pump **1001**.

Inside the liquid ejection unit **2**, a print element substrate **10** and a flow path member **20** that supports the print element substrate **10** are laminated in the laminated direction (z-direction). The liquid ejection unit **2** receives ink supplied from the ink supply unit **3** and ejects ink based on a control signal from the electric wiring substrate **102** of the liquid ejection apparatus **100**. A supply flow path **22** is provided in the flow path member **20**. The upstream side of the supply flow path **22** is connected to the ink supply unit **3**, and the downstream side of the supply flow path **22** is connected to the common flow path **21** of the print element substrate **10**. That is, the supply flow path **22** includes a connection port connected to the ink supply unit **3** and a connection port connected to the common flow path **21**. Furthermore, a collection flow path **23** is provided in the flow path member **20**. The common flow path **21** is a flow path that is commonly connected to multiple pressure chambers **17**. The upstream side of the collection flow path **23** is connected to the common flow path **21** of the print element substrate **10**, and the downstream side of the collection flow path **23** communicates with the circulating pump **1001** via the ink supply unit **3**. That is, the collection flow path **23** includes a connection port connected to the common flow path **21** and a connection port connected to the ink supply unit **3**.

As illustrated in FIG. **3**, each of the supply flow path **22** and the collection flow path **23** has an oblique flow path wall that is inclined relative to the laminated direction. Specifically, the flow path wall of the flow path member **20** forming the supply flow path **22** forms a slope that becomes nearer the collection flow path **23** as approaching the common flow path **21**. Further, the flow path wall of the flow path member **20** forming the collection flow path **23** forms a slope that becomes nearer the supply flow path **22** as approaching the common flow path **21**.

More specifically, as illustrated in FIG. **3**, the flow path member **20** includes a wall portion **24** between the supply flow path **22** and the collection flow path **23** in the direction of ink flow in the flow path member **20**, which is generated by driving of the circulating pump **1001** (hereinafter referred to as "ink flow direction"). The wall portion **24** includes a first wall **25** and a second wall **27**. The supply flow path **22** is formed by the first wall **25** of the wall portion **24** and the third wall **26**, which faces the first wall **25**. The collection flow path **23** is formed by the second wall **27** and the fourth wall **28**, which faces the second wall **27**. Further, the first wall **25** and the third wall **26** are inclined relative to the laminated direction such that, compared to the inlet port of the supply flow path **22**, the outlet port to the common flow path **21** is nearer the collection flow path side. The second wall **27** and the fourth wall **28** are inclined relative to the laminated direction such that, compared to the outlet port of the collection flow path **23**, the inlet port from the common flow path **21** is nearer the supply flow path side.

Further, as illustrated in FIG. **3**, the wall portion **24** extends nearer the print element substrate **10** side (ejection opening formed surface side) in the laminated direction (z-direction), compared to the third wall **26**, which is the other wall that forms the supply flow path **22**, and the fourth wall **28**, which is the other wall that forms the collection flow path **23**.

In a case where the circulating pump **1001** is driven in such a configuration as illustrated in FIG. **3**, ink flows from the supply flow path **22** through the common flow path **21** into the collection flow path **23** (see the outlined white arrows in FIG. **3**). That is, as illustrated in FIG. **3**, ink flows in the ink flow direction. In a case where print operation is started, the flow rate in the supply flow path **22** increases or decreases in accordance with the image to be printed. However, the pressure on the inlet side of the supply flow path **22** is controlled by the negative pressure control unit **32** to be within a predetermined range of negative pressure regardless of change in the flow rate.

<Explanation of Print Element Substrate and Ink Circulation in Substrate>

FIG. **4** is a schematic view illustrating a print element substrate **10** in the present embodiment. An explanation is given of the print element substrate **10** and ink circulation in the print element substrate **10** with reference to FIG. **3** and FIG. **4**. In the present embodiment, ink is ejected by a system in which the print element substrate **10** includes a heating resistance element as an energy generating element that generates energy utilized for ejecting a liquid so that the heating resistance element is used as a print element. Another system such as a system using a piezo element as a print element may be used as well.

The print element substrate **10** illustrated in FIG. **3** is a cross section taken along line A-A' in FIG. **4**. In the print element substrate **10**, a substrate **11**, an intermediate layer **12**, and an ejection opening formed layer **13** are laminated in that order from the flow path member **20** side. It is preferable that a photosensitive resin material is used as the material of the intermediate layer **12** and the ejection opening formed layer **13** and that an ejection opening **15** and an internal flow path are formed by a photolithography process.

As illustrated in FIG. **3** and FIG. **4**, the substrate **11** is provided with ink communication ports (communication ports **181** through **183**) to communicate with the common flow path **21**, print elements **14**, and pumps **16**. In the ejection opening formed layer **13**, an ejection opening **15** is formed at a position facing a print element **14** in the laminated direction. A print element **14** and a pump **16** perform ink ejection operation and ink circulation operation, based on signals from the electric wiring substrate **102** of the liquid ejection apparatus **100**, respectively.

As illustrated in FIG. **3** and FIG. **4**, each separate flow path, which includes an ejection opening **15** and a pressure chamber **17** that have liquid connection with a pump **16**, is connected to the common flow path **21**. In a case where a pump **16** is driven, ink in the common flow path **21** passes through a communication port **181**, which is positioned in the vicinity of the intermediate part in the width direction of the common flow path **21**, and through a pressure chamber **17** corresponding to the pump **16** and the print element **14** of each separate flow path. Then, a flow (as indicated by the black arrow lines in FIG. **3** and FIG. **4**) that flows back to the common flow path **21** from another communication port (a communication port **182** or a communication port **183**), which is positioned in the vicinity of an end portion of the width direction of the common flow path **21**, is generated. Therefore, it is possible to discharge a foreign substance and thickened ink, which is generated due to moisture evaporation from an ejection opening **15**, to the common flow path **21**, by driving a pump **16** so as to generate an ink flow in an ejection opening **15** and a pressure chamber **17** in a non-printing state. The pump **16** may be anything as long as the pump **16** has a function of circulating ink through the pressure chamber **17**. For example, it is possible to use a heating resistance element that is able to generate a bubble of ink, a piezo element, or an electrode element that generates an electroosmotic flow. In general, flow paths between communication ports are usually designed to be considerably small cross-sectional areas due to restriction on the size of an ejection liquid droplet for reducing granularity of an image, for example. For this reason, it is preferable that the circulation flow rate generated by a pump **16** is smaller than the maximum ejection flow rate per ejection opening, so that an excessive negative pressure is not applied to the meniscus of ink at the ejection opening **15**.

On the other hand, to an ejection opening **15** and a pressure chamber **17** in an ejecting state, ink is supplied from the common flow path **21** via both communication ports (a communication port **181** and a communication port **182**, or a communication port **181** and a communication port **183**) in accordance with ink ejection operation. At this time, the circulation operation by the pump **16** is basically in the off state. The pump **16** is driven at a timing right before the print element **14** is driven for ejection based on a drive signal from the liquid ejection apparatus **100**, so that concentrated/thickened ink stagnating in the ejection opening **15** and the pressure chamber **17** is discharged to the common flow path **21**.

As described above, because of ink circulation by a pump **16**, it is possible to prevent ejection from being ink non-discharge due to ink thickening in the vicinity of an ejection opening **15** and to remove bubbles or foreign substances. Therefore, it is possible to eject a desired liquid with less possibility of ink non-discharge, without performing such recovery operation with waste ink as preliminary ejection operation or cap suction operation. Thus, high-quality printing can be performed.

<Explanation of Ink Circulation After Stopping for a Long Period of Time>

In a case where a pump **16** has not been driven for a long period of time because the print element substrate **10** or the liquid ejection head **1** has been in a stopped state, an area of concentrated ink due to moisture evaporation from an ejection opening **15** is diffused. As a result, concentration/thickening may proceed to the ink in the communication ports **181** through **183** and the common flow path **21**. In this case, even though the pump **16** is driven, the ink concentration/viscosity in the ejection opening **15** and the pressure chamber **17** does not recover, which causes a trouble in ejection operation.

In the present embodiment, the common flow path **21** in the print element substrate **10** has liquid connection with multiple flow paths (that is, the supply flow path **22** and the collection flow path **23**) used for ink circulation with the outside of the print element substrate **10**. That is, the supply flow path **22** and the collection flow path **23** formed in the flow path member **20** have liquid connection with the same common flow path **21**. Further, in a case where a pump **16** provided in a print element substrate **10** is a first pump, the liquid ejection apparatus includes the circulating pump **1001** as the second pump at a position different from the print element substrate **10**. In the present embodiment, such two different pumps function synergistically, so as to perform preferable circulation in the entire liquid ejection apparatus. Specifically, in addition to the circulation generated by the first pump (pump **16**) as described above, the circulating pump **1001**, which is the second pump, generates a flow of liquid in the upstream side of the circulation flow path for the circulation generated by the first pump, that is, in the order of the supply flow path **22**, the common flow path **21**, and the collection flow path **23**. With such a configuration, in the upstream side of the circulation flow path for the circulation generated by the first pump, concentrated ink in the common flow path **21**, or the like, is pushed away by non-concentrated ink supplied from the supply flow path **22** by the circulating pump **1001**, which is the second pump. As a result, it is possible to discharge concentrated ink from the collection flow path **23**. That is, by driving the circulating pump **1001** to circulate ink between the buffer tank **1002** and the liquid ejection head **1**, it is possible to generate an ink flow in the common flow path **21** (as indicated by the outlined white arrows in FIG. **3** and FIG. **4**). With the ink flow, it is possible to recover concentration and viscosity of ink in the common flow path **21** to a normal state. The ink volumes in the buffer tank **1002** and in the ink supply unit **3** are usually sufficiently larger than the ink volume in the print element substrate **10**. Therefore, even though the recovery process by the circulation operation is performed, there is only a slight increase of concentration as a whole, and the effect on the quality of printed images is sufficiently small.

The ink flow can be generated by the circulating pump **1001** continuously or intermittently during print operation, not just after stopping for a long period of time. For example, usage for ink having a high pigment precipitation speed, such as white ink, is more effective.

In the present embodiment, as illustrated in FIG. **3**, a part of the partition (wall portion **24**) between the supply flow path **22** and the collection flow path **23** of the flow path member **20** protrudes into the common flow path **21** so as to be disposed in the vicinity of the communication port **181**, which serves as an inlet port to a pump **16**. That is, the wall portion **24** is positioned nearer the ejection opening formed surface in the laminated direction, compared to the bonding surface between the print element substrate **10** and the flow path member **20**. Further, each of the supply flow path **22** and the collection flow path **23** has a slope that continues from the protruding portion. That is, the connection ports, which are formed in the supply flow path **22** and the collection flow path **23** to be connected to the common flow path **21**, are connected to oblique flow path walls having an acute angle relative to the direction intersecting the array direction in which the ejection openings **15** are aligned. With such a shape as described above, ink from the supply flow path **22** flows preferentially into the vicinity of the inlet port of the pump **16** (that is, in the vicinity of the communication port **181**).

Although the present embodiment is a mode in which all of the first wall **25**, the second wall **27**, the third wall **26**, and the fourth wall **28** form slopes, respectively, the present embodiment is not limited to this example. For example, there may be a mode in which only the first wall **25** forms a slope and the other walls are vertical walls. In a case where the first wall **25** that forms the supply flow path **22** is a vertical wall, a stagnation portion may occur at a portion where an ink flow from the supply flow path **22** is bent. As a result, it becomes difficult for non-concentrated ink to flow into the vicinity of the inlet port of the pump **16** in the common flow path **21**, and therefore it takes time to discharge concentrated ink after the circulating pump **1001** is driven. On the other hand, in a case where the first wall **25** forms a slope, ink flows preferentially into the vicinity of the inlet port of the pump **16** as described above. Therefore, the concentration and viscosity of the ink supplied to the pump **16** can be reduced in a short period of time, and the downtime after stopping for a long period of time until a restart of ejection operation can be shortened.

As illustrated in FIG. **3**, it is preferable that the second wall **27** is also a slope. This is because, in a case where the second wall **27** is a slope, a stagnation portion is less likely to occur, compared to a case in which the second wall **27** is a vertical wall, and thus it is possible to discharge concentrated ink efficiently. Moreover, as illustrated in FIG. **3**, it is preferable that the third wall **26** and the fourth wall **28** are also slopes. This is because, in a case where the third wall **26** and the fourth wall **28** are slopes, the flow becomes stronger because of the rectifying effect, and thus it is possible to improve the efficiency of replacing ink in the common flow path **21**.

Although the supply flow path **22** and the collection flow path **23** are in symmetrical shapes in the explanation of the example of FIG. **3**, the present embodiment is not limited to the example. The supply flow path **22** and the collection flow path **23** may have different shapes.

Although the present embodiment is a mode in which the liquid ejection apparatus **100** is an apparatus that circulates ink between the buffer tank **1002** and the liquid ejection head **1**, there may be other modes. For example, there may be a mode in which, instead of circulating ink, two tanks are provided on the upstream side and the downstream side of a liquid ejection head. Further, by repeating operation of flowing ink from the upstream to the downstream or from the downstream to the upstream, it is possible to obtain the same effect as well. That is, as for a time other than print operation, there may be a mode in which ink moves in a single direction by circulation or a mode in which ink reciprocally moves in the forward direction and the opposite direction. In such a case where ink reciprocally moves, it is preferable that the shape of the supply flow path **22** and the shape of the collection flow path **23** are symmetric.

In addition, the liquid ejection apparatus according to the present embodiment includes the replenishing pump **1003** as the third pump, which is different from the first pump (pump **16**) and the second pump (circulating pump **1001**). Since the liquid ejection apparatus includes the replenishing pump **1003** as the third pump, a flow of liquid is generated in the order of the main tank **1004**, the supply flow path **22**, the common flow path **21**, and the collection flow path **23**.

Second Embodiment

In the first embodiment, the configuration in which ink is circulated between the buffer tank **1002** and the liquid ejection head **1** by the buffer tank **1002** and the circulating pump **1001** provided outside the liquid ejection head **1** is taken as an example for the explanation. In the present embodiment, an explanation is given of a configuration in which the buffer tank **1002** is not provided outside the liquid ejection head **1** and ink is circulated inside the liquid ejection head **1**. In the following explanation, parts that are different from the first embodiment are mainly explained, and the explanation of the parts that are the same as those in the first embodiment are omitted.

FIG. **5** is a schematic view illustrating an ink path corresponding to one color in the liquid ejection apparatus and the liquid ejection head **1** of the present embodiment, in which the liquid ejection head **1** is connected to the pressure pump **1005** and the main tank **1004**.

Unlike the first embodiment, ink is pressurized and supplied from the main tank **1004** by the pressure pump **1005**. Further, the ink supply unit **3** in the liquid ejection head **1** includes a built-in circulating pump **1001** and air buffer **1006**. The air buffer **1006** and the circulating pump **1001** are connected to the collection flow path **23** of the liquid ejection unit **2** in that order. The purpose and effect of driving the circulating pump **1001** are the same as those in the first embodiment, and ink is circulated between the ink supply unit **3** and the liquid ejection unit **2** by driving the circulating pump **1001**. Here, because of the action of the negative pressure control unit **32**, the pressure in the vicinity of the junction of the downstream of the circulating pump **1001** and the downstream of the negative pressure control unit **32** is maintained within a preset constant range of negative pressure. In addition, the pressure in the air buffer

1006 is lowered by the pump head pressure difference of the circulating pump **1001** in accordance with the flow rate in the circulating pump **1001**.

The air buffer **1006** includes an outside air communication hole and an openable valve (not illustrated in FIG. **5**). The air buffer **1006** is able to discharge bubbles, which are discharged from the liquid ejection unit **2** by circulation, to the outside. In a case where ink is consumed in the liquid ejection unit **2** because of print operation or suction recovery, the consumed amount of ink is replenished from the main tank **1004** through the pressure pump **1005** and the negative pressure control unit **32** to the liquid ejection unit **2**.

FIG. **6** is a schematically illustrated top view of a print element substrate **10**. As illustrated in FIG. **6**, the pumps **16** are disposed in the same array as the ejection openings **15** (that is, the print elements **14**) in the array direction (also referred to as the ejection opening array direction), in which the ejection openings **15** are disposed in line. According to such a configuration, electrical wiring can be simplified. In the present embodiment, the common flow path **21** is a flow path extending in the ejection opening array direction (y-direction). The pumps **16** suction ink from the common flow path **21** and generate ink flows (as indicated by the black arrows in FIG. **6**) that flow through the separate flow paths, each of which is a U-shaped flow path, to the print elements **14** and the ejection openings **15**.

The common flow path **21** communicates with a first supply flow path **221** and a second supply flow path **222** of the flow path member **20** through a communication port **184** and a communication port **185**, respectively. Further, the common flow path **21** communicates with the collection flow path **23** of the flow path member **20** via a communication port **186**. The print element substrate **10** in FIG. **5** is a cross sectional view taken along line B-B' of FIG. **6**. An ink circulatory flow generated by the circulating pump **1001** is indicated by the outlined white arrows in FIG. **5** and FIG. **6**. As described above, the connection ports, which are formed in the first supply flow path **221**, the second supply flow path **222**, and the collection flow path **23** to be connected to the common flow path **21**, are disposed apart from each other in the extending direction of the common flow path **21**.

In the present embodiment, the first supply flow path **221**, the second supply flow path **222**, and the collection flow path **23**, which are formed in the flow path member **20**, have liquid connection with the same common flow path **21** as well. Further, in a case where a pump **16** provided in the print element substrate **10** is a first pump, the liquid ejection apparatus includes the circulating pump **1001** as the second pump at a position different from the print element substrate **10**. Specifically, in the present embodiment, the circulating pump **1001** is provided inside the liquid ejection head. Since the liquid ejection apparatus includes the circulating pump **1001** as the second pump, a flow of liquid is generated in the order of the supply flow paths (the first supply flow path **221** and the second supply flow path **222**), the common flow path **21**, and the collection flow path **23**. With such a configuration, concentrated ink in the common flow path **21**, which is positioned in the upstream of the circulation flow path for circulation generated by the first pump, is pushed away by non-concentrated ink supplied from the supply flow paths by the circulating pump **1001**, which is the second pump, for example. As a result, it is possible to discharge concentrated ink from the collection flow path **23**.

In addition, the liquid ejection apparatus according to the present embodiment includes the pressure pump **1005** as the third pump, which is different from the first pump (pump **16**) and the second pump (circulating pump **1001**). Since the liquid ejection apparatus includes the pressure pump **1005** as the third pump, a flow of liquid is generated in the order of the main tank **1004**, the supply flow paths (the first supply flow path **221** and the second supply flow path **222**), the common flow path **21**, and the collection flow path **23**.

As illustrated in FIG. **5** and FIG. **6**, the circulatory flow of ink generated by the circulating pump **1001** flows from both end portions of the common flow path **21** (end portions in the ejection opening array direction of the print element substrate **10**) toward the central portion of the common flow path **21** (the central portion of the print element substrate **10** in the ejection opening array direction).

As illustrated in FIG. **5**, the partition **242** between the first supply flow path **221** and the collection flow path **23** and the partition **241** between the second supply flow path **222** and the collection flow path **23** have shapes that protrude into the common flow path **21**. As with the first embodiment, the purpose and effect thereof are improvement of the efficiency of replacing concentrated/thickened ink in the common flow path. For example, since the partition **241** and the partition **242** protrude into the common flow path **21**, it is possible to let fresh ink (non-concentrated ink) pass by as close to the liquid intake (inlet) of a pump **16** in the common flow path **21** as possible. Further, since the partition **241** and the partition **242** protrude into the common flow path **21**, the flow path area of the common flow path **21** is reduced. Thus, since the speed of an ink flow becomes higher, the efficiency of replacement is improved.

Further, in the present embodiment, as illustrated in FIG. **5**, the flow path walls of the first supply flow path **221** and the second supply flow path **222** are present such that a part of the ink flow flowing in from the first supply flow path **221** and the second supply flow path **222** is directed toward the ejection openings positioned at the end portions of the ejection opening array. That is, each of the connection ports, which are formed in the first supply flow path **221** and the second supply flow path **222** to be connected to the common flow path **21**, extends along the extending direction (ejection opening array direction), in which the common flow path **21** extends.

More specifically, as illustrated in FIG. **5**, the first supply flow path **221** is formed by the fifth wall **291**, which is on an end portion side in the ejection opening array direction, and the sixth wall **292**, which is on the collection flow path **23** side in the ejection opening array direction. Further, the fifth wall **291** forms a slope in the laminated direction, such that, compared to the inlet port of the first supply flow path **221**, the outlet port to the common flow path **21** is nearer the end portion side (farther from the collection flow path **23**) in the ejection opening array direction. Contrarily, the sixth wall **292** forms a slope in the laminated direction, such that, compared to the inlet port of the first supply flow path **221**, the outlet port to the common flow path **21** is nearer the collection flow path **23** in the ejection opening array direction.

Further, the second supply flow path **222** is formed by the seventh wall **293**, which is on an end portion side in the ejection opening array direction, and the eighth wall **294**, which is on the collection flow path **23** side in the ejection opening array direction. Further, the seventh wall **293** forms a slope in the laminated direction, such that, compared to the inlet port of the second supply flow path **222**, the outlet port to the common flow path **21** is nearer the end portion side in the ejection opening array direction. The eighth wall **294** forms a slope in the laminated direction, such that, compared to the inlet port of the second supply flow path **222**, the outlet port to the common flow path **21** is nearer the collection flow path **23** in the ejection opening array direction.

With such shapes, the ink flow from the first supply flow path **221** and the second supply flow path **222** flows around the end portions of the common flow path **21**. That is, because of the shape of a slope of the fifth wall **291**, it is made easier for the ink flow from the first supply flow path **221** to flow into the pump **16***a*, which is positioned on the opposite side of the collection flow path **23** in the ejection opening array direction. Further, because of the shape of a slope of the seventh wall **293**, it is made easier for the ink flow from the second supply flow path **222** to flow into the pump **16***b*, which is positioned on the opposite side of the collection flow path **23** in the ejection opening array direction. Therefore, the concentration and viscosity of the ink supplied to the pump **16** can be reduced in a short period of time, and the downtime after stopping for a long period of time until a restart of ejection operation can be shortened.

Furthermore, the collection flow path **23** is formed by the ninth wall **295**, which is on the first supply flow path **221** side, and the tenth wall **296**, which is on the second supply flow path **222** side. Further, the ninth wall **295** forms a slope in the laminated direction, such that, compared to the outlet port of the collection flow path **23**, the inlet port from the common flow path **21** is nearer the first supply flow path **221** in the ejection opening array direction. Moreover, the tenth wall **296** forms a slope in the laminated direction, such that, compared to the outlet port of the collection flow path **23**, the inlet port from the common flow path **21** is nearer the second supply flow path **222** in the ejection opening array direction. That is, at least a part of the connection ports, which are formed in the first supply flow path **221**, the second supply flow path **222**, and the collection flow path **23** to be connected to the common flow path **21**, is connected to an oblique flow path wall having an acute angle relative to the array direction in which the ejection openings **15** are aligned.

In this way, by forming slopes in the first supply flow path **221**, the second supply flow path **222**, and the collection flow path **23**, it is possible to prevent a flow stagnation area from occurring or to improve the efficiency of replacing concentrated ink by the rectifying effect.

Other Embodiments

In the first embodiment, an explanation has been given of the configuration in which such a liquid ejection head **1** as illustrated in FIG. **3** and FIG. **4** is applied to the mode in which ink is circulated between the buffer tank **1002** and the liquid ejection head **1**. Further, in the second embodiment, an explanation is given of the configuration in which such a liquid ejection head **1** as illustrated in FIG. **5** and FIG. **6** is applied to the mode in which ink is circulated inside the liquid ejection head **1**. However, combinations of a circulation configuration and a liquid ejection head configuration are not limited to the combinations described above. For example, there may be a mode in which such a liquid ejection head **1** as illustrated in FIG. **5** and FIG. **6** is applied to the mode in which ink is circulated between the buffer tank **1002** and the liquid ejection head **1** as explained in the first embodiment. Further, there may be a mode in which such a liquid ejection head **1** as illustrated in FIG. **3** and FIG. **4** is applied to the mode in which ink is circulated inside the liquid ejection head **1** as explained in the second embodiment.

Moreover, in FIG. **3** and FIG. **4**, an explanation has been given of the example in which one set of a supply flow path **22** and a collection flow path **23** has liquid connection with one common flow path **21**. However, the embodiment is not limited to the example. Multiple common flow paths and one pair of a supply flow path and a collection flow path corresponding to the common flow paths may be provided in the liquid ejection head **1**. Further, as illustrated in FIG. **5** and FIG. **6**, a pair of multiple supply flow paths and one collection flow path may be arranged for one common flow path **21**. Alternatively, multiple collection flow paths may be arranged for one common flow path. In addition, multiple supply flow paths and multiple collection flow paths may be arranged for one common flow path **21**.

Further, in the above-described embodiments, an explanation has been given of the mode in which a time for decreasing ink concentration and viscosity is shortened by circulation operation performed by the circulating pump **1001**. Further, it has been explained that waste ink can thereby be reduced as preliminary ejection operation or cap suction operation is not performed. However, it is also possible that the liquid ejection apparatus is configured to be able to perform preliminary ejection operation and cap suction operation.

According to the present disclosure, even after a long period of time being in a state in which ejection is not performed, it is possible to eject a desired liquid from an ejection opening.

While the present disclosure has been described with reference to exemplary embodiments, it is to be understood that the disclosure is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2018-248110, filed Dec. 28, 2018, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. A liquid ejection head comprising:

an ejection opening forming member having a plurality of ejection openings being configured to eject liquid; and

an element substrate having elements configured to generate energy to eject liquid from the ejection openings, wherein

the element substrate includes:

a plate portion having a first surface and a second surface, the second surface being opposite to the first surface,

pressure chambers configured in such a way that pressure to eject the liquid by the elements is applied and provided on a side of the first surface,

a supply flow path and a collection flow path which are openings penetrating through the first surface and the second surface of the plate portion,

a common flow path provided on a side of the second surface of the plate portion and fluidically connected with the supply flow path and the collection flow path, and

pumps, provided on the side of the first surface, configured to generate liquid flow, wherein the liquid flows in an order of the common flow path, the supply flow path, the pressure chamber, the collection flow path, and the common flow path,

wherein the collection flow path and the supply flow path are positioned across an ejection opening array, in which the plurality of ejection openings are aligned, in a direction intersecting the ejection opening array, and wherein, in a planar view of the element substrate, the supply flow path, the pumps, the elements, and the collection flow path are positioned in the listed order in a direction intersecting the ejection opening array.

2. The liquid ejection head according to claim **1**, wherein at least two ejection opening arrays in which the ejection openings are aligned are provided and the ejection openings of two ejection opening arrays are positioned so as to be displaced from each other in a direction orthogonal to a direction in which the ejection opening arrays extend.

3. The liquid ejection head according to claim **1**, wherein a plurality of ejection opening arrays are in fluid communication with the common flow path.

4. The liquid ejection head according to claim **1**, wherein a first ejection opening array and a second ejection opening array are in fluid communication with the common flow path.

5. The liquid ejection head according to claim **4**, wherein in the planar view of the element substrate, the collection flow path, the first ejection opening array, the supply flow path, the second ejection opening array, and the collection flow path are positioned in the listed order in a direction orthogonal to a direction in which the ejection opening arrays extend.

6. The liquid ejection head according to claim **1**, wherein the pumps are configured to circulate liquid between the common flow path and the pressure chambers.

7. The liquid ejection head according to claim **1**, wherein a circulation flow rate generated by each of the pumps is configured to be lower than a maximum ejection flow rate per ejection opening.

8. The liquid ejection head according to claim **1**, wherein each of the pumps is driven in a case in which a corresponding element configured to generate energy is not driven.

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