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(71) **Applicant** *(for all designated States except US)*: **RICOH COMPANY, LTD.** [JP/JP]; 3-6, Nakamagome, 1-Chome, Ohta-ku, Tokyo 1438555 (JP).

(72) **Inventor; and**
(71) **Applicant** *(for US only)*: **HANADA, Takaya** [JP/JP]; c/o Ricoh Company, Ltd. 3-6, Nakamagome 1-Chome, Ohta-ku, Tokyo 1438555 (JP).

(74) **Agent: SUZUKI, Yasushi**; 2-7-1, Izumi, Ebina-shi, Kanagawa 2430460 (JP).

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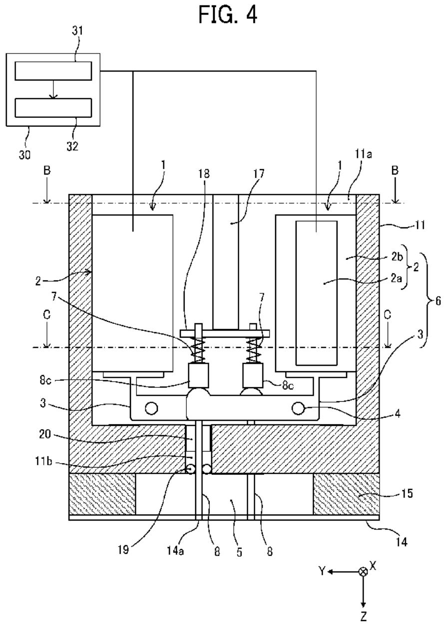
(54) **Title:** LIQUID DISCHARGE HEAD AND LIQUID DISCHARGE APPARATUS

FIG. 4



(57) **Abstract:** A liquid discharge head includes a nozzle plate having a nozzle array having multiple nozzles arrayed in a nozzle array direction, a first liquid discharge module on a first side, and a second liquid discharge module on a second side. Each of the first liquid discharge module and the second liquid discharge module includes a valve to open and close a corresponding nozzle, an actuator to displace to move the valve, and an arm to amplify a displacement of the actuator to move the valve. The actuator of the first liquid discharge module is on the first side and the actuator of the second liquid discharge module is on the second side with respect to the nozzle array. A part of the arm of the first liquid discharge module overlaps a part of the arm of the second liquid discharge module in the nozzle array direction.

[DESCRIPTION]

[Title of Invention]

LIQUID DISCHARGE HEAD AND LIQUID DISCHARGE APPARATUS

[Technical Field]

[0001]

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

[Background Art]

[0002]

In the related art, a liquid discharge head includes a nozzle plate and multiple liquid discharge modules. The nozzle plate has a nozzle array in which multiple nozzles, from which a liquid is dischargeable, are arrayed. Each of the multiple liquid discharge modules includes a valve to open and close the nozzle and a moving mechanism to move the valve between an open position at which the nozzle is opened and a closed position at which the nozzle is closed.

In PTL 1, the liquid discharge head includes the moving mechanism including an actuator and an arm. The arm is swingably supported to move the valve in conjunction with the displacement of the actuator. The multiple liquid discharge modules are arranged alternately in a nozzle array direction such that a part of the arm and a part of another arm overlap each other when viewed in the nozzle array direction. The pitch between the nozzles can be narrowed by such a configuration.

[Citation List]

[Patent Literature]

[0003]

[PTL 1]

Japanese Patent No. 7181925

[Summary of Invention]

[Technical Problem]

[0004]

However, in PTL 1, the amount of movement of the valve is small, and the size of liquid droplets discharged from the nozzle is small.

[Solution to Problem]

[0005]

A liquid discharge head includes a nozzle plate, a first liquid discharge module, and a second liquid discharge module. The nozzle plate has a nozzle array having multiple nozzles to discharge a liquid in a liquid discharge direction. The multiple nozzles are arrayed in a nozzle array direction orthogonal to the liquid discharge direction. The first liquid discharge module is disposed on a first side in an orthogonal direction orthogonal to the nozzle array direction and the liquid discharge direction. The second liquid discharge module is disposed on a second side opposite the first side in the orthogonal direction. Each of the first liquid discharge module and the second liquid discharge module includes a valve, an actuator, and an arm. The valve opens and closes a corresponding nozzle of the multiple nozzles. The actuator displaces to move the valve. The arm amplifies a displacement of the actuator to move the valve between an open position at which the corresponding nozzle is opened and a closed position at which the corresponding nozzle is closed by the valve by an amplified displacement. The actuator of the first liquid discharge module is on the first side with respect to the nozzle array in the orthogonal direction. The actuator of the second liquid discharge module is on the second side with respect to the nozzle array in the orthogonal direction. A part of the arm of the first liquid discharge module overlaps a part of the arm of the second liquid discharge module in the nozzle array direction.

[Advantageous Effects of Invention]

[0006]

According to one aspect of the present disclosure, the size of liquid droplets discharged from the nozzle can be increased.

[Brief Description of Drawings]

[0007]

A more complete appreciation of embodiments of the present disclosure and many of the attendant advantages and features thereof can be readily obtained and understood from the following detailed description with reference to the accompanying drawings.

[FIG. 1]

FIG. 1 is an external perspective view of a liquid discharge head.

[FIGS. 2A and 2B]

FIGS. 2A and 2B are diagrams each illustrating the arrangement of nozzles of a nozzle plate.

[FIGS. 3A and 3B]

FIGS. 3A and 3B are diagrams illustrating the mechanical fixation of a nozzle plate and a channel substrate.

[FIG. 4]

FIG. 4 is a cross-sectional view taken along line A-A in FIG. 1.

[FIG. 5]

FIG. 5 is a partial detailed view of a liquid discharge module.

[FIG. 6]

FIG. 6 is an enlarged view of a portion surrounded by broken line J in FIG. 5.

[FIG. 7]

FIG. 7 is a schematic diagram illustrating a part of a cross section taken along line B-B in FIG. 4.

[FIG. 8]

FIG. 8 is a schematic diagram illustrating a part of a cross section taken along line C-C in FIG. 4.

[FIGS. 9A to 9C]

FIGS. 9A to 9C are schematic views of an arm.

[FIGS. 10A and 10B]
FIGS. 10A and 10B are schematic views of an arm according to a modification.
[FIG. 11]
FIG. 11 is another schematic view of an arm according to a modification.
[FIG. 12]
FIG. 12 is a schematic plan view of a part of a liquid discharge head according to a first modification.
[FIGS. 13A and 13B]
FIGS. 13A and 13B are schematic views of a part of a liquid discharge head according to a second modification.
[FIG. 14]
FIG. 14 is a schematic view of a part of a liquid discharge head according to a third modification.
[FIG. 15]
FIG. 15 is another schematic view of a part of a liquid discharge head according to the third modification.
[FIGS. 16A and 16B]
FIGS. 16A and 16B are schematic views of a part of a liquid discharge head according to a fourth modification.
[FIG. 17]
FIG. 17 is an enlarged view of a portion indicated by broken line G in FIG. 16B.
[FIGS. 18A and 18B]
FIGS. 18A and 18B are schematic views of a part of a liquid discharge head according to a fifth modification.
[FIG. 19]
FIG. 19 is a schematic perspective view of a liquid discharge apparatus.
[FIG. 20]
FIG. 20 is a diagram illustrating a supply device that supplies paint to multiple liquid discharge heads of a liquid discharge apparatus.
[FIG. 21]
FIG. 21 is a diagram illustrating an electrode manufacturing apparatus including a liquid discharge head.
The accompanying drawings are intended to depict embodiments of the present disclosure and should not be interpreted to limit the scope thereof. The accompanying drawings are not to be considered as drawn to scale unless explicitly noted. Also, identical or similar reference numerals designate identical or similar components throughout the several views.
[Description of Embodiments]
[0008]

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

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

[0009]

Embodiments of the present disclosure are described below with reference to the drawings. It is to be understood that those skilled in the art can easily modify and change the present disclosure within the scope of the appended claims to form other embodiments, and these modifications and changes are included in the scope of the appended claims. The following embodiments are illustrative and do not limit the scope of the appended claims.

[0010]

FIG. 1 is an external perspective view of a liquid discharge head 10.

In the following description, a nozzle array direction (longitudinal direction of the liquid discharge head 10) is an X direction, a liquid discharge direction from nozzles (height direction of the liquid discharge head 10) is a Z direction, and a direction (transverse direction of the liquid discharge head 10) orthogonal to both the X direction and the Z direction is a Y direction.

[0011]

The liquid discharge head 10 includes a nozzle plate 14, a channel substrate 15, and a cover 11 as a housing. The channel substrate 15 is provided with a supply port 12, through which liquid is supplied, at one end of the channel substrate 15 in the X direction, and a drain port 13, through which the liquid is drained, at the other end of the channel substrate 15 in the X direction. The cover 11 is provided with a harness hole 16, through which a harness for communicating with an actuator 2 accommodated in the cover 11 is inserted, in an upper portion of the cover 11.

The nozzle plate 14, the channel substrate 15, and the cover 11 are made of metal, resin, or ceramics. The cover 11 accommodates and supports liquid discharge modules 1 described below (see FIG. 4). The channel substrate 15 defines channels through which liquid flows, and the nozzle plate 14 has multiple nozzles from which liquid is dischargeable. The nozzle plate 14 is mechanically (and removably) fixed to the channel substrate 15, and the cover 11 is mechanically (and removably) fixed to the channel substrate 15.

[0012]

FIGS. 2A and 2B are diagrams each illustrating the arrangement of nozzles 14a of the nozzle plate 14.

As illustrated in FIG. 2A, one nozzle array may be disposed at the center of the nozzle plate 14 in the Y direction (the transverse direction of the liquid discharge head 10). Alternatively, as illustrated in FIG. 2B, two nozzle arrays, in which the nozzles 14a are arrayed in a staggered manner, may be disposed in the Y direction. The arrangements of the nozzles 14a illustrated in FIGS. 2A and 2B are examples. For example, the nozzle plate 14 may have four nozzle arrays in total, i.e., two sets of two nozzle arrays are disposed in the Y direction in a staggered manner. Alternatively, the nozzle plate 14 may have multiple nozzle arrays in which the nozzles 14a are arrayed at the same positions in the X direction (the longitudinal direction of the liquid discharge head 10). In the following description, the liquid discharge head 10 includes the nozzle plate 14 having two nozzle arrays in the Y direction. The nozzles 14a are arrayed in a staggered manner in the nozzle plate 14 as illustrated in FIG. 2B.

[0013]

FIGS. 3A and 3B are diagrams illustrating the mechanical fixation of the nozzle plate 14 and the channel substrate 15. FIG. 3A is a schematic diagram illustrating a configuration of the nozzle plate 14, and FIG. 3B is a schematic diagram illustrating a configuration of the channel substrate 15.

The nozzle plate 14 has five through holes 14b, through which screws are inserted, at equal intervals in the X direction at each end of the nozzle plate 14 in the Y direction. Further, the nozzle plate 14 has positioning holes 14c for positioning the nozzle plate 14 with respect to the channel substrate 15 at both ends of the nozzle plate 14 in the X direction. The positioning hole 14c at one end in the X direction is a primary reference for positioning. The positioning hole 14c as the primary reference is a round hole having substantially the same diameter as that of a positioning pin. The positioning hole 14c at the other end in the X direction is a secondary reference for positioning. The positioning hole 14c as the secondary reference is a slotted hole elongated in the X direction.

[0014]

As illustrated in FIG. 3B, the channel substrate 15 has a channel 5 through which liquid flows. A seal 15a made of an elastic member such as rubber is disposed on the lower face of the channel substrate 15 so as to surround the channel 5. The channel substrate 15 has five female screws 15b, each of which has a screw groove on the inner circumferential face, at equal intervals in the X direction at each end of the lower face of the channel substrate 15 in the Y direction. Further, the channel substrate 15 has pin fitting holes 15c into which the positioning pins are fitted at both ends of the channel substrate 15 in the X direction. The positioning pins may be formed directly on the channel substrate 15.

[0015]

First, the positioning pins fitted into the pin fitting holes 15c of the channel substrate 15 are inserted into the positioning holes 14c of the nozzle plate 14 to position the nozzle plate 14 with respect to the channel substrate 15. Then, screws are inserted through the through holes 14b of the nozzle plate 14 and screwed into the female screws 15b of the channel substrate 15 to mechanically (and removably) fix the nozzle plate 14 to the channel substrate 15. The seal 15a on the channel substrate 15 is pressed by screwing the nozzle plate 14 onto the channel substrate 15 to bring the seal 15a into close contact with the nozzle plate 14. As a result, the gap between the nozzle plate 14 and the channel substrate 15 is sealed.

[0016]

In the present embodiment, since the nozzle plate 14 is fixed to the channel substrate 15 by screwing, the nozzle plate 14 can be easily removed by removing the screws, and the nozzle plate 14 can be easily replaced. Accordingly, for example, the nozzle plate 14 can be replaced with a nozzle plate having nozzles with a desired diameter to obtain optimal discharge properties with respect to a discharge target onto which liquid is discharged.

[0017]

FIG. 4 is a cross-sectional view taken along line A-A in FIG. 1, and FIG. 5 is a partial detailed view of the liquid discharge modules 1.

The cover 11 accommodates multiple liquid discharge modules 1 corresponding to the respective nozzles 14a in a housing portion 11a of the cover 11. The multiple liquid discharge modules 1 are arranged in two rows in a staggered manner. Each of the liquid discharge modules 1 includes a needle valve 8 to open and close the nozzle 14a, and a moving mechanism 6 including an arm 3 and the actuator 2.

[0018]

The multiple liquid discharge modules 1 are alternately arranged in the X direction in two rows in the housing portion 11a of the cover 11. The face of the liquid discharge module 1 in one row is diagonally opposite the face of the liquid discharge module 1 in the other row on the side the needle valve 8 is disposed (see FIG. 8 as well). As illustrated in FIG. 4, the arm 3 of the liquid discharge module 1 in one of the two rows partially overlaps the arm 3 of the liquid discharge module 1 in the other row when viewed in the X direction. In the present embodiment, the nozzles 14a are arrayed in a staggered manner in two nozzle arrays of the nozzle plate 14 as illustrated in FIG. 2B. Even when the nozzles 14a are arrayed in one nozzle array of the nozzle plate 14 as illustrated in FIG. 2A, the arm 3 of the liquid discharge module 1 in one of the two rows partially overlaps the arm 3 of the liquid discharge module 1 in the other row when viewed in the X direction.

[0019]

In the present embodiment, the liquid discharge modules 1 are alternately arranged in two rows. In other words, the liquid discharge modules 1 including the actuator 2 on one side with respect to the nozzle array(s) are diagonally opposite the liquid discharge modules 1 including the actuator 2 on the other side with respect to the nozzle array(s). The liquid discharge modules 1 are alternately arranged in the nozzle array direction (X direction) such that a part of the arm 3 on the one side overlaps a part of the arm 3 on the other side when viewed in the nozzle array direction (X direction).

[0020]

The actuator 2 includes a piezoelectric element 2a and a fixing element 2b. The fixing element 2b fixes the piezoelectric element 2a and applies a preload for compressing the piezoelectric element 2a. The fixing element 2b is fixed to the inner wall, which is orthogonal to the Y direction, of the housing portion 11a of the cover 11. More specifically, the fixing element 2b fixes the end of the piezoelectric element 2a in the Z direction to the inner wall of the housing portion 11a. The piezoelectric element 2a expands and contracts in the Z direction. For example, mechanical fixing using screws or chemical fixing such as bonding using an adhesive or thermal diffusion is used to fix the piezoelectric element 2a.

[0021]

The arm 3 is swingably supported by a support shaft 4 as an arm support shaft. One end (i.e., a first end) of the arm 3 is bonded and fixed to the actuator 2, and the other end (i.e., a second end) of the arm 3 contacts an arm receiving portion 8c fixed to the needle valve 8. The other end of the arm 3 is a contact portion 3a as a second connection portion contacting the arm receiving portion 8c. The contact portion 3a has a hemispherical shape or a half-moon shape when viewed in the X direction projecting toward the arm receiving portion 8c. Thus, the contact portion 3a smoothly contacts the arm receiving portion 8c when the arm 3 swings.

[0022]

At the other end of the arm 3, a clearance hole 3b through which the needle valve 8 is inserted is formed. The inner diameter of the clearance hole 3b is larger than the outer diameter of the needle valve 8 so that the needle valve 8 does not contact the arm 3 when the arm 3 swings.

[0023]

Multiple valve through holes 11b through which the needle valves 8 corresponding to the respective nozzles 14a are inserted are disposed in the bottom face of the housing portion 11a of the cover 11. A seal 19 such as an O-ring is disposed at an end of the valve through hole 11b adjacent to the channel substrate 15, and a valve bearing 20 that slidably bears the needle valve 8 is disposed at the other end of the valve through hole 11b opposite the channel substrate 15. The end of the needle valve 8 opposite the nozzle plate 14 penetrates a spring receiving plate 18. The needle valve 8 is held parallel to the Z direction by the seal 19, the valve bearing 20, and the spring receiving plate 18.

[0024]

A compression spring 7 as a biasing member is disposed between the arm receiving portion 8c fixed to the needle valve 8 and the spring receiving plate 18 to press the needle valve 8 toward the nozzle plate 14 via the arm receiving portion 8c.

[0025]

Since the needle valve 8 is pressed toward the nozzle plate 14 by the compression spring 7, the needle valve 8 can be stably moved between an open position at which the nozzle 14a is opened and a closed position at which the nozzle 14a is closed. The spring receiving plate 18 is attached to a stationary component 17 fixed to the cover 11.

[0026]

As illustrated in FIG. 4, the actuators 2 of the liquid discharge modules 1 are connected to a drive control device 30 via the harness. The drive control device 30 includes a waveform generation circuit 31 as a drive pulse generator and an amplification circuit 32.

[0027]

The waveform generation circuit 31 generates a waveform of a drive pulse described later, and the amplification circuit 32 amplifies the voltage of the waveform to a desired value. The amplified voltage signal is applied to the actuator 2. The drive control device 30 controls the displacement of the piezoelectric element 2a with the voltage applied to the actuator 2 to cause the needle valve 8 to open and close the nozzle 14a. Thus, the liquid discharge head 10 is controlled so as to discharge liquid. When the waveform generation circuit 31 can apply a voltage of a sufficient value, the amplification circuit 32 may be omitted from the drive control device 30.

[0028]

In the present embodiment, the nozzle 14a is normally closed. The needle valve 8 closes the nozzle 14a by the biasing force of the compression spring 7 when the drive control device 30 applies no signal to the actuator 2. The phrase “no signal is applied to the actuator 2” means that either a voltage of 0 V or a constant static voltage is constantly applied to the actuator 2.

[0029]

The waveform generation circuit 31 generates the drive pulse having the waveform in which the voltage applied to the actuator 2 is changed with time. The waveform generation circuit 31 receives, for example, print data from an external personal computer (PC) or a microcomputer in a liquid discharge apparatus, and generates a drive pulse based on the received print data. The waveform generation circuit 31 can change the voltage applied to the actuator 2 and generate multiple drive pulses. As described above, the waveform generation circuit 31 generates the drive pulse, and the piezoelectric element 2a of the actuator 2 expands and contracts in accordance with the drive pulse.

[0030]

Specifically, the piezoelectric element 2a expands when a predetermined voltage is applied to the piezoelectric element 2a. When the piezoelectric element 2a expands, the arm 3 swings in a direction in which the other end (i.e., the second end) of the arm 3 lifts the arm receiving portion 8c. As a result, the arm receiving portion 8c is moved upward (toward the spring receiving plate 18) against the biasing force of the compression spring 7, and the needle valve 8 is moved upward together with the arm receiving portion 8c. As a result, the nozzle 14a is opened, and a liquid droplet is discharged from the nozzle 14a by the pressure applied to the liquid in the channel 5.

[0031]

As the voltage applied to the piezoelectric element 2a decreases, the piezoelectric element 2a contracts. When the piezoelectric element 2a contracts, the arm 3 swings such that the other end (i.e., the second end) of the arm 3 is moved downward (toward the nozzle plate 14).

Thus, the arm receiving portion 8c is also moved downward by the biasing force of the compression spring 7, following the movement of the other end of the arm 3. As a result, the nozzle 14a is closed by the needle valve 8 to stop discharging the liquid droplet from the nozzle 14a.

[0032]

In the present embodiment, the piezoelectric element 2a is used as the actuator 2, but the actuator 2 may be any actuator driven by electricity, such as a pneumatic piston provided with a solenoid or an electromagnetic valve. Further, in the present embodiment, the compression spring 7 is used, but a tension spring for pulling the needle valve 8 toward the nozzle plate 14 may be used. In this case, for example, one end of the tension spring may be fixed to the bottom face of the housing portion 11a, and the other end of the tension spring may be fixed to the needle valve 8 or the arm receiving portion 8c with the tension spring extended.

[0033]

FIG. 6 is an enlarged view of a portion surrounded by broken line J in FIG. 5.

As illustrated in FIG. 6, a sealing member 8a is disposed at the tip of the needle valve 8. The sealing member 8a is made of elastomer, hard rubber, metals, or ceramics. The needle valve 8 and the sealing member 8a may be formed as a single piece. The sealing member 8a contacts a channel opening-closing portion 14d of the nozzle plate 14. The sealing member 8a and the channel opening-closing portion 14d may be subjected to ceramic coating or diamond-like coating to enhance slidability or durability.

[0034]

The tip of the sealing member 8a has a needle shape with a tapered cross section, and the channel opening-closing portion 14d of the nozzle plate 14 also has a funnel shape with a tapered cross section. However, such shapes are examples. The tip of the sealing member 8a may have a smooth convex curved surface such as a spherical shape, and the channel opening-closing portion 14d of the nozzle plate 14 may have a smooth concave curved surface that tightly contacts the smooth convex curved surface of the tip of the sealing member 8a. Alternatively, the tip of the sealing member 8a may have a flat surface, and the tip of the sealing member 8a may contact the periphery of an inlet of the nozzle 14a to close the nozzle 14a.

[0035]

The nozzle plate 14 may include multiple layers including a layer having the nozzle 14a and a layer having the channel opening-closing portion 14d. In this case, the layers of the nozzle plate 14 have a structure for defining the positions thereof to firmly fix the layers to each other by chemical fixing such as bonding by adhesion or joining by thermal diffusion to prevent liquid from leaking from between the layers.

[0036]

When the sealing member 8a is pressed against the channel opening-closing portion 14d by the biasing force of the compression spring 7, the sealing member 8a disposed at the tip of the needle valve 8 tightly contacts the channel opening-closing portion 14d to reliably close the nozzle 14a.

[0037]

FIG. 7 is a schematic diagram illustrating a part of a cross section taken along line B-B in FIG. 4.

As illustrated in FIG. 7, the spring receiving plate 18 is attached to the lower end of the stationary component 17. The stationary component 17 extends in the X direction (longitudinal direction of the liquid discharge head 10) of the cover 11, and is bridged between a pair of inner walls of the cover 11 orthogonal to the X direction. Thus, the stationary component 17 is fixed to the cover 11.

[0038]

The spring receiving plate 18 is disposed between the actuator 2 positioned on one side (left side in FIG. 4) in the Y direction with respect to the arrangement of the nozzles 14a and the actuator 2 positioned on the other side (right side in FIG. 4) in the Y direction when viewed in the nozzle array direction (X direction) in FIG. 4. In the present embodiment, the actuator 2 and the needle valve 8 are connected by the arm 3. Accordingly, the actuator 2 and the needle valve 8 are arranged so as not to overlap each other when viewed in a moving direction (Z direction) of the needle valve 8. Due to such an arrangement, in the present embodiment, the spring receiving plate 18 can be disposed in a space in the vicinity of the needle valve 8, i.e., in the space above the needle valve 8 in the Z direction in FIG. 4. With such a configuration, the size of the liquid discharge head 10 in the Y direction and the size of the liquid discharge head 10 in the Z direction can be reduced.

[0039]

In the present embodiment, the actuator 2, which is the largest component among the components constructing the liquid discharge module 1, can be disposed at the end in the Y direction in the housing portion 11a due to the arm 3. Thus, as illustrated in FIGS. 4 and 7, the stationary component 17 can be disposed at the center in the Y direction in the housing portion 11a, and the spring receiving plate 18 can be fixed by the single stationary component 17. For example, when the actuator 2 is disposed at the center in the Y direction without the arm 3, both ends of the spring receiving plate 18 in the Y direction or both ends of the spring receiving plate 18 in the X direction are held by two stationary components 17, respectively. In this way, when the actuator 2 is disposed at the center in the Y direction, the two stationary components 17 may increase the size of the liquid discharge head 10 in the X direction or the Y direction. Further, the spring receiving plate 18 may be extended to a position not facing the actuator 2, and thus the size of the spring receiving plate 18 may also be increased.

[0040]

By contrast, in the present embodiment, the spring receiving plate 18 can be held by the single stationary component 17 disposed at the center in the Y direction in the housing portion 11a, and thus the size of the liquid discharge head 10 can be reduced. Further, the spring receiving plate 18 extended to a position not facing the actuator 2 is unnecessary, and thus the size of the spring receiving plate 18 can be reduced. Furthermore, the arm 3 allows the actuator 2 to be disposed at the end in the Y direction in the housing portion 11a, and thus the distance between the nozzle arrays in the Y direction can be shortened. Accordingly, the length of the spring receiving plate 18 in the Y direction can be further shortened, the material cost can be reduced, and the cost of the liquid discharge head 10 can be reduced.

[0041]

FIG. 8 is a schematic diagram illustrating a part of a cross section taken along line C-C in FIG. 4.

In FIG. 8, the illustrations of the arm receiving portion 8c and the compression spring 7 are omitted.

A group of the liquid discharge modules 1 arranged on the upper side of FIG. 8 (one side in the Y direction, e.g., a first side) corresponds to a nozzle array arrayed on the lower side of FIG 8 (the other side in the Y direction, e.g., a second side) in the nozzle plate 14. A group of the liquid discharge modules 1 arranged on the lower side of FIG. 8 (the other side in the Y direction, e.g., the second side) corresponds to a nozzle array arrayed on the upper side of FIG 8 (the one side in the Y direction, e.g., the first side) in the nozzle plate 14.

[0042]

In the present embodiment, as illustrated in FIG. 4, the liquid discharge modules 1 are alternately arranged in the X direction, and the arm 3 of the liquid discharge module 1 on the one side partially overlaps the arm 3 of the liquid discharge module 1 on the other side when viewed in the X direction. Thus, a length D of the housing portion 11a of the cover 11 in the Y direction is smaller than twice a length L of the liquid discharge module 1 in the Y direction (i.e., $D < 2L$). In this way, the arms 3 partially overlap each other. As a result, the length D of the housing portion 11a of the cover 11 in the Y direction is less than twice the length L of the liquid discharge module 1 in the Y direction, and thus the liquid discharge head 10 can be downsized in the Y direction. The length L of the liquid discharge module 1 in the Y direction is defined as the longer distance of the horizontal distances from the back face of the actuator 2 fixed to the inner wall of the cover 11 either to the end face of the needle valve 8 in the Y direction (the longitudinal direction of the arm 3) or to the end face of the arm 3 farthest from the actuator 2.

[0043]

In the present embodiment, the arm 3 allows the actuator 2 to be disposed at the end in the Y direction in the housing portion 11a. As illustrated in FIG. 8, the width (length in the X direction) of the arm 3 is narrower than the width (length in the X direction) of the actuator 2. Accordingly, when the liquid discharge modules 1 are alternately arranged in the X direction, the arm 3 and a part of the actuator 2 of the liquid discharge module 1 on the one side overlaps a part of the actuator 2 of the liquid discharge module 1 on the other side when viewed in the Y direction. As a result, a nozzle pitch d can be shorter than a width W (length in the X direction) of the liquid discharge module 1 (i.e., d < W), the nozzle pitch d can be narrowed, and thus the liquid discharge head 10 can be downsized in the X direction.

[0044]

In the present embodiment, the liquid discharge head 10 is a so-called valve jet system, and can throw (discharge) a liquid droplet having high viscosity farther. The size of the liquid droplet is larger than that of a system that does not have a valve for each nozzle. Accordingly, for example, the valve jet system is suitable for printing on a large discharge target such as a vehicle body of a large vehicle, a fuselage of an airplane, a wall surface of a building, or a road surface. In the case of printing on such a large discharge target, an image to be printed is also large, and the printing time is greatly extended when the size of the liquid droplet discharged from the nozzles is small as in a system that does not have a valve for each nozzle. For this reason, the valve jet system is preferable. Further, a liquid discharge head may not be arranged in close proximity to a vehicle body of a vehicle, a fuselage of an airplane, a wall surface of a building, or a road surface. In addition, since the liquid is applied to an inclined surface or a surface orthogonal to the horizontal direction, a liquid having high viscosity is used so that the applied liquid does not drip. For such reasons, the liquid discharge head 10 that adopts the valve jet system and can discharge the liquid having high viscosity is suitable for printing on a large discharge target such as a vehicle body of a large vehicle, a fuselage of an airplane, a wall surface of a building, or a road surface.

[0045]

The displacement of the actuator 2 is increased, and the amount of movement of the needle valve 8 is increased to increase the clearance between the nozzle 14a and the sealing member 8a when the needle valve 8 is in the open position so that the liquid having high viscosity easily flows into the nozzle 14a. Accordingly, the size of the liquid droplet discharged from the nozzle 14a can be increased. However, if the displacement of the actuator 2 is increased, the size of the actuator 2 may be increased. As described above, the actuator 2 is the largest component among the components constructing the liquid discharge module 1, and an increase in the size of the actuator 2 directly leads to an increase in the size of the liquid discharge head 10.

[0046]

In the present embodiment, the amount of displacement of the actuator 2 is amplified by the arm 3 to increase the amount of movement of the needle valve 8.

[0047]

FIGS. 9A to 9C are schematic views of the arm 3. FIG. 9A is a view of the arm 3 as viewed in the X direction, FIG. 9B is a view of the arm 3 as viewed in the Z direction, and FIG. 9C is a view of the arm 3 as viewed in the Y direction.

The arm 3 has a fixing portion 3d as a first connection portion at one end (i.e., the first end) and a contact portion 3a as a second connection portion at the other end (i.e., the second end). The actuator 2 is bonded and fixed onto the fixing portion 3d. The contact portion 3a contacts the arm receiving portion 8c. The arm 3 has a support hole 3e into which the support shaft 4 (see FIG. 4) is inserted to support the arm 3. The support shaft 4 is attached to the housing portion 11a of the cover 11. The support hole 3e is disposed between the center of the arm 3 and the fixing portion 3d in the longitudinal direction of the arm 3 (Y direction). Accordingly, the distance between the support hole 3e and the fixing portion 3d is shorter than the distance between the support hole 3e and the contact portion 3a as illustrated in FIG. 9A.

[0048]

As described above, the contact portion 3a projects in the direction (−Z direction) opposite to the liquid discharge direction, and the contact surface contacting the arm receiving portion 8c has an arc shape when viewed in the X direction as illustrated in FIG. 9A. As illustrated in FIG. 9B, a clearance hole 3b through which the needle valve 8 is inserted is disposed in the center of the contact portion 3a in the X direction. As described above, the clearance hole 3b has an inner diameter larger than the outer diameter of the needle valves 8, so that the needle valve 8 does not contact the arm 3 when the arm 3 is swung.

[0049]

The fixing portion 3d has a bonding face 3d1 and a connector 3d2. The bonding face 3d1 is orthogonal to the Z direction and has a rectangular shape. The connector 3d2 extends in the Z direction and connects the bonding face 3d1 and a body 3f of the arm 3. The connector 3d2 is flexibly deformable. As illustrated in FIG. 9A, the connector 3d2 extends from one end of the body 3f of the arm 3 in the Z direction.

[0050]

The piezoelectric element 2a of the actuator 2 is bonded and fixed to the bonding face 3d1. As described above, the arm 3 has the rectangular bonding face 3d1 orthogonal to the Z direction. Thus, the adhesive area on the bonding face 3d1 to the piezoelectric element 2a is increased, and the arm 3 can be firmly fixed to the piezoelectric element 2a. In addition, the influence on the displacement due to the variations in the bonding position of the piezoelectric element 2a can be reduced.

[0051]

When the bonding face 3d1 is displaced in the Z direction together with the piezoelectric element 2a by the displacement of the piezoelectric element 2a, the arm 3 is swung about the support shaft 4. The swing of the arm 3 generates force that inclines the bonding face 3d1 with the left end in FIG. 9A positioned upward. At this time, the connector 3d2, which is bendable, is deformed (bent), and thus the force for inclining the bonding face 3d1 is absorbed. As a result, the arm 3 can be smoothly swung. Thus, the needle valve 8 can be stably displaced, and the variations of the liquid droplets can be reduced.

[0052]

When the arm 3 is swung by the displacement of the piezoelectric element 2a, the contact portion 3a is moved in the direction indicated by arrow K1 in FIG. 9A, and the contact portion 3a is displaced in the Z direction and the Y direction. In the present embodiment, the contact portion 3a is not fixed to the arm receiving portion 8c, and is only in contact with the arm receiving portion 8c. As a result, the contact portion 3a slides in the Y direction with respect to the arm receiving portion 8c and can be displaced in the Y direction. Thus, the arm 3 can be smoothly swung, and the needle valve 8 can be stably displaced. Accordingly, the variations of the liquid droplets can be reduced.

[0053]

Before the arm 3 is swung, the top of the contact portion 3a is in contact with the arm receiving portion 8c. When the arm 3 is swung by the displacement of the piezoelectric element 2a, the contact position of the contact portion 3a with the arm receiving portion 8c is shifted to the left in FIG. 9A (toward the second end of the arm 3). In the present embodiment, as described above, the contact surface of the contact portion 3a with the arm receiving portion 8c has an arc shape when viewed in the X direction, and thus the contact position of the contact portion 3a with the arm receiving portion 8c can be smoothly shifted. Thus, the arm 3 can be smoothly swung, and the needle valve 8 can be stably displaced. Accordingly, the variations of the liquid droplets can be reduced.

[0054]

In the arm 3, the support hole 3e is disposed between the center of the arm 3 and the fixing portion 3d in the longitudinal direction (Y direction). The support shaft 4 (see FIG. 4) is inserted into the support hole 3e to support the arm 3. Accordingly, the radius of swing of the contact portion 3a is longer than the radius of swing of the fixing portion 3d, and the displacement of the contact portion 3a in the Z direction is larger than the displacement of the fixing portion 3d in the Z direction. Thus, the displacement of the arm receiving portion 8c lifted by the contact portion 3a in the Z direction is larger than the displacement of the piezoelectric element 2a in the Z direction. As a result, the arm 3 amplifies the displacement of the piezoelectric element 2a, and the amount of movement of the needle valve 8 can be increased. In other words, the arm 3 moves the needle valve 8 by the amplified displacement. Accordingly, the clearance between the nozzle 14a and the sealing member 8a when the needle valve 8 is in the open position can be increased, liquid having high viscosity easily flows into the nozzle 14a, and the size of the liquid droplets discharged from the nozzle 14a can be increased. Thus, printing efficiency can be increased, and printing time can be shortened. In addition, the actuator 2 which is displaced by a small amount can be used, the actuator 2 can be downsized, and the liquid discharge head 10 can be effectively downsized.

[0055]

As illustrated in FIGS. 9B and 9C, a width E1 (length in the X direction) of the body 3f and the contact portion 3a of the arm 3 is narrower than a width E2 (length in the X direction) of the bonding face 3d1 of the arm 3. Accordingly, as illustrated in FIG. 8, when the liquid discharge modules 1 are alternately arranged in the X direction so that the arms 3 partially overlap each other, the arms 3 can be closely arranged as compared with arms having a body

3f and a contact portion 3a with the width E1 equal to the width E2 of the bonding face 3d1. Thus, the nozzle pitch can be narrowed favorably.

[0056]

The above description is an example, and as illustrated in FIGS. 10A and 10B, the width (length in the X direction) of the body 3f of the arm 3 may be gradually narrowed toward the contact portion 3a. Alternatively, for example, the body 3f of the arm 3 may have a stepped shape so that the width of the body 3f may be narrowed stepwise toward the contact portion 3a. At least, by making the width, in the X direction, of portions of the arms 3 overlapping each other when viewed in the X direction narrower than the other portions, the arms 3 can be closely arranged, and the nozzle pitch can be narrowed. If the width of the body 3f of the arm 3 is too narrow, the rigidity of the arm 3 is weakened, and the body 3f of the arm 3 may be deformed (bent) when the actuator 2 is displaced, which may cause a loss of the displacement of the actuator 2. For this reason, the width of the body 3f of the arm 3 is set so that the body 3f of the arm 3 has a sufficient geometrical moment of inertia in the direction of swing of the arm 3.

[0057]

FIG. 11 is a schematic view of an arm 3 according to a modification.

As illustrated in FIG. 11, in this modification, a support hole 3e into which the support shaft 4 (see FIG. 4) is inserted is disposed between the fixing portion 3d and the one end (first end) of the arm 3. The support shaft 4 is attached to the housing portion 11a of the cover 11. In other words, the support hole 3e (arm supported portion) is disposed outside the region between the fixing portion 3d (i.e., the first connection portion) and the contact portion 3a (i.e., the second connection portion).

[0058]

In this modification, when a voltage is applied to the piezoelectric element 2a to displace the piezoelectric element 2a, the arm 3 swings such that the contact portion 3a is moved downward. Accordingly, with the arm 3 according to this modification, the needle valve 8 opens the nozzle 14a when no signal (voltage) is applied from the drive control device 30 to the actuator 2. When a signal (voltage) is applied to the actuator 2, the needle valve 8 closes the nozzle 14a, which is a so-called normally open configuration. The needle valve 8 is positioned at the open position at which the nozzle 14a is open when no signal (voltage) is applied to the piezoelectric element 2a and the piezoelectric element 2a is not displaced. The needle valve 8 is positioned at the closed position at which the nozzle 14a is closed when a signal (voltage) is applied to the piezoelectric element 2a.

[0059]

In this modification, the compression spring 7 is provided as illustrated in FIG. 5. The compression spring 7 presses the needle valve 8 in a direction opposite to the nozzle 14a. When the piezoelectric element 2a is not displaced, the needle valve 8 is positioned at the open position by the biasing force of the compression spring 7, and when the piezoelectric element 2a expands, the needle valve 8 is moved to the closed position against the biasing force of the compression spring 7.

[0060]

In the arm 3 according to this modification, the distance between the support hole 3e (arm supported portion) and the fixing portion 3d (i.e., the first connection portion) is shorter than the distance between the support hole 3e and the contact portion 3a (i.e., the second connection portion). Accordingly, the radius of swing of the contact portion 3a about the support hole 3e is larger than the radius of swing of the fixing portion 3d about the support hole 3e. As a result, the arm 3 amplifies the displacement of the piezoelectric element 2a and moves the needle valve 8 by the amplified displacement.

[0061]

In the above-described embodiment, the arrangement of the multiple liquid discharge modules 1 has been described as viewed in the nozzle array direction (X direction) with reference to FIG. 4. In other words, this configuration can be described as follows as viewed in the liquid discharge direction (Z direction). When viewed in the liquid discharge direction (Z direction) as illustrated in FIGS. 7 and 8, the actuators 2 of some of the multiple liquid discharge modules 1 are positioned on one side (+Y direction side) in an orthogonal direction (Y direction) orthogonal to the nozzle array direction (X direction) with respect to the nozzles 14a (i.e., with respect to the needle valves 8 in FIGS. 7 and 8). Further, when viewed in the liquid discharge direction (Z direction) as illustrated in FIGS. 7 and 8, the actuators 2 of the rest of the multiple liquid discharge modules 1 are positioned on the other side (−Y direction side) in the orthogonal direction (Y direction) with respect to the nozzles 14a. A part of the arm 3 of the liquid discharge module 1 including the actuator 2 on the −Y direction side overlaps a part of the arm 3 of the liquid discharge module 1 including the actuator 2 on the +Y direction side in the nozzle array direction (X direction). In addition, a part of the actuator 2 on the −Y direction side overlaps a part of the actuator 2 on the −Y direction side in the orthogonal direction (Y direction).

[0062]

In the above-described embodiment with reference to FIGS. 7 and 8, the liquid discharge head 10 includes, but is not limited to, 12 or more liquid discharge modules 1 which are alternately arranged in the nozzle array direction (X direction).

A liquid discharge head according to an embodiment of the present disclosure includes multiple liquid discharge modules 1, i.e., at least two liquid discharge modules 1. All the liquid discharge modules 1 are not necessarily arranged alternately, and some of the liquid discharge modules 1 may be arranged alternately. In other words, the actuator 2 of at least one of the multiple liquid discharge modules 1 may be arranged on one side in the orthogonal direction (Y direction), and the rest of the multiple liquid discharge modules 1 may be arranged on the other side. Even in such an arrangement, the size of the liquid discharge head

10 in the direction (Y direction) orthogonal to the nozzle array direction (X direction) can be reduced.

[0063]

As illustrated in FIGS. 7 and 8, when all the liquid discharge modules 1 are alternately arranged, the size of the liquid discharge head 10 in the nozzle array direction (X direction) can be minimized, but the size can be reduced when some of the liquid discharge modules 1 are alternately arranged. For example, the actuators 2 of the liquid discharge modules 1 at both ends in the nozzle array direction may be arranged on one side with respect to the nozzles 14a, and the actuators 2 of the liquid discharge modules 1 in the central portion in the nozzle array direction may be alternately arranged on both sides with respect to the nozzles 14a.

[0064]

First Modification

FIG. 12 is a schematic plan view of a part of a liquid discharge head 10A according to a first modification.

In the first modification illustrated in FIG. 12, the liquid discharge modules 1 are inclined with respect to the X direction. In this way, the liquid discharge modules 1 inclined with respect to the X direction can downsize the liquid discharge head 10A in the Y direction as compared with a liquid discharge head including the liquid discharge modules arranged in the direction orthogonal to the X direction.

[0065]

In the first modification illustrated in FIG. 12, the axis of swing of the arm 3 is inclined with respect to the X direction, and the liquid discharge modules 1 are arranged such that the longitudinal direction of the arm 3, which is a direction from the fixing portion 3d to the contact portion 3a of the arm 3, is inclined with respect to the X direction. In this way, the liquid discharge module 1 inclined with respect to the X direction allows the length of the arm 3 to increase and allows the width of the arranged liquid discharge modules 1 in the Y direction (i.e., the length D of the housing portion 11a in the Y direction) to decrease. Such a configuration can amplify the amount of movement of the needle valve 8.

[0066]

In the configuration having two nozzle arrays in which the nozzles 14a are arrayed in a staggered manner, when the liquid discharge modules 1 are alternately arranged and inclined with respect to the X direction, the arrangement pitches of the liquid discharge modules 1 are not constant and has uneven density.

As a result, it may be difficult to arrange the liquid discharge modules 1, and the manufacturing cost of the liquid discharge head may increase.

[0067]

For this reason, in the first modification, the nozzle plate 14 has one nozzle array at the center in the Y direction (see FIG. 2A). Accordingly, as illustrated in FIG. 12, the liquid discharge modules 1 can be alternately arranged at a constant arrangement pitch (i.e., the nozzle pitch d) and inclined with respect to the X direction. Accordingly, the liquid discharge modules 1 can be easily arranged, and an increase in the manufacturing cost can be prevented.

In the first modification, at least the ends of the arms 3 near the contact portion 3a overlap each other when viewed in the X direction.

[0068]

Second Modification

FIGS. 13A and 13B are schematic views of a part of a liquid discharge head 10B according to a second modification. FIG. 13A is a view when viewed in the Z direction, and FIG. 13B is a cross-sectional view taken along line D-D in FIG. 13A.

In the liquid discharge head 10B according to the second modification, as illustrated in FIG. 13A, the actuators 2 are alternately arranged such that the actuators 2 partially overlap each other when viewed in the Z direction in a group of liquid discharge modules 1 corresponding to one nozzle array.

Portions a of the actuators 2 overlap each other as illustrated in FIG. 13A.

[0069]

In this way, the actuators 2 are alternately arranged such that the actuators 2 partially overlap each other when viewed in the Z direction, and thus pitch between the nozzles can be narrowed. Such a configuration can downsize the liquid discharge head 10B in the X direction or increase the number of nozzles 14a without changing the length of the liquid discharge head 10B in the X direction.

[0070]

Third Modification

FIG. 14 is a schematic view of a part of a liquid discharge head 10C according to a third modification.

In the third modification, in a group of liquid discharge modules 1 corresponding to one nozzle array, a liquid discharge module 1B having the long arm 3 and a liquid discharge module 1A having the short arm 3 are alternately arranged in the X direction.

The actuator 2 of the liquid discharge module 1A having the short arm 3 is fixed to the inner wall of the housing portion 11a of the cover 11 via a fixing jig 40.

[0071]

The liquid discharge module 1B having the long arm 3 can amplify the displacement of the actuator 2 more greatly than the liquid discharge module 1A having the short arm 3 and increase the amount of movement of the needle valve 8 more greatly than the liquid discharge module 1A having the short arm 3. Accordingly, the size of the liquid droplet discharged from the nozzle 14a corresponding to the liquid discharge module 1B having the long arm 3 can be larger than the size of the liquid droplet discharged from the nozzle 14a corresponding to the liquid discharge module 1A having the short arm 3. As a result, the liquid discharge head 10C can discharge liquid droplets having different sizes.

[0072]
For example, white streaks may occur when the liquid droplets landed on the discharge target do not spread sufficiently. However, as in the third modification, the liquid droplets having different sizes can be discharged, even under the condition in which white streaks occur, to make the white streaks less conspicuous, and thus the deterioration of image quality can be prevented. For example, in the configuration illustrated in FIG. 14, liquid droplets of small, small, large, large, small, small, ... are discharged in the X direction. Accordingly, even under the condition in which white streaks occur, no gap is generated between landed liquid droplets of small and large and between landed liquid droplets of large and large, and thus the deterioration of image quality can be prevented.

[0073]
As illustrated in FIG. 14, the actuators 2 are alternately arranged such that the actuators 2 partially overlap each other when viewed in the Y direction in a group of the liquid discharge modules 1 (1A and 1B) corresponding to one nozzle array. Accordingly, the pitch between nozzles can be narrowed as in the second modification. Such a configuration can downsize the liquid discharge head 10C in the X direction or increase the number of nozzles 14a without changing the length of the liquid discharge head 10C in the X direction.

[0074]
In the third modification, the liquid discharge modules 1 are alternately arranged in the X direction such that the arms 3 overlap each other when viewed in the X direction. Such a configuration can make the length D of the housing portion 11a in the Y direction less than twice a length Ld of the liquid discharge module 1B having the long arm 3 in the Y direction, and thus an increase in the size of the liquid discharge head 10C in the Y direction can be prevented.

[0075]
As illustrated in FIG. 15, the liquid discharge module 1B having the long arm 3 and the liquid discharge module 1A having the short arm 3 may be alternately arranged in the X direction. In the configuration illustrated in FIG. 15, the size of the discharged liquid droplets is small, large, small, large, ... in the X direction, and the white streaks can be further prevented. Further, in the configuration illustrated in FIG. 15, the actuator 2 having a large amount of displacement is used for the liquid discharge module 1B having the long arm 3. Accordingly, the size of the liquid droplet discharged from the nozzle 14a corresponding to the liquid discharge module 1B having the long arm 3 can be further increased.

[0076]
In the configuration illustrated in FIG. 15, the liquid discharge modules 1 are alternately arranged in the X direction such that the arms 3 overlap each other when viewed in the X direction. Accordingly, the length D of the housing portion 11a in the Y direction can be less than twice the length Ld of the liquid discharge module 1B having the long arm 3 in the Y direction.

[0077]
When the actuator 2 having a large amount of displacement is used for the liquid discharge module 1B having the long arm 3, a width Wd (length in the X direction) of the actuator 2 may be increased, and the width Wd of the liquid discharge module 1B may be increased. However, since the liquid discharge modules 1A and 1B are alternately arranged in the X direction, the nozzle pitch d can be narrower than the width Wd of the liquid discharge module 1B.
[0078]
Fourth Modification
FIGS. 16A and 16B are schematic views of a part of a liquid discharge head 10D according to a fourth modification. FIG. 16A is a view when viewed in the Z direction, and FIG. 16B is a cross-sectional view taken along line E-E in FIG. 16A. FIG. 17 is an enlarged view of a portion indicated by broken line G in FIG. 16B.
The liquid discharge head 10D according to the fourth modification has a configuration in which the needle valve 8 opens and closes the multiple nozzles 14a.
In the fourth modification, as illustrated in FIG. 16A, the nozzle plate 14 has the nozzles 14a arrayed in the Y direction, i.e., in two rows and two columns.
[0079]
As illustrated in FIG. 17, the nozzle plate 14 has a bifurcated channel 14f branching in two directions in the X direction from the channel opening-closing portion 14d. The sealing member 8a at the tip of the needle valve 8 tightly contacts the channel opening-closing portion 14d. Channels of the bifurcated channel 14f communicate with the corresponding nozzles 14a. If the flow velocities of the liquid droplets discharged from the respective nozzles 14a are approximately the same and the landing timings are synchronized well, the dimensions of the channels of the bifurcated channel 14f and the diameters and depths of the multiple nozzles 14a may be made different from each other. Further, if the landing timings are synchronized well, the liquid may be discharged from three or more nozzles by one liquid discharge module.
[0080]
In the fourth modification, liquid droplets can be discharged from multiple nozzles by one liquid discharge module. Accordingly, the number of liquid discharge modules can be reduced, and the cost of the apparatus can be reduced.
[0081]
In the fourth modification, the nozzle pitch in the nozzle array can be reduced as compared with the configuration in which one nozzle is disposed on the axis of the needle valve 8. Such a configuration can obtain, with one nozzle array, a resolution in the X direction that is substantially the same as that obtained when two nozzle arrays are arranged in a staggered manner. With such a configuration, for example, in combination with the configuration illustrated in FIG. 15, a group of liquid discharge modules 1A having the short arms 3

discharge small droplets from one nozzle array. A group of liquid discharge modules 1B having long arms 3 discharge large droplets from the other nozzle array. By switching the nozzle array for discharging, two discharge modes: a small droplet mode and a large droplet mode, can be provided. Thus, for example, when a line is drawn, the large droplet mode is used to discharge large droplets from the nozzle array for large droplets, and when characters or a picture is formed, the small droplet mode is used to discharge small droplets from the nozzle array for small droplets. In this way, the discharge modes in which the liquid droplet sizes are different from each other can be obtained by one liquid discharge head. As a result, a liquid discharge apparatus, which will be described later, can be downsized, and the cost of the liquid discharge apparatus can be reduced.

[0082]

Fifth Modification

FIGS. 18A and 18B are schematic views of a part of a liquid discharge head 10E according to a fifth modification. FIG. 18A is a view when viewed in the Z direction, and FIG. 18B is a cross-sectional view taken along line F-F in FIG. 18A.

In the fifth modification, the needle valves 8 are arranged in a staggered manner. The nozzle plate 14 has introduction paths 14e extending in the Y direction and one nozzle array disposed at the center in the Y direction as illustrated in FIG. 2A. The introduction paths 14e are not limited to the configuration illustrated in FIGS. 18A and 18B, and the introduction paths may have any shape as long as the liquid in the channel 5 flows smoothly to the nozzles 14a when the needle valves 8 are positioned at the open position.

[0083]

Due to such a configuration, the length, in the Y direction, of overlapping portions of the arms 3 when viewed in the X direction can be increased as compared with the first modification illustrated in FIG. 12. Accordingly, even in a configuration using the nozzle plate 14 in which one nozzle array is disposed at the center in the Y direction, the length in the Y direction can be equal to that of the configuration using the nozzle plate 14 in which the nozzles are arrayed in a staggered manner. Further, by using the nozzle plate 14 in which one nozzle array is disposed at the center in the Y direction as illustrated in FIG. 2A, a process of controlling the landing timings is unnecessary, and the drive control of each actuator 2 can be simplified as compared with the nozzle plate 14 in which the nozzles are arrayed in a staggered manner.

[0084]

The liquid discharge head according to the present embodiment adopts the valve jet system, and can discharge liquid having high viscosity or large droplets (diameter of several tens to several hundred μm) toward a discharge target at a distance (several tens mm ahead). Further, the nozzle diameter can be increased, and for example, a liquid containing a material with a large particle diameter can be favorably discharged. Since liquid having high viscosity can be discharged as described above, the liquid discharge head according to the present embodiment is suitable for coating, for example, a vehicle body of a car or a truck, a fuselage of an airplane, a wall surface of a building, or a road surface, or printing an image. The liquid discharge head according to the present embodiment is also suitable for forming, for example, an electrode of a lithium ion battery mounted on a vehicle body.

[0085]

An example of a liquid discharge apparatus including the liquid discharge head 10 described above will be described below.

[0086]

FIG. 19 is a schematic perspective view of a liquid discharge apparatus 100.

The liquid discharge apparatus 100 includes a movable frame unit 120 which is installable to face a discharge target 200.

The frame unit 120 includes a Y-axis rail 101 extending in the horizontal direction, multiple X-axis rails 102 extending in the vertical direction at predetermined intervals in the horizontal direction, and a Z-axis rail 103 intersecting the X-axis rails 102 and the Y-axis rail 101.

[0087]

The X-axis rails 102 hold the Y-axis rail 101 such that the Y-axis rail 101 extending horizontally can move in the X direction (i.e., the nozzle array direction of the liquid discharge head 10, and the vertical direction). The Y-axis rail 101 movably holds the Z-axis rail 103 in the Y direction. The Z-axis rail 103 movably holds a carriage 110 in the Z direction.

[0088]

The carriage 110 includes a head holder 130. The head holder 130 holds, for example, liquid discharge heads for different colors. For example, the head holder 130 holds a liquid discharge head for discharging cyan paint, a liquid discharge head for discharging magenta paint, a liquid discharge head for discharging yellow paint, and a liquid discharge head for discharging black paint. The head holder 130 may further hold a liquid discharge head for discharging white paint. The head holder 130 may further hold a liquid discharge head for discharging a clear (transparent) coating material to perform coating simultaneously with printing.

[0089]

The frame unit 120 further includes a first Z-direction driver 140a that moves the carriage 110 in the Z direction (i.e., the liquid discharge direction, and the direction of approaching and separating from the discharge target 200) along the Z-axis rail 103. The frame unit 120 further includes a Y-direction driver 150 that moves the Z-axis rail 103 in the Y direction (i.e., the direction orthogonal to both the liquid discharge direction and the nozzle array direction of the liquid discharge head 10, and the horizontal direction) along the Y-axis rail 101. The frame unit 120 further includes an X-direction driver 160 that moves the Y-axis rail 101 in the X direction (the nozzle array direction of the liquid discharge head 10, and the vertical direction) along the X-axis rail 102. The Y-axis rail 101 is supported by X-direction driver 160 held by the X-axis rails 102. The frame unit 120 further includes a second Z-direction driver 140b that moves the head holder 130 relative to the carriage 110 in the Z direction.

[0090]

The liquid discharge apparatus 100 discharges paint from the liquid discharge head 10 mounted on the head holder 130 while moving the carriage 110 along the X-axis, the Y-axis, and the Z-axis to draw images on the discharge target 200. The paint is an example of liquid. The movement of the carriage 110 and the head holder 130 in the Z direction may not be parallel to the Z direction, and may be an oblique movement including at least a Z direction component. When the liquid discharge head has one nozzle array, the liquid discharge head may be held by the carriage 110 so as to be inclined with respect to the X direction of the liquid discharge head to change the nozzle pitch. With such a configuration, the carriage 110 is moved to move the liquid discharge head 10 mounted on the carriage 110.

[0091]

FIG. 20 is a diagram illustrating a supply device 170 that supplies paint as a liquid to multiple liquid discharge heads 10 (e.g., liquid discharge heads 10a, 10b, 10c, and 10d) included in the liquid discharge apparatus 100.

The supply device 170 includes tanks 172a to 172d as closed containers that accommodate paints 171a to 171d to be discharged from the liquid discharge heads 10a to 10d held by the head holder 130. These components may be collectively referred to without suffixes.

[0092]

The tanks 172 and the supply ports 12 of the liquid discharge heads 10 (see FIG. 1) are respectively connected to each other via tubes 173. The tanks 172 are coupled to a compressor 176 via a pipe 175 including an air regulator 174. The compressor 176 supplies pressurized air to the tanks 172. Thus, the paint 171 in the liquid discharge head 10 is pressurized, and the paint 171 is discharged from the nozzle 14a opened by the needle valve 8.

[0093]

Although the discharge target 200 is flat in FIG. 19, the discharge target 200 may have a surface shape which is nearly vertical or a curved surface with a large radius of curvature, such as the body of a car, a truck, or an aircraft.

[0094]

FIG. 21 is a diagram illustrating an electrode manufacturing apparatus 700 as a liquid discharge apparatus including the liquid discharge head 10.

The electrode manufacturing apparatus 700 includes a discharge process unit 710 and a heating process unit 730. The discharge process unit 710 performs the discharge process in which the liquid composition is applied to a print base material 704 having the discharge target to form the liquid composition layer. The heating process unit 730 performs a heating process in which the liquid composition layer is heated to obtain the electrode composite layer.

[0095]

The print base material 704 is not limited to any particular object and can be suitably selected to suit any application. The print base material 704 is any object on which a layer containing an electrode material can be formed, such as an electrode substrate (current collector), an active material layer, and a layer containing a solid electrode material.

[0096]

The discharge process unit 710 may directly discharge the liquid composition to form the layer having the electrode material on the print base material 704. Alternatively, the discharge process unit 710 may indirectly discharge the liquid composition to form the layer having the electrode material on the print base material 704.

The heating process unit 730 heats the liquid composition discharged onto the print base material 704 by the discharge process unit 710. The liquid composition layer can be dried by heating.

[0097]

The electrode manufacturing apparatus 700 further includes a conveyance unit 705 that conveys the print base material 704. The conveyance unit 705 conveys the print base material 704, at a preset speed, to the discharge process unit 710 and the heating process unit 730 in this order. A method of producing the print base material 704 having the discharge target such as an active material layer is not limited to any particular method, and a known method can be appropriately selected. The discharge process unit 710 includes a printer 281a including the liquid discharge head 10 that discharges a liquid composition onto the printing base material 704. The discharge process unit 710 further includes a storage container 281b, and a supply tube 281c. The storage container 281b stores a liquid composition 707. The supply tube 281c supplies the liquid composition 707 stored in the storage container 281b to the printer 281a.

[0098]

The storage container 281b stores the liquid composition 707, and the discharge process unit 710 discharges the liquid composition 707 from the printer 281a to apply the liquid composition 707 onto the print base material 704 to form the liquid composition layer in a thin film shape. The storage container 281b may be integrated with the electrode manufacturing apparatus that forms the electrode composite layer or may be detachable from the electrode manufacturing apparatus. The storage container 281b may include a container for adding the liquid composition 707 to the storage container integrated with the electrode manufacturing apparatus or the storage container detachable from the electrode manufacturing apparatus.

The storage container 281b that stably stores the liquid composition 707 and the supply tube 281c that stably supplies the liquid composition 707 can be used.

[0099]

The heating process unit 730 includes a heater 703 to perform a solvent removing process in which the solvent remaining in the liquid composition layer is heated and dried by the heater 703 to be removed. Thus, the electrode composite layer can be formed. The heating process unit 730 may perform the solvent removing process under reduced pressure.

[0100]

The heater 703 is not limited to any particular device and can be suitably selected to suit any application. Examples of the heater 703 include a substrate heater, an infrared (IR) heater, a hot-air heater, and the combination thereof. The heating temperature and time can be appropriately selected according to the boiling point of the solvent contained in the liquid composition 707 and the thickness of the formed film.

[0101]

When the electrode manufacturing apparatus 700 including the liquid discharge head 10 is used, the liquid composition can be discharged to a desired position of the discharge target. The electrode composite layer can be suitably used, for example, as a part of the configuration of an electrochemical element. The configuration of the electrochemical element other than the electrode composite layer is not limited to any particular configuration and may be appropriately selected from known configurations. Examples thereof include a positive electrode, a negative electrode, and a separator.

[0102]

The above-described embodiments are illustrative and do not limit the present disclosure. Numerous additional modifications and variations are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims.

[0103]

In the above description, the embodiments in which the drive control device 30 applies a voltage to the driver such as the piezoelectric element 2a to move the needle valve 8 to open and close the nozzle 14a have been described. However, the present disclosure is not limited thereto, and the needle valve 8 may be moved to open and close the nozzle 14a by pneumatic pressure or hydraulic pressure. In such a case, the drive pulse generated by the drive control device 30 is a drive waveform for driving a pneumatic or hydraulic pressurizing mechanism with a preset pressure.

[0104]

In the above-described embodiments, the “liquid discharge apparatus” includes the liquid discharge head or the liquid discharge unit in which the liquid discharge head is integrated with a functional part(s) or mechanism(s) and drives the liquid discharge head to discharge liquid. The above integration may be achieved by, for example, a combination in which the liquid discharge head and a functional part(s) or mechanism(s) are fixed to each other through, e.g., fastening, bonding, or engaging, and a combination in which one of the liquid discharge head and a functional part(s) or mechanism(s) is movably held by another. The liquid discharge head may be detachably attached to the functional part(s) or mechanism(s) each other.

[0105]

The liquid discharge head and the head tank may be assembled, or the liquid discharge head and the head tank may be coupled (connected) to each other via, for example, a tube to form the liquid discharge unit as a single unit. A unit including a filter may further be added to a portion between the head tank and the liquid discharge head of the liquid discharge unit.

[0106]

The liquid discharge unit may be an integrated unit in which the liquid discharge head and the carriage are integrated as a single unit, or the liquid discharge head, the carriage, and a scanning moving mechanism are integrated as a single unit. As yet another example, the liquid discharge unit is a unit in which the liquid discharge head and the scanning moving mechanism are combined into a single unit. The liquid discharge head is movably held by a guide that is a part of the scanning moving mechanism.

[0107]

In another example, the cap that forms a part of the maintenance mechanism is fixed to the carriage mounting the liquid discharge head so that the liquid discharge head, the carriage, and the maintenance mechanism are integrated as a single unit to form the liquid discharge unit. Further, in another example, the liquid discharge unit includes a tube connected to the liquid discharge head mounting the head tank or the channel component so that the liquid discharge head and the supply device are integrated as a single unit. Through the tube, the liquid in a liquid storage source is supplied to the liquid discharge head.

[0108]

The scanning moving mechanism may be a guide only. The supply mechanism may be a tube(s) only or a loading unit only.

[0109]

The “liquid discharge apparatus” may be, for example, any apparatus that can discharge liquid to a medium onto which liquid can adhere or any apparatus to discharge liquid toward gas or into a different liquid.

[0110]

For example, the “liquid discharge apparatus” may further include devices relating to feeding, conveying, and ejecting of the medium onto which liquid can adhere and also include a pretreatment device and an aftertreatment device.

[0111]

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

[0112]

The "liquid discharge apparatus" is not limited to an apparatus that discharges liquid to visualize meaningful images such as letters or figures. For example, the liquid discharge apparatus may be an apparatus that forms patterns having no meaning or an apparatus that fabricates three-dimensional images.

[0113]

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

[0114]

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

[0115]

The liquid discharge apparatus may be an apparatus to relatively move a head unit (e.g., a unit including the liquid discharge head) and the medium onto which liquid can adhere. However, the liquid discharge apparatus is not limited to such an apparatus. For example, the liquid discharge apparatus may be a serial head apparatus that moves the head unit or a line head apparatus that does not move the head unit.

[0116]

Examples of the "liquid discharge apparatus" further include a treatment liquid coating apparatus to discharge a treatment liquid to a sheet to coat a surface of the sheet with the treatment liquid to reform the sheet surface.

Examples of the "liquid discharge apparatus" further include an injection granulation apparatus in which a composition liquid including raw materials dispersed in a solution is injected through nozzles to granulate fine particles of the raw materials.

[0117]

The above-described embodiments are illustrative and do not limit the present disclosure. Thus, numerous additional modifications and variations are possible in light of the above teachings, unless otherwise specified.

[0118]

The embodiments described above are just examples, and the various aspects of the present disclosure attain respective effects as follows.

Aspect 1

A liquid discharge head 10 includes a nozzle plate 14 and multiple liquid discharge modules 1. The nozzle plate 14 has a nozzle array in which multiple nozzles 14a for discharging liquid are arrayed. The liquid discharge module 1 includes a valve such as a needle valve 8 to open and close the nozzle 14a and a moving mechanism 6 to move the valve between an open position for opening the nozzle 14a and a closed position for closing the nozzle 14a. The moving mechanism 6 includes an actuator 2 and an arm 3 to move the valve in conjunction with the displacement of the actuator 2. When viewed in a liquid discharge direction (Z direction), at least one of the multiple liquid discharge modules 1 is disposed such that the actuator 2 is positioned on one side with respect to the nozzle 14a in an orthogonal direction (Y direction) orthogonal to a nozzle array direction (X direction). When viewed in the liquid discharge direction (Z direction), the rest of the multiple liquid discharge modules 1 is disposed such that the actuator 2 is positioned on the other side with respect to the nozzle 14a in the orthogonal direction (Y direction), and a part of the arm 3 overlaps a part of the arm 3 of the liquid discharge module 1 whose actuator 3 is positioned on the one side, in the nozzle array direction. The arm 3 amplifies the displacement of the actuator 2 to move the valve.

In other words, a liquid discharge head includes a nozzle plate, a first liquid discharge module, and a second liquid discharge module. The nozzle plate has a nozzle array having multiple nozzles to discharge a liquid in a liquid discharge direction. The multiple nozzles are arrayed in a nozzle array direction orthogonal to the liquid discharge direction. The first liquid discharge module is disposed on a first side in an orthogonal direction orthogonal to the nozzle array direction and the liquid discharge direction. The second liquid discharge module is disposed on a second side opposite the first side in the orthogonal direction. Each of the first liquid discharge module and the second liquid discharge module includes a valve, an actuator, and an arm. The valve opens and closes a corresponding nozzle of the multiple nozzles. The actuator displaces to move the valve. The arm amplifies a displacement of the actuator to move the valve between an open position at which the corresponding nozzle is opened and a closed position at which the corresponding nozzle is closed by the valve by an amplified displacement. The actuator of the first liquid discharge module is on the first side with respect to the nozzle array in the orthogonal direction. The actuator of the second liquid discharge module is on the second side with respect to the nozzle array in the orthogonal direction. A part of the arm of the first liquid discharge module overlaps a part of the arm of the second liquid discharge module in the nozzle array direction.

As described above, the multiple liquid discharge modules 1 are arranged such that a part of the arm 3 of the liquid discharge module 1 in which the actuator 2 is arranged on the one side and a part of the arm 3 of the liquid discharge module 1 in which the actuator 2 is arranged on the other side overlap each other in the nozzle array direction (X direction). Due to such a configuration, the liquid discharge head can be downsized in the orthogonal direction (Y direction) orthogonal to both the nozzle array direction (X direction) and the liquid discharge

direction (Z direction). The pitch between the nozzles can be narrowed as compared with the case where all the actuators 2 are arranged on the one side or the other side.
Since the arm amplifies the displacement of the actuator, the amount of movement of the valve is increased, and the gap between the nozzle and the valve when the valve is in the open position can be increased. As a result, liquid easily flows to the nozzle, the amount of the liquid discharged from the nozzle is increased, and the size of liquid droplets can be increased.
An actuator having a small displacement amount can be used, and the actuator can be downsized. Since the actuator is a large component among components constructing the liquid discharge module, if the actuator can be downsized, the liquid discharge head can be effectively downsized.
[0119]
Aspect 2
In the Aspect 1, when viewed in the liquid discharge direction (Z direction), the liquid discharge module 1 in which the actuator 2 is positioned on the one side with respect to the nozzle 14a and the liquid discharge module 1 in which the actuator 2 is positioned on the other side are alternately arranged in the nozzle array direction (X direction).
In other words, the first liquid discharge module and the second liquid discharge module are alternately arranged in the nozzle array direction.
As described above, the multiple liquid discharge modules are alternately arranged such that a part of the arm of the liquid discharge module in which the actuator 2 is arranged on the one side and a part of the arm of the liquid discharge module in which the actuator 2 is arranged on the other side overlap each other in the nozzle array direction (X direction). Due to such a configuration, the liquid discharge head can be downsized in the nozzle array direction (X direction).
[0120]
Aspect 3
In the aspect 1 or 2, when viewed in the liquid discharge direction (Z direction), a part of the arm 3 of the liquid discharge module 1 in which the actuator 2 is positioned on the one side with respect to the nozzle 14a and a part of the arm 3 of the liquid discharge module 1 in which the actuator 2 is positioned on the other side overlap each other when viewed in the nozzle array direction (X direction).
In other words, a part of the actuator of the first liquid discharge module overlaps a part of the actuator of the second liquid discharge module in the orthogonal direction.
As described above, a part of the arm of the liquid discharge module in which the actuator 2 is arranged on the one side and a part of the arm of the liquid discharge module in which the actuator 2 is arranged on the other side are arranged so as to overlap each other when viewed in the nozzle array direction (X direction). Due to such a configuration, the height of the actuator 2 and the height of a biasing-member support such as the spring receiving plate 18

can be lowered, and thus the height (size in the Z direction) of the liquid discharge head 10 can be reduced.

[0121]

Aspect 4

In any one of Aspects 1 to 3, the liquid discharge module 1 includes a biasing member such as the compression spring 7 to bias the valve such as the needle valve 8 to be positioned at the open position or the closed position when the actuator 2 is not displaced.

In other words, each of the first liquid discharge module and the second liquid discharge module includes a biasing member pressing the valve toward the open position or the closed position.

Due to such a configuration, as described in the above embodiment, the valve such as the needle valve 8 can be stably displaced and the variations of liquid droplets can be reduced as compared with the case where the biasing member such as the compression spring 7 is not provided.

[0122]

Aspect 5

In the aspect 4, the liquid discharge head 10 further includes a biasing-member support (including the spring receiving plate 18 and the stationary component 17 in the above embodiment) that supports the biasing members such as the multiple compression springs 7. The biasing-member support is disposed between the actuator positioned on the one side and the actuator positioned on the other side when viewed in the nozzle array direction.

In other words, the liquid discharge head further includes a biasing-member support supporting multiple biasing members including the biasing member. The biasing-member support is disposed between the actuator on the first side and the actuator on the second side in the orthogonal direction.

Due to such a configuration, when the actuator 2 is not displaced, the valve such as the needle valve 8 can be smoothly biased by the biasing member so as to be positioned at the open position or the closed position. As described in the above embodiment, the size of the liquid discharge head in the orthogonal direction (Y direction) and the size of the liquid discharge head in the liquid discharge direction (Z direction) can be reduced.

[0123]

Aspect 6

In Aspect 5, the biasing-member support (including the spring receiving plate 18 and the stationary component 17 in the above embodiment) is fixed to a housing such as the cover 11 that accommodates the multiple liquid discharge modules 1.

In other words, the liquid discharge head further includes a housing having a housing portion accommodating the first liquid discharge module and the second liquid discharge module. The biasing-member support is fixed to the housing.

Due to such a configuration, by fixing the biasing-member support to the housing such as the cover 11 that accommodates the biasing-member support, the deformation and vibration due to the reaction force from the multiple biasing members can be reduced.

[0124]

Aspect 7

In any one of Aspects 1 to 6, the arm 3 has a first connection portion such as the fixing portion 3d to which the actuator 2 is fixed, and a second connection portion such as the contact portion 8c in contact with an arm receiving portion 3a of the needle valves 8.

In other words, the valve has an arm receiving portion. The arm has a first connection portion to which the actuator is fixed and a second connection portion contacting the arm receiving portion of the valve.

Due to such a configuration, as described in the above embodiment, the actuator 2 is fixed to the first connection portion such as the fixing portion 3d, and thus the arm 3 can be swung while reducing the loss of the displacement of the actuator 2. Since the second connection portion such as the contact portion 3a is merely in contact with the arm receiving portion 8c, the arm receiving portion 8c does not hinder the arm 3 from swinging, and thus the arm 3 can smoothly swing. Accordingly, the valve can be stably displaced, and the variations of the liquid droplets discharged from the nozzle can be reduced.

[0125]

Aspect 8

In Aspect 7, the arm receiving portion 8c is biased toward the second connection portion such as the contact portion 3a by the biasing member such as the compression spring 7.

In other words, each of the first liquid discharge module and the second liquid discharge module further includes a biasing member pressing the valve toward the open position or the closed position, and

the arm receiving portion is pressed toward the second connection portion by the biasing member.

Due to such a configuration, as described in the above embodiment, the biasing member such as the compression spring 7 can keep the arm receiving portion 8c in contact with the second connection portion such as the contact portion 3a. Accordingly, when the actuator 2 is displaced, the second connection portions of the arm 3 move the arm receiving portions 8c against the biasing force of the biasing member, and the valve such as the needle valve 8 can be moved in one direction. When the displacement of the actuator 2 is released, the valve can be moved in the other direction by the biasing force of the biasing member. Thus, the valve can be stably displaced, and the variations of the liquid droplets discharged from the nozzle can be reduced.

[0126]

Aspect 9

In Aspect 7 or 8, the arm 3 has a shorter length in a rotation axis direction (X direction) of the arm 3 on the second connection portion side than on the first connection portion side.

In other words, the arm has a first portion and a second portion. The first portion is close to the first connection portion. The first portion has a first width in the nozzle array direction. The second portion is closer to the second connection portion than the first portion. The second portion has a second width narrower than the first width in the nozzle array direction.

Due to such a configuration, since the length (width) of the arm 3 on the second connection portion side such as the contact portion 3a of the arm 3 in the rotation axis direction (X direction) are shorter than that on the first connection portion side, and thus, as described in the above embodiment, the arms 3 can be closely arranged in the X direction. As a result, the nozzle pitch can be narrowed.

[0127]

Aspect 10

In any one of Aspects 7 to 9, the liquid discharge head 10 further includes an arm support such as a support shaft 4 that swingably supports the arm 3. In a direction orthogonal to both the displacement direction (Z direction) of the actuator 2 and the rotation axis direction of the arm 3, the distance between the first connection portion such as the fixing portion 3d and the arm support is shorter than the distance between the second connection portion such as the contact portions 3a and the arm support.

In other words, the liquid discharge head further includes an arm support shaft swingably supporting the arm. The arm support shaft extends in the nozzle array direction. The arm swings around the arm support shaft in a plane extending in the liquid discharge direction and the orthogonal direction. A distance between the first connection portion and the arm support shaft is shorter than a distance between the second connection portion and the arm support shaft in the orthogonal direction.

Due to such a configuration, as described in the above embodiment, the valve can be moved by amplifying the displacement of the actuator 2.

[0128]

Aspect 11

In Aspect 10, the arm support such as the support shaft 4 is disposed between the first connection portion such as the fixing portion 3d and the second connection portion such as the contact portion 3a.

In other words, the arm support shaft is disposed between the first connection portion and the second connection portion in the orthogonal direction.

Due to such a configuration, as described in the above embodiment, when the actuator is displaced, the second connection portion is displaced in the direction opposite to the direction of the displacement of the first connection portion. Accordingly, when the actuator 2 is displaced toward the nozzle plate in response to a voltage applied to the actuator 2, a so-called normally closed configuration can be formed.

[0129]

Aspect 12

In Aspect 10, the arm support such as the support shaft 4 is disposed outside a region between the first connection portion such as the fixing portion 3d and the second connection portion such as the contact portion 3a.

In other words, the arm support shaft is disposed outside a region between the first connection portion and the second connection portion in the orthogonal direction.

Due to such a configuration, as described in the above embodiment, when the actuator is displaced, the second connection portion is displaced in the same direction as the direction of the displacement of the first connection portion. Accordingly, when the actuator 2 is displaced toward the nozzle plate in response to a voltage applied to the actuator 2, a so-called normally open configuration can be formed.

[0130]

Aspect 13

In any one of Aspects 1 to 12, the length of a liquid discharge module housing space of the housing such as the cover 11 that accommodates the multiple liquid discharge modules 1 in the orthogonal direction (Y direction) orthogonal to both the nozzle array direction (X direction) and the liquid discharge direction (Z direction) is less than twice the length of the liquid discharge module 1 in the orthogonal direction. A nozzle arrangement pitch is shorter than the length of the liquid discharge module in the nozzle array direction.

In other words, the liquid discharge head further includes a housing having a housing portion accommodating the first multiple liquid discharge module and the second liquid discharge module. A length of the housing portion of the housing in the orthogonal direction is less than twice a length of each of the first liquid discharge module and the second liquid discharge module in the orthogonal direction. A pitch of the multiple nozzles is shorter than a width of each of the first liquid discharge module and the second liquid discharge moduke in the nozzle array direction.

Due to such a configuration, as described in the above embodiment, the multiple liquid discharge modules 1 are alternately arranged in the nozzle array direction (X direction) such that the arms 3 partially overlap each other when viewed in the nozzle array direction (X direction). Thus, the length D of the liquid discharge module housing space of the housing such as the cover 11 in the orthogonal direction (Y direction) can be less than twice the length L of the liquid discharge module 1 in the orthogonal direction. The arrangement pitch of the nozzles (nozzle pitch d) can be shorter than the length W of the liquid discharge module 1 in the nozzle array direction (X direction). Accordingly, the liquid discharge head 10 can be downsized.

[0131]

Aspect 14

In any one of Aspects 7 to 12, the nozzle plate 14 has multiple nozzle arrays, and the multiple liquid discharge modules are arranged such that portions between the first connection portion such as the fixing portion 3d of the arm 3 and the second connection portion such as the contact portion 3a of the arm 3 overlap each other when viewed in the nozzle array direction.
In other words, the nozzle plate has multiple nozzle arrays including the nozzle array, and a part of the arm, between the first connection portion and the second connection portion, corresponding one of the multiple nozzle arrays overlaps a part of the arm, between the first connection portion and the second connection portion, corresponding another of the multiple nozzle arrays in the nozzle array direction.
Due to such a configuration, the liquid discharge head 10 can be downsized in the orthogonal direction (Y direction) orthogonal to both the nozzle array direction (X direction) and the liquid discharge direction (Z direction). In addition, the liquid discharge head can be downsized in the liquid discharge direction (Z direction) as compared with the case where the arms are disposed at different positions in the liquid discharge direction (Z direction) and do not overlap each other.
[0132]
Aspect 15
In any one of Aspects 1 to 14, the multiple liquid discharge modules are arranged such that the valves such as the needle valves 8 are arranged in the nozzle array direction (X direction) in a row.
In other words, the liquid discharge head according to any one of Aspects 1 to 14, further includes multiple liquid discharge modules including the first liquid discharge module and the second liquid discharge module. The multiple liquid discharge modules include multiple valves including the valve, respectively. The multiple valves are arranged in the nozzle array direction in one row.
Due to such a configuration, the arrangement pitch of the liquid discharge modules 1 can be made constant. Accordingly, the liquid discharge modules 1 can be easily arranged, and an increase in the manufacturing cost can be prevented.
[0133]
Aspect 16
In Aspect 15, the multiple liquid discharge modules 1 are inclined with respect to the nozzle array direction (X direction) when viewed in the liquid discharge direction (Z direction).
In other words, the multiple liquid discharge modules are inclined with respect to the nozzle array direction.
Due to such a configuration, as described in the first modification, the liquid discharge head can be shortened in the orthogonal direction (Y direction) orthogonal to both the nozzle array direction (X direction) and the liquid discharge direction (Z direction), as compared with the case where the multiple liquid discharge modules 1 are arranged at an angle of 90° with

respect to the nozzle array direction (X direction) when viewed in the liquid discharge direction (Z direction). Thus, the liquid discharge head can be downsized.

[0134]

Aspect 17

In any one of Aspects 1 to 16, the actuators 2 are alternately arranged in the nozzle array direction when viewed in the orthogonal direction (Y direction) orthogonal to both the nozzle array direction (X direction) and the liquid discharge direction (Z direction), and a part of the actuator 2 overlaps with an adjacent actuator when viewed in the liquid discharge direction (Z direction).

In other words, a part of the actuator overlaps an adjacent actuator adjacent to the actuator in the liquid discharge direction.

Due to such a configuration, as described in the second modification, the pitch between the nozzles can be narrowed. Thus, the liquid discharge head can be downsized in the X direction, or the number of nozzles can be increased without changing the length in the X direction.

[0135]

Aspect 18

In any one of Aspects 1 to 17, at least one of the multiple liquid discharge modules 1 has a larger amount of movement of the valve such as the needle valve 8 than the other liquid discharge modules 1.

In other words, the liquid discharge head according to any one of Aspects 1 to 14, further includes multiple liquid discharge modules including the first liquid discharge module and the second liquid discharge module. At least one of the multiple liquid discharge modules has a larger amount of movement of the valve than a rest of the multiple liquid discharge modules.

Due to such a configuration, as described in the third modification, liquid droplets having different sizes can be discharged from the nozzles, and white streaks can be prevented.

[0136]

Aspect 19

In Aspect 18, the arm 3 of the liquid discharge module 1B, which has the amount of movement of the valve such as the needle valve 8 larger than the amount of movement of the valve of the other liquid discharge modules 1A, is longer than those of the other liquid discharge modules 1A, or the amount of movement of the actuator 2 is larger than those of the other liquid discharge modules 1A.

Due to such a configuration, as described in the third modification, the amount of movement of the valve such as the needle valve 8 can be larger than those of the other liquid discharge modules 1A.

[0137]

Aspect 20

In Aspect 18, the arm 3 of the liquid discharge module 1B, which has the amount of movement of the valve such as the needle valve 8 larger than the amount of movement of the valve of the other liquid discharge modules 1A, is longer than those of the other liquid discharge modules 1A, and the amount of movement of the actuator 2 is larger than those of the other liquid discharge modules 1A.
Due to such a configuration, as described in the third modification, the size difference of the liquid droplets can be increased, and the white streaks can be favorably prevented.
[0138]
Aspect 21
In any one of Aspects 18 to 20, in a group of liquid discharge modules corresponding to the nozzle array, the liquid discharge module having the long arm and the liquid discharge module having the short arm are alternately arranged.
Due to such a configuration, as described in the third modification, the actuators 2 can be arranged in a staggered manner such that the actuators 2 partially overlap each other when viewed in the Y direction. Accordingly, the pitch between nozzles can be narrowed as in the second modification. Such a configuration can downsize the liquid discharge head 10 in the nozzle array direction (X direction) or increase the number of nozzles without changing the length in the nozzle array direction (X direction).
[0139]
Aspect 22
In any one of Aspects 18 to 21, the length in the orthogonal direction (Y direction) orthogonal to both the nozzle array direction (X direction) and the liquid discharge direction (Z direction) is less than twice the length Ld of the liquid discharge module 1B, which has the amount of movement of the needle valve 8 larger than the amount of movement of the other liquid discharge modules 1A, in the orthogonal direction. The nozzle arrangement pitch (nozzle pitch d) is shorter than the length Wd of the liquid discharge module 1B, which has the amount of movement of the needle valve 8 larger than the amount of movement of the other liquid discharge modules 1A.
Due to such a configuration, as described in the third modification, the multiple liquid discharge modules 1 are alternately arranged in the nozzle array direction (X direction) such that the arms 3 partially overlap when viewed in the nozzle array direction (X direction). Thus, the length D of the liquid discharge module housing space of the housing such as the cover 11 in the orthogonal direction (Y direction) can be less than twice the length Ld of the liquid discharge module 1B, which has the amount of movement of the needle valve 8 larger than the amount of movement of the other liquid discharge modules 1A, in the orthogonal direction. The arrangement pitch of the nozzles (nozzle pitch d) can be shorter than the length Wd in the nozzle array direction of the liquid discharge module 1B, which has the amount of movement of the valve larger than the amount of movement of the valve of the other liquid discharge modules 1A.

[0140]
Aspect 23
In any one of Aspects 1 to 22, the valve such as the needle valve 8 opens and closes the multiple nozzle 14a.
Due to such a configuration, as described in the fourth modification, the number of liquid discharge modules can be reduced, and the cost of the apparatus can be reduced.
[0141]
Aspect 24
In Aspect 23, the nozzle plate 14 has bifurcated channel 14f branching to each nozzle from the channel opening-closing portion 14d that is opened and closed by the valve such as the needle valve 8.
Due to such a configuration, as described in the fourth modification, the multiple nozzles 14a can be opened and closed by the valve such as the needle valve 8.
[0142]
Aspect 25
In any one of Aspects 1 to 24, the multiple needle valves 8 are arranged in a staggered manner. The nozzle plate 14 has channels such as multiple channel opening-closing portions 14d and multiple introduction paths 14e. The channel opening-closing portions 14d are opened and closed by the needle valves 8, respectively. Liquid flows from the channel opening-closing portion 14d to the nozzle 14a of the corresponding nozzle array through the introduction path 14e.
In other words, the liquid discharge head according to any one of Aspects 1 to 24, further includes multiple liquid discharge modules including the first liquid discharge module and the second liquid discharge module. The multiple liquid discharge modules include multiple valves including the valve, respectively. The multiple valves are arranged in a staggered manner. The nozzle plate has multiple channel opening-closing portions that the multiple valves open and close, respectively, and multiple channels through which the liquid flows from the multiple channel opening-closing portions to the multiple nozzles, respectively.
Due to such a configuration, as described in the fifth modification, even in the configuration using the nozzle plate 14 in which one nozzle array is disposed at the center in the orthogonal direction (Y direction) orthogonal to both the nozzle array direction (X direction) and the liquid discharge direction (Z direction), the length of the liquid discharge head in the orthogonal direction (Y direction) can be equal to that of the configuration using the nozzle plate 14 in which the nozzles are arrayed in a staggered manner. Accordingly, the liquid discharge head can be favorably downsized in the orthogonal direction (Y direction).
[0143]
Aspect 26

In a liquid discharge apparatus 100 including the liquid discharge head 10, the liquid discharge head according to any one of Aspects 1 to 25 is used as the liquid discharge head 10.

In other words, a liquid discharge apparatus includes the liquid discharge head according to any one of Aspects 1 to 25, to discharge a liquid onto a medium and a carriage mounting the liquid discharge head to move the liquid discharge head relative to the medium.

Due to such a configuration, a high-quality image can be obtained, and the liquid discharge apparatus can be downsized.

[0144]

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

[0145]

This patent application is based on and claims priority to Japanese Patent Application No. 2023-202850, filed on November 30, 2023, in the Japan Patent Office, the entire disclosure of which is hereby incorporated by reference herein.

[Reference Signs List]

[0146]

1 Liquid discharge module

1A Liquid discharge module including short arm

1B Liquid discharge module including long arm

2 Actuator

2a Piezoelectric element

2b Fixing element

3 Arm

3a Contact portion

3b Clearance hole

3d Fixing portion

3d1 Bonding face

3d2 Connector

3e Support hole

3f Body

4 Support shaft

5 Channel

6 Moving mechanism

7 Compression spring

8 Needle valve

8a Sealing member
8c Arm receiving portion
10 Liquid discharge head
10A Liquid discharge head according to first modification
10B Liquid discharge head according to second modification
10C Liquid discharge head according to third modification
10D Liquid discharge head according to fourth modification
10E Liquid discharge head according to fifth modification
11 Cover
11a Housing portion
11b Valve through hole
12 Supply port
13 Discharge port
14 Nozzle plate
14a Nozzle
14b Through hole
14c Positioning hole
14d Channel opening-closing portion
14e Introduction path
14f Bifurcated channel
15 Channel substrate
15a Seal
15b Female screw portion
15c Pin fitting hole
16 Harness through hole
17 Fixing member
18 Spring receiving plate
19 Seal
20 Valve bearing
30 Drive control device
31 Waveform generation circuit
32 Amplification circuit
40 Fixing jig
100 Liquid discharge apparatus
101 Y-axis rail
102 X-axis rail
103 Z-axis rail
110 Carriage
120 Frame unit

130 Head holder
140a First Z-direction driver
140b Second Z-direction driver
150 Y-direction driver
160 X-direction driver
170 Supply device
171 Paint
172 Tank
173 Tube
174 Air regulator
175 Pipe
176 Compressor
200 Discharge target
281a Printer
281b Storage container
281c Supply tube
700 Electrode manufacturing apparatus
703 Heating device
704 Printing base material
705 Conveyance unit
707 Liquid composition
710 Discharge process unit
730 Heating process unit

[CLAIMS]

[Claim 1]

A liquid discharge head comprising:
a nozzle plate having a nozzle array having multiple nozzles to discharge a liquid in a liquid discharge direction, the multiple nozzles arrayed in a nozzle array direction orthogonal to the liquid discharge direction;
a first liquid discharge module disposed on a first side in an orthogonal direction orthogonal to the nozzle array direction and the liquid discharge direction; and
a second liquid discharge module disposed on a second side opposite the first side in the orthogonal direction,
each of the first liquid discharge module and the second liquid discharge module including:
a valve to open and close a corresponding nozzle of the multiple nozzles; and
an actuator to displace to move the valve; and
an arm to amplify a displacement of the actuator to move the valve between an open position at which the corresponding nozzle is opened and a closed position at which the corresponding nozzle is closed by the valve by an amplified displacement,
wherein the actuator of the first liquid discharge module is on the first side with respect to the nozzle array in the orthogonal direction,
the actuator of the second liquid discharge module is on the second side with respect to the nozzle array in the orthogonal direction, and
a part of the arm of the first liquid discharge module overlaps a part of the arm of the second liquid discharge module in the nozzle array direction.

[Claim 2]

The liquid discharge head according to claim 1,
wherein the first liquid discharge module and the second liquid discharge module are alternately arranged in the nozzle array direction.

[Claim 3]

The liquid discharge head according to claim 1,
wherein a part of the actuator of the first liquid discharge module overlaps a part of the actuator of the second liquid discharge module in the orthogonal direction.

[Claim 4]

The liquid discharge head according to claim 1,
wherein each of the first liquid discharge module and the second liquid discharge module further includes a biasing member pressing the valve toward the open position or the closed position.

[Claim 5]

The liquid discharge head according to claim 4, further comprising a biasing-member support supporting multiple biasing members including the biasing member, wherein the biasing-member support is disposed between the actuator on the first side and the actuator on the second side in the orthogonal direction.

[Claim 6]

The liquid discharge head according to claim 5, further comprising a housing having a housing portion accommodating the first liquid discharge module and the second liquid discharge module,

wherein the biasing-member support is fixed to the housing.

[Claim 7]

The liquid discharge head according to any one of claims 1 to 6,

wherein the valve has an arm receiving portion, and

the arm has:

a first connection portion to which the actuator is fixed; and

a second connection portion contacting the arm receiving portion of the valve.

[Claim 8]

The liquid discharge head according to claim 7,

wherein each of the first liquid discharge module and the second liquid discharge module further includes a biasing member pressing the valve toward the open position or the closed position, and

the arm receiving portion is pressed toward the second connection portion by the biasing member.

[Claim 9]

The liquid discharge head according to claim 7 or 8,

wherein the arm has:

a first portion close to the first connection portion, the first portion having a first width in the nozzle array direction; and

a second portion closer to the second connection portion than the first portion, the second portion having a second width narrower than the first width in the nozzle array direction.

[Claim 10]

The liquid discharge head according to any one of claims 7 to 9, further comprising an arm support shaft swingably supporting the arm, the arm support shaft extending in the nozzle array direction,

wherein the arm swings around the arm support shaft in a plane extending in the liquid discharge direction and the orthogonal direction, and

a distance between the first connection portion and the arm support shaft is shorter than a distance between the second connection portion and the arm support shaft in the orthogonal direction.

[Claim 11]

The liquid discharge head according to claim 10,

wherein the arm support shaft is disposed between the first connection portion and the second connection portion in the orthogonal direction.
[Claim 12]
The liquid discharge head according to claim 10,
wherein the arm support shaft is disposed outside a region between the first connection portion and the second connection portion in the orthogonal direction.
[Claim 13]
The liquid discharge head according to any one of claims 1 to 12, further comprising a housing having a housing portion accommodating the first liquid discharge module and the second liquid discharge module,
wherein a length of the housing portion of the housing in the orthogonal direction is less than twice a length of each of the first liquid discharge module and the second liquid discharge module in the orthogonal direction, and
a pitch of the multiple nozzles is shorter than a width of each of the first liquid discharge module and the second liquid discharge module in the nozzle array direction.
[Claim 14]
The liquid discharge head according to any one of claims 7 to 12,
wherein the nozzle plate has multiple nozzle arrays including the nozzle array, and
a part of the arm, between the first connection portion and the second connection portion, corresponding one of the multiple nozzle arrays overlaps a part of the arm, between the first connection portion and the second connection portion, corresponding another of the multiple nozzle arrays in the nozzle array direction.
[Claim 15]
The liquid discharge head according to any one of claims 1 to 14, further comprising multiple liquid discharge modules including the first liquid discharge module and the second liquid discharge module,
wherein the multiple liquid discharge modules include multiple valves including the valve, respectively, and
the multiple valves are arranged in the nozzle array direction in one row.
[Claim 16]
The liquid discharge head according to claim 15,
wherein the multiple liquid discharge modules are inclined with respect to the nozzle array direction.
[Claim 17]
The liquid discharge head according to any one of claims 1 to 16,
wherein a part of the actuator overlaps an adjacent actuator adjacent to the actuator in the liquid discharge direction.
[Claim 18]

The liquid discharge head according to any one of claims 1 to 17, further comprising multiple liquid discharge modules including the first liquid discharge module and the second liquid discharge module,
wherein at least one of the multiple liquid discharge modules has a larger amount of movement of the valve than a rest of the multiple liquid discharge modules.
[Claim 19]
The liquid discharge head according to any one of claims 1 to 18, further comprising multiple liquid discharge modules including the first liquid discharge module and the second liquid discharge module,
wherein the multiple liquid discharge modules include multiple valves including the valve, respectively,
the multiple valves are arranged in a staggered manner, and
the nozzle plate has:
multiple channel opening-closing portions that the multiple valves open and close, respectively; and
multiple channels through which the liquid flows from the multiple channel opening-closing portions to the multiple nozzles, respectively.
[Claim 20]
A liquid discharge apparatus comprising:
the liquid discharge head according to any one of claims 1 to 19, to discharge a liquid onto a medium; and
a carriage mounting the liquid discharge head to move the liquid discharge head relative to the medium.

FIG. 1

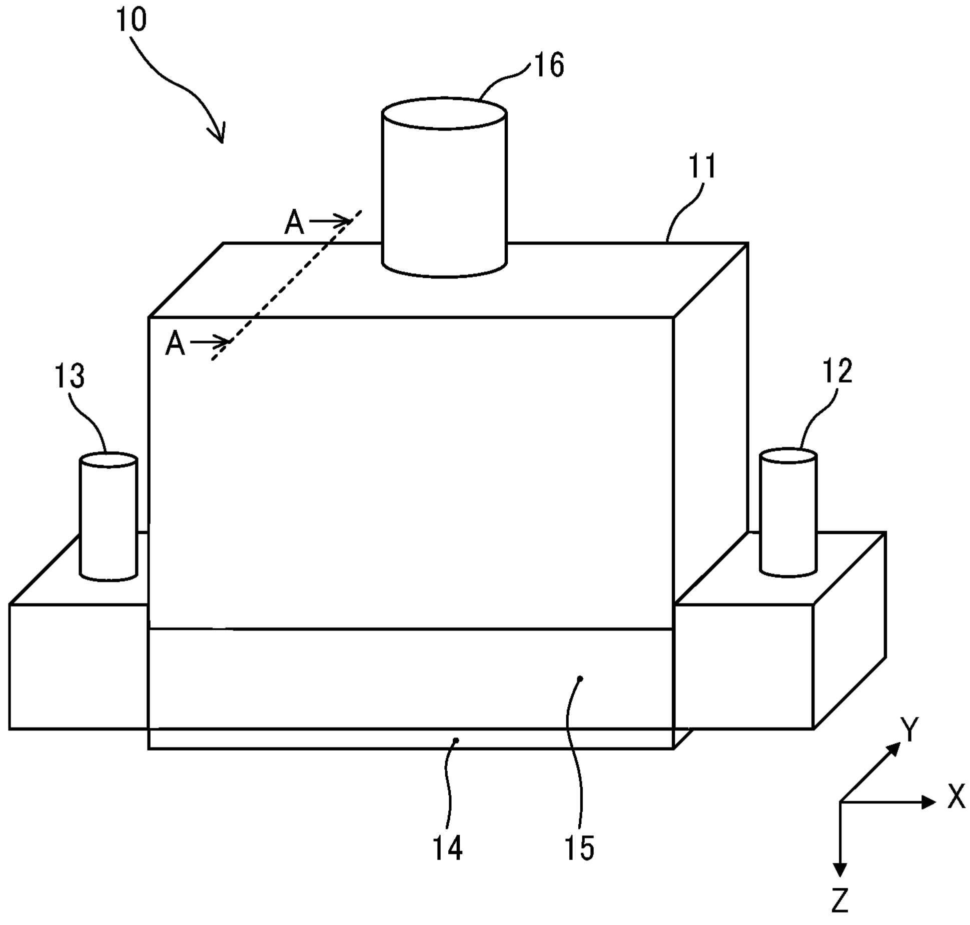


FIG. 2A

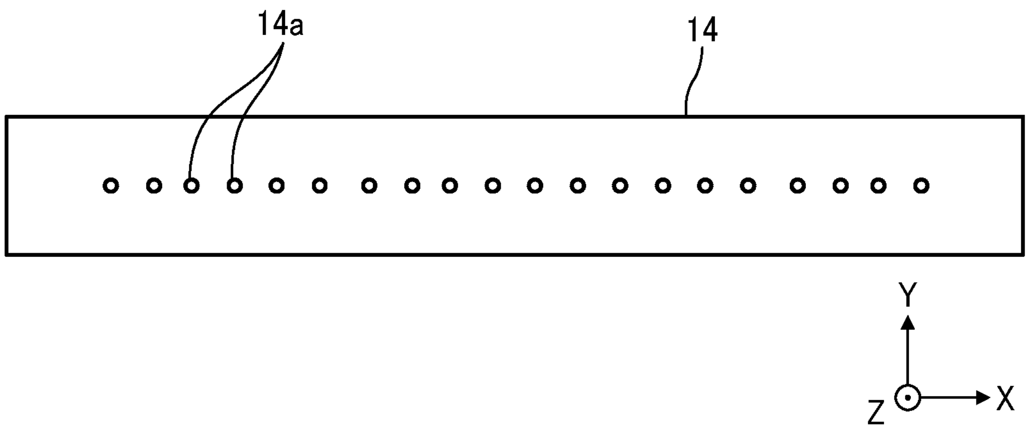


FIG. 2B

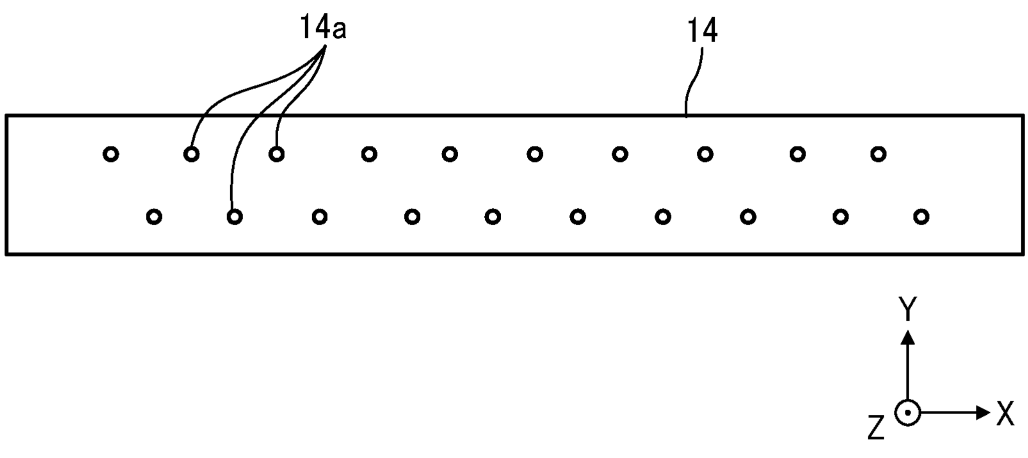


FIG. 3A

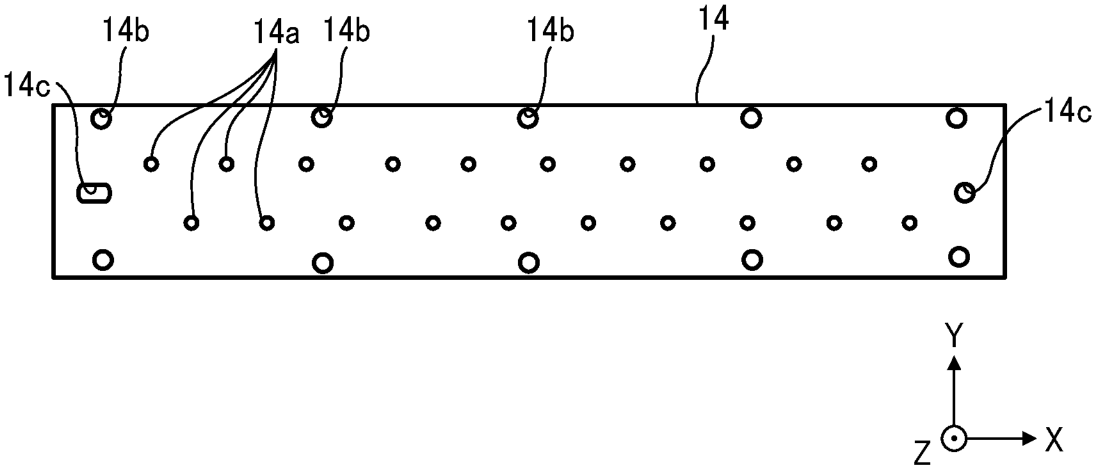


FIG. 3B

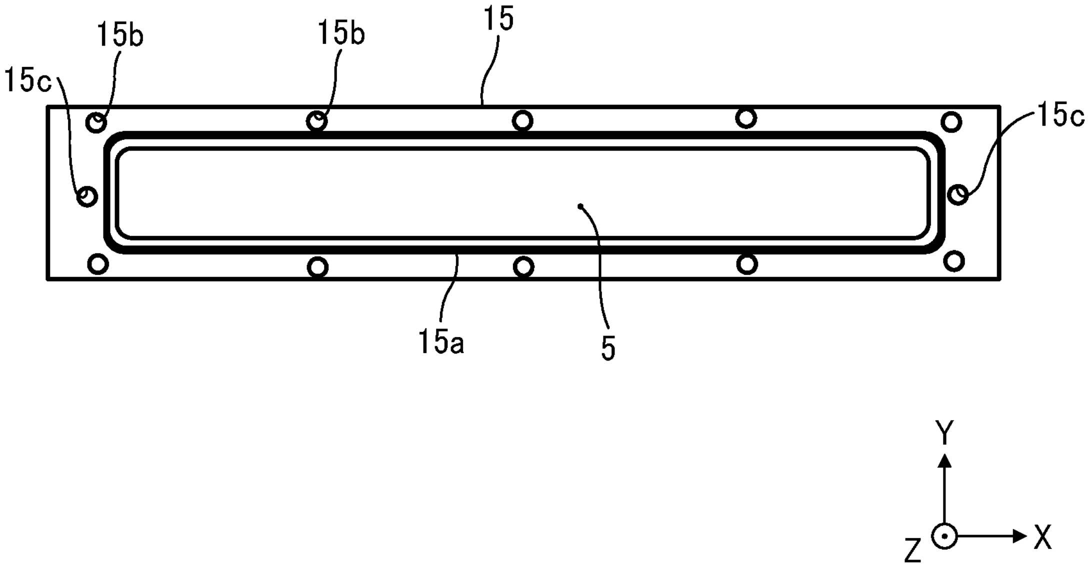
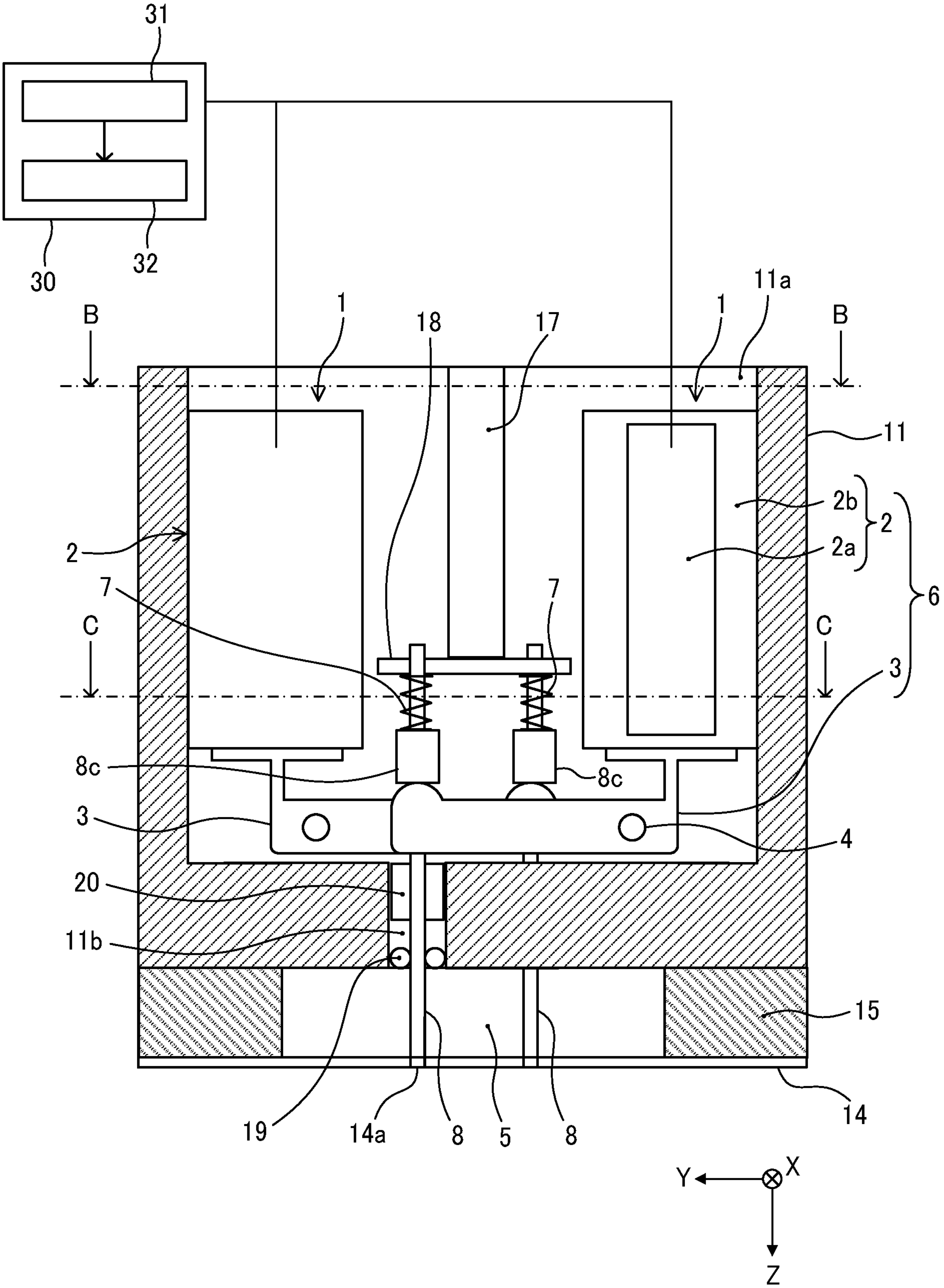


FIG. 4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14a
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FIG. 5

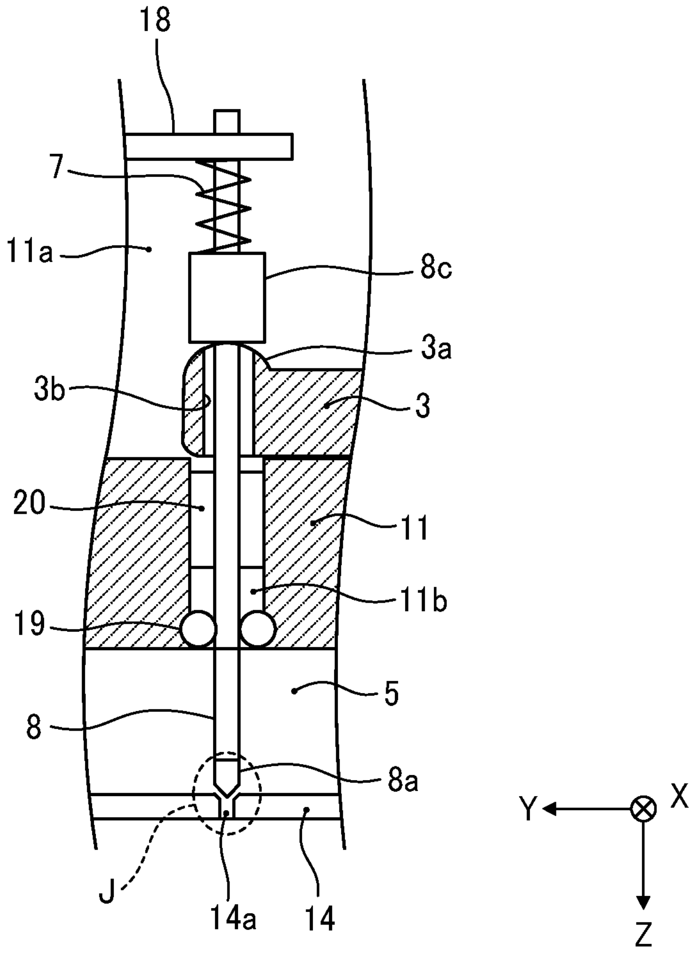

FIG. 6

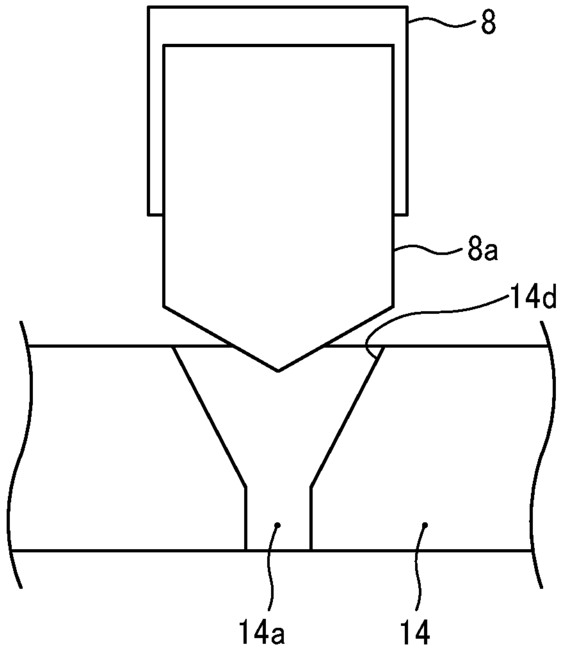

FIG. 7

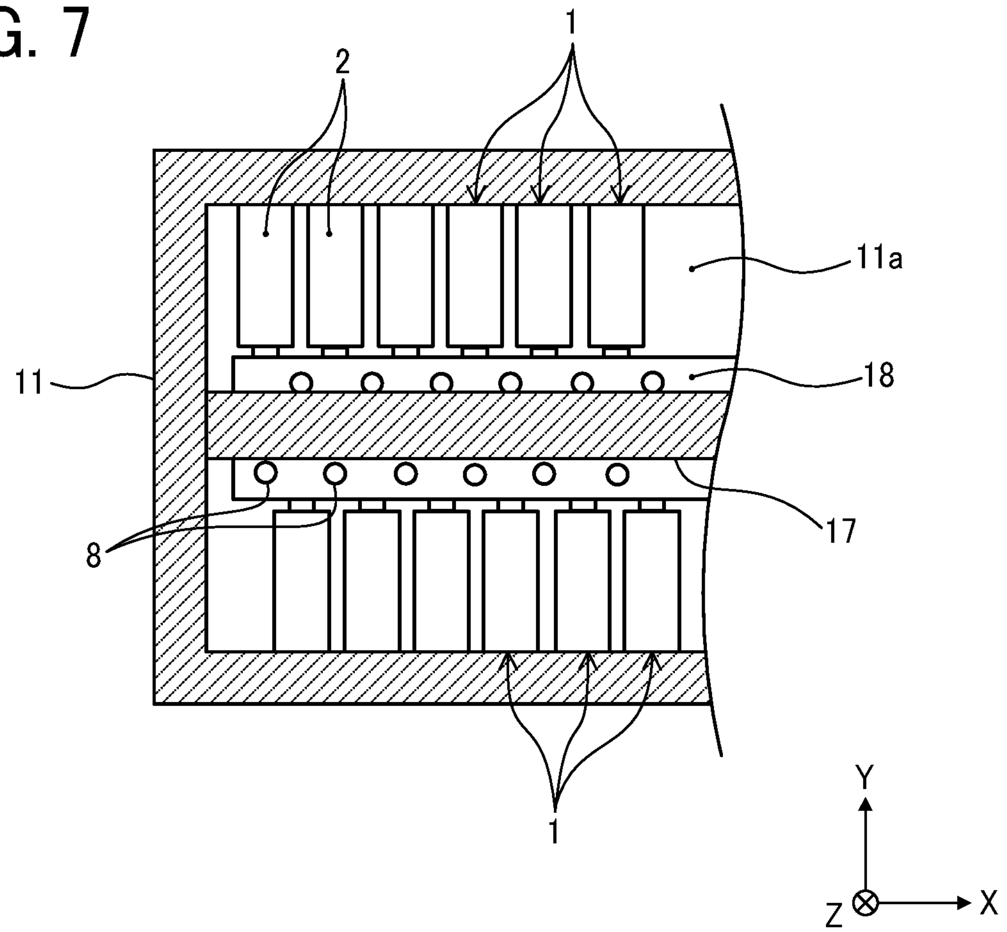

FIG. 8

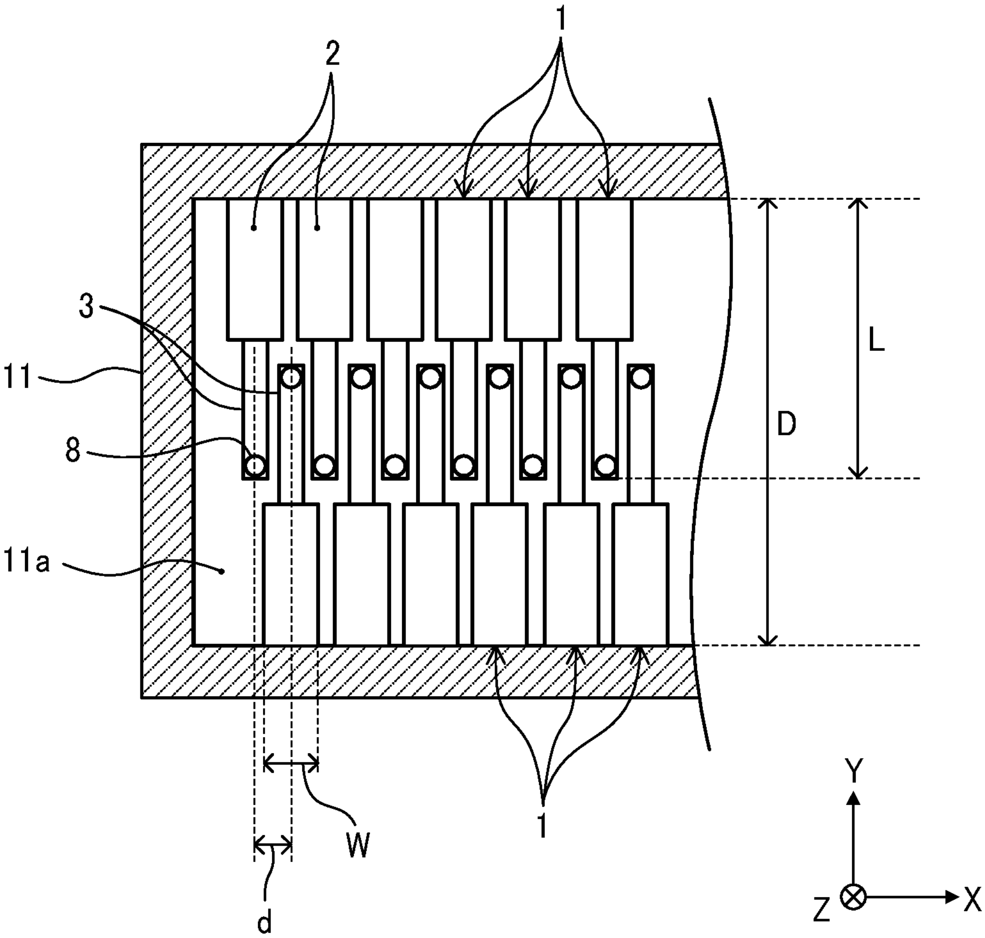

FIG. 9A

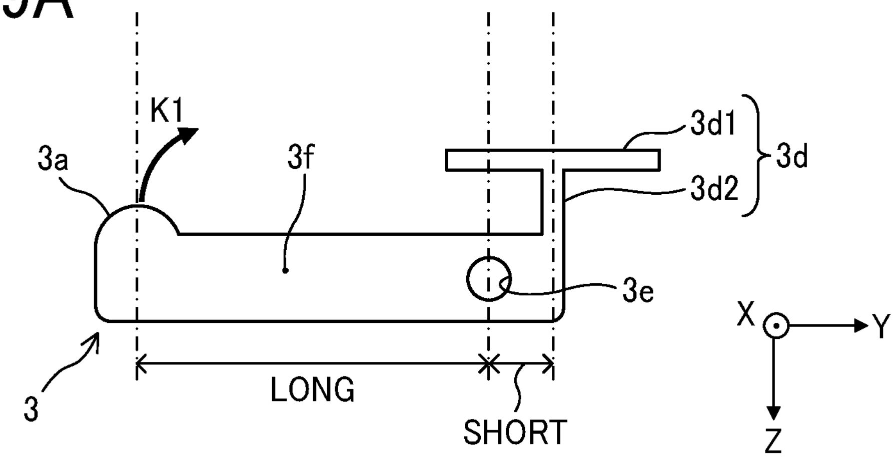

FIG. 9B

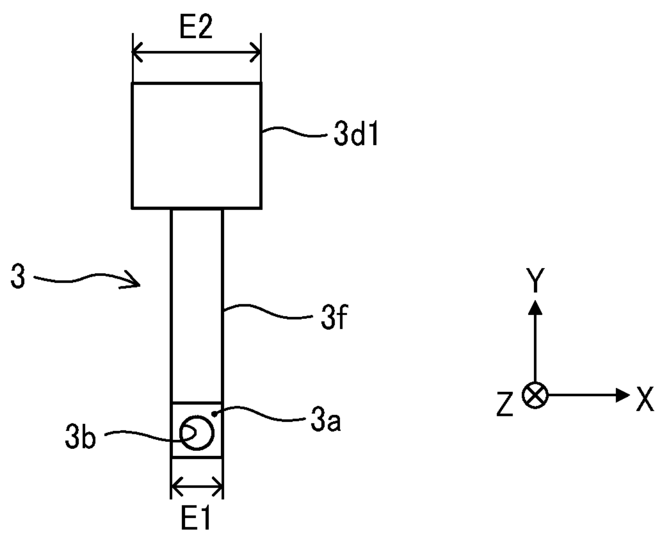

FIG. 9C

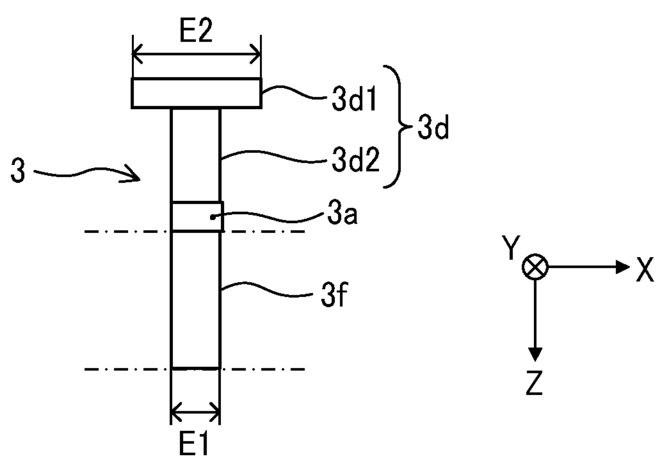

FIG. 10A

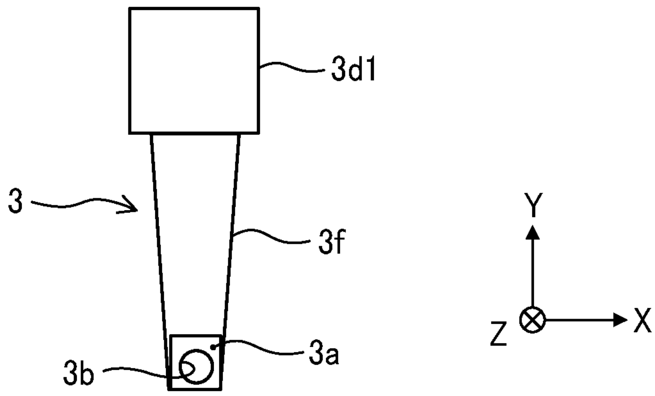

FIG. 10B

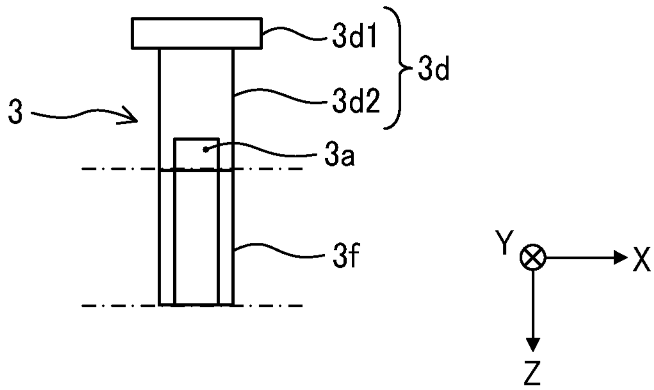

FIG. 11

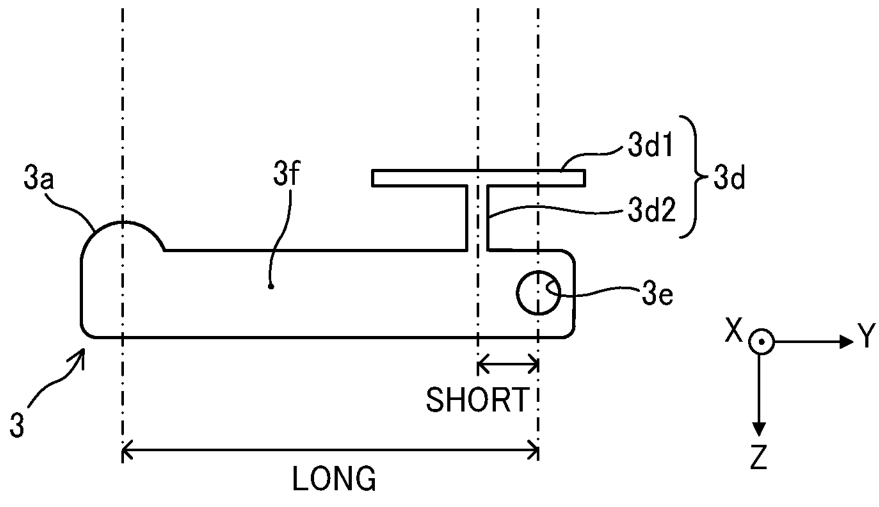

FIG. 12

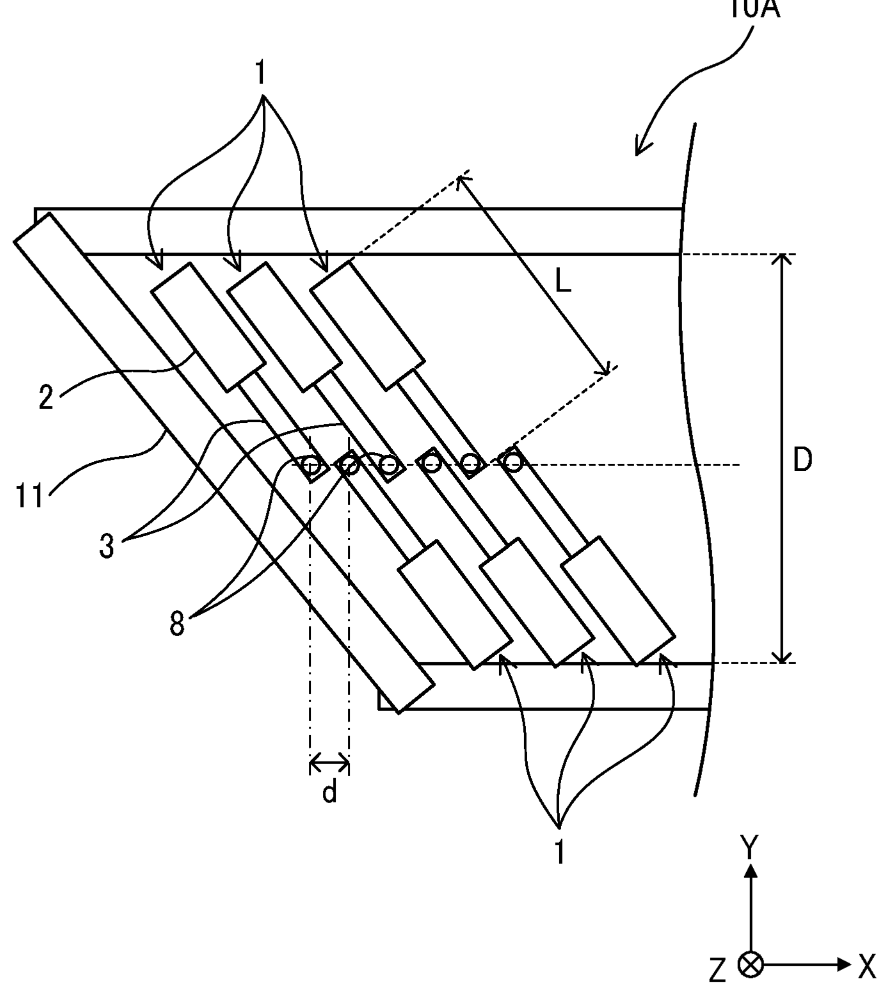

FIG. 13A

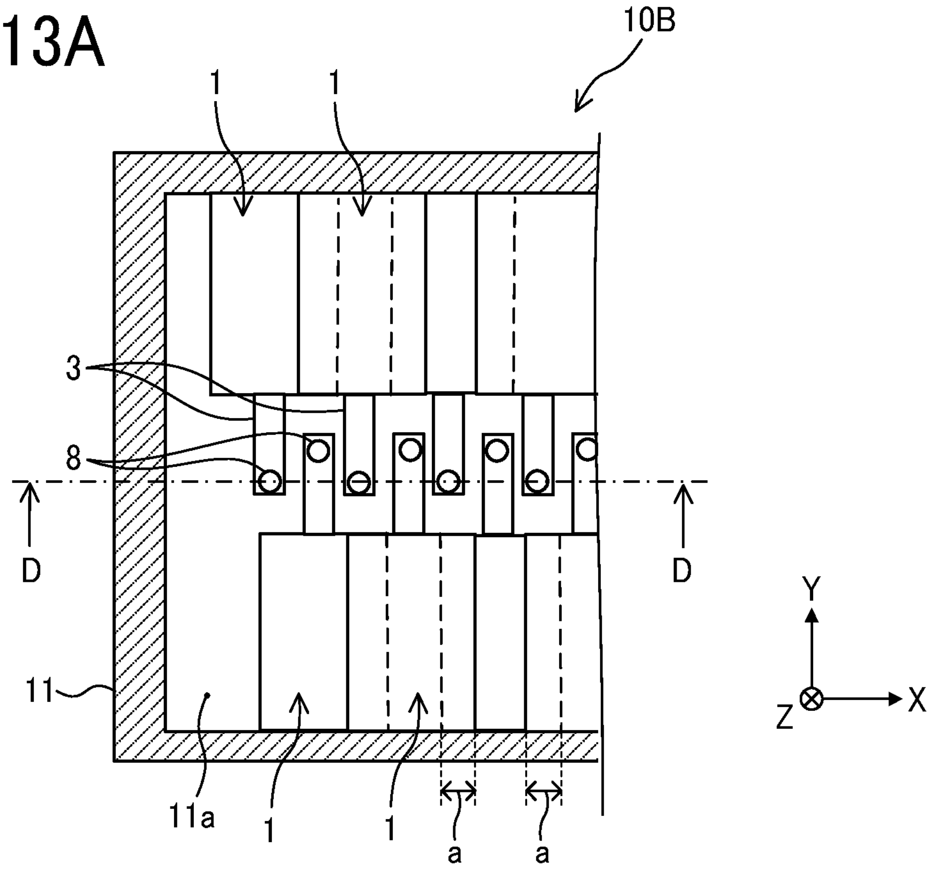

FIG. 13B

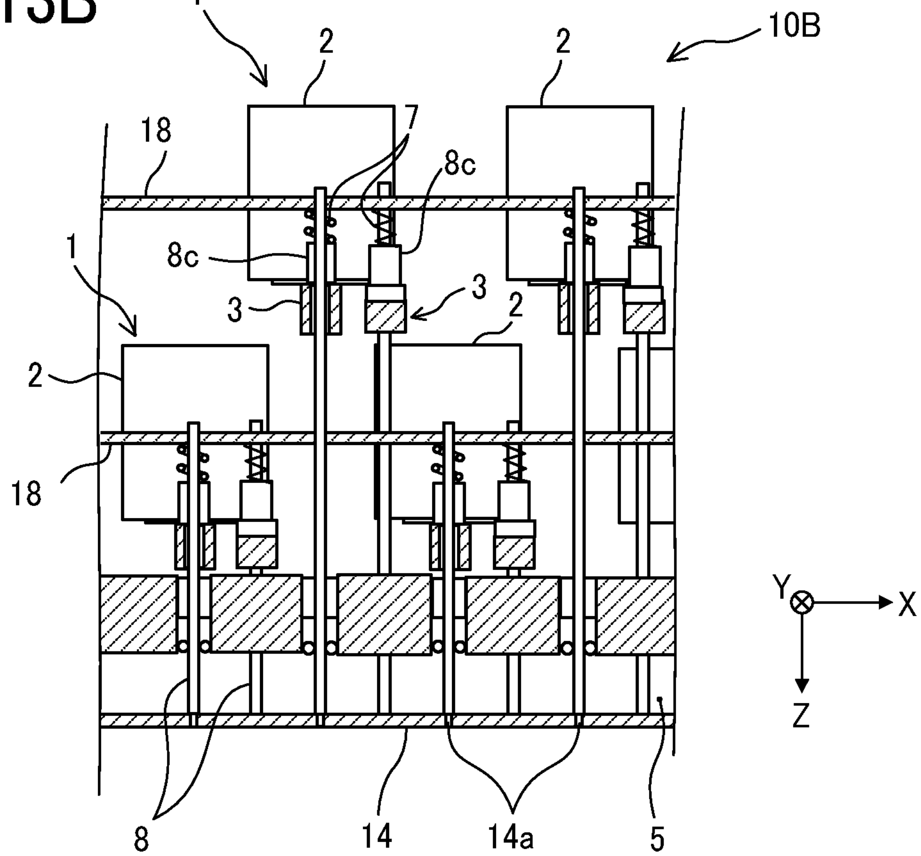

FIG. 14

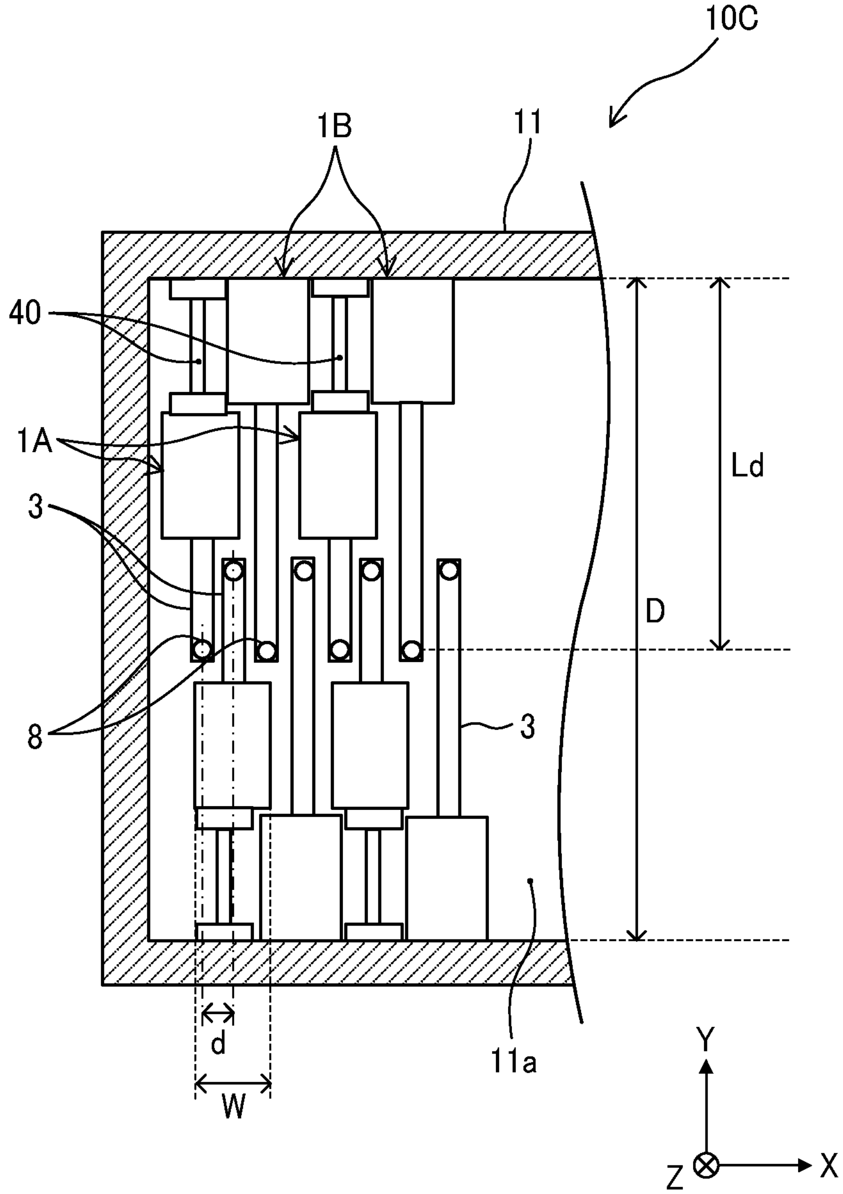

FIG. 15

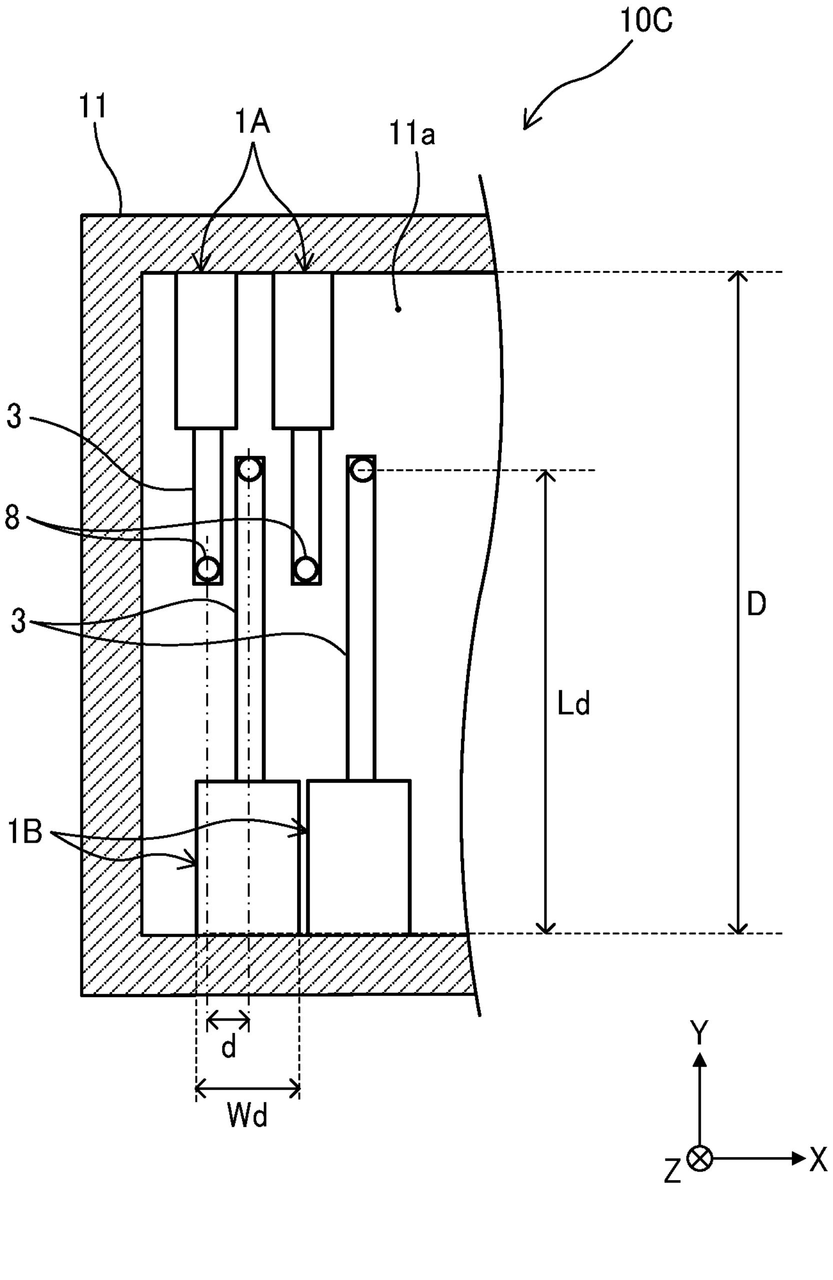

FIG. 16A

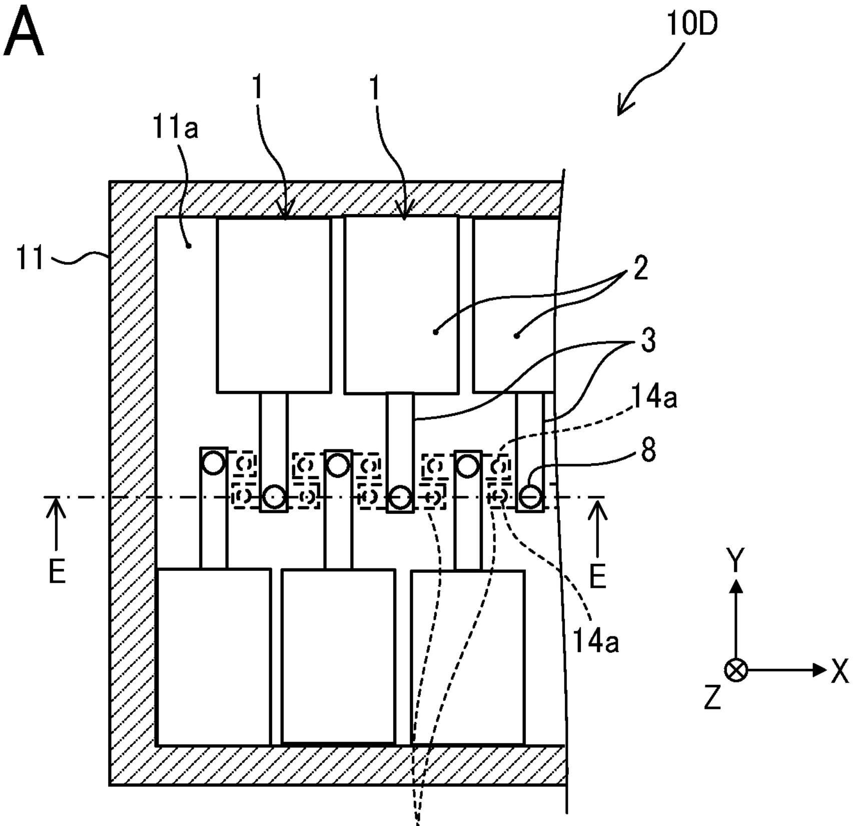

FIG. 16B

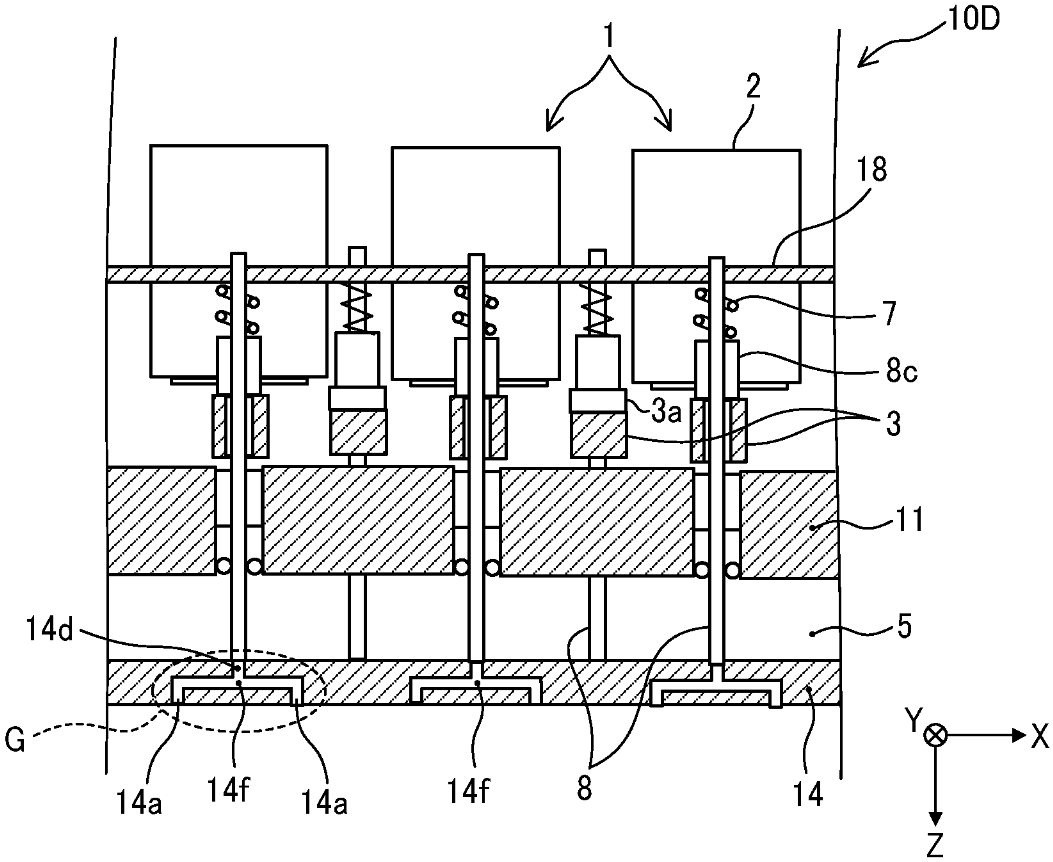

FIG. 17

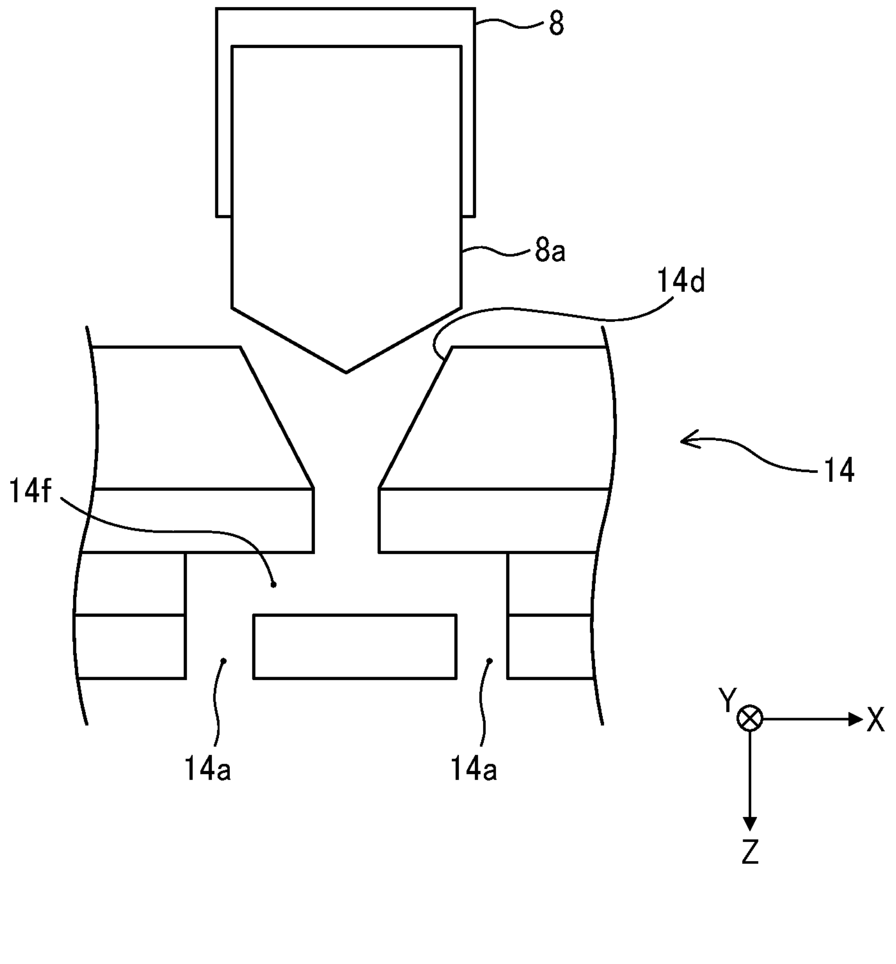

FIG. 18A

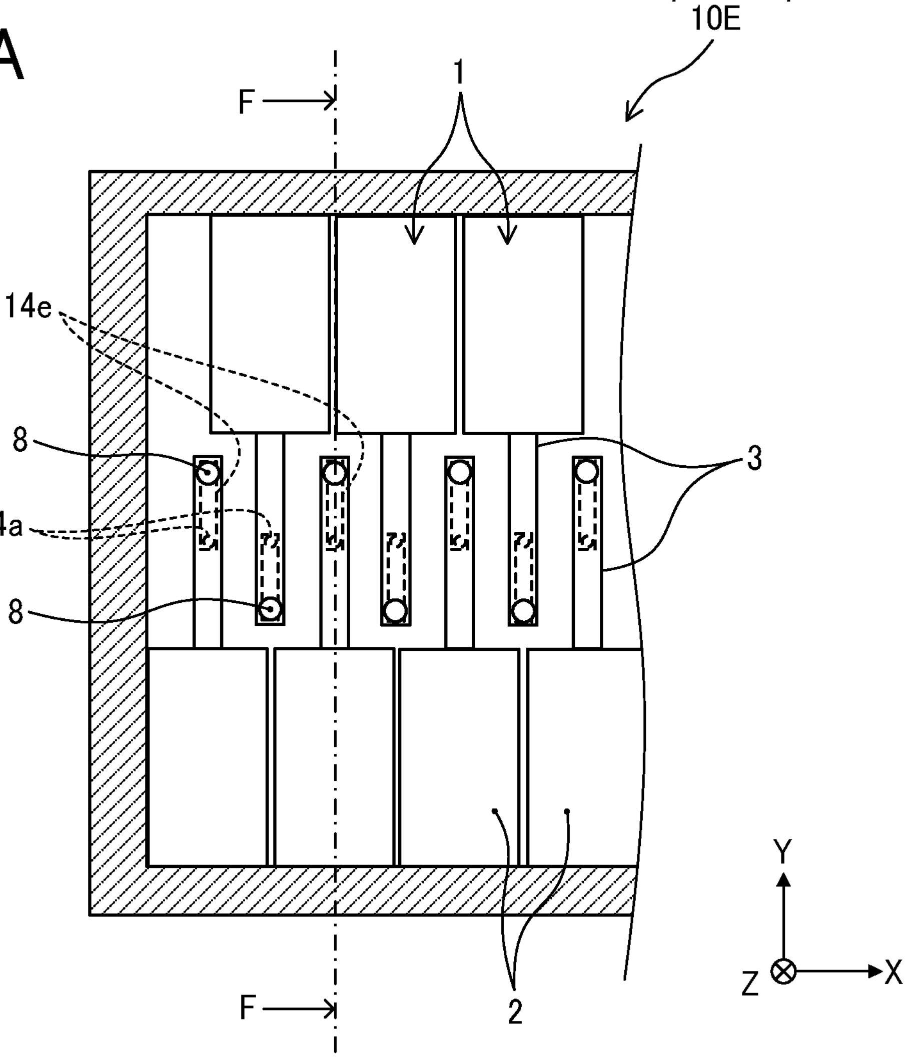

FIG. 18B

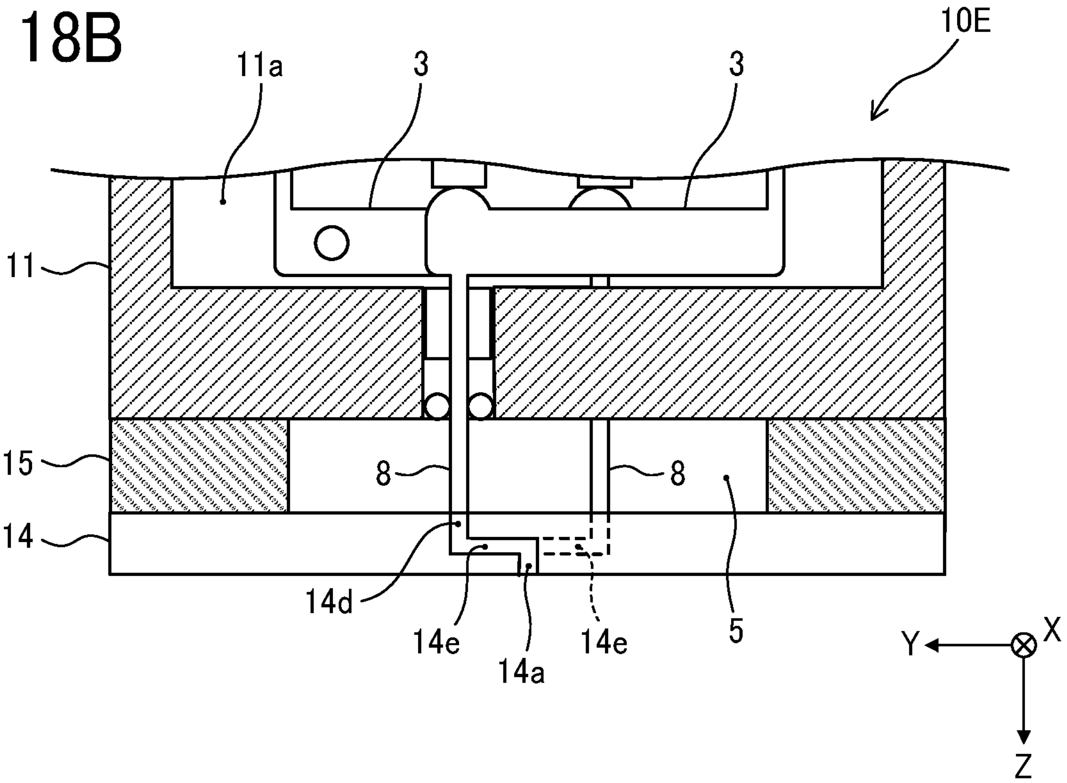

FIG. 19

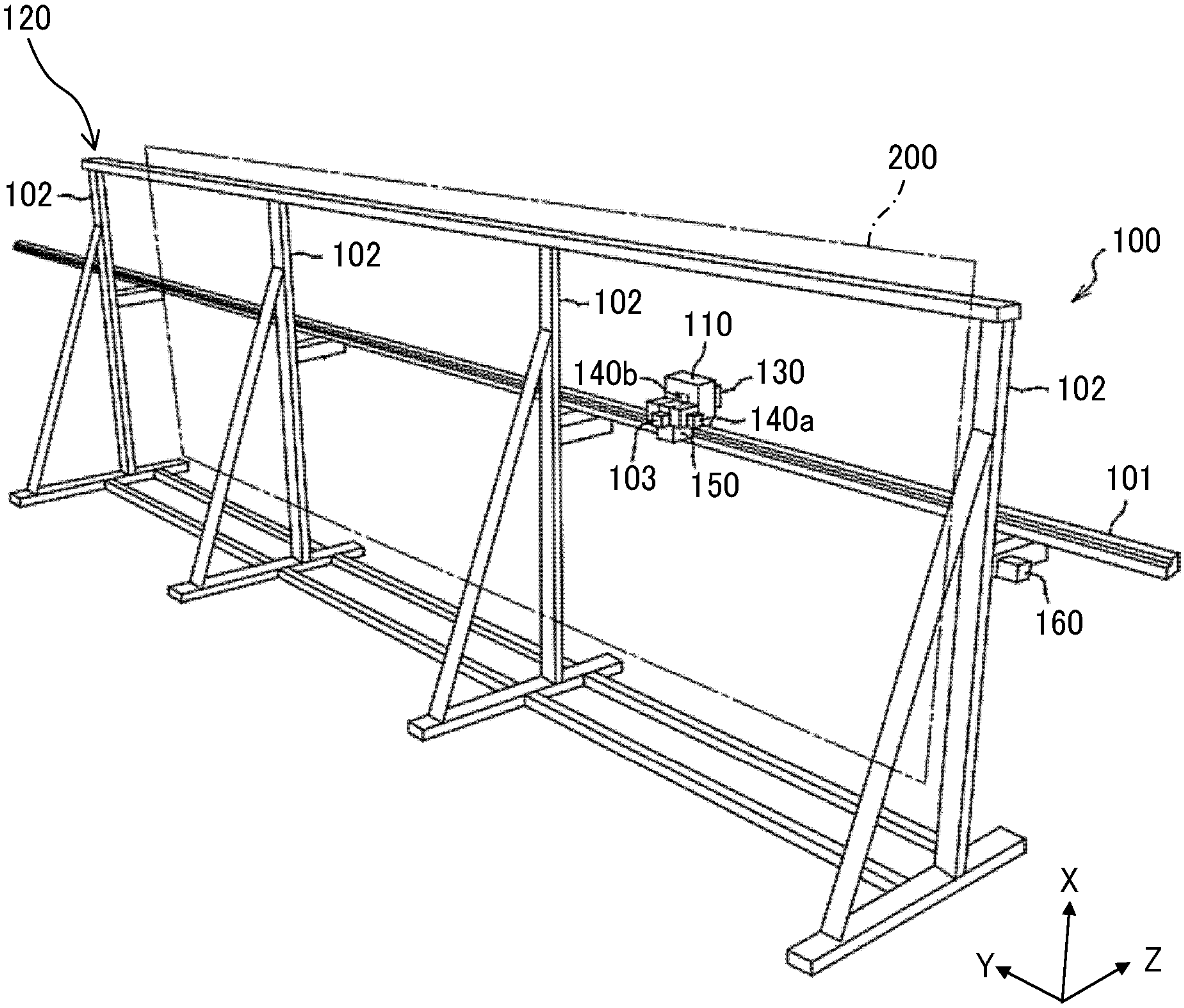
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FIG. 20

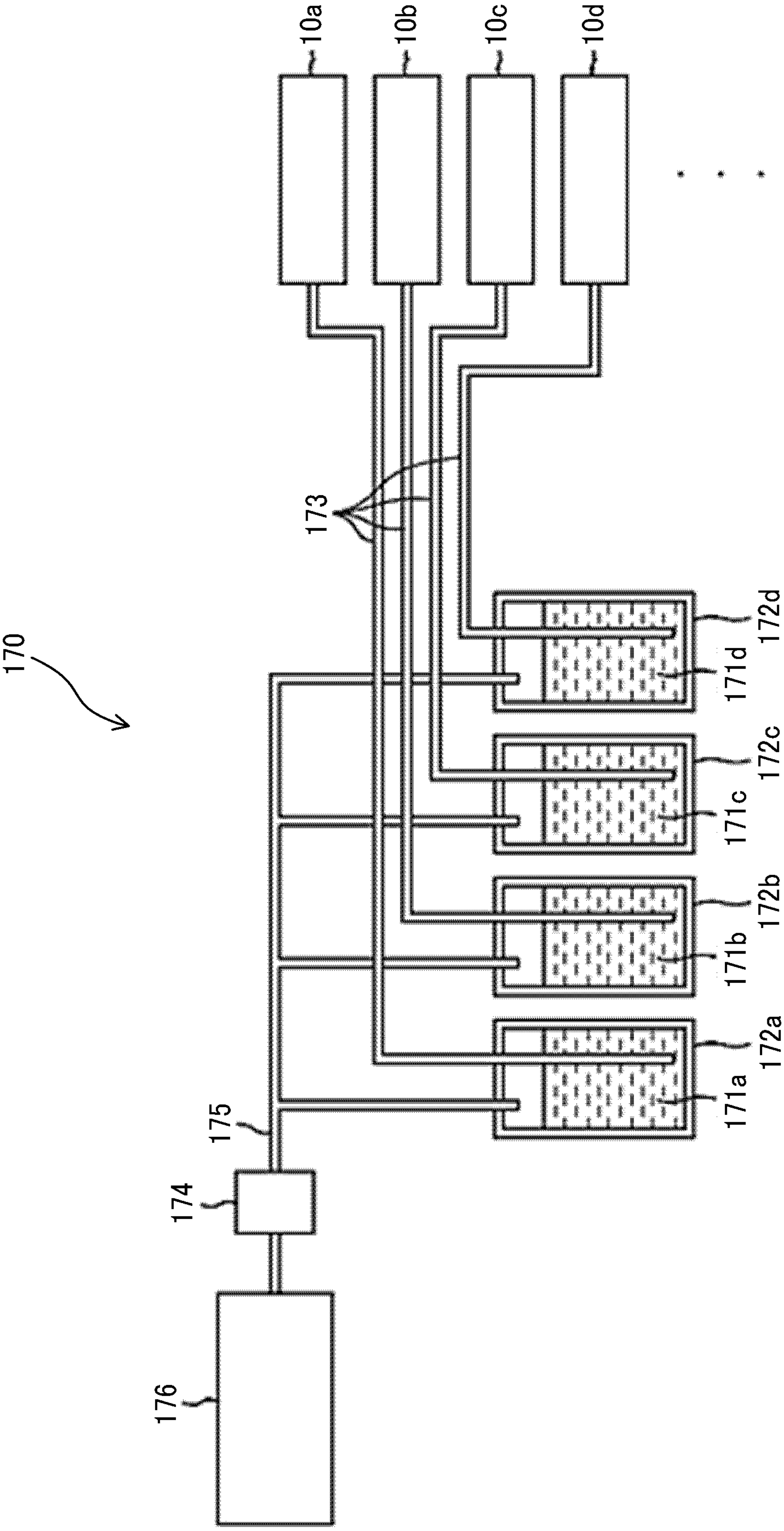
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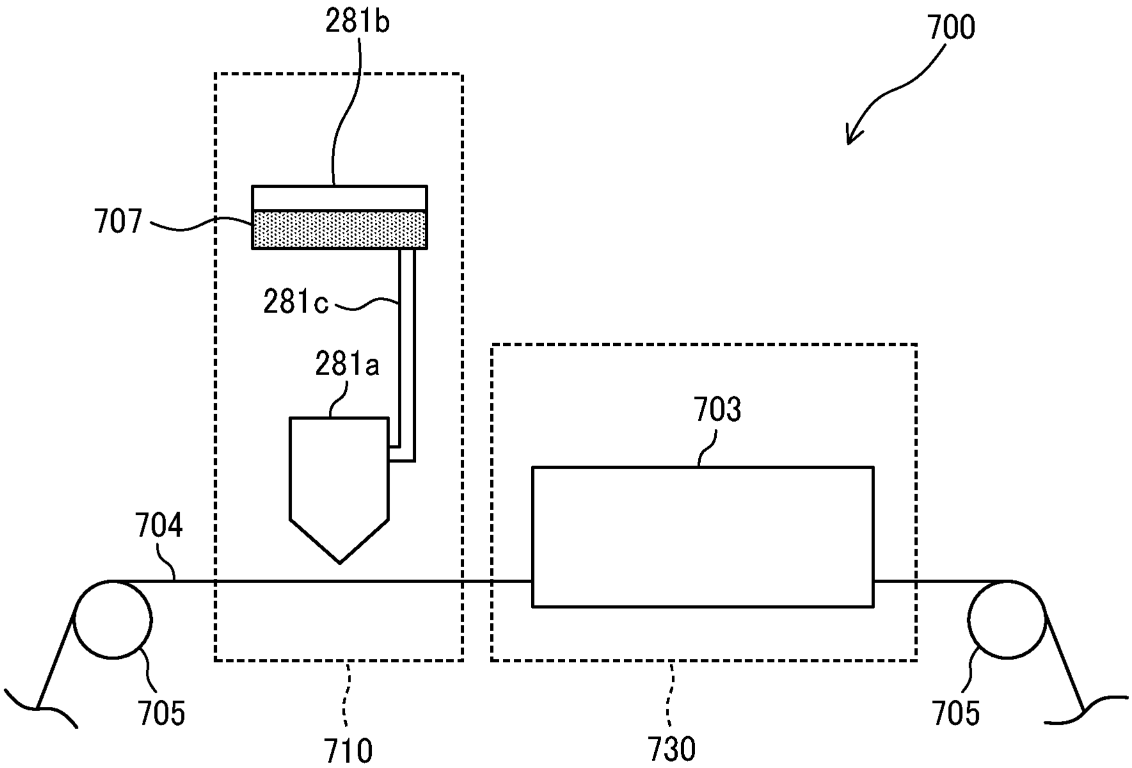
FIG. 21



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/060736

A. CLASSIFICATION OF SUBJECT MATTER
INV. B41J2/14
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B41J B05B B05C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2012/139996 A1 (MCNESTRY MARTIN [GB]) 7 June 2012 (2012-06-07) figures 5,12 -----	1-20
Y	US 2009/115816 A1 (PAULY MANFRED [DE]) 7 May 2009 (2009-05-07) figure 3 -----	1-20
A	JP 6 600274 B2 (XEROX CORP) 30 October 2019 (2019-10-30) figure 6 -----	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 February 2025	21/02/2025

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Bardet, Maude

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2024/060736

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