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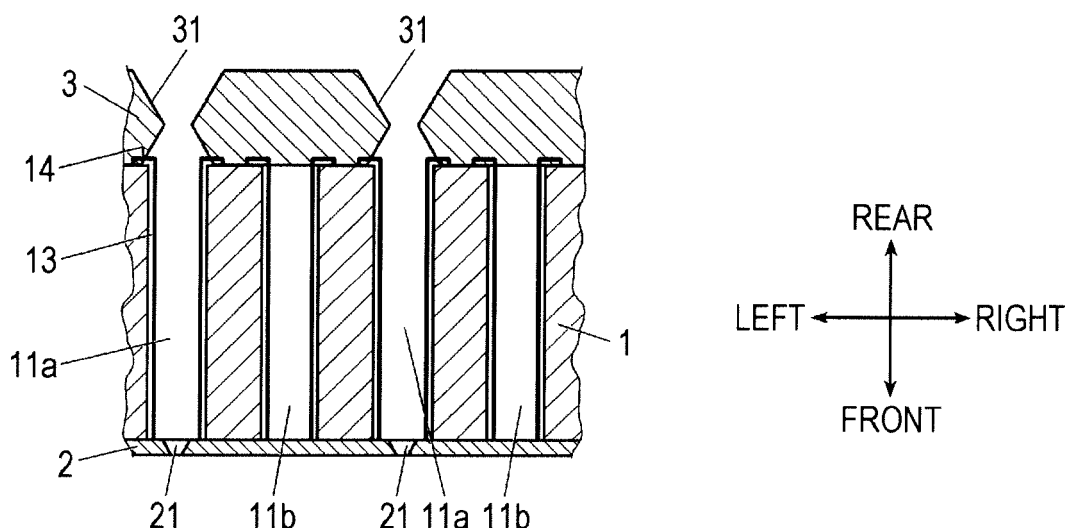
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(54) **INKJET HEAD, INKJET RECORDING DEVICE, AND METHOD OF MANUFACTURING INKJET HEAD**

(57) An inkjet head includes a head chip 1 including a driving channel 11a and a nozzle 21 ejecting ink in the driving channel 11a and provided on a surface of a driving wall facing an inside of the driving channel 11a with a driving electrode 13 and a wiring board 3 connected to a rear surface of the head chip 1 to cover the driving channel 11a. The wiring board 3 is provided at a position thereof corresponding to the driving channel 11a with a

through hole 31 adapted to introduce ink into the driving channel 11a. A constricted portion having a smaller cross-sectional area than those of the end portions is formed between end portions of the through hole 31 in an ink introducing direction, and flow path resistance of the through hole 31 is a value of 0.2 or higher. Accordingly, even low-viscosity ink can be ejected in a stable manner.

**FIG. 4**



## Description

### Technical Field

5     **[0001]** The present invention relates to an inkjet head, an inkjet recording apparatus including the inkjet head, and a method for manufacturing the inkjet head.

### Background Art

10    **[0002]** Conventionally known is a shear mode type inkjet head in which voltage is applied to driving walls partitioning ink channels to cause the driving walls to be subject to shear deformation and in which ink in the ink channels is ejected with use of pressure generated at the time of the shear deformation (for example, refer to Patent Literature 1).

### Citation List

15

#### Patent Literature

**[0003]** Patent Literature 1: JP 2004-268315 A

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### Summary of Invention

#### Technical Problem

25    **[0004]** However, in the conventional shear mode type inkjet head, overflow of ink cannot be restricted in a case in which low-viscosity ink is used. When the overflow occurs, the ink is in a shape in which a meniscus is deformed, such as a gourd shape in which the ink goes out of a nozzle surface, pressure is not transmitted normally, and the ink cannot be ejected normally.

30    **[0005]** One way to restrict the overflow of the ink seems to be an increase in flow path resistance of through holes formed in a wiring board laminated on the channels in the opposite direction of the nozzles. However, in a case in which the flow path resistance of the through holes is increased, and in which the inkjet head is driven in a high driving cycle, for example, supply of the ink into the through holes will be delayed, which may lead to an ejection failure.

**[0006]** In consideration of the above problems, the present inventor has focused attention on the flow path resistance of the through hole and the shape of the through hole and has reached the present invention.

35    **[0007]** An object of the present invention is to provide an inkjet head, an inkjet recording apparatus including the inkjet head, and a method for manufacturing an inkjet head enabling even low-viscosity ink to be ejected in a stable manner.

#### Solution to Problem

40    **[0008]** To solve the above problem, according to an aspect of the present invention, an inkjet head includes:

a head chip including a channel and a nozzle ejecting ink in the channel and provided on a surface of a driving wall facing an inside of the channel with a driving electrode; and

a board connected to a rear surface of the head chip to cover the channel,

45    wherein the board is provided at a position thereof corresponding to the channel with a through hole adapted to introduce ink into the channel, and

a constricted portion having a smaller cross-sectional area than those of the end portions is formed between end portions of the through hole in an ink introducing direction, and flow path resistance of the through hole is a value of 0.2 or higher.

50    **[0009]** Furthermore, according to another aspect of the present invention, an inkjet recording apparatus includes:

a supporting unit supporting a recording medium;

the inkjet head; and

a traveling unit adapted to cause the recording medium or the inkjet head to travel.

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**[0010]** Furthermore, according to another aspect of the present invention, a method for manufacturing the inkjet head includes:

a through hole forming process of sandblasting both surfaces of a board main body of the board to form the through hole.

**[0011]** Furthermore, according to another aspect of the present invention, a method for manufacturing the inkjet head includes:

a hole portion forming process of sandblasting either or both surfaces of each of a plurality of board main bodies of the board to form hole portions; and

a through hole forming process of laminating the plurality of board main bodies having formed therein the hole portions so that the hole portions may overlap with each other to form the through hole of the board.

#### Advantageous Effects of Invention

**[0012]** According to the present invention, even low-viscosity ink can be ejected in a stable manner.

#### Brief Description of Drawings

**[0013]**

Fig. 1 is a schematic configuration diagram of an inkjet recording apparatus.

Fig. 2 is an exploded perspective view illustrating an example of an inkjet head.

Fig. 3 is a view of a head chip of the inkjet head illustrated in Fig. 2 seen from the rear side.

Fig. 4 is a partial cross-sectional view of the inkjet head illustrated in Fig. 2.

Fig. 5 illustrates a through hole of a wiring board.

Fig. 6 illustrates an example of a method for manufacturing the wiring board.

Fig. 7A is a cross-sectional view illustrating another mode of the through hole of the wiring board.

Fig. 7B is a cross-sectional view illustrating another mode of the through hole of the wiring board.

Fig. 8 illustrates an example of a driving signal to be used in the present embodiment.

#### Description of Embodiments

**[0014]** Hereinbelow, preferred embodiments of the present invention will be described with reference to the drawings. It is to be noted that the scope of the invention is not limited to the illustrated embodiments.

**[0015]** Fig. 1 is a schematic configuration diagram of an inkjet recording apparatus 100.

**[0016]** The inkjet recording apparatus 100 includes a conveyance belt (supporting unit) 101 supporting a recording medium, a carriage rail (traveling unit) 102 adapted to cause a carriage 103 including an inkjet head H to travel, a cleaning liquid supplying unit 104 including a cleaning roller 80, an ink rack 105, and a computer 106.

**[0017]** Fig. 2 is an exploded perspective view illustrating an example of the inkjet head H. Fig. 3 is a view of a head chip of the inkjet head H illustrated in Fig. 2 seen from the rear side. Fig. 4 is a partial cross-sectional view of the inkjet head H illustrated in Fig. 2. It is to be noted that, in Fig. 4, illustration of a manifold is omitted.

**[0018]** The inkjet head H includes a head chip 1, a nozzle plate 2, a wiring board 3, and a manifold 4.

**[0019]** The head chip 1 is a hexahedron including a front surface 1a, a rear surface 1b, and four upper, lower, right, and left side surfaces interposed between the front surface 1a and the rear surface 1b. In a range from the front surface 1a to the rear surface 1b located to be opposed to each other, multiple straight channels 11 are formed. Partition walls partitioning the adjacent channels 11 are driving walls 12 made of a piezoelectric device. The multiple channels 11 and driving walls 12 are alternately arranged to constitute each of channel rows 10A to 10D.

**[0020]** That is, the head chip 1 is a so-called harmonica type head chip in which the channels 11 and the driving walls 12 are alternately arrayed and in which an outlet and an inlet of each channel 11 are disposed to be opposed to each other on the front surface 1a and the rear surface 1b of the head chip 1.

**[0021]** Here, the four channel rows 10A to 10D are provided and are arrayed in an up-down direction in Fig. 2.

**[0022]** It is to be noted that, in the present embodiment, "the front surface" of the head chip 1 is a surface on a side on which nozzles are arranged to eject ink, and "the rear surface" is an opposite surface.

**[0023]** Furthermore, the inkjet head H according to the present embodiment is an inkjet head of an independent driving type in which the channels 11 in the respective channel rows 10A to 10D include driving channels 11a into which ink is supplied and from which the ink is ejected and dummy channels 11b into which no ink is supplied and from which no ink is ejected. In each of the channel rows 10A to 10D, the driving channels 11a and the dummy channels 11b are alternately arranged.

**[0024]** The head chip 1 is a shear mode type head chip, and in the driving channel 11a, an opening on the side of the

front surface 1a is an outlet of ink while an opening 110 on the side of the rear surface 1b is an inlet of ink. The dummy channel 11b has similar openings, and the openings of the dummy channel 11b are closed by the below-mentioned nozzle plate 2 and wiring board 3 and do not allow ink to go therein or thereout.

**[0025]** On a surface of the driving wall 12 facing an inside of each of the channels 11a and 11b, a driving electrode 13 for voltage application configured to deform the driving wall 12 is closely attached and formed by means of sputtering, deposition, non-electrolytic plating, or the like. On the rear surface 1b of the head chip 1, a connecting electrode 14 electrically connected to the driving electrode 13 via the opening 110 of each of the channels 11a and 11b is formed by means of sputtering, deposition, non-electrolytic plating, or the like to be extracted from one side of each opening 110 of each of the channels 11a and 11b.

**[0026]** Furthermore, the connecting electrode 14 of each of the channels 11a and 11b in the two channel rows 10A and 10B out of the channel rows 10A to 10D is formed to extend from the opening 110 of each of the channels 11a and 11b toward a side edge e1 close to the channel row 10A while the connecting electrode 14 of each of the channels 11a and 11b in the two other channel rows 10C and 10D is formed to extend from the opening 110 of each of the channels 11a and 11b toward a side edge e2 close to the channel row 10D. Furthermore, each of the connecting electrodes 14 in the channel rows 10B and 10C stops behind the channel rows 10A and 10D respectively adjacent to the channel rows 10B and 10C.

**[0027]** To the front surface 1a of the head chip 1, the nozzle plate 2 is attached. Nozzles 21 are formed to pass through the nozzle plate 2 only at positions corresponding to the driving channels 11a. Thus, the openings of the dummy channels 11b on the side of the front surface 1a are closed by the nozzle plate 2.

**[0028]** To the rear surface 1b of the head chip 1, the wiring board 3 is connected via adhesive (not illustrated). The wiring board 3 is larger in area than the rear surface 1b of the head chip 1, and, in a state in which the wiring board 3 is attached to the rear surface 1b of the head chip 1, end portions 3a and 3b arranged in a direction perpendicular to the channel row direction extend further than the head chip 1 and project significantly in the up-down direction in Fig. 2.

**[0029]** Furthermore, the wiring board 3 is provided only at positions thereof corresponding to the driving channels 11a of the head chip 1 individually with through holes 31 adapted to supply the respective driving channels 11a with ink stored in the manifold 4 to be connected to a back surface side of the wiring board 3.

**[0030]** That is, the wiring board 3 is provided at positions thereof corresponding to the dummy channels 11b with no through holes. Thus, the openings 110 of the dummy channels 11b on the side of the rear surface 1b are closed by the wiring board 3.

**[0031]** As a material for the wiring board 3, an appropriate material such as glass, ceramic, silicon, and one of various plastics such as polyamide can be used. Among these, the glass is preferable in that the glass is adequately rigid, cheap, and easy to process. Furthermore, by using a transparent glass board, (below-mentioned) wiring electrodes 32 and the connecting electrodes 14 of the head chip 1 can be seen through the wiring board 3 from the rear side, and positioning between the wiring electrodes 32 and the connecting electrodes 14 can be performed easily.

**[0032]** Furthermore, the thickness of the wiring board 3 is preferably in the range of 200  $\mu\text{m}$  or more and 800  $\mu\text{m}$  or less. Setting the thickness of the wiring board 3 to 200  $\mu\text{m}$  or more can provide favorable handling at the time of manufacture. Setting the thickness of the wiring board 3 to 800  $\mu\text{m}$  or less can prevent formation of the through holes 31 from being extremely time-consuming and can provide favorable bubble removability at the time of introduction of ink into the through holes 31.

**[0033]** Furthermore, the elastic modulus of the wiring board 3 is preferably 30 GPa or more. Setting the elastic modulus of the wiring board 3 to 30 GPa or more can prevent pressure waves (energy) generated in the channels in the shear mode from being attenuated due to a damping effect of the wiring board to cause ejection of ink to be unstable.

**[0034]** Fig. 5 illustrates a shape of the through hole 31 formed in the wiring board 3.

**[0035]** As illustrated in Fig. 5, in an ink introducing direction (front-back direction), the through hole 31 is formed at a center thereof in a shape in which a constricted portion 31b having a shorter distance in the right-left direction than those of a front end portion 31a and a rear end portion 31c of the through hole 31 (having a smaller cross-sectional area as seen in the front-back direction) is formed. Furthermore, the front end portion 31a, the constricted portion 31b, and the rear end portion 31c of the through hole 31 are circular as seen in the front-back direction.

**[0036]** It is to be noted that, in the following description, such a stereoscopic shape will be expressed as "a drum shape."

**[0037]** The front end portion 31a of the through hole 31 has an equivalent or smaller opening area to or than that of the opening 110 to face the head chip 1, and the rear end portion 31c of the through hole 31 has an equivalent or larger opening area to or than that of the front end portion 31a.

**[0038]** Due to the above shape, since ink to be supplied into the channel is smoothly introduced through the constricted portion 31b, ink introducing performance can be improved further than in a case in which the stereoscopic shape is a cylindrical shape.

**[0039]** Furthermore, as for bubbles in the channel, since the bubbles are smoothly introduced into the constricted portion 31b and are removed out of the channel, bubble removability can be improved.

**[0040]** The flow path resistance of the through hole 31 is set to a value of 0.2 or higher. Setting the flow path resistance

of the through hole 31 to a value of 0.2 or higher enables overflow of ink to be restricted even when low-viscosity ink having viscosity resistance of 5 cp or less is used.

[0041] Accordingly, since the through hole 31 is formed in the above shape, the through hole 31 can restrict ink overflow while keeping ink introducing performance. Thus, ink can be ejected in a stable manner even when low-viscosity ink is ejected in a high driving cycle, for example.

[0042] It is more preferable to set the flow path resistance of the through hole 31 to a value in a range of 0.4 or higher and 1.0 or lower. Setting the flow path resistance of the through hole 31 to 0.4 or higher can provide favorable ejection stability of ink having viscosity resistance of 5 cp or less. Setting flow path resistance of the through hole 31 to 1.0 or lower can prevent a problem in which refilling gets poor to disable high-speed driving from being generated.

[0043] The through hole 31 can be formed by means of any of various processing methods such as sandblasting, laser processing, electric spark forming, and ultrasonic processing, and the sandblasting is especially preferable in terms of quality, cost, and productivity.

[0044] For example, in the sandblasting, a glass plate (board main body) serving as a material for the wiring board 3 is provided with a masking material that protects a non-processed region, and a processed region of the glass plate is cut by spraying compressed air mixed with a polishing agent to the processed region from a nozzle. The processing amount at this time is adjusted in accordance with a targeted processing shape. By sandblasting both the surfaces of the glass plate, the drum shape can be formed (through hole forming process).

[0045] Meanwhile, as illustrated in Fig. 6, three glass plates (board main bodies) 3A, 3B, and 3C may respectively be sandblasted on either or both surfaces to form hole portions having different areas (hole portion forming process) and may be attached to each other so that the hole portions may overlap with each other to produce the wiring board 3 provided with the drum-shaped through holes 31 (through hole forming process).

[0046] Furthermore, the shape of the through hole 31 is not limited to one illustrated in Figs. 5 and 6 and may be one illustrated in each of Figs. 7A and 7B.

[0047] Fig. 7A illustrates an example of the through hole 31 having a constricted portion 31d having a predetermined length in the front-back direction. Fig. 7B illustrates an example of the through hole 31 having a constricted portion 31e formed in a curved shape. Furthermore, a plurality of constricted portions may be formed although illustration thereof is omitted.

[0048] On a surface of the wiring board 3 serving as a connecting surface to the head chip 1, the wiring electrodes 32 are formed by means of sputtering, deposition, non-electrolytic plating, or the like to correspond to the respective connecting electrodes 14 arrayed on the rear surface 1b of the head chip 1 in a one-to-one relationship.

[0049] In a state in which the head chip 1 and the wiring board 3 are attached, one end of each of the wiring electrodes 32 reaches the vicinity of the corresponding opening 110 of each of the driving channels 11a and the dummy channels 11b while the other end extends toward each of the end portions 3a and 3b of the wiring board 3 projecting in the up-down direction of the head chip 1. The other end of each of the wiring electrodes 32 corresponding to the channel rows 10A and 10B extends toward the end portion 3a on the upper side of the figure while the other end of each of the wiring electrodes 32 corresponding to the channel rows 10C and 10D extends toward the end portion 3b on the lower side of the figure.

[0050] To the respective end portions 3a and 3b of the wiring board 3, external wiring members 5 and 5 such as FPCs are connected, to electrically connect the end portions 3a and 3b to a not-illustrated driving circuit. As a result, a driving signal (driving voltage) from the driving circuit is applied to the driving electrode 13 in each of the channels 11a and 11b via each of the external wiring members 5 and 5, the wiring electrode 32 of the wiring board 3, and the connecting electrode 14 of the head chip 1.

[0051] Fig. 8 illustrates an example of the driving signal to be used in the present embodiment. In this example, the driving signal in Fig. 8 is applied to each of the driving channels 11a adapted to eject ink, and each of the dummy channels 11b is connected to the earth.

[0052] As illustrated in Fig. 8, the driving signal includes in a driving cycle T a first pulse Pa serving as a positive voltage (+ Von) rectangular wave that expands the volume of the channel and recovers the original volume after a lapse of a predetermined period of time and a second pulse Pb serving as a negative voltage (- Voff) rectangular wave that contracts the volume of the channel and recovers the original volume after a lapse of a predetermined period of time.

[0053] Meanwhile, the predetermined period of time, which is a duration period for expanding or contracting the volume of the channel 11, is expressed as an AL (Acoustic Length). The AL is 1/2 of an acoustic resonance period of the pressure wave in the channel 11. The AL is derived as a pulse width that maximizes the flying speed of ink droplets to be ejected at the time of applying the rectangular wave driving pulse to the driving electrode when a voltage value of the rectangular wave is set to be constant, and when the pulse width of the rectangular wave is changed.

[0054] Furthermore, the pulse is a rectangular wave whose peak value is constant voltage. When 0 V is 0%, and peak value voltage is 100%, the pulse width is defined as a period of time between a 10% rising point from 0 V and a 10% falling point from the peak value voltage.

[0055] Further, the rectangular wave is a waveform in which each of the rising time and the falling time between 10%

and 90% of voltage is within 1/2 of the AL, preferably within 1/4 of the AL.

**[0056]** In particular, in the shear mode type head chip 1, ink is ejected from the nozzle 21 with use of resonance of the pressure wave generated in the channel 11. Thus, by using the rectangular wave, ink can be ejected more efficiently.

**[0057]** Furthermore, in the shear mode type head chip 1, since a meniscus response to application of the rectangular wave driving signal is quick, the driving voltage can be kept low. In general, since the head chip 1 receives voltage at all times regardless of whether or not ink is ejected, low driving voltage is important to suppress heat generation of the head chip 1 and to eject ink in a stable manner.

**[0058]** Further, since the rectangular wave can easily be generated by using a simple digital circuit, the rectangular wave is advantageous in that the circuit configuration can be simplified further than in a case of using a trapezoidal wave having an inclined wave.

**[0059]** As described above, according to the present embodiment, the inkjet head H includes the head chip 1 including the driving channel 11a and the nozzle 21 ejecting ink in the driving channel 11a and provided on a surface of the driving wall 12 facing an inside of the driving channel 11a with the driving electrode 13 and the wiring board 3 connected to the rear surface 1b of the head chip 1 to cover the driving channel 11a. In the inkjet head H, the wiring board 3 is provided at a position thereof corresponding to the driving channel 11a with the through hole 31 adapted to introduce ink into the driving channel 11a. Between the end portions 31a and 31c of the through hole 31 in the ink introducing direction, the constricted portion 31b having a smaller cross-sectional area than those of the end portions 31a and 31c is formed, and flow path resistance of the through hole 31 is a value of 0.2 or higher.

**[0060]** Accordingly, overflow of ink can be restricted when low-viscosity ink is used, and even low-viscosity ink can be ejected in a stable manner.

**[0061]** Furthermore, according to the present embodiment, the end portions 31a and 31c and the constricted portion 31b of the through hole 31 are circular as seen in the ink introducing direction.

**[0062]** Accordingly, even low-viscosity ink can be ejected in a more stable manner.

**[0063]** Furthermore, according to the present embodiment, the flow path resistance of the through hole 31 is a value in a range of 0.4 or higher and 1.0 or lower.

**[0064]** Accordingly, setting the flow path resistance of the through hole 31 to 0.4 or higher can provide favorable ejection stability of ink having viscosity resistance of 5 cp or less. Setting flow path resistance of the through hole 31 to 1.0 or lower can prevent a problem in which refilling gets poor to disable high-speed driving from being generated.

**[0065]** Furthermore, according to the present embodiment, an elastic modulus of the wiring board 3 is 30 GPa or more.

**[0066]** This can prevent pressure waves (energy) generated in the channels in the shear mode from being attenuated due to a damping effect of the wiring board 3 to cause ejection of ink to be unstable.

**[0067]** Furthermore, according to the present embodiment, in the head chip 1, an outlet and an inlet of the driving channel 11a are disposed to be opposed to each other on the front surface 1a and the rear surface 1b of the head chip 1.

**[0068]** Accordingly, the head chip 1 is easy to manufacture and is easily provided with multiple nozzles.

**[0069]** Furthermore, according to the present embodiment, in the head chip 1, the driving channel 11a ejecting ink and the dummy channel 11b ejecting no ink are alternately arranged via the driving wall 12, and the wiring board 3 has the through hole 31 at a position corresponding to the driving channel 11a ejecting ink.

**[0070]** This can prevent speed fluctuation from being generated by an influence (stroke) of the adjacent driving channel 11a, and favorable ejecting performance can be achieved.

**[0071]** Furthermore, according to the present embodiment, a thickness of the wiring board 3 is in a range of 200  $\mu\text{m}$  or more and 800  $\mu\text{m}$  or less.

**[0072]** Accordingly, setting the thickness of the wiring board 3 to 200  $\mu\text{m}$  or more can provide favorable handling at the time of manufacture. Setting the thickness of the wiring board 3 to 800  $\mu\text{m}$  or less can provide favorable bubble removability at the time of introduction of ink into the through hole 31.

**[0073]** Furthermore, according to the present embodiment, the board is the wiring board 3 provided with the wiring electrode 32 adapted to apply a driving signal to the driving electrode 13.

**[0074]** This can provide a configuration in which the wiring board 3 is connected to the rear surface 1b of the head chip 1.

**[0075]** Meanwhile, although the head chip 1 of the inkjet head H includes the four channel rows 10A to 10D in the description of the above embodiment, the number of channel rows of the head chip 1 is not particularly limited in the present invention. The number may be only one, two, three, or a plural such as five or more.

**[0076]** Furthermore, although the inkjet head of the independent driving type including the driving channels 11a and the dummy channels 11b is illustrated in the description of the above embodiment, an inkjet head not including the dummy channels 11b may be provided.

**[0077]** Furthermore, although the inkjet head in which the partition wall between the adjacent channels is used as the driving wall and is subject to shear deformation is illustrated in the description of the above embodiment, the present invention is not limited to this. For example, an upper wall or a lower wall of the channel may be a driving wall made of a piezoelectric device such as a PZT, and the upper wall or the lower wall may be subject to shear deformation.

**[0078]** Furthermore, although the so-called serial head inkjet recording apparatus 100, which conveys a recording

medium while conveying a carriage in a direction perpendicular to a conveying direction of the recording medium and ejects ink to the recording medium from an upper side, is illustrated in the description of the above embodiment, the inkjet recording apparatus is not limited to one having such a configuration. For example, a so-called line head inkjet recording apparatus, which performs image formation only by means of conveyance of the recording medium, may be employed.

**[0079]** Furthermore, although the configuration including the driving wall 12 made of a piezoelectric device is illustrated in the description of the above embodiment, the driving wall may be driven by an actuator.

**[0080]** Furthermore, although the configuration in which the wiring board 3 is connected to the rear surface 1b of the head chip 1 is illustrated in the description of the above embodiment, another configuration may be employed such as a configuration in which the connecting electrodes are extracted from a side surface of the head chip 1, and in which the wiring board is connected to the side surface.

#### Examples

**[0081]** Hereinbelow, the effect of the present invention will be verified by examples.

#### (1. Inkjet head)

**[0082]** A head chip, a nozzle plate, and a wiring board of each inkjet head are as follows.

**[0083]** As the head chip, a shear mode type head chip in which a PZT was used as a material for a driving wall, and in which a groove width was 70  $\mu\text{m}$ , a depth was 250  $\mu\text{m}$ , and a length was 2.0 mm was used.

**[0084]** As the nozzle plate, a polyimide sheet provided with nozzles each having a diameter of 25  $\mu\text{m}$  was used.

**[0085]** As the wiring boards, ones having thicknesses [ $\mu\text{m}$ ] and elastic moduli [GPa] were as shown in Comparative Examples 1 to 4 and Examples 1 to 13 in Table 1 were used. As for specific materials for the wiring boards, a glass plate was used in Comparative Examples 1 to 4 and Examples 1 to 10 and 13, and polyamide was used in Examples 11 and 12.

**[0086]** Furthermore, in the wiring boards, through holes having cross-sectional shapes and stereoscopic shapes as seen in the front-back direction as shown in Comparative Examples 1 to 4 and Examples 1 to 13 in Table 1 were formed.

**[0087]** The through holes in Examples 1 to 12 were formed in a drum shape illustrated in Fig. 5, and the through hole in Example 13 was formed in a drum shape illustrated in Fig. 7A.

**[0088]** In Table 1, as for each of the drum-shaped through holes, a diameter (A)  $\mu\text{m}$  of a front end portion, a diameter (B)  $\mu\text{m}$  of a constricted portion, and a diameter (C)  $\mu\text{m}$  of a rear end portion are shown as (A/B/C).

[Table 11]

	Physical Properties of Wiring Board		Through Hole		Flow Path Resistance	Ink Introducing Performance	Upper Limit Driving Frequency [KHz]		Overflow [%]		Overall Evaluation
	Thickness [ $\mu\text{m}$ ]	Elastic Modulus [GPa]	Cross-sectional Shape	Stereoscopic Shape							
Comparative Example 1	300	60	Oval	Cylindrical	0.18	○	24	×	90	×	1
Comparative Example 2	300	60	Circular	Cylindrical	0.18	○	25	△	70	×	2
Comparative Example 3	300	60	Circular	Tapered	0.37	×	18	×	40	△	1
Comparative Example 4	300	60	Circular	Drum	0.18	○	22	×	50	△	2
Example 1	300	60	Circular	Drum	0.20	○	27	△	48	△	3
Example 2	300	60	Circular	Drum	0.38	○	29	△	40	△	3
Example 3	300	60	Circular	Drum	0.41	○	35	○	35	△	4
Example 4	300	60	Circular	Drum	0.53	○	45	○	30	○	5
Example 5	300	60	Circular	Drum	0.70	○	40	○	30	○	5
Example 6	300	60	Circular	Drum	0.85	△	35	○	25	○	4
Example 7	300	60	Circular	Drum	1.00	△	30	○	20	○	4
Example 8	300	60	Circular	Drum	1.13	△	29	△	18	○	3
Example 9	200	60	Circular	Drum	0.25	○	25	△	45	△	3
Example 10	800	60	Circular	Drum	1.00	△	29	△	20	○	3
Example 11	300	30	Circular	Drum	0.53	○	35	○	35	△	4
Example 12	300	20	Circular	Drum	0.53	○	25	△	40	△	3
Example 13	300	60	Circular	Drum	0.58	○	45	○	30	○	5



## (2. Evaluation Items)

**[0089]** Ink was ejected with use of the inkjet heads shown in Comparative Examples 1 to 4 and Examples 1 to 13 in Table 1, and three-level (○, Δ, and ×) evaluation was performed based on the following criteria in terms of evaluation items of ink introducing performance, upper limit driving frequency (KHz), and overflow (liquid ratio) (%).

**[0090]** Furthermore, the flow path resistance of each inkjet head was calculated.

## &lt;Ink Introducing Performance&gt;

**[0091]** Ink was introduced at 7 KPa, and after three-time purge, a case in which the ratio of nozzles that cannot eject ink was over 10% was evaluated as x, a case in which the ratio was 5% or less was evaluated as Δ, and a case in which the ratio was zero was evaluated as ○.

## &lt;Driving Frequency (KHz)&gt;

**[0092]** Aqueous ink having viscosity resistance of 3 cp was used. A case in which the driving frequency was 20 KHz or higher was evaluated as Δ, a case in which the driving frequency was 30 KHz or higher was evaluated as ○, and the other case was evaluated as x.

## &lt;Overflow (Liquid Ratio) (%)&gt;

**[0093]** A difference between the liquid amount at 1 KHz and the liquid amount ejected from each of the inkjet heads shown in Comparative Examples 1 to 4 and Examples 1 to 13 in Table 1 was expressed as a liquid ratio (%). It is to be noted that, as the overflow is more significant, the liquid ratio (%) is higher, which is not preferable. A case in which the liquid ratio was 50% or less was evaluated as Δ, a case in which the liquid ratio was 30% or less was evaluated as ○, and the other case was evaluated as x.

## &lt;How To Calculate Flow Path Resistance&gt;

**[0094]** In a case of the drum shape illustrated in Fig. 5, the flow path resistance was calculated by calculating the flow path resistance on each of right and left sides of the through hole having a drum-shaped stereoscopic shape in accordance with the following equation (1) and adding up the two values.

$$\text{Flow path resistance } R = R_a + R_c \dots (1)$$

**[0095]** In this equation,  $R_a$  and  $R_c$  were calculated based on  $R_x$  in the following equation (2).

$$R_x = 128 / 3 \times 1.0 / \pi \times (L / (D2 - D1)) \times ((1 / D1)^3 - (1 / D2)^3) \times 1000 \dots (2)$$

**[0096]** In this equation,  $D1$ ,  $D2$ , and  $L$  represent the following values.

$D1$  = a diameter of a cross-section at a front end portion or a rear end portion ( $\mu\text{m}$ )

$D2$  = a diameter of a cross-section at a constricted portion ( $\mu\text{m}$ )

$L$  is a length from the surface A to the surface B or from the surface C to the surface B in Fig. 5 ( $\mu\text{m}$ )

**[0097]** Furthermore, in a case of the drum shape illustrated in Fig. 7A, the flow path resistance was calculated in accordance with the following equation (3).

$$\text{Flow path resistance } R = R_a + R_b + R_c \dots (3)$$

**[0098]** In this equation,  $R_a$ ,  $R_b$ , and  $R_c$  were calculated based on  $R_x$  in the above equation (2). At this time,  $L$  in  $R_a$  is a length from the surface A to the surface B1 in Fig. 7A,  $L$  in  $R_b$  is a length from the surface B1 to the surface B2 in Fig. 7A, and  $L$  in  $R_c$  is a length from the surface B2 to the surface C in Fig. 7A.

**[0099]** Furthermore, at the time of calculation of  $R_b$ , in a case in which the diameters of the surface B1 and the surface

B2 are totally equal, the flow path resistance of a cylinder is calculated. The flow path resistance was calculated with the diameter of the surface B1 set as  $D_{b1}$  and with the diameter of the surface B2 set as  $D_{b2} = D_{b1} + 0.1 \mu\text{m}$ .

### (3. Overall Evaluation)

**[0100]** Based on the results of the above evaluation items, overall evaluation was performed in accordance with the following criteria. It is to be noted that, when overall evaluation is 2 or less, practical use is difficult.

5 ... three circles (○)

4 ... two circles (○) and one triangle (Δ)

3 ... one circle (○) and two triangles (Δ)

2 ... one cross (×)

1 ... two or more crosses (×)

**[0101]** As is apparent from the above description, in a case in which the wiring board is provided with a through hole whose cross-section is circular and whose stereoscopic shape is a drum shape, and in which the flow path resistance of the through hole is approximately 0.2 or higher, the overflow restricting effect is high, and stable ink ejecting performance can be achieved.

**[0102]** Furthermore, in a case in which the thickness and the elastic modulus are under the same conditions, the overall evaluation is 4 or 5 when the flow path resistance is a value in a range of 0.4 or higher and 1.0 or lower, which is more favorable.

**[0103]** Furthermore, when the thickness of the wiring board is  $200 \mu\text{m}$  or more and  $800 \mu\text{m}$  or less, the overall evaluation is 3 or higher, which can achieve the effect of the present invention. When the thickness is less than  $200 \mu\text{m}$ , handling at the time of manufacture is difficult. When the thickness is more than  $800 \mu\text{m}$ , it takes time to form the through holes.

**[0104]** Furthermore, when the elastic modulus of the wiring board is 30 GPa or higher, more favorable overall evaluation can be obtained. When the elastic modulus of the wiring board is less than 30 GPa, internal resonance interferes in the through hole, ink ejection is slightly unstable, and the upper value of the driving frequency is lowered.

### Industrial Applicability

**[0105]** The present invention can be applied to an inkjet head, an inkjet recording apparatus, and a method for manufacturing an inkjet head.

### Reference Signs List

#### **[0106]**

H	inkjet head
1	head chip
1a	front surface
1b	rear surface
11	channel
11a	driving channel
11b	dummy channel
10A to 10D	channel row
12	driving wall
13	driving electrode
14	connecting electrode
110	opening
2	nozzle plate
21	nozzle
3	wiring board
3a, 3b	end portion
31	through hole
31a	front end portion
31b	constricted portion
31c	rear end portion
32	wiring electrode

4	manifold
5	external wiring member
100	inkjet recording apparatus
101	conveyance belt (supporting unit)
5 102	carriage rail (traveling unit)
103	carriage

## Claims

### 1. An inkjet head comprising:

a head chip including a channel and a nozzle ejecting ink in the channel and provided on a surface of a driving wall facing an inside of the channel with a driving electrode; and  
a board connected to a rear surface of the head chip to cover the channel, wherein the board is provided at a position thereof corresponding to the channel with a through hole adapted to introduce ink into the channel, and  
a constricted portion having a smaller cross-sectional area than those of the end portions is formed between end portions of the through hole in an ink introducing direction, and flow path resistance of the through hole is a value of 0.2 or higher.

2. The inkjet head according to claim 1, wherein the end portions and the constricted portion of the through hole are circular as seen in the ink introducing direction.

3. The inkjet head according to claim 1 or 2, wherein the flow path resistance of the through hole is a value in a range of 0.4 or higher and 1.0 or lower.

4. The inkjet head according to any one of claims 1 to 3, wherein an elastic modulus of the board is 30 GPa or more.

5. The inkjet head according to any one of claims 1 to 4, wherein, in the head chip, an outlet and an inlet of the channel are disposed to be opposed to each other on a front surface and a rear surface of the head chip.

6. The inkjet head according to any one of claims 1 to 5, wherein, in the head chip, the channel ejecting ink and a dummy channel ejecting no ink are alternately arranged via the driving wall, and the board has the through hole at a position corresponding to the channel ejecting ink.

7. The inkjet head according to any one of claims 1 to 6, wherein a thickness of the board is in a range of 200  $\mu\text{m}$  or more and 800  $\mu\text{m}$  or less.

8. The inkjet head according to any one of claims 1 to 7, wherein the board is a wiring board provided with a wiring electrode adapted to apply a driving signal to the driving electrode.

### 9. An inkjet recording apparatus comprising:

a supporting unit supporting a recording medium;  
the inkjet head according to any one of claims 1 to 8; and  
a traveling unit adapted to cause the recording medium or the inkjet head to travel.

### 10. A method for manufacturing the inkjet head according to any one of claims 1 to 8, comprising:

a through hole forming process of sandblasting both surfaces of a board main body of the board to form the through hole.

### 11. A method for manufacturing the inkjet head according to any one of claims 1 to 8, comprising:

a hole portion forming process of sandblasting either or both surfaces of each of a plurality of board main bodies of the board to form hole portions; and  
a through hole forming process of laminating the plurality of board main bodies having formed therein the hole

## EP 3 235 643 A1

portions so that the hole portions may overlap with each other to form the through hole of the board.

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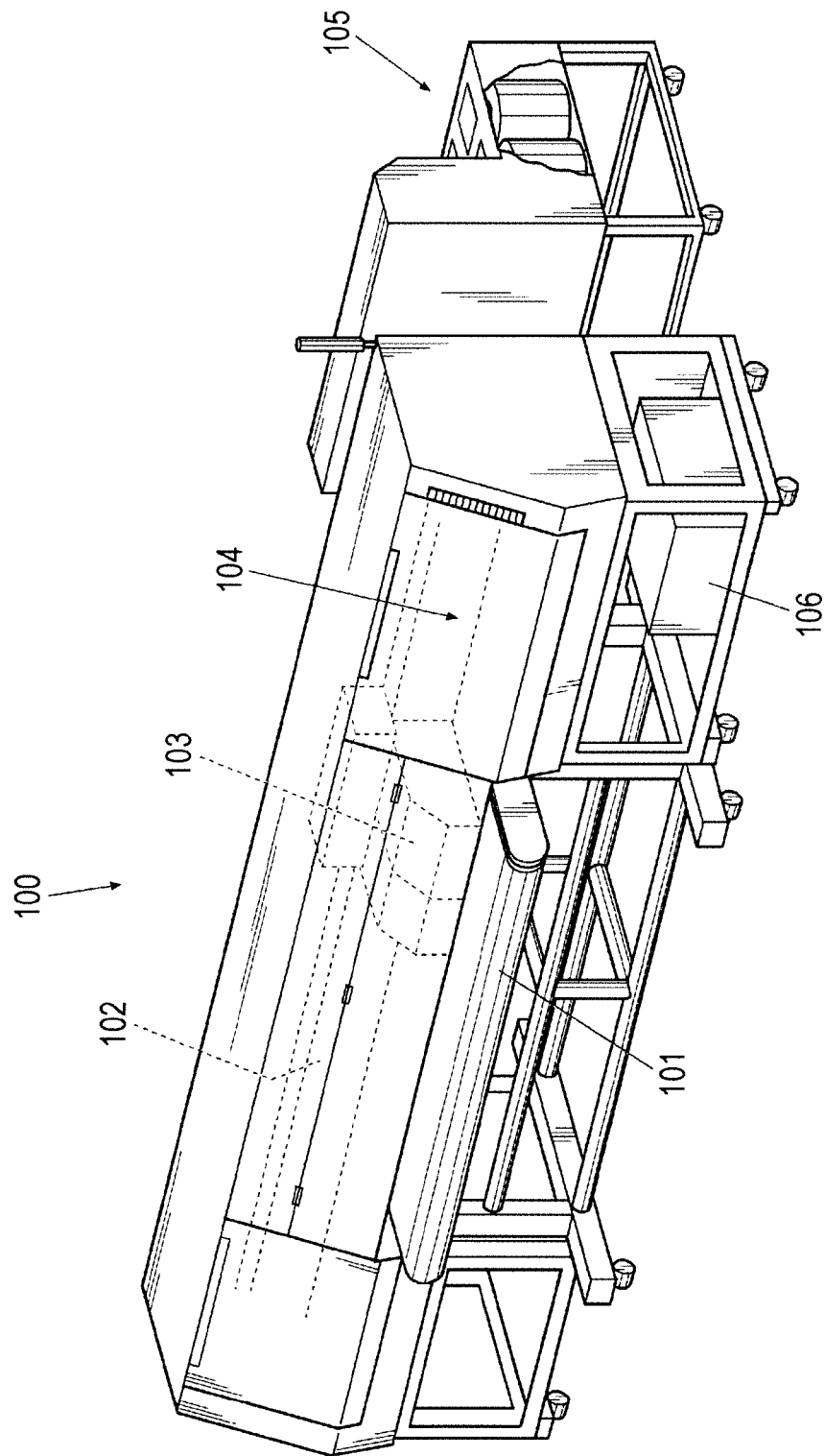
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FIG. 1



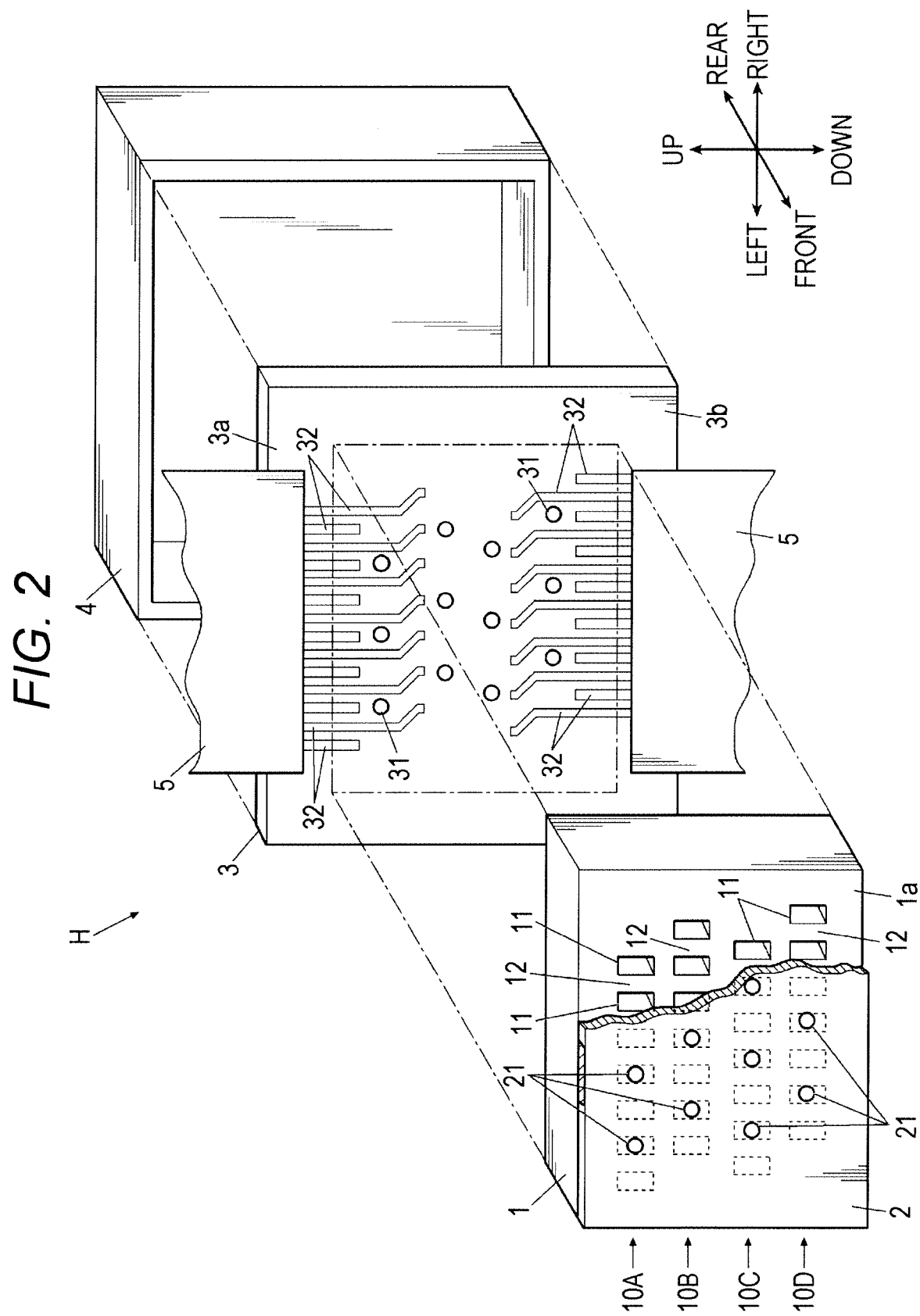


FIG. 3

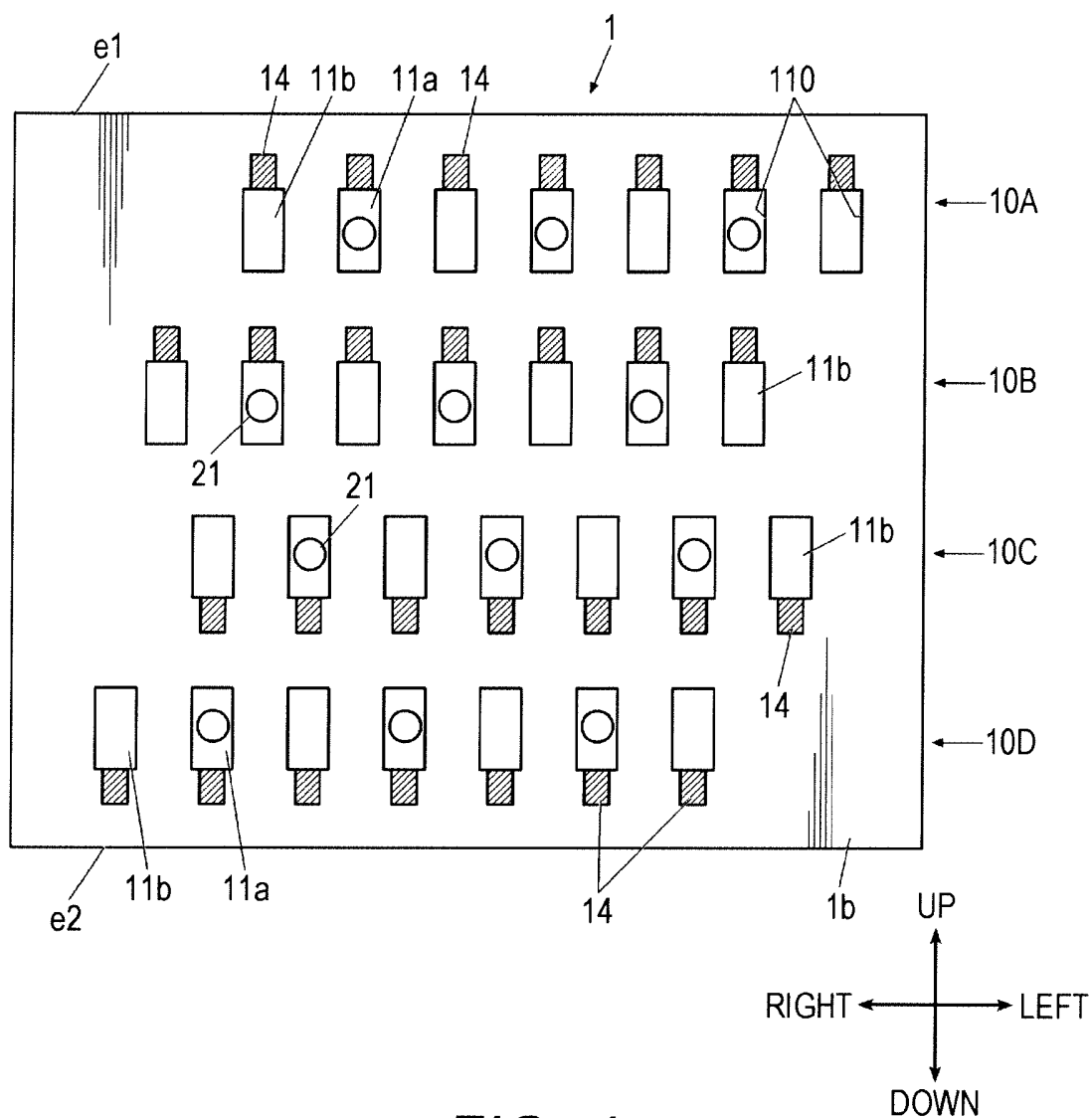
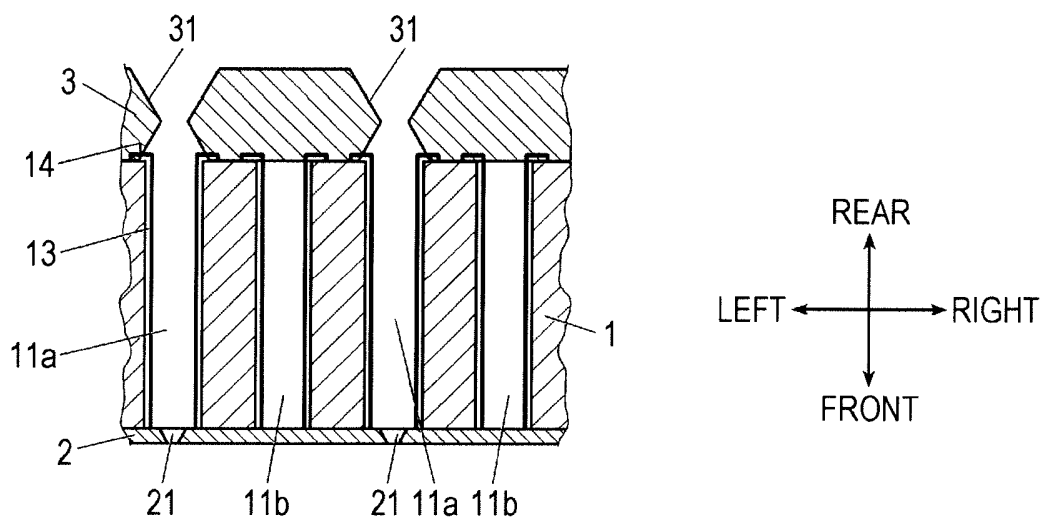
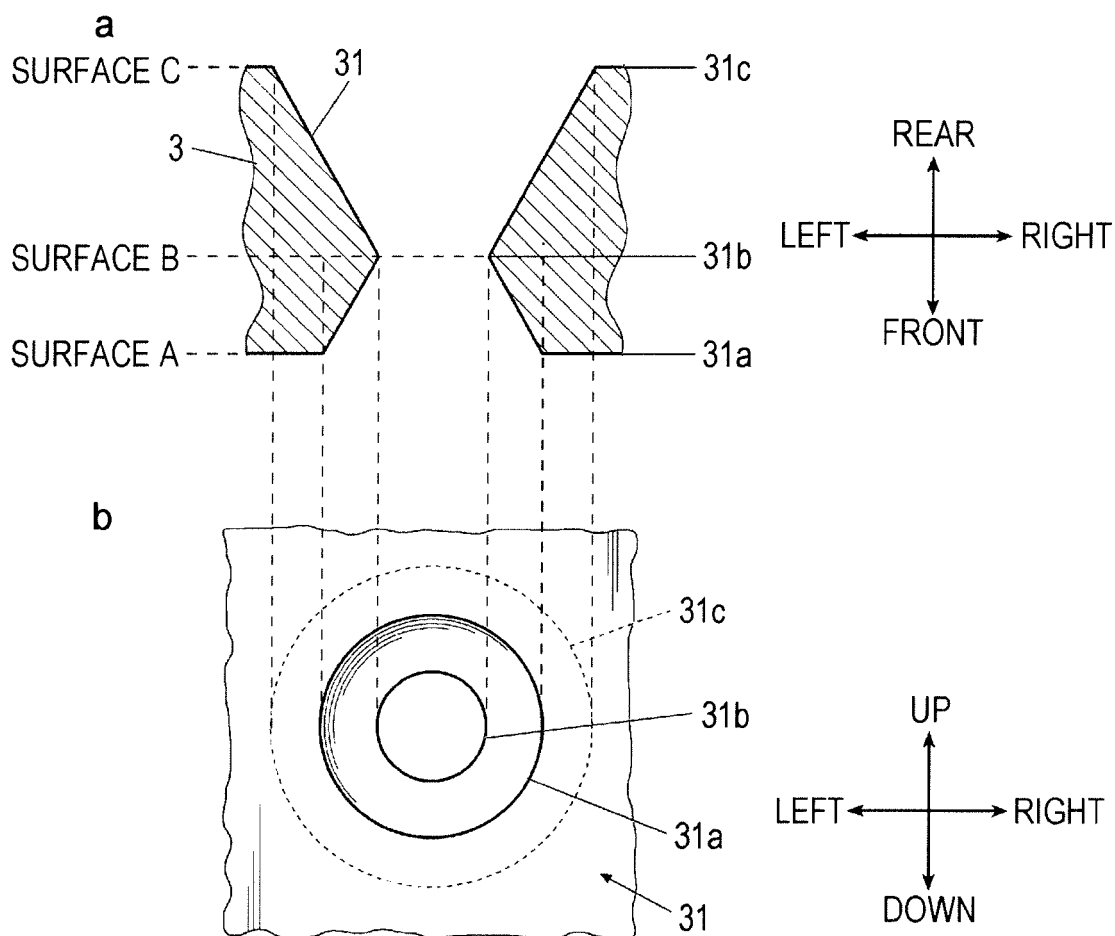


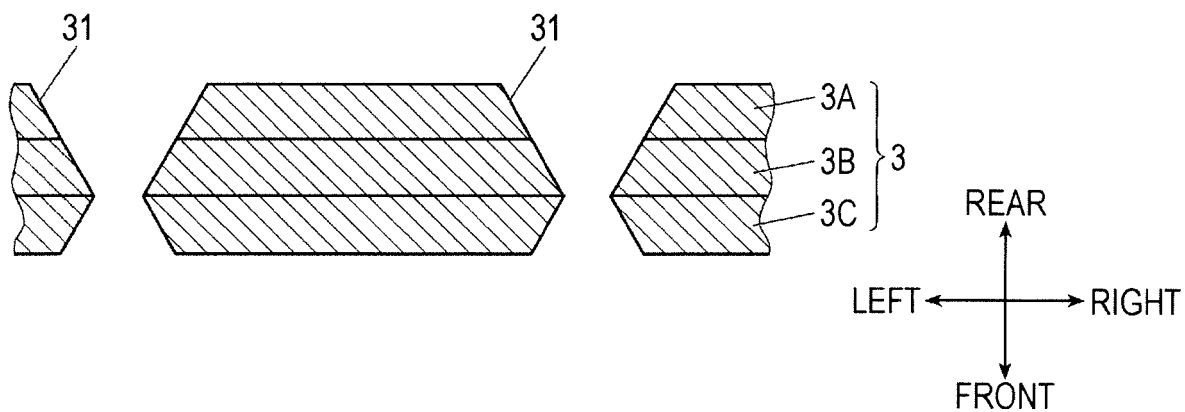
FIG. 4



**FIG. 5**

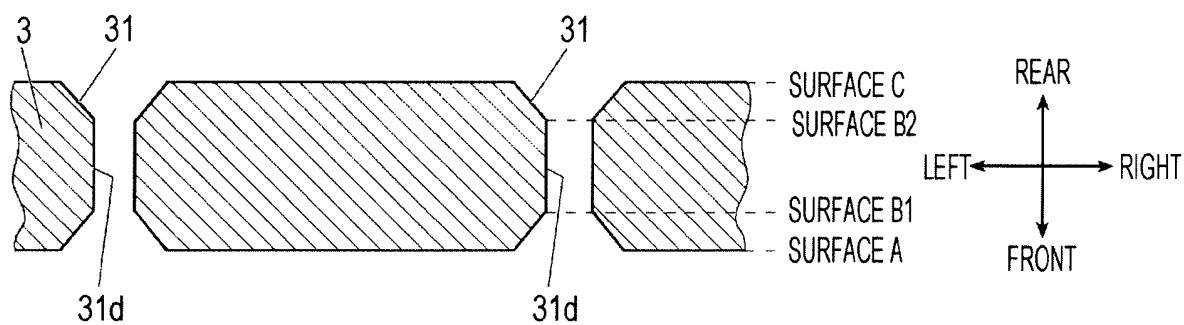


**FIG. 6**

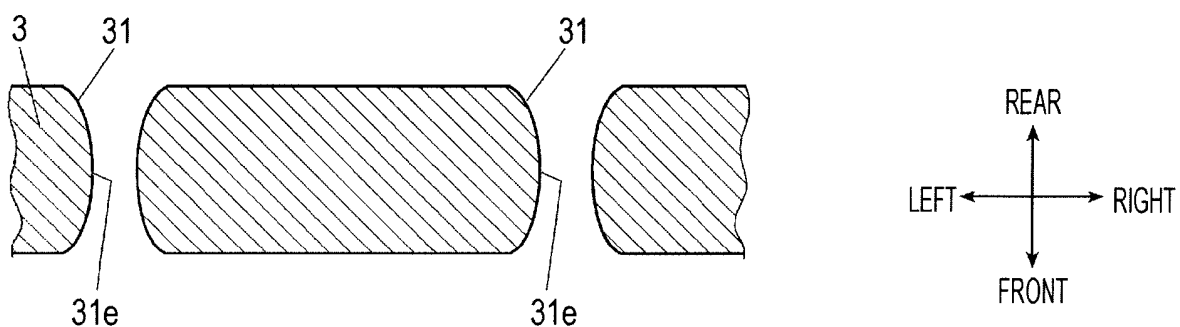




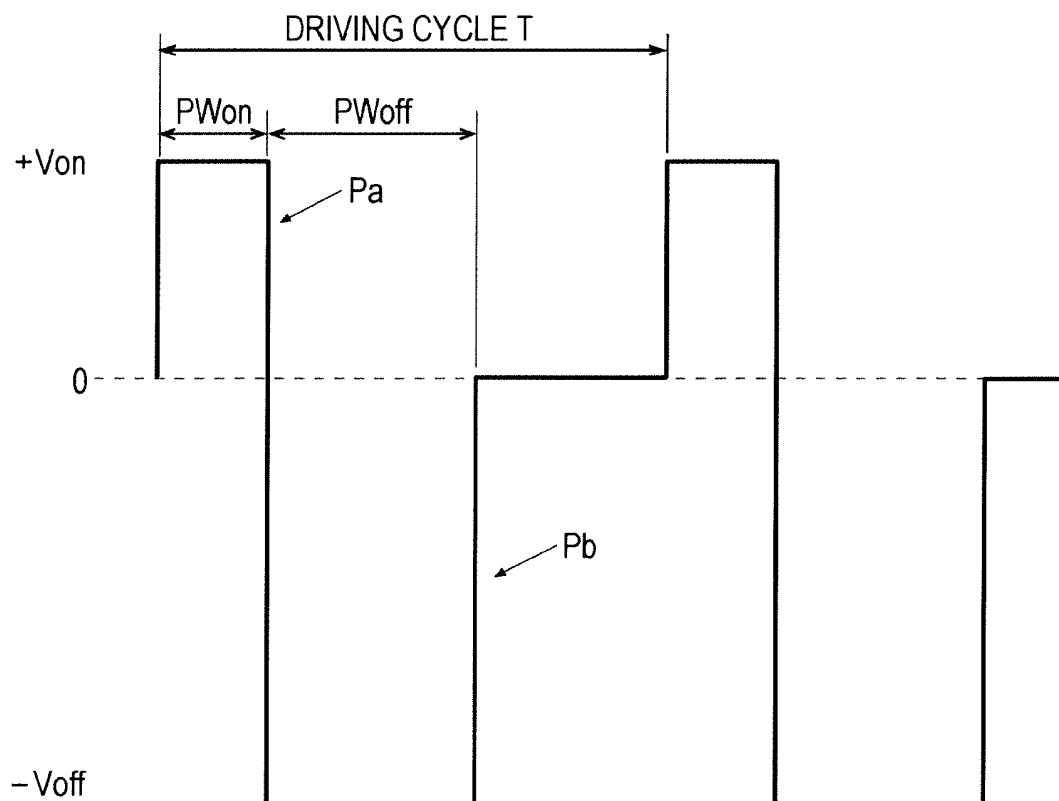
**FIG. 7A**



**FIG. 7B**



**FIG. 8**



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/084260

## A. CLASSIFICATION OF SUBJECT MATTER

B41J2/14(2006.01)i, B41J2/16(2006.01)i

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)

B41J2/14, B41J2/16

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2013/105403 A1 (Konica Minolta, Inc.), 18 July 2013 (18.07.2013), entire text; all drawings (Family: none)	1-11
A	JP 2012-131175 A (Konica Minolta IJ Technologies, Inc.), 12 July 2012 (12.07.2012), entire text; all drawings (Family: none)	1-11
A	JP 2004-167951 A (Ricoh Co., Ltd.), 17 June 2004 (17.06.2004), paragraph [0051]; fig. 12 (Family: none)	1-11

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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Date of the actual completion of the international search

28 January 2016 (28.01.16)

Date of mailing of the international search report

09 February 2016 (09.02.16)

Name and mailing address of the ISA/

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3-4-3, Kasumigaseki, Chiyoda-ku,

Tokyo 100-8915, Japan

Authorized officer

Telephone No.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/084260

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2012-152970 A (Seiko Epson Corp.), 16 August 2012 (16.08.2012), paragraph [0048]; fig. 9 (Family: none)	1-11

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

**REFERENCES CITED IN THE DESCRIPTION**

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