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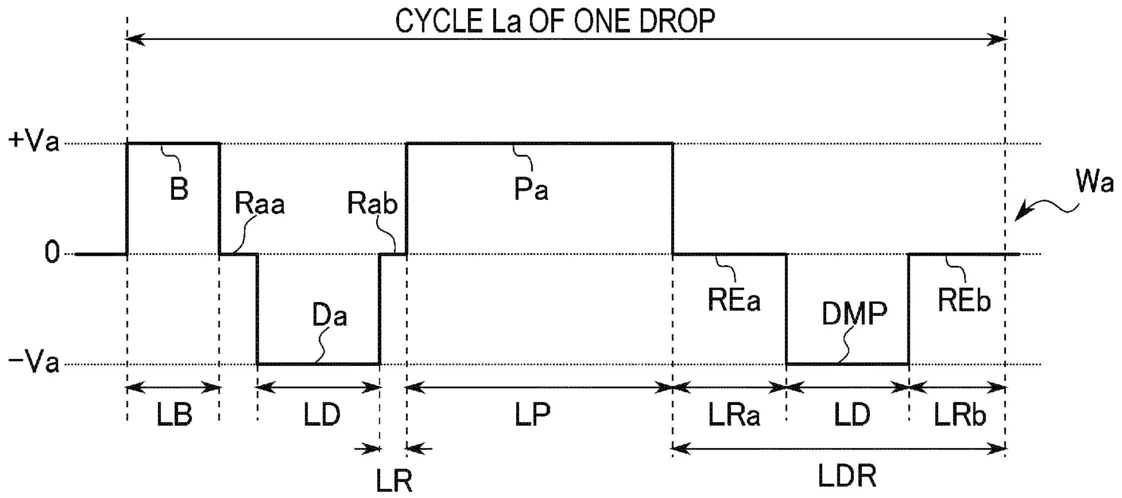
(54) LIQUID EJECTION HEAD AND LIQUID EJECTION DEVICE

(57) According to one embodiment, a drive signal includes an auxiliary pulse (B), an ejection pulse (Da), a cancel pulse (Pa), and a damping pulse (DMP), in this order. The auxiliary pulse drives an actuator so that the pressure is increased. The ejection pulse drives the actuator so that the pressure is reduced to eject the liquid. The cancel pulse drives the actuator so that the pressure is increased to suppress residual vibration of the liquid. The damping pulse drives the actuator so that the pressure is reduced to suppress the residual vibration. A pulse width of the auxiliary pulse is AL or less . A pulse width of the cancel pulse is 2 AL. A length from an end of the application of the cancel pulse to a start of the application of the damping pulse is 0.2 AL to 0.4 AL. A pulse width of the damping pulse is 0.2 AL to 0.4 AL.

FIG. 10



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Description

FIELD

[0001] Embodiments described herein relate to a liquid ejection head and a liquid ejection device.

BACKGROUND

[0002] A liquid ejection device (inkjet printer) equipped with a liquid ejection head (inkjet head) that ejects liquid such as ink from a nozzle is known. Such a liquid ejection head ejects a droplet by an operation of an actuator by application of a drive signal to the actuator. In the related art, in order to change an ejected droplet amount by a driving method of the liquid ejection head, a change of the head structure such as a change of the diameter of a nozzle and a change of the strength of the actuator to the different strength is required. If the shape of the nozzle is changed, the print quality is also changed, and thus it takes time to adjust the drive waveform.

DESCRIPTION OF THE DRAWINGS

[0003]

FIG. 1 is a block diagram illustrating an example of a main configuration of an inkjet recording device according to an embodiment;
FIG. 2 is a perspective view illustrating an example of an inkjet head in FIG. 1;
FIG. 3 is a schematic view of a liquid supply device in FIG. 1;
FIG. 4 is a plan view of a head substrate that can be applied to an inkjet head illustrated in FIG. 1;
FIG. 5 is a sectional view of the head substrate taken along line AA illustrated in FIG. 4;
FIG. 6 is a perspective view of the head substrate illustrated in FIG. 4;
FIG. 7 is a diagram illustrating a state of a pressure chamber;
FIG. 8 is a diagram illustrating a state in which one pressure chamber is expanded;
FIG. 9 is a diagram illustrating a state in which one pressure chamber is shrunk;
FIG. 10 is a diagram illustrating an example of a drive waveform according to the embodiment which is applied by a drive circuit to an actuator;
FIG. 11 is a diagram illustrating an example of a drive waveform in the related art which is applied by the drive circuit to the actuator;
FIG. 12 is a graph indicating pulse width-ejection volume characteristics of an auxiliary pulse;
FIG. 13 is a graph indicating the ejection volume for each number of drops with respect to the drive waveform of the embodiment and the drive waveform in the related art; and
FIG. 14 is a graph indicating the ejection speed for each number of drops with respect to the drive waveform of the embodiment and the drive waveform in the related art.

DETAILED DESCRIPTION

[0004] An object to be solved by the embodiment is to provide a liquid ejection head and a liquid ejection device that can change an ejection amount without changing a head structure.

[0005] In general, according to one embodiment, a liquid ejection head includes a pressure chamber, an actuator, and a drive circuit. The pressure chamber contains liquid. The actuator changes pressure of the liquid in response to an applied drive signal. The drive circuit applies, to the actuator, the drive signal including an auxiliary pulse, an ejection pulse, a cancel pulse, and a damping pulse, in this order. The auxiliary pulse drives the actuator so that the pressure is increased. The ejection pulse drives the actuator so that the pressure is reduced to eject the liquid from a nozzle that communicates with the pressure chamber. The cancel pulse drives the actuator so that the pressure is increased to suppress residual vibration of the liquid. The damping pulse drives the actuator so that the pressure is reduced to suppress the residual vibration. A pulse width of the auxiliary pulse is equal to or less than a half cycle of a main acoustic resonance frequency of a liquid in the pressure chamber. A pulse width of the cancel pulse is 2 times of the half cycle. A length from an end of the cancel pulse to a start of the damping pulse is 0.2 times to 0.4 times of the half cycle. The pulse width of the damping pulse is 0 .2 times to 0.4 times of the half cycle .

[0006] Preferably, the drive circuit continuously applies the drive signal to the actuator by the number of times of continuous ejection of the liquid, and a length from an end of the damping pulse to a start of the subsequent drive signal is 0.2 times to 0.4 times of the half cycle.

[0007] Preferably, a cycle of the drive signal is an odd multiple of the half cycle.

[0008] Preferably, a pulse width of the ejection pulse is the half cycle.

[0009] The invention also relates to a liquid ejection device comprising the abovementioned liquid ejection head and a liquid supplying device configured to supply the liquid to the pressure chamber of the liquid ejection head.

[0010] Hereinafter, an inkjet recording device according to an embodiment is described with reference to the drawings. In each drawing used for the description of the following embodiments, the scale of each part may be changed as appropriate. In addition, in each drawing used in the following embodiment, the configuration may be omitted for the sake of explanation. Further, in each drawing and in the present specification, the same reference numerals indicate similar elements.

[0011] FIG. 1 is a block diagram illustrating an example of a main configuration of an inkjet recording device 1 according to the embodiment.

[0012] The inkjet recording device 1 forms an image on an image forming medium S with a liquid recording material such as ink. For example, the inkjet recording device 1 includes a plurality of liquid ejection units 2, a head supporting mechanism 3 that movably supports the liquid ejection units 2, and a medium supporting mechanism 4 that movably supports the image forming medium S. For example, the image forming medium S is sheet-shaped paper. The inkjet recording device 1 is an example of a liquid ejection device.

[0013] As illustrated in FIG. 1, the plurality of liquid ejection units 2 are supported by the head supporting mechanism 3 in a state of being disposed in parallel in a predetermined direction. The head supporting mechanism 3 is attached to a belt 6 hung on a roller 5. The inkjet recording device 1 can move the head supporting mechanism 3 in a main deflection direction M orthogonal to a conveyance direction of the image forming medium S by rotating the roller 5. The liquid ejection unit 2 integrally includes an inkjet head 10 and a liquid supply device 20. The liquid ejection unit 2 performs an ejection operation by ejecting liquid I such as ink from the inkjet head 10. For example, the inkjet recording device 1 operates in a scanning method of forming a desired image on the facing image forming medium S by performing a liquid ejection operation while reciprocating the head supporting mechanism 3 in the main deflection direction M. Otherwise, the inkjet recording device 1 may operate in a single-pass method of performing a liquid ejection operation without moving the head supporting mechanism 3. In this case, the roller 5 and the belt 6 may not be provided. In this case, the head supporting mechanism 3 is fixed to, for example, the housing of the inkjet recording device 1 or the like. Further, in this case, the conveyance direction of the image forming medium S is, for example, the M direction. Further, the inkjet head 10 is an example of the liquid ejection head.

[0014] The plurality of liquid ejection units 2 respectively correspond to any one of four color ink of cyan, magenta, yellow, and key (black) (CMYK). That is, the plurality of liquid ejection units 2 respectively correspond to any one of cyan ink, magenta ink, yellow ink, and black ink. Also, each of the plurality of liquid ejection units 2 ejects the corresponding color ink. The liquid ejection units 2 can continuously eject one or a plurality of droplets of the corresponding color ink to one pixel on the image forming medium S. As the pixel has a larger number of times of the continuous ejection, the amount of the droplet landing to one pixel becomes larger. Accordingly, as the pixel has a larger number of times of the continuous ejection, the corresponding color becomes thicker. Therefore, the inkjet recording device 1 can express the gradation of the image formed on the image forming medium S.

[0015] FIG. 2 is a perspective view illustrating an example of the inkjet head 10. The inkjet head 10 includes nozzles 101, a head substrate 102, a drive circuit 103, and a manifold 104.

[0016] The manifold 104 includes an ink supply port 105 and an ink discharge port 106. The ink supply port 105 is a supply port for supplying the liquid I to the nozzles 101. The ink discharge port 106 is a discharge port of the liquid I. The nozzle 101 ejects droplets of the liquid I supplied from the ink supply port 105 in response to a drive signal from the drive circuit 103. The liquid I ejected from the nozzles 101 is discharged from the ink discharge port 106.

[0017] FIG. 3 is a schematic view of the liquid supply device 20 used in the inkjet recording device 1. The liquid supply device 20 is a device for supplying the liquid I to the inkjet head 10. The liquid supply device 20 includes a supply-side ink tank 21, a discharge-side ink tank 22, a supply-side pressure adjustment pump 23, a transport pump 24, a discharge-side pressure adjustment pump 25, and a supply pump 26. These are connected to each other by a tube through which the liquid I can flow.

[0018] The supply-side ink tank 21 is connected to the ink supply port 105 via a tube. The supply-side ink tank 21 supplies the liquid I to the ink supply port 105 of the inkjet head 10.

[0019] The discharge-side ink tank 22 is connected to the ink discharge port 106 via the tube. The discharge-side ink tank 22 temporarily stores the liquid I discharged from the ink discharge port 106 of the inkjet head 10

[0020] The supply-side pressure adjustment pump 23 adjusts the pressure of the supply-side ink tank 21.

[0021] The transport pump 24 causes the liquid I stored in the discharge-side ink tank 22 to flow back to the supply-side ink tank 21 via the tube.

[0022] The discharge-side pressure adjustment pump 25 adjusts the pressure of the discharge-side ink tank 22.

[0023] The supply pump 26 sends the liquid I in an ink cartridge 30 to the supply-side ink tank 21 of the liquid supply device 20.

[0024] The ink cartridge 30 includes a tank that can contain the liquid I. The ink cartridge 30 stores liquid information. The liquid information is information relating to the liquid I in the ink cartridge 30.

[0025] The inkjet head 10 is specifically described.

[0026] FIG. 4 is a plan view of the head substrate 102 that can be applied to the inkjet head 10. In FIG. 4, the internal structure of the head substrate 102 is illustrated with a part of the lower left portion of a nozzle plate 109 not illustrated. FIG. 5 is a sectional view of the head substrate 102 taken along line AA illustrated in FIG. 4. FIG. 6 is a perspective view of the head substrate 102 illustrated in FIG. 4.

[0027] As illustrated in FIGS. 4 and 5, the head substrate 102 includes a piezoelectric member 107, an ink flow path member 108, the nozzle plate 109, a frame member 110, and a plate wall 111. In the ink flow path member 108, an ink supply hole 112 and an ink discharge hole 113 are formed. A space that is surrounded by the ink flow path member 108, the nozzle plate 109, the frame member 110, and the plate wall 111 and in which the ink supply hole 112 is formed is an ink supply path 114. A space that is surrounded by the ink flow path member 108, the nozzle plate 109, the frame member 110, and the plate wall 111 and in which the ink discharge hole 113 is formed is an ink discharge path 117. The ink supply hole 112 communicates with the ink supply path 114. The ink discharge hole 113 communicates with the ink discharge path 117. The ink supply hole 112 is fluidly connected to the ink supply port 105 of the manifold 104. The ink discharge hole 113 is fluidly connected to the ink discharge port 106 of the manifold 104.

[0028] The piezoelectric member 107 has a plurality of long grooves from the ink supply path 114 to the ink discharge path 117. These long grooves become a portion of pressure chambers 115 or air chambers 116. The pressure chambers 115 and the air chambers 116 are formed one by one. That is, the piezoelectric member 107 is formed by alternating the pressure chambers 115 and the air chambers 116. The air chambers 116 are formed by blocking both ends of the long grooves with the plate wall 111. The blocking of the both ends of the long grooves with the plate wall 111 prevents the liquid I of the ink supply path 114 and the ink discharge path 117 from flowing into the air chambers 116. Grooves are formed in portions of the plate wall 111 that are in contact with the pressure chambers 115. Accordingly, the liquid I flows from the ink supply path 114 into the pressure chambers 115 and is discharged from the pressure chambers 115 to the ink discharge path 117. The pressure chambers 115 contain the inflow liquid I.

[0029] As illustrated in FIGS. 6 to 9, wiring electrodes 119 (1191, 1192, 1193, and the like) are formed in the piezoelectric member 107. Electrodes 120 described below are formed on the inner surfaces of the piezoelectric members of the pressure chambers 115 and the air chambers 116. The wiring electrodes 119 are electrically connected to the electrodes 120 and the drive circuit 103. The ink flow path member 108, the frame member 110, and the plate wall 111 are preferably configured, for example, with a material with a small dielectric constant and a small difference in thermal expansion coefficient from the piezoelectric member. For example, as the material, alumina (Al_2O_3), silicon nitride (Si_3N_4), silicon carbide (SiC), aluminum nitride (AlN), or lead zirconate titanate (PZT) can be used.

[0030] As illustrated in FIGS. 7 to 9, the piezoelectric member 107 is formed by stacking the piezoelectric member 1071 and the piezoelectric member 1072. FIGS. 7 to 9 are diagrams illustrating states of the pressure chamber. The polarization directions of the piezoelectric member 1071 and the piezoelectric member 1072 are opposite to each other along the plate thickness direction. In the piezoelectric member 107, a plurality of long grooves that connect the ink supply path 114 and the ink discharge path 117 are formed in parallel.

[0031] The electrodes 120 (1201, 1202, 1203, and the like) are formed on the inner surface of each long groove. Spaces surrounded by the long grooves and one surface of the nozzle plate 109 that covers the long grooves become the pressure chambers 115 and the air chambers 116. In the example of FIG. 7, spaces indicated by reference numerals of 1152, 1154, 1156, and the like are the pressure chambers 115, and spaces indicated by reference numerals of 1161, 1163, 1165, and the like are the air chambers 116.

[0032] As described above, the pressure chambers 115 and the air chambers 116 are alternately arranged. The electrodes 120 are connected to the drive circuit 103 via the wiring electrodes 119. The piezoelectric members 107 that configure the partition walls of the pressure chambers 115 are sandwiched by the electrodes 120 provided on the inner walls of the long grooves. The piezoelectric member 107 and the electrodes 120 configure actuators 118.

[0033] The drive circuit 103 applies an electric field to the actuators 118 by drive signals. In the same manner as the actuator 1184 and 1185 of FIG. 8, the actuators 118 are shear-deformed by the applied electric field with the joint portion between the piezoelectric member 1071 and the piezoelectric member 1072 as an apex. Due to the deformation of the actuators 118, the volumes of the pressure chambers 115 change. The liquid I inside the pressure chambers 115 is pressurized or depressurized by the change of the volumes of the pressure chambers 115. The liquid I is ejected from the nozzles 101 (1012, 1014, 1016, and the like) by the pressurization or depressurization. As the piezoelectric member 107, for example, lead zirconate titanate (PZT: Pb $(Zr,Ti)O_3$), lithium niobate ($LiNbO_3$), or lithium tantalate ($LiTaO_3$) can be used. Lead zirconate titanate (PZT) having a high piezoelectric constant is preferable.

[0034] The electrode 120 has, for example, a two-layer structure of nickel (Ni) and gold (Au) . The electrodes 120 are uniformly formed in the long grooves by, for example, a plating method. In addition to the plating method, as the method of forming the electrodes 120, a sputtering method or an evaporation method can be used. The long grooves in a shape of 1.5 to 2.5 [mm] in a longitudinal direction with a depth of 150.0 to 300.0 [μm], and a width of 30.0 to 110.0 [μm] are arranged in parallel at a pitch of 70 to 180 [μm]. As described above, the long grooves become a portion of the pressure chambers 115 or the air chambers 116. The pressure chambers 115 and the air chambers 116 are arranged in parallel.

[0035] The nozzle plates 109 are adhered onto the piezoelectric member 107. The nozzles 101 are formed in the central portion in the longitudinal direction with respect to the pressure chambers 115 of the nozzle plate 109. The material of the nozzle plate 109 is, for example, a polyimide film. Otherwise, the material of the nozzle plate 109 may be a metal material such as stainless steel, an inorganic material such as single crystal silicon, or a resin material such as a polyimide film.

[0036] The inkjet head 10 described above includes the ink supply path 114 at one ends of the pressure chambers 115, the ink discharge path 117 at the other ends thereof, and the nozzles 101 in the centers of the pressure chambers 115. The inkjet head 10 is not limited to the configuration example. For example, the inkjet head may include nozzles at one ends of the pressure chambers 115 and ink supply paths at the other ends thereof.

[0037] Subsequently, the operation principle of the inkjet head 10 according to the embodiment is described by using FIGS. 7 to 9.

[0038] FIG. 7 illustrates the head substrate 102 in the state in which a ground voltage is applied to all of the electrodes 120 via the wiring electrodes 119. In FIG. 7, all of the electrodes 120 have the same potential, and thus no electric field is applied to the actuators 1181 to 1188. Therefore, the actuators 1181 to 1188 are not deformed.

[0039] FIG. 8 illustrates the head substrate 102 in the state in which a voltage Va is applied only to the electrode 1204. In the state illustrated in FIG. 8, there is the potential difference between the electrode 1204 and the electrodes 1203 and 1205 adjacent to the electrode 1204. A voltage -Va is applied to the actuators 1184 and 1185. The actuators 1184 and 1185 are shear-deformed so that the volume of the pressure chamber 1154 is expanded by the applied potential difference. Here, if the voltage of the electrode 1204 returns from Va to the ground voltage, the actuators 1184 and 1185 return from the state of FIG. 8 to the state of FIG. 7.

[0040] In FIG. 9, the volume of the pressure chamber 1154 is reduced. In FIG. 9, the actuators 1184 and 1185 are deformed to a shape opposite to the state illustrated in FIG. 8.

[0041] FIG. 9 illustrates the head substrate 102 in a state in which the electrode 1204 is set to the ground voltage, and the voltage Va is applied only to the electrodes 1203 and 1205. In the state illustrated in FIG. 9, a potential difference (opposite electric field) opposite to that in FIG. 8 occurs between the electrode 1204 and the electrodes 1203 and 1205 adjacent to the electrode 1204. The voltage Va is applied to the actuators 1184 and 1185. The actuators 1184 and 1185 are shear-deformed in a direction opposite to the shape illustrated in FIG. 8 due to the applied potential difference. Here, if the voltages of the electrodes 1203 and 1205 return from Va to the ground voltage, the actuators 1184 and 1185 return from the state of FIG. 9 to the state of FIG. 7.

[0042] In the case of the transition from the state of FIG. 8 to the state of FIG. 7 and the case of the transition from the state of FIG. 7 to the state of FIG. 9, the volumes of the pressure chambers 115 decrease so that the pressures of the liquid I in the pressure chambers 115 increase, and droplets are ejected from the nozzles 101.

[0043] A method of applying a voltage for deforming the pressure chamber 1154 is not limited to the examples of FIGS. 7 to 9.

[0044] For example, the drive circuit 103 applies the same voltage as the voltage Va or the like to the electrodes 1203 to 1205, that is, causes the electrodes 1203 to 1205 to have the same potential. Accordingly, the actuators 1184 and 1185 are in an undeformed state. In this case, the pressure chamber 1154 is in an undeformed state.

[0045] For example, the drive circuit 103 applies the ground voltage to the electrode 1204 and applies the negative voltage -Va to the electrodes 1203 and 1205 adjacent thereto. Accordingly, the voltage -Va is applied to the actuators 1184 and 1185 in the same manner as in the case of FIG. 8. Also, the actuators 1184 and 1185 are deformed so as to expand the volume of the pressure chamber 1154 in the same manner as in the case of FIG. 8. For example, the drive circuit 103 applies the positive voltage Va/2 to the electrode 1204 and applies the negative voltage -Va/2 to the electrodes 1203 and 1205 adjacent thereto. Accordingly, the voltage -Va is applied to the actuators 1184 and 1185 in the same manner as in the case of FIG. 8. Also, the actuators 1184 and 1185 are deformed so that the volume of the pressure chamber 1154 is expanded in the same manner as in the case of FIG. 8.

[0046] For example, the drive circuit 103 applies the negative voltage -Va to the electrode 1204 and applies the ground voltage to the electrodes 1203 and 1205 adjacent thereto. Accordingly, the voltage Va is applied to the actuators 1184 and 1185 in the same manner as in the case of FIG. 9. The actuators 1184 and 1185 are deformed so that the volume of the pressure chamber 1154 is shrunk in the same manner as in the case of FIG. 9. For example, the drive circuit 103 applies the negative voltage -Va/2 to the electrode 1204 and applies the voltage Va/2 to the electrodes 1203 and 1205 adjacent thereto. According to this, the voltage Va is applied to the actuators 1184 and 1185 in the same manner as in the case of FIG. 9. The actuators 1184 and 1185 are deformed so that the volume of the pressure chamber 1154 is shrunk in the same manner as in the case of FIG. 9.

[0047] From the above, the drive circuit 103 is an example of an application unit that applies a drive signal to the actuator 118.

[0048] FIG. 10 is a diagram illustrating an example of a drive waveform Wa according to the embodiment which is applied by the drive circuit 103 to the actuator 118. The drive waveform Wa indicates the waveform for one time of the droplet ejection. A drive waveform in a case where droplets are continuously ejected a plurality of times is formed by continuously repeating the drive waveform Wa by the number of times of the ejection. The drive waveform Wa includes an auxiliary pulse B, a holding element Raa, an ejection pulse Da, a holding element Rab, a cancel pulse Pa, and a damping waveform. The damping waveform is configured with a holding element REa, a damping pulse DMP, and a holding element REb.

[0049] The auxiliary pulse B is a square wave pulse of the voltage Va applied to the actuator 118 in order to generate pressure vibration for promoting the droplet ejection. The auxiliary pulse B is the reduction pulse for increasing the pressure in the pressure chamber 115 by reducing the volume of the pressure chamber 115. A pulse width LB of the auxiliary pulse B is 1 AL or less. This is because, if the pulse width LB is 1 AL or less, the pulse width of the pressure vibration of the liquid I in the pressure chamber 115 can be increased. The droplet ejection amount can be changed by changing the pulse width of the auxiliary pulse B. The pulse width is the time from the start of the application of the pulse to the end of the application. AL is the time of a half of a natural vibration cycle (a cycle in a main acoustic resonance frequency) of the liquid I in the pressure chamber 115 (half cycle). AL is an abbreviation of an acoustic length.

[0050] The holding element Raa indicates a period when a voltage 0 is applied to the actuators 118 from the end of the application of the auxiliary pulse B to the start of the application of the ejection pulse Da.

[0051] The ejection pulse Da is a square wave pulse of the voltage -Va that is applied to the actuator 118 for the droplet ejection. The ejection pulse Da is an expansion pulse for reducing the pressure in the pressure chamber 115 by expanding the volume of the pressure chamber 115. A pulse width LD of the ejection pulse Da is preferably 1 AL. This is because the droplet ejection force is increased.

[0052] The holding element Rab indicates a period when the voltage 0 is applied to the actuator 118 from the end of the application of the ejection pulse Da to the start of the application of the cancel pulse Pa. A length LR of the period of the holding element Rab is preferably the minimum time when the drive circuit 103 can apply the voltage 0 to the actuator 118. The corresponding minimum time depends on, for example, the performance of the drive circuit 103.

[0053] The cancel pulse Pa is a square wave pulse of the voltage Va applied to the actuator 118 for suppressing the residual vibration. The cancel pulse Pa is a reduction pulse that increases the pressure in the pressure chamber 115 by reducing the volume of the pressure chamber 115. A pulse width LP of the cancel pulse Pa is preferably 2 AL. This is because the residual vibration can be effectively suppressed.

[0054] The damping waveform is a waveform that is applied to the actuator 118 for suppressing the residual vibration.

[0055] The holding element REa indicates a period when the voltage 0 is applied to the actuator 118 from the end of the application of the cancel pulse Pa to the start of the application of the damping pulse DMP. A length LRa of the period of the holding element REa is preferably 0.2 AL to 0.4 AL. If the length LRa is 0.2 AL to 0.4 AL, the residual vibration can be effectively suppressed. If the length LRa has a value close to 1 AL, the residual vibration increases in some cases, and thus the length LRa is set to the time shorter than 1 AL.

[0056] The damping pulse DMP is a square wave pulse of the voltage -Va applied to the actuator 118. The damping pulse DMP is an expansion pulse for reducing the pressure in the pressure chamber 115 by expanding the volume of the pressure chamber 115. The pulse width LD of the damping pulse DMP is preferably 0.2 AL to 0.4 AL.

[0057] The holding element REb indicates a period when the voltage 0 is applied to the actuator 118 from the end of the application of the damping pulse DMP to the end of the application of the drive waveform Wa. If the drive waveform Wa is continuously applied subsequent to the drive waveform Wa, the holding element REb indicates a period when the voltage 0 is applied to the actuator 118 from the end of the application of the damping pulse DMP to the start of the application of the auxiliary pulse B of the subsequent drive waveform Wa. A length LRb of the period of the holding element REb is preferably 0.2 AL to 0.4 AL.

[0058] A length LDR of the damping waveform is preferably 1 AL or less. The length LDR is a length of the total period of the length LRa, the pulse width LD, and the length LRb.

[0059] A cycle La of the drive waveform Wa is preferably an odd multiple of AL and more preferably 5 AL.

[0060] FIG. 11 is a diagram illustrating an example of a drive waveform Wb in the related art which is applied by the drive circuit 103 to the actuator 118. The drive waveform Wb indicates a waveform for one time of the droplet ejection. The drive waveform in a case where droplets are continuously ejected a plurality of times is formed by continuously repeating the drive waveform Wa by the number of times of the ejection. The drive waveform Wa includes an ejection pulse Db, a holding element Rb, and a cancel pulse Pb.

[0061] The ejection pulse Db is a square wave pulse of the voltage -Va applied to the actuator 118 for the droplet ejection. The ejection pulse Da is an expansion pulse for reducing the pressure in the pressure chamber 115 by expanding the volume of the pressure chamber 115. The pulse width of the ejection pulse Db is 1 AL.

[0062] The holding element Rb indicates a period when the voltage 0 is applied to the actuator 118 from the end of the application of the ejection pulse Db to the start of the application of the cancel pulse Pb.

[0063] The cancel pulse Pb is a square wave pulse of the voltage Va applied to the actuator 118 for suppressing the residual vibration. The cancel pulse Pb is a reduction pulse for increasing the pressure in the pressure chamber 115 by reducing the volume of the pressure chamber 115.

[Examples]

[0064] An embodiment for carrying out the above embodiment is described with reference to an example. The example does not limit the scope of the above embodiment.

[0065] The drive waveform Wa with LD = 2.55 [μs], LR = 0.2 [μs], LP = 5.10 [μs], LRa = 0.85 [μs], LD = 0.85 [μs], and LRb = 0.65 [μs] is applied to the inkjet head 10 of the example. In the example, 1 AL = 2.55 [μs]. In this case, the volume of the droplet ejected if the pulse width

LB of the auxiliary pulse B changes variously is illustrated in FIG. 12. FIG. 12 is a graph indicating pulse width-ejection volume characteristics of an auxiliary pulse. As illustrated in FIG. 12, as the pulse width LB is longer, the droplet ejection volume becomes larger.

[0066] The drive waveform Wa with LB = 1.40 [μs], LD = 2.55 [μs], LR = 0.2 [μs], LP = 5.10 [μs], LRa = 0.85 [μs], LD = 0. 85 [μs], and LRb = 0.65 [μs] is applied to the inkjet heads 10 of the example. The drive waveform Wb in the related art as a comparative example is applied to the inkjet head 10. In this case, the ejection volumes of droplets for each number of drops with respect to the respective drive waveforms are indicated in FIG. 13. The ejection speeds of the droplets for each number of drops with respect to the respective drive waveforms in this case are indicated in FIG. 14. FIG. 13 is a graph indicating the ejection volume for each number of drops with respect to the drive waveform of the embodiment and the drive waveform in the related art. FIG. 14 is a graph indicating the ejection speed for each number of drops with respect to the drive waveform of the embodiment and the drive waveform in the related art. The number of drops indicates the number of times of the continuous ejection of the droplets.

[0067] As illustrated in FIG. 13, it is understood that, in the drive waveform Wa of the embodiment, the ejection volume increases in proportion to the number of drops in the same manner as in the drive waveform Wb in the related art. Accordingly, the inkjet head 10 of the embodiment can express stable gradation by using the drive waveform Wa of the embodiment.

[0068] As illustrated in FIG. 14, it is understood that, in the drive waveform Wa of the embodiment, the ejection speed is in the same level regardless of the number of drops in the same manner as in the drive waveform Wb in the related art. Accordingly, the inkjet head 10 of the embodiment can perform stable ejection by using the drive waveform Wa of the embodiment.

[0069] The above embodiment can be deformed as follows.

[0070] The inkjet recording device 1 of the embodiment is an inkjet printer for forming a two-dimensional image with ink on the image forming medium S. However, the inkjet recording device of the embodiment is not limited thereto. The inkjet recording device of the embodiment may be, for example, a 3D printer, an industrial manufacturing machine, or a medical machine. If the inkjet recording device of the embodiment is a 3D printer, an industrial manufacturing machine, a medical machine, or the like, the inkjet recording device of the embodiment forms a three-dimensional object, for example, by ejecting a substance to be a raw material, a binder for solidifying the raw material, or the like from the inkjet head.

[0071] The inkjet recording device 1 of the embodiment includes four liquid ejection units 2, and colors of the liquid I respectively used by the liquid ejection units 2 are cyan, magenta, yellow, and black. However, the number of the liquid ejection units 2 included in the inkjet recording device is not limited to four, and may not be plural. The colors and characteristics of the liquid I respectively used by the liquid ejection units 2 are not limited.

[0072] The liquid ejection unit 2 can eject transparent glossy ink, ink that develops color when irradiated with infrared rays, ultraviolet rays, or the like, or other special ink. Further, the liquid ejection unit 2 may be a unit that can eject liquid other than ink. The liquid I ejected by the liquid ejection unit 2 may be dispersion liquid such as a suspension. Examples of the liquid other than the ink ejected by the liquid ejection unit 2 include liquid containing conductive particles for forming a wiring pattern of a printed wiring substrate, liquid containing cells for artificially forming a tissue or an organ, a binder such as an adhesive, wax, and a liquid resin.

[0073] In addition to the embodiment, the inkjet head 10 may have, for example, a structure of ejecting ink by deforming a diaphragm with static electricity or a structure of ejecting ink from a nozzle by using thermal energy of a heater or the like. In these cases, the diaphragm, the heater, or the like is an actuator that changes the pressure of ink in the pressure chamber.

[0074] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions . Indeed, the novel embodiment described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the scope of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope of the inventions.

Claims

1. A liquid ejection head comprising:

a pressure chamber configured to contain liquid;
an actuator configured to change pressure of the liquid in response to an applied drive signal; and
a drive circuit configured to apply, to the actuator, the drive signal including an auxiliary pulse for driving the actuator so that the pressure is increased, an ejection pulse for driving the actuator so that the pressure is reduced to eject the liquid from a nozzle that communicates with the pressure chamber, a cancel pulse for driving the actuator so that the pressure is increased to suppress residual vibration of the liquid, and a damping pulse for driving the actuator so that the pressure is reduced to suppress the residual vibration, in this order,
wherein a pulse width of the auxiliary pulse is equal to or less than a half cycle of a main acoustic resonance frequency of the liquid in the pres-

sure chamber,
a pulse width of the cancel pulse is two times of the half cycle,
a length from an end of the cancel pulse to a start of the damping pulse is 0.2 times to 0.4 times of the half cycle, and
a pulse width of the damping pulse is 0.2 times to 0.4 times of the half cycle.

2. The liquid ejection head according to claim 1, wherein the drive circuit continuously applies the drive signal to the actuator by the number of times of continuous ejection of the liquid, and
a length from an end of the damping pulse to a start of the subsequent drive signal is 0.2 times to 0.4 times of the half cycle.

3. The liquid ejection head according to claim 1 or 2, wherein a cycle of the drive signal is an odd multiple of the half cycle.

4. The liquid ejection head according to any one of claims 1 to 3,
wherein a pulse width of the ejection pulse is the half cycle.

5. A liquid ejection device comprising:

the liquid ejection head according to any one of claims 1 to 4; and
a liquid supplying device configured to supply the liquid to the pressure chamber of the liquid ejection head.

FIG. 1

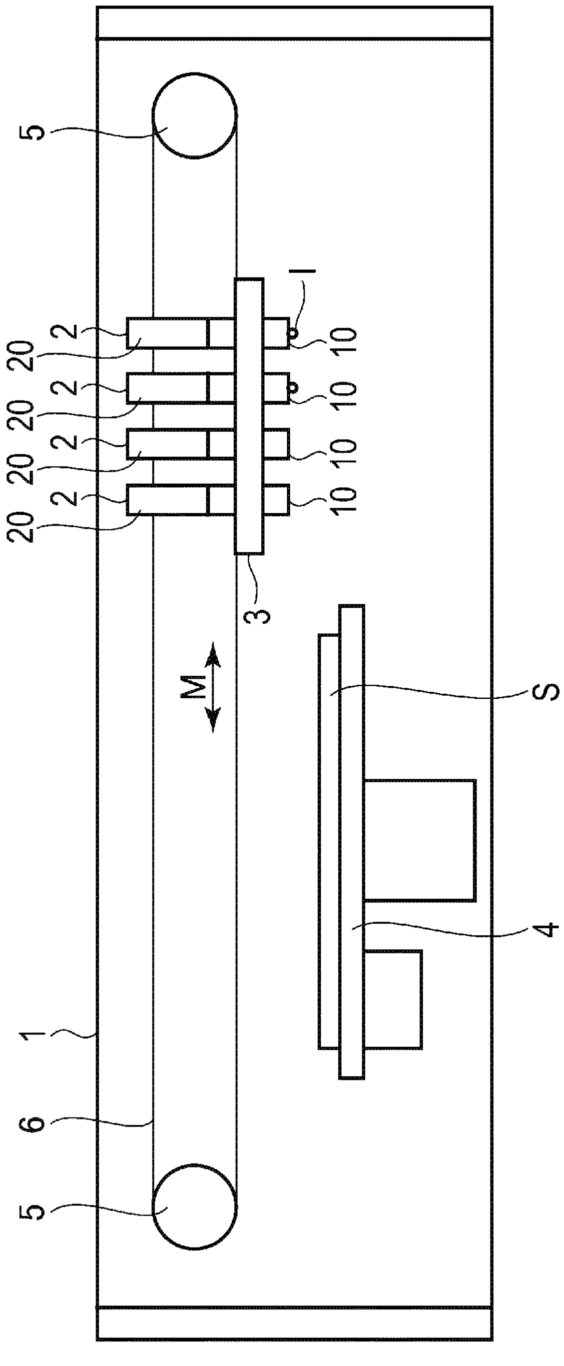


FIG. 2

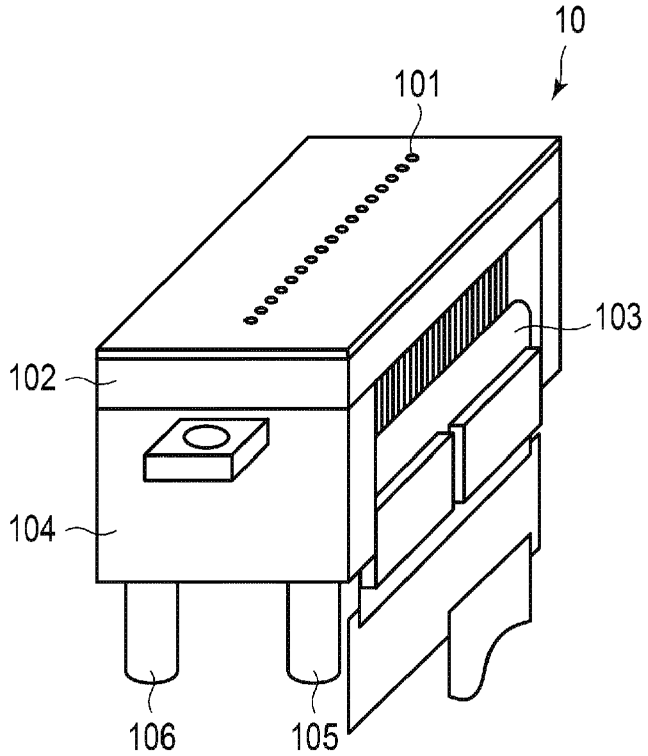


FIG. 3

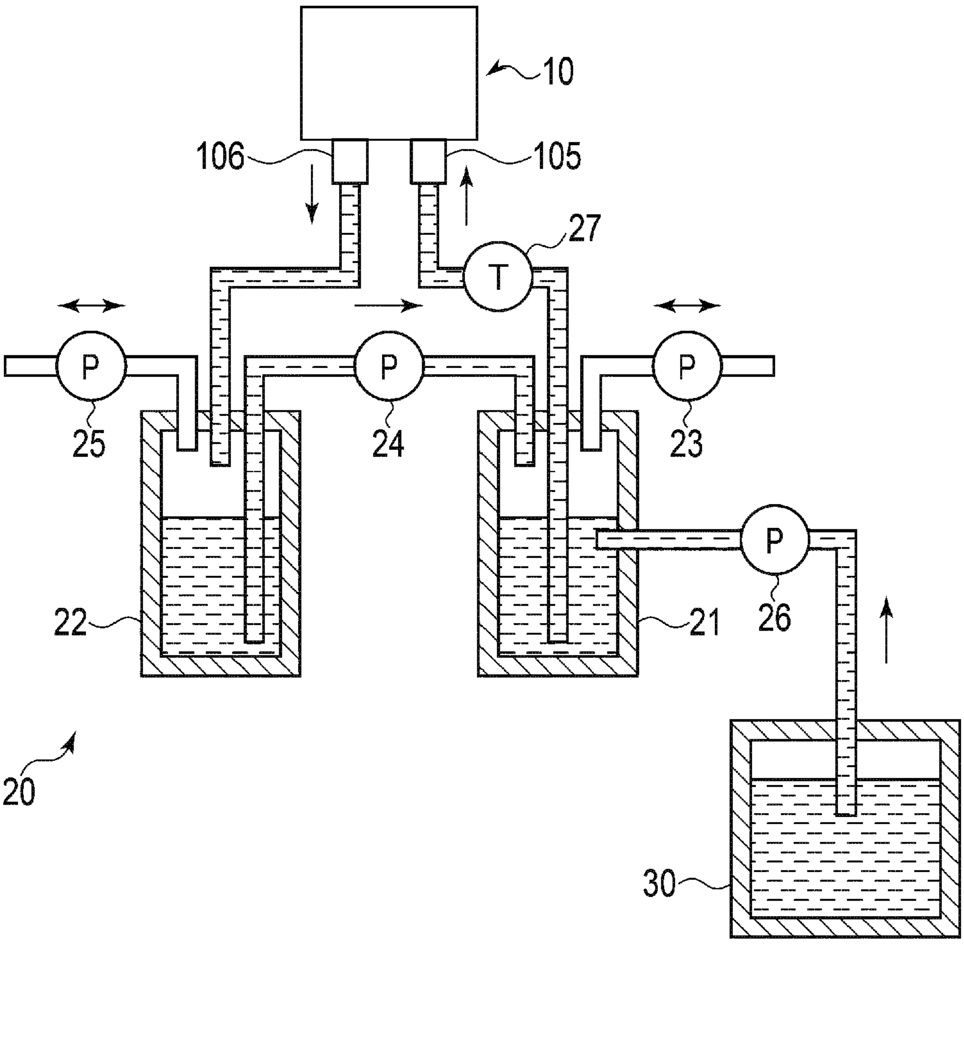
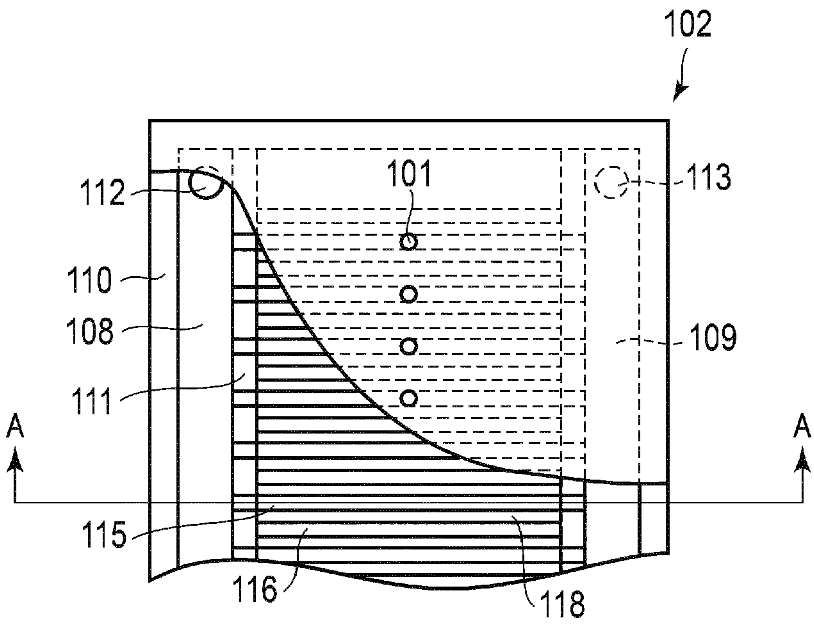


FIG. 4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109
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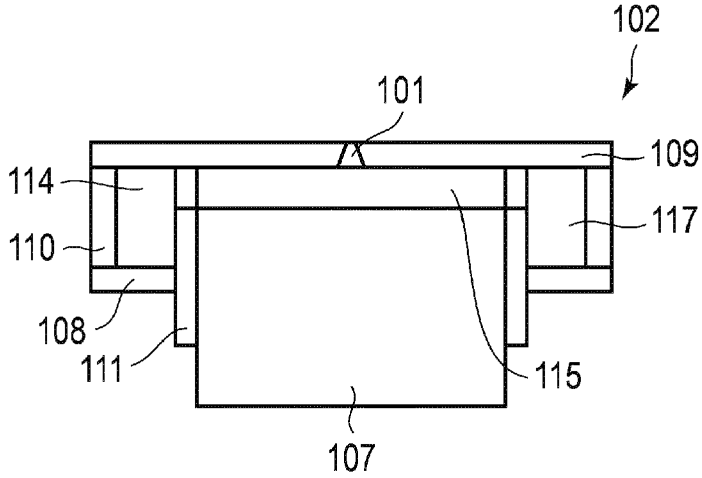
A
A
115
116
118

FIG. 5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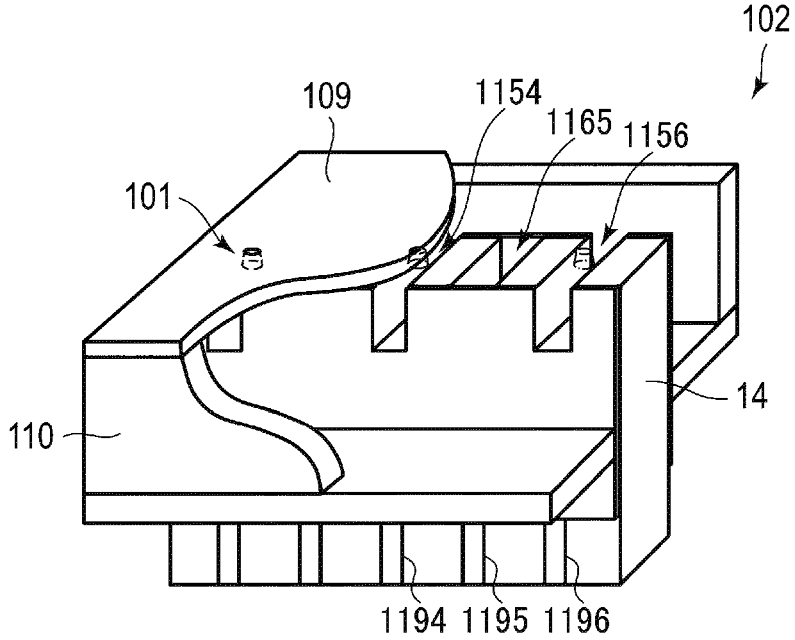
107

A-A

FIG. 6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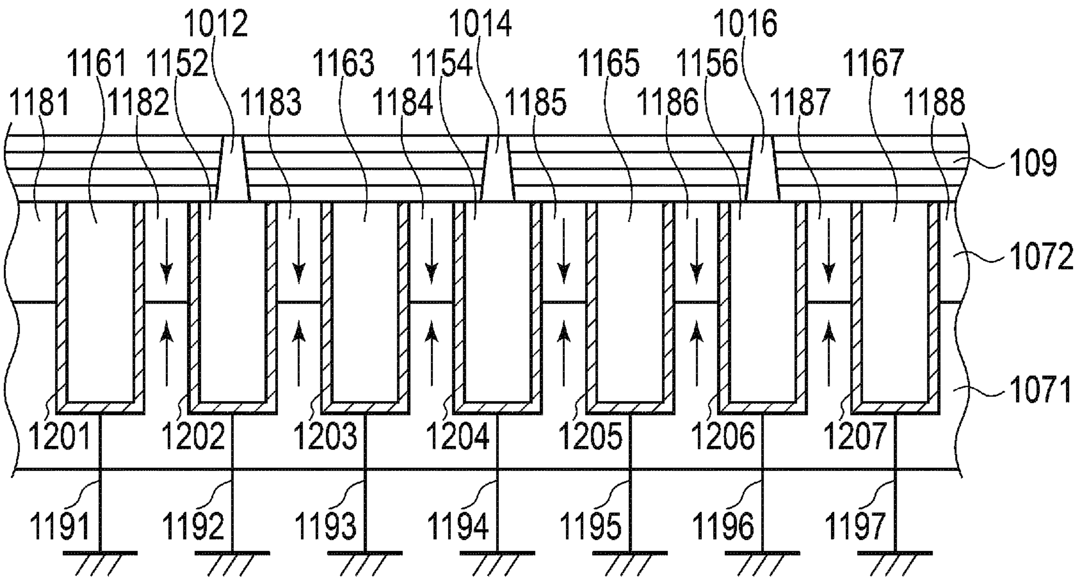
101
14
110
1194
1195
1196

FIG. 7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1187
1188
109
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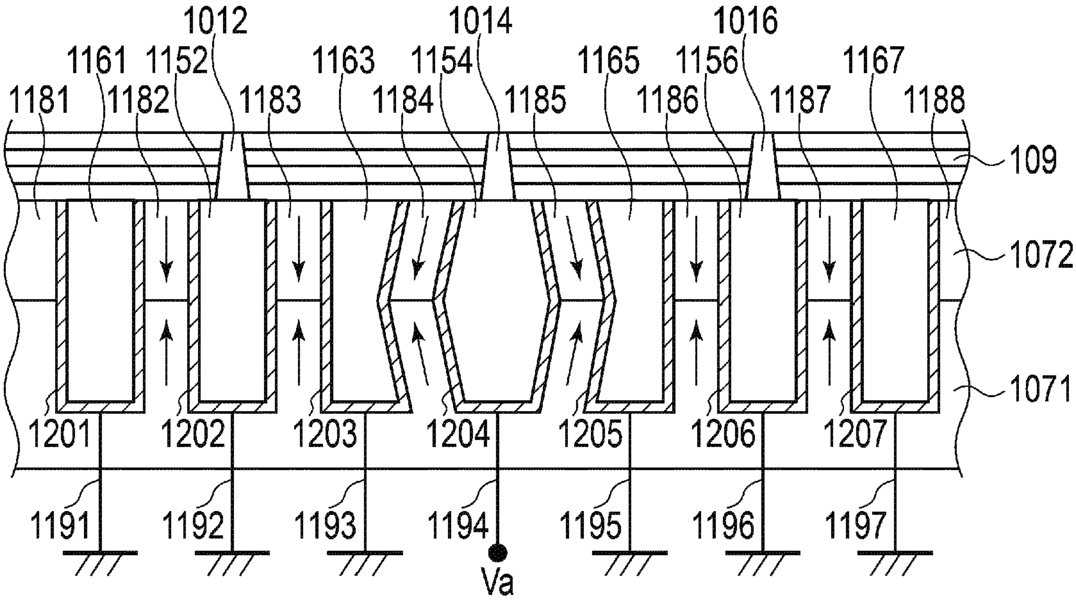
FIG. 8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1071
1201
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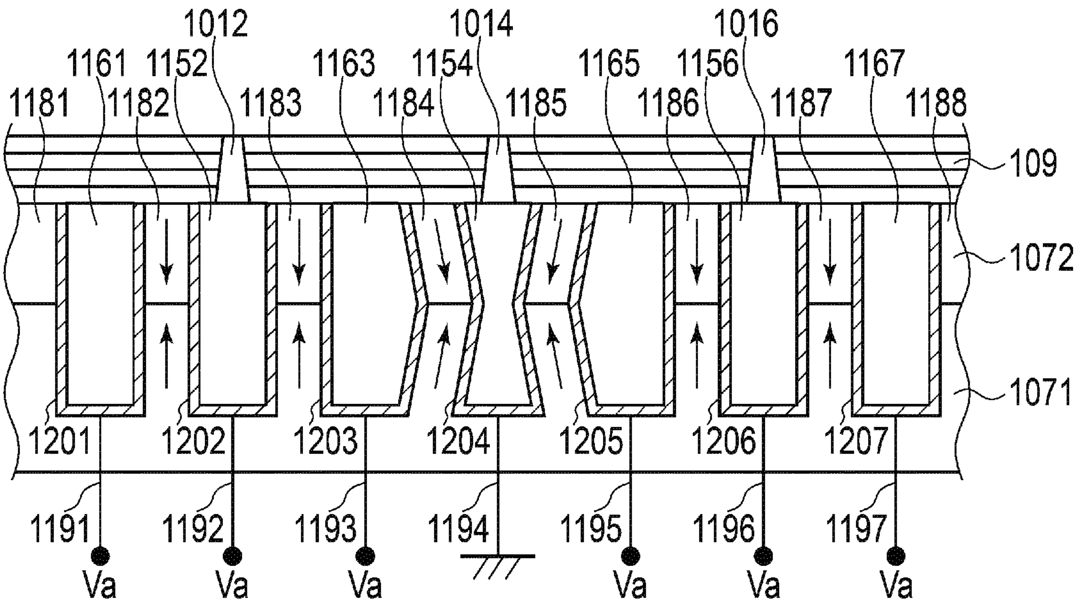
1197
Va

FIG. 9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1071
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1204
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Va
Va
Va
Va
Va
Va

FIG. 10

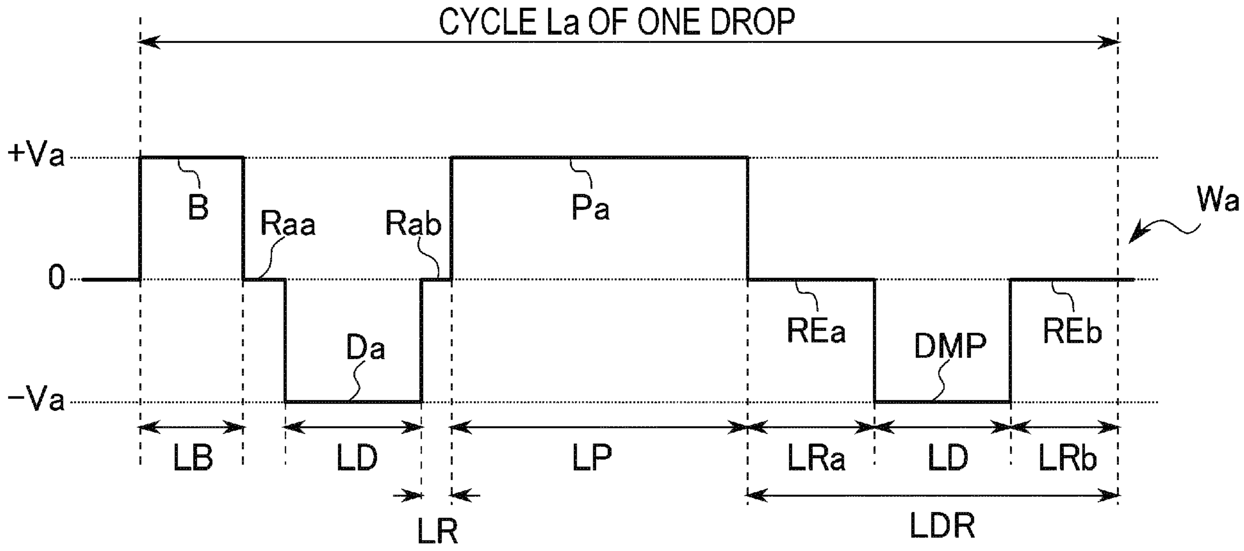

CYCLE La OF ONE DROP
+Va
0
−Va
B
Raa
Rab
Pa
Wa
Da
REa
DMP
REb
LB
LD
LP
LRa
LD
LRb
LR
LDR

FIG. 11

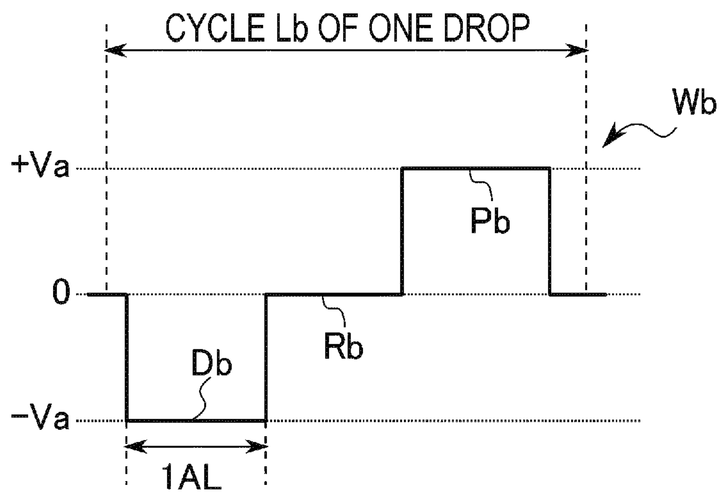

CYCLE Lb OF ONE DROP
Wb
+Va
Pb
0
Rb
Db
−Va
1AL

FIG. 12

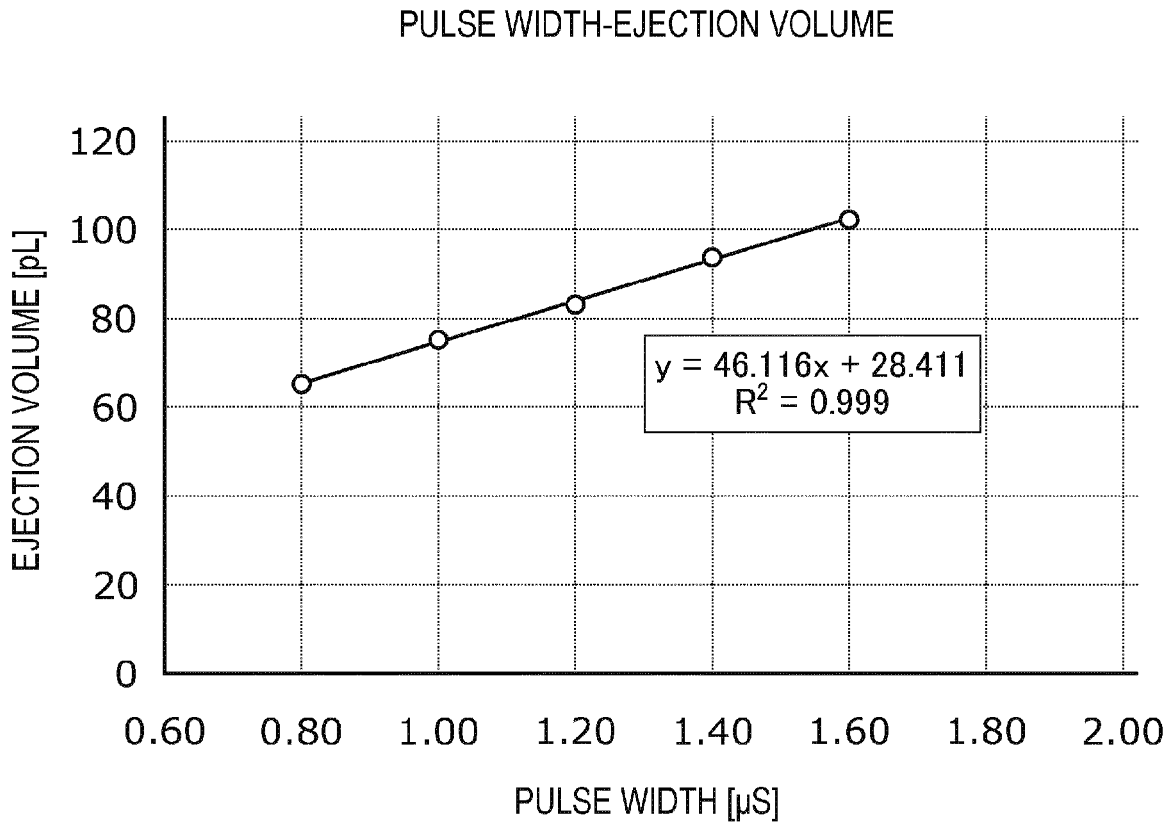

PULSE WIDTH-EJECTION VOLUME
120
100
80
60
40
20
0
EJECTION VOLUME [pL]
y = 46.116x + 28.411
R2 = 0.999
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
PULSE WIDTH [μS]

FIG. 13

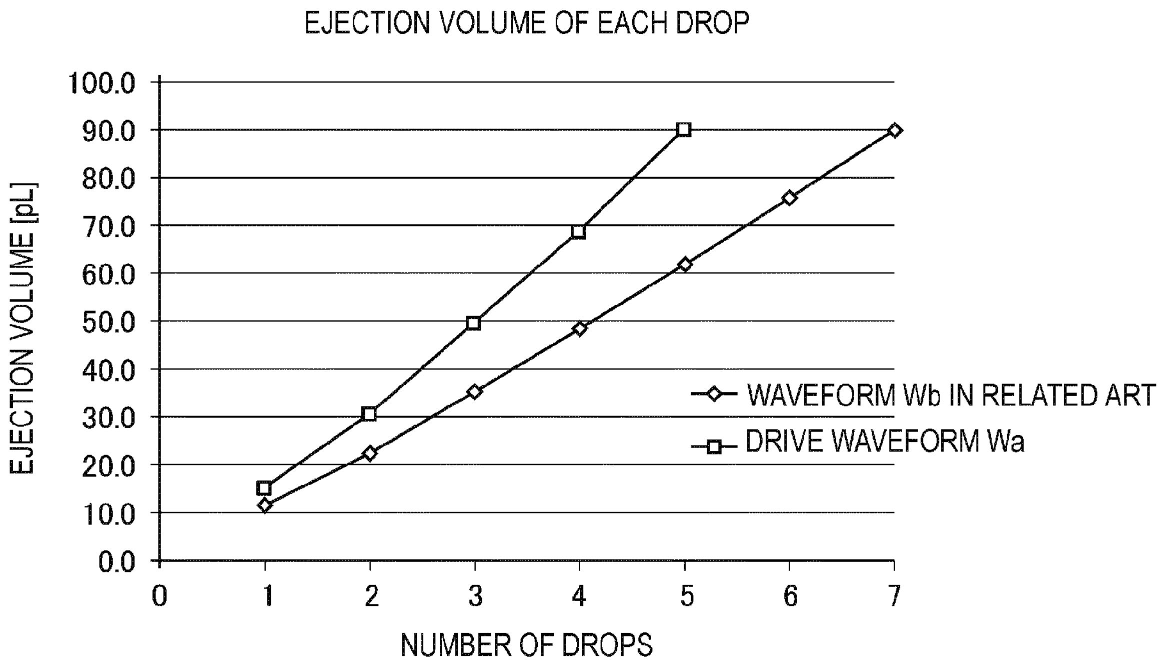
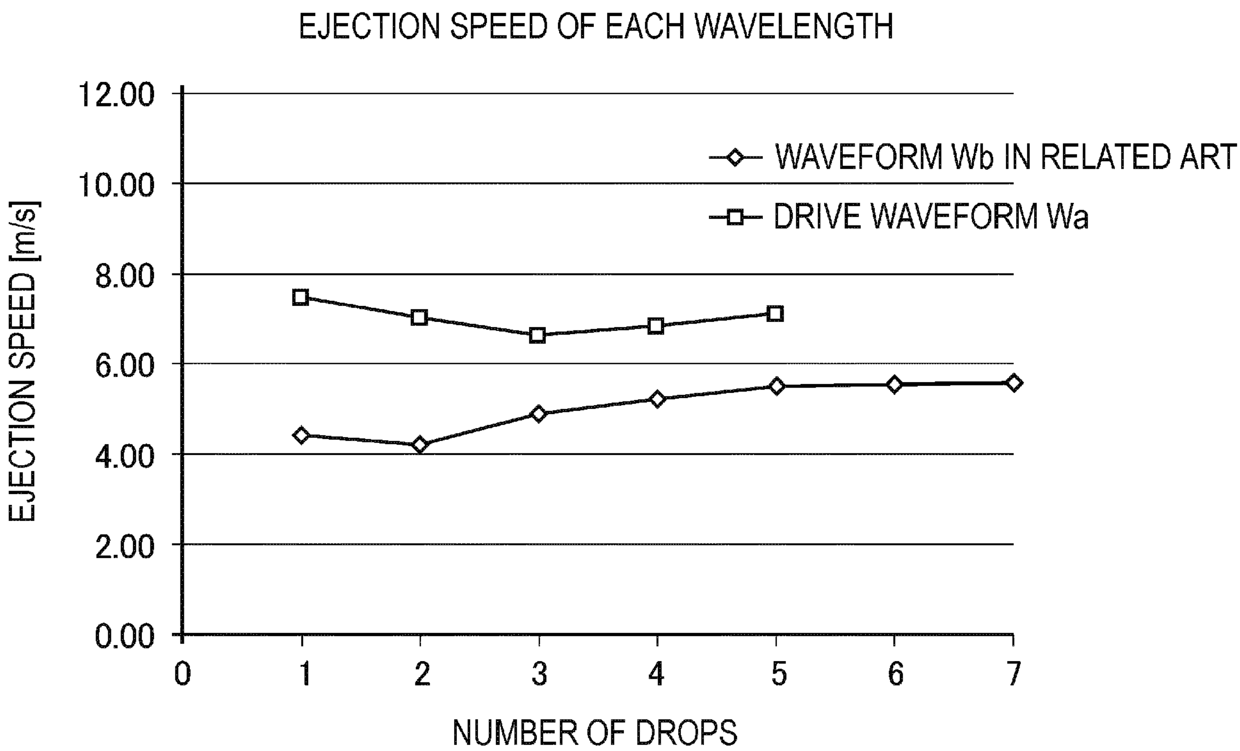

EJECTION VOLUME OF EACH DROP
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
EJECTION VOLUME [pL]
WAVEFORM Wb IN RELATED ART
DRIVE WAVEFORM Wa
0
1
2
3
4
5
6
7
NUMBER OF DROPS

FIG. 14


EJECTION SPEED OF EACH WAVELENGTH
12.00
10.00
8.00
6.00
4.00
2.00
0.00
EJECTION SPEED [m/s]
WAVEFORM Wb IN RELATED ART
DRIVE WAVEFORM Wa
0
1
2
3
4
5
6
7
NUMBER OF DROPS

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 20 20 9864

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2019/210365 A1 (TAKAMURA JUN [JP]) 11 July 2019 (2019-07-11) * the whole document * -----	1-5	INV. B41J2/045
A	EP 3 556 560 A1 (TOSHIBA TEC KK [JP]) 23 October 2019 (2019-10-23) * the whole document * -----	1-5	
A	US 2017/341384 A1 (ICHIKAWA MASAYA [JP]) 30 November 2017 (2017-11-30) * the whole document * -----	1-5	
A	US 2014/022294 A1 (SATOU TAKASHI [JP] ET AL) 23 January 2014 (2014-01-23) * the whole document * -----	1-5	

TECHNICAL FIELDS SEARCHED (IPC)
B41J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	20 April 2021	Dewaele, Karl

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20-04-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2019210365 A1	11-07-2019	CN 110014738 A	16-07-2019
		JP 2019119175 A	22-07-2019
		US 2019210365 A1	11-07-2019
EP 3556560 A1	23-10-2019	EP 3556560 A1	23-10-2019
		JP 2019188613 A	31-10-2019
		US 2019322102 A1	24-10-2019
US 2017341384 A1	30-11-2017	CN 107443904 A	08-12-2017
		JP 2017213755 A	07-12-2017
		US 2017341384 A1	30-11-2017
US 2014022294 A1	23-01-2014	JP 2014019050 A	03-02-2014
		US 2014022294 A1	23-01-2014

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