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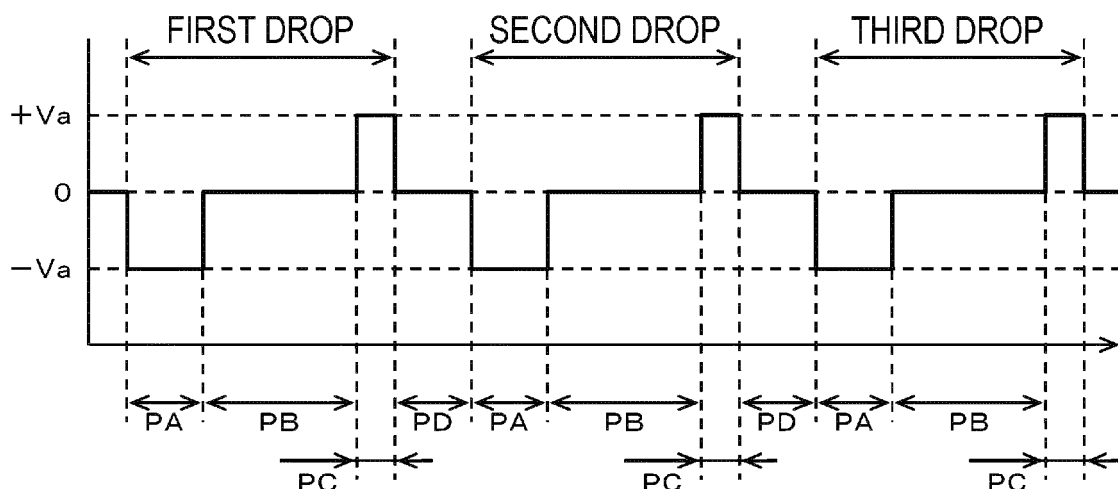
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(54) **DROPLET DISCHARGE HEAD AND DROPLET DISCHARGE APPARATUS**

(57) According to one embodiment, a droplet discharge head includes a head body and a drive unit. The head body discharges a liquid sucked into a pressure chamber from a nozzle provided in communication with the pressure chamber by changing a volume of the pressure chamber by an actuator. The drive unit drives the actuator to selectively form a first state in which the liquid is sucked into the pressure chamber, a second state in

which the liquid is pushed out from the pressure chamber into the nozzle, and a third state in which the liquid is not sucked and the liquid is not pushed out, and drives the actuator so that a droplet is repeatedly discharged from the nozzle a plurality of times by sequentially forming the first state, the third state, and the second state in a state of providing the third state between the respective drops of the droplet, when one pixel is formed.

FIG. 5



Description

FIELD

[0001] Embodiments described herein relate generally to a droplet discharge head and a droplet discharge apparatus.

BACKGROUND

[0002] A droplet discharge head is known as, for example, an inkjet head or the like. An end shooter type is known as one type of the inkjet head. The inkjet head of the end shooter type discharges ink, which is sucked from an end part of a pressure chamber into the pressure chamber, from a nozzle provided at an end part opposite to a side of the end part of the pressure chamber.

[0003] When the above-described inkjet head continuously discharges ink a plurality of times with respect to one pixel by using a multi-drop method, a discharge speed after a second drop tends to be lower than a discharge speed of a first drop, which may affect accuracy of pixel formation.

[0004] Considering such circumstances, it is desired to be able to reduce a variation in a discharge speed when continuous discharge is performed for one pixel a plurality of times.

DESCRIPTION OF THE DRAWINGS

[0005]

FIG. 1 is a block diagram illustrating a configuration example of a printer according to an embodiment;
 FIG. 2 is a perspective view illustrating a part of an inkjet head illustrated in FIG. 1 in an exploded manner;
 FIG. 3 is a cross-sectional view of the inkjet head illustrated in FIG. 1 and a block diagram illustrating a main circuit configuration of a drive IC;
 FIG. 4 is a vertical cross-sectional view of the inkjet head illustrated in FIG. 1;
 FIG. 5 is a diagram illustrating an example of a drive waveform for discharging ink from one of a plurality of nozzles;
 FIG. 6 is a diagram illustrating a state around a periphery of a target channel during a draw period;
 FIG. 7 is a diagram illustrating the state around the periphery of the target channel during a release period;
 FIG. 8 is a diagram illustrating the state around the periphery of the target channel during a push period;
 FIG. 9 is a diagram illustrating a state of a concave meniscus;
 FIG. 10 is a diagram illustrating a relationship between a length of a rest period and a discharge speed; and
 FIG. 11 is a diagram illustrating the relationship be-

tween the length of the rest period and the discharge speed.

DETAILED DESCRIPTION

[0006] Embodiments described herein provide a droplet discharge head and a droplet discharge apparatus capable of reducing a variation in a discharge speed when continuous discharge is performed for one pixel a plurality of times.

[0007] In general, according to one embodiment, a droplet discharge head includes a head body and a drive unit. The head body discharges a liquid sucked into a pressure chamber from a nozzle provided in communication with the pressure chamber by changing a volume of the pressure chamber by an actuator. The drive unit drives the actuator to selectively form a first state in which the liquid is sucked into the pressure chamber, a second state in which the liquid is pushed out from the pressure chamber into the nozzle, and a third state in which the liquid is not sucked and the liquid is not pushed out. In forming one pixel, the drive unit drives the actuator so that a droplet is repeatedly discharged from the nozzle a plurality of times by sequentially forming the first state, the third state, and the second state, with the third state further provided between the respective drops of the droplet.

[0008] Preferably, given that pressure propagation time in the pressure chamber is UL, the drive unit sets 1/2 UL to UL as a period of forming the third state between the second state and formation of the first state for discharging the next droplet.

[0009] Preferably, given that pressure propagation time in the pressure chamber is UL, the drive unit sets UL as a period of forming the third state between the second state and formation of the first state for discharging the next droplet.

[0010] Preferably, the drive unit sets a period of forming the first state for discharging the droplet one time to UL, sets a period of forming the third state to 2UL, and sets a period of forming the second state to 0.9 μ sec.

[0011] There is also provided a droplet discharge apparatus, comprising the droplet discharge head as described above, wherein the drive unit is comprised in the droplet discharge apparatus outside the droplet discharge head.

[0012] Hereinafter, a droplet discharge apparatus as an example of the embodiment will be described with reference to the drawings. In the following, an example of achieving the droplet discharge apparatus as a printer adapted for the use of printing an image by spraying an ink droplet on paper (a recording medium) will be described.

[0013] FIG. 1 is a block diagram illustrating a configuration example of a printer 100 according to the embodiment.

[0014] As illustrated in FIG. 1, the printer 100 includes a processor 101, a main memory 102, an auxiliary stor-

age unit 103, an operation panel 104, a communication interface 105, a conveyance unit 106, a conveyance control unit 107, a pump 108, a pump drive unit 109, an inkjet head 110, and a transmission path 111.

[0015] The processor 101, the main memory 102, and the auxiliary storage unit 103 are connected to each other with the transmission path 111, thereby forming a computer that performs information processing for controlling the printer 100.

[0016] The processor 101 corresponds to a central portion of the computer. The processor 101 executes the above-described information processing according to an information processing program such as an operating system, middleware, or an application program.

[0017] The main memory 102 corresponds to a main memory portion of the computer. The main memory 102 includes a non-volatile memory area and a volatile memory area. The main memory 102 stores the information processing program in the non-volatile memory area. The main memory 102 may store data necessary for the processor 101 to execute processing for controlling each unit in the non-volatile memory area or the volatile memory area. The main memory 102 uses the volatile memory area as a work area where data can be appropriately rewritten by the processor 101.

[0018] The auxiliary storage unit 103 corresponds to an auxiliary storage portion of the computer. As the auxiliary storage unit 103, well-known storage devices such as an electric erasable programmable read-only memory (EEPROM), a hard disk drive (HDD), a solid state drive (SSD), or the like can be used independently or in combination of a plurality thereof. The auxiliary storage unit 103 stores data used by the processor 101 for performing various processing and data generated by the processing of the processor 101. The auxiliary storage unit 103 stores the information processing program.

[0019] The operation panel 104 includes an input device and a display device. The operation panel 104 inputs an instruction from an operator by the input device. The operation panel 104 displays various information to be notified to the operator by the display device. As the operation panel 104, for example, a touch panel can be used. However, as the input device and the display device, various other devices can be appropriately used.

[0020] The communication interface 105 transmits and receives data to and from an external device via a communication network such as a local area network (LAN) or the like. The external device is, for example, an information processing apparatus that requests printing with respect to the printer 100. As the communication interface 105, a well-known device such as a communication device for LAN or the like can be used.

[0021] The conveyance unit 106 includes a motor, a gear, a roller, or the like, and conveys paper in a state of crossing a flight path of an ink droplet discharged from the inkjet head 110.

[0022] The conveyance control unit 107 controls the conveyance unit 106 so that the paper is conveyed at a

predetermined timing synchronized with a discharge operation of the ink droplet by the inkjet head 110 under the control of the processor 101.

[0023] The pump 108 supplies liquid ink from an ink tank which is not illustrated to the inkjet head 110. That is, ink is an example of a liquid.

[0024] The pump drive unit 109 drives the pump 108 under the control of the processor 101.

[0025] The inkjet head 110 discharges the ink supplied by the pump 108 as the ink droplet based upon print data. The ink droplet is an example of a droplet, and the inkjet head 110 is an example of a droplet discharge head.

[0026] The transmission path 111 includes an address bus, a data bus, a control signal line, or the like, and transmits data and a control signal transmitted and received between respective connected units.

[0027] FIG. 2 is a perspective view illustrating a part of the inkjet head 110 in an exploded manner. FIG. 3 is a cross-sectional view of the inkjet head 110 and a block diagram illustrating a main circuit configuration of a drive integrated circuit (IC) 10 illustrated in FIG. 2. FIG. 4 is a vertical cross-sectional view of the inkjet head 110. In the following description of each of the drawings of FIGS. 2 to 4, a vertical direction in the drawing is defined as a vertical direction of the inkjet head 110. A right side in FIGS. 2 and 4 and a back side in FIG. 3 are defined as a tip side. A left side in FIGS. 2 and 4 and a front side in FIG. 3 are defined as a rear end side.

[0028] The inkjet head 110 includes a substrate 1, a first piezoelectric member 2, a second piezoelectric member 3, an electrode 4, a top plate 5, a nozzle plate 6, a conductive path 7, a circuit board 8, a wire 9, and the drive IC 10.

[0029] The substrate 1 is an elongated plate-shaped member. It is desirable that the substrate 1 has a small dielectric constant. It is desirable that the substrate 1 has a small difference in a coefficient of thermal expansion between the first piezoelectric member 2 and the second piezoelectric member 3. Materials suitable for the substrate 1 are, for example, alumina (Al_2O_3), silicon nitride (Si_3N_4), silicon carbide (SiC), aluminum nitride (AlN), lead zirconate titanate (PZT), or the like. Materials of the first piezoelectric member 2 and the second piezoelectric member 3 are, for example, lead zirconate titanate (PZT), lithium niobate (LiNbO_3), lithium tantalate (LiTaO_3), or the like.

[0030] The first piezoelectric member 2 is joined to an upper surface of the substrate 1. The second piezoelectric member 3 is joined onto the first piezoelectric member 2. As illustrated by an arrow in FIG. 3, the first piezoelectric member 2 and the second piezoelectric member 3 are polarized in mutually opposite directions in a state of having a joint surface therebetween as a boundary.

[0031] A part of an upper side of a structure formed by stacking the first piezoelectric member 2 and the second piezoelectric member 3 is cut out at a plurality of places from the tip side to the rear end side, and a plurality of long channels CH are formed thereat. A distance be-

tween adjacent channels CH is almost constant. For example, the plurality of channels CH are almost parallel to each other. The channel CH is opened on the tip side and a depth of the channel CH gradually decreases on the rear end side. A maximum depth, width and pitch of the channel CH are, for example, 300 μm , 80 μm and 169 μm . The number of channels CH is, for example, 318.

[0032] The electrode 4 is a conductive film in a state of covering a side wall and a bottom surface of the channel CH. The electrode 4 has, for example, a two-layer structure of nickel (Ni) and gold (Au). The electrode 4 is uniformly formed in the channel CH by, for example, a plating method. A method for forming the electrode 4 therein is not limited to the plating method, and may include a sputtering method, a vapor deposition method, or the like.

[0033] The top plate 5 is joined to an upper surface of the second piezoelectric member 3 and closes an upper part of each of the plurality of channels CH. A common ink chamber 51 is formed in the top plate 5. The common ink chamber 51 is formed by providing a recessed part in the vicinity of an end part of a rear end side of a lower surface of the top plate 5. The common ink chamber 51 is located above all channels CH. The ink supplied from the ink tank to the inkjet head 110 by the pump 108 flows into the common ink chamber 51.

[0034] The nozzle plate 6 is joined to an end surface of the tip side of the first piezoelectric member 2 and the second piezoelectric member 3, and closes the tip side of each of the plurality of channels CH. A plurality of nozzles 61 are formed in the nozzle plate 6 in association with each of the plurality of channels CH. The nozzle 61 connects one of the plurality of channels CH, which corresponds thereto, to the outside of the inkjet head 110. As illustrated in FIG. 4, the nozzle 61 has a constricted part at a location slightly on the tip side from a center of the nozzle 61, and is gradually widened from the constricted part toward both the tip side and the rear end side. The nozzle 61 is not limited to such shape. For example, the nozzle 61 may have a tapered truncated cone shape in which a nozzle diameter on a discharge surface side becomes smaller. The nozzle 61 is formed as a set of three nozzles corresponding to three adjacent channels CH. The three nozzles 61 of the same set are shifted in the vertical direction at a regular distance as illustrated in FIGS. 2 and 3.

[0035] Accordingly, the channel CH is a closed space except a portion in contact with the common ink chamber 51 and a portion in contact with the nozzle 61. The channel CH communicates with the common ink chamber 51 and the nozzle 61. The channel CH is also referred to as a pressure chamber or an ink chamber.

[0036] A plurality of conductive paths 7 are provided in parallel from the tip side to the rear end side in a state of extending from the channel CH. The plurality of conductive paths 7 are electrically connected to one corresponding electrode 4 of a plurality of electrodes 4.

[0037] The circuit board 8 is juxtaposed with the first

piezoelectric member 2 and the second piezoelectric member 3, and is joined to an upper surface on the rear end side of the substrate 1. As the circuit board 8, for example, a printed circuit board is used. A plurality of conductive paths 81 and a plurality of conductive paths 82 are formed on an upper surface of the circuit board 8, for example, as printed wiring. The plurality of conductive paths 81 respectively correspond to the plurality of electrodes 4. The conductive path 82 is connected to an interface circuit (not illustrated) for being connected to the transmission path 111.

[0038] The wire 9 is a wire formed of a conductive material. A plurality of wires 9 are provided in parallel. The plurality of wires 9 respectively correspond to the plurality of electrodes 4 and the plurality of conductive paths 81. One end of the wire 9 is connected to one corresponding electrode 4 of the plurality of electrodes 4. The other end of the wire 9 is connected to one corresponding conductive path 81 of the plurality of conductive paths 81. Accordingly, the wire 9 electrically connects the corresponding electrode 4 and the corresponding conductive path 81.

[0039] The drive IC 10 is mounted on the circuit board 8 in a state of being electrically connected to the conductive paths 81 and 82. The drive IC 10 drives a head body to allow the nozzle 61 to discharge ink.

[0040] As illustrated in FIG. 3, the drive IC 10 includes a pixel separation circuit 11, a waveform generation circuit 12, a switch control circuit 13, and a plurality of switches 14.

[0041] Print data is inputted to the pixel separation circuit 11 via the conductive path 82. The print data is a set of pixel data representing a gradation value for each pixel. The pixel separation circuit 11 separates the pixel data in the print data into three groups for each corresponding nozzle 61 of which vertical position is the same as illustrated FIG. 3. That is, the pixel separation circuit 11 separates the pixel data so that the pixel data corresponding to each of the three nozzles 61 belonging to the same set belongs to different groups, respectively. Next, the pixel separation circuit 11 provides the pixel data belonging to each group to the waveform generation circuit 12 in parallel at respectively different timings. As a result, the inkjet head 110 is a so-called three-division drive system in which pixel formation for one line is performed three times. Control for correctly printing an image by the three-division drive may be the same as that of another existing inkjet head of the three-division drive system.

[0042] The waveform generation circuit 12 determines the number of drops for forming one pixel based upon each gradation value of the pixel data. Next, the waveform generation circuit 12 generates a drive waveform, which will be described later, for continuously discharging the ink droplets of the determined number of drops. Next, the waveform generation circuit 12 provides the drive waveform related to each of the pixel data belonging to one group to the switch control circuit 13 in parallel.

[0043] The switch control circuit 13 controls a plurality

of switches 14 according to the drive waveform as described later.

[0044] The plurality of switches 14 are electrically connected to one corresponding electrode 4 of the plurality of electrodes 4 via the conductive path 81, the wire 9, and the conductive path 7. FIG. 3 illustrates only three switches 14 respectively corresponding to three electrodes 4 located at the center of the cross-sectional view. The switch 14 selectively forms two states in which a potential of the corresponding electrode 4 is set to a voltage + Va or a ground potential under the control of the switch control circuit 13.

[0045] The inkjet head 110 having the above-described configuration is formed in such a manner that the head body including the first piezoelectric member 2, the second piezoelectric member 3, the electrode 4, the top plate 5, the nozzle plate 6, and the conductive path 7, and the drive unit including the circuit board 8, the wire 9, and the drive IC 10 are integrated to be connected to each other by the substrate 1. The inkjet head 110 is an end shooter type that discharges ink sucked from the rear end side of the head body from the tip side. The inkjet head 110 is a shared wall type in which the first piezoelectric member 2 and the second piezoelectric member 3 located between two channels CH are shared as an actuator for changing a volume of the two channels CH.

[0046] Next, an operation of the printer 100 configured as described above will be described. A characteristic operation of the printer 100 is that the head body is driven by the drive IC 10 when image printing is performed by the multi-drop method, and other operations thereof may be the same as those of an existing printer of the same type. Therefore, hereinafter, the characteristic operation thereof will be mainly described.

[0047] FIG. 5 is a diagram illustrating an example of the drive waveform for discharging ink from one of the plurality of nozzles 61.

[0048] In the description of FIG. 5, one nozzle 61 in which ink is discharged by the driving of the drive waveform illustrated in FIG. 5 is referred to as a target nozzle 61-1. One channel CH connected to the target nozzle 61-1 is referred to as a target channel CH-1. The electrode 4 surrounding the target channel CH-1 is referred to as a target electrode 4-1. Two channels CH adjacent to the target channel CH-1 are respectively referred to as adjacent channels CH-2 and CH-3. Two electrodes 4 surrounding the adjacent channels CH-2 and CH-3 are respectively referred to as adjacent electrodes 4-2 and 4-3.

[0049] The drive waveform illustrated in FIG. 5 is a drive waveform for generating continuous discharge of three drops for forming one pixel from the target nozzle 61-1.

[0050] When the ink droplets of three drops are continuously discharged, the waveform generation circuit 12 provided in the drive IC 10 drives the inkjet head 110 by the drive waveform illustrated in FIG. 5. A period PA in

FIG. 5 is a draw period. A period PB is a release period. A period PC is a push period. A period PD is a rest period.

[0051] FIG. 6 is a diagram illustrating a state around a periphery of the target channel CH-1 in the draw period PA.

[0052] In the draw period PA, the switch control circuit 13 controls the switch 14 so that a potential of the target electrode 4-1 is set to the ground potential and both potentials of the adjacent electrodes 4-2 and 4-3 are set to the voltage + Va. As a result, the voltage - Va is respectively applied between the target electrode 4-1 and the adjacent electrode 4-2 and between the target electrode 4-1 and the adjacent electrode 4-3. Here, a portion of the first piezoelectric member 2 and the second piezoelectric member 3 sandwiched between the target electrode 4-1 and the adjacent electrode 4-2 is orthogonal to a polarization direction, and an electric field from the adjacent electrode 4-2 toward the target electrode 4-1 acts. By such action, the portion of the first piezoelectric member 2 and the second piezoelectric member 3 sandwiched between the target electrode 4-1 and the adjacent electrode 4-2 is deformed to a side of the adjacent channel CH-2. A portion of the first piezoelectric member 2 and the second piezoelectric member 3 sandwiched between the target electrode 4-1 and the adjacent electrode 4-3 is also similarly deformed to a side of the adjacent channel CH-3. As a result, a volume of the target channel CH-1 is enlarged, and ink is sucked into the target channel CH-1 from the common ink chamber 51. That is, the state of the target channel CH-1 in the draw period PA corresponds to a first state.

[0053] FIG. 7 is a diagram illustrating the state around the periphery of the target channel CH-1 in the release period PB.

[0054] In the release period PB, the switch control circuit 13 controls the switch 14 so that all the potentials of the target electrode 4-1 and the adjacent electrodes 4-2 and 4-3 are set to the voltage + Va. Here, since a potential difference does not occur between the target electrode 4-1 and the adjacent electrode 4-2, an electric field does not act on the portion of the first piezoelectric member 2 and the second piezoelectric member 3 sandwiched between the target electrode 4-1 and the adjacent electrode 4-2. Therefore, deformation caused by the action of the electric field does not occur in the portion of the first piezoelectric member 2 and the second piezoelectric member 3 sandwiched between the target electrode 4-1 and the adjacent electrode 4-2. In the same manner, the deformation also does not occur in the portion of the first piezoelectric member 2 and the second piezoelectric member 3 sandwiched between the target electrode 4-1 and the adjacent electrode 4-3. As a result, the volume of the target channel CH-1 becomes a neutral state. Here, ink is not newly sucked into the target channel CH-1, and ink is not discharged from the target channel CH-1 via the target nozzle 61-1. That is, the state of the target channel CH-1 in the release period PB corresponds to a third state.

[0055] FIG. 8 is a diagram illustrating the state around the periphery of the target channel CH-1 in the push period PC.

[0056] In the push period PC, the switch control circuit 13 controls the switch 14 so that the potential of the target electrode 4-1 is set to voltage + Va and both potentials of the adjacent electrodes 4-2 and 4-3 are set to the ground potentials. Accordingly, the voltage + Va is respectively applied between the target electrode 4-1 and the adjacent electrode 4-2 and between the target electrode 4-1 and the adjacent electrode 4-3. Here, the portion of the first piezoelectric member 2 and the second piezoelectric member 3 sandwiched between the target electrode 4-1 and the adjacent electrode 4-2 is orthogonal to the polarization direction, and an electric field from the target electrode 4-1 toward the adjacent electrode 4-2 acts. By such action, the portion of the first piezoelectric member 2 and the second piezoelectric member 3 sandwiched between the target electrode 4-1 and the adjacent electrode 4-2 is deformed to a side of the target channel CH-1. In the same manner, the portion of the first piezoelectric member 2 and the second piezoelectric member 3 sandwiched between the target electrode 4-1 and the adjacent electrode 4-3 is also deformed to a side of the target channel CH-1. As a result, the volume of the target channel CH-1 is reduced, and ink is discharged from the target channel CH-1 via the target nozzle 61-1. For example, a length of the push period PC is set to a short time of about 0.90 μ sec. As a result, a small amount of ink, for example, about 12 pL, is discharged from the target nozzle 61-1 in a state of the ink droplet. That is, the state of the target channel CH-1 in the push period PC corresponds to a second state.

[0057] As described above, a first drop is discharged according to state transition in the order of draw, release, and push.

[0058] In the rest period PD, the switch control circuit 13 controls the switch 14 so that all the potentials of the target electrode 4-1 and the adjacent electrodes 4-2 and 4-3 are set to the voltage + Va. That is, the switch control circuit 13 is in the same state as that of the release period PB. Here, ink is not newly sucked into the target channel CH-1, and ink is not discharged from the target channel CH-1 via the target nozzle 61-1. That is, the state of the target channel CH-1 in the rest period PD corresponds to the third state. The pressure applied to the ink in the target channel CH-1 in the push period PC is reduced, and a meniscus of the ink in the target nozzle 61-1 changes to a concave shape on the side of the target channel CH-1.

[0059] FIG. 9 is a diagram illustrating a state of a concave meniscus ME.

[0060] In FIG. 9, a reference sign IN represents the ink in the target channel CH-1. An end part of the meniscus ME of the ink IN is located at a constricted part of the target nozzle 61-1, and a liquid surface is recessed.

[0061] After the end of the rest period PD, the waveform generation circuit 12 causes the nozzle to discharge

a second drop by the state transition in the order of draw, release, and push in the same manner as that of the first drop.

[0062] The waveform generation circuit 12 also causes the nozzle to discharge a third drop by the state transition in the order of draw, release, and push in the same manner as that of the first drop, and also provides the rest period PD between the second drop and the third drop.

[0063] As described above, the waveform generation circuit 12, the switch control circuit 13, and the switch 14 drive the actuator including the first piezoelectric member 2 and the second piezoelectric member 3 so that the ink droplet as a droplet is repeatedly discharged from the nozzle 61 a plurality of times by sequentially forming the first state in the draw period PA, the third state in the release period PB, and the second state in the push period PC in a state of providing the third state in the rest period between the respective drops of the ink droplet. Therefore, a function as the drive unit is achieved by cooperation of the waveform generation circuit 12, the switch control circuit 13, and the switch 14.

[0064] As such, even while the ink droplet is continuously discharged by multi-drop, the rest period PD is provided between the respective drops of the ink droplet, and the meniscus ME is formed to be the concave shape prior to the state transition for performing the next drop, thereby making it possible to prevent the discharge speed after the second drop from decreasing.

[0065] FIGS. 10 and 11 are diagrams illustrating a relationship between a length of the rest period PD and a discharge speed.

[0066] FIG. 10 shows a result of respectively measuring the discharge speed for each of the first drop, the second drop, and the third drop by driving as described above by defining the length of the rest period PD as 0, UL/4, UL/2, 2UL/3, and UL. FIG. 11 is a table showing a result of determining the discharge speed, the flight state, and the voltage of the drive waveform with respect to the third drop in comparison with a case where the rest period PD is not provided. The discharge speed and the flight state of FIG. 11 are results of determination by rule of thumb visually by an observer from an image obtained by photographing the ink droplet discharged from the inkjet head 110.

[0067] The lengths of the draw period PA, the release period PB, and the push period PC are respectively set to UL, 2UL, and 0.90 μ sec.

[0068] Here, UL is time obtained by performing appropriate fraction processing when half the time of a natural vibration period of the channel CH is defined as pressure propagation time (AL: acoustic length). As an example, UL is 2 μ sec or less. A type of specific processing to be applied as the fraction processing may be freely determined by a designer of the inkjet head 110.

[0069] As can be seen from FIG. 10, between 0 and UL, the discharge speed increases as the rest period PD generally becomes longer. As can be seen from FIG. 11, when the rest period PD exceeds UL and becomes long-

er, the discharge speed at the third drop decreases, and dot separation also occurs.

[0070] As described above, it is desirable that the length of the rest period PD is set in a range of $UL/2$ or more and UL or less. As can be seen from FIG. 10, when the length of the rest period PD is UL , the discharge speeds of the first drop, the second drop, and the third drop are almost the same as each other. Therefore, it is most desirable to set the rest period PD to UL .

[0071] As described above, in the inkjet head 110, when the continuous discharge is performed for one pixel a plurality of times, the rest period PD is provided after the push period PC of the preceding drop and before the draw period PA of the subsequent drop, such that it is possible to prevent a decrease in the discharge speed of the subsequent drop, and to reduce a variation in the discharge speed of each drop. As a result, accuracy of pixel formation can be improved and quality of a printed image can be improved.

[0072] The inkjet head 110 can further reduce the variation in the discharge speed of each drop by setting the length of the rest period PD in the range of $UL/2$ or more and UL or less.

[0073] The inkjet head 110 can minimize the variation in the discharge speed of each drop by setting the length of the rest period PD to UL .

[0074] Various modifications of the embodiment can be made as follows.

[0075] The waveform generation circuit 12 may be provided in the printer 100 outside the inkjet head 110.

[0076] The embodiment can also be realized as a printer for other uses such as a printer for document printing, a printer for barcode printing, and a printer for printing a certificate such as a receipt or the like. Alternatively, the embodiment can also be realized as a printer for other uses other than image printing such as a printer for forming a three-dimensional object or the like. Therefore, the liquid to be discharged is not limited to ink, and may be a material for forming an object or the like.

[0077] The three-division drive system is only an example, and a four-division drive system, a five-division drive system, or the like may be adopted.

[0078] 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 embodiments 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 droplet discharge head, comprising:

a head body configured to discharge a liquid sucked into a pressure chamber from a nozzle provided in communication with the pressure chamber by changing a volume of the pressure chamber by an actuator; and
a drive unit configured to:

drive the actuator to selectively form a first state in which the liquid is sucked into the pressure chamber, a second state in which the liquid is pushed out from the pressure chamber into the nozzle, and a third state in which the liquid is not sucked and the liquid is not pushed out; and

in forming one pixel, drive the actuator so that a droplet is repeatedly discharged from the nozzle a plurality of times by sequentially forming the first state, the third state, and the second state, with the third state further provided between the respective drops of the droplet.

2. The droplet discharge head according to claim 1, wherein
given that pressure propagation time in the pressure chamber is UL , the drive unit sets $1/2 UL$ to UL as a period of forming the third state between the second state and formation of the first state for discharging the next droplet.

3. The droplet discharge head according to claim 1, wherein
given that pressure propagation time in the pressure chamber is UL , the drive unit sets UL as a period of forming the third state between the second state and formation of the first state for discharging the next droplet.

4. The droplet discharge head according to claim 2 or 3, wherein
the drive unit sets a period of forming the first state for discharging the droplet one time to UL , sets a period of forming the third state to $2UL$, and sets a period of forming the second state to $0.9 \mu\text{sec}$.

5. A droplet discharge apparatus, comprising the droplet discharge head according to any one of claims 1 to 4, wherein the drive unit is comprised in the droplet discharge apparatus outside the droplet discharge head.

FIG. 1

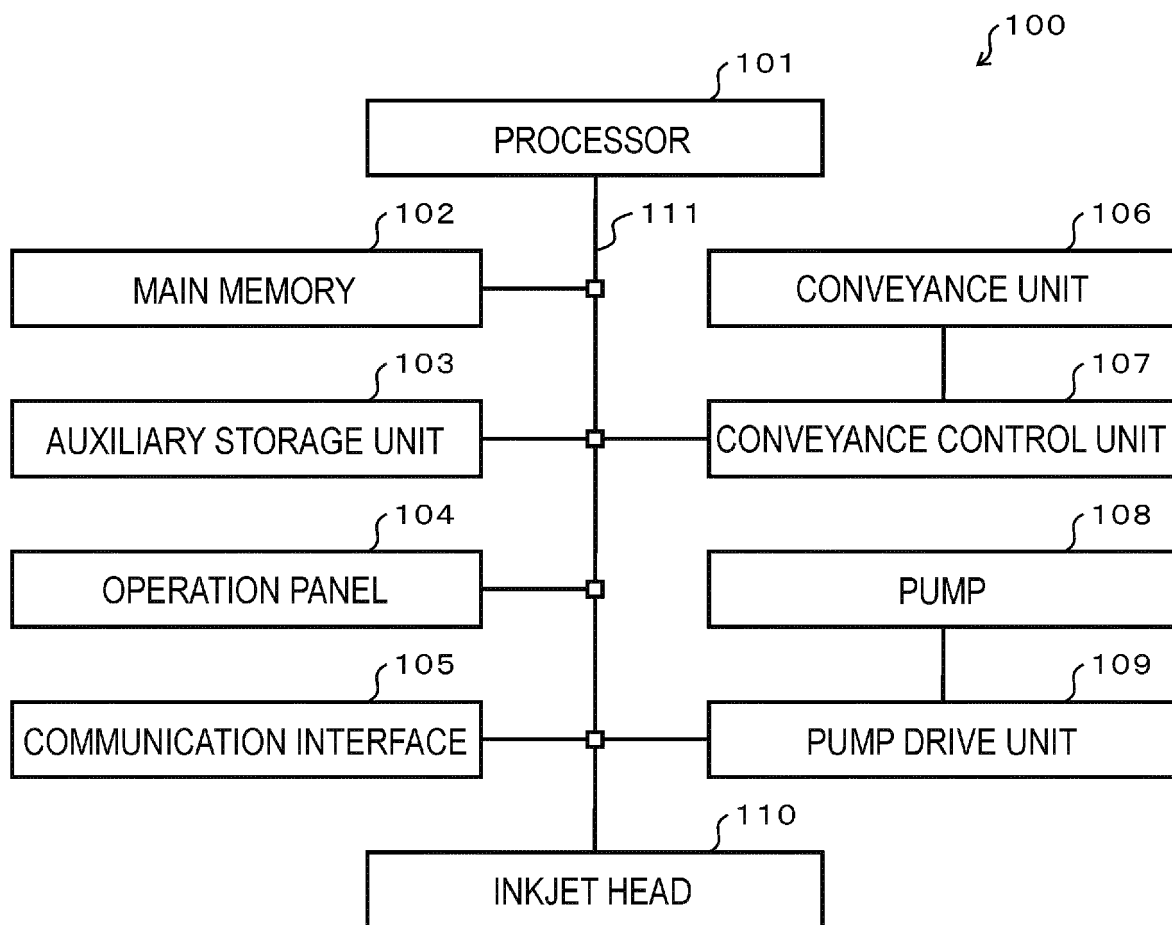


FIG. 2

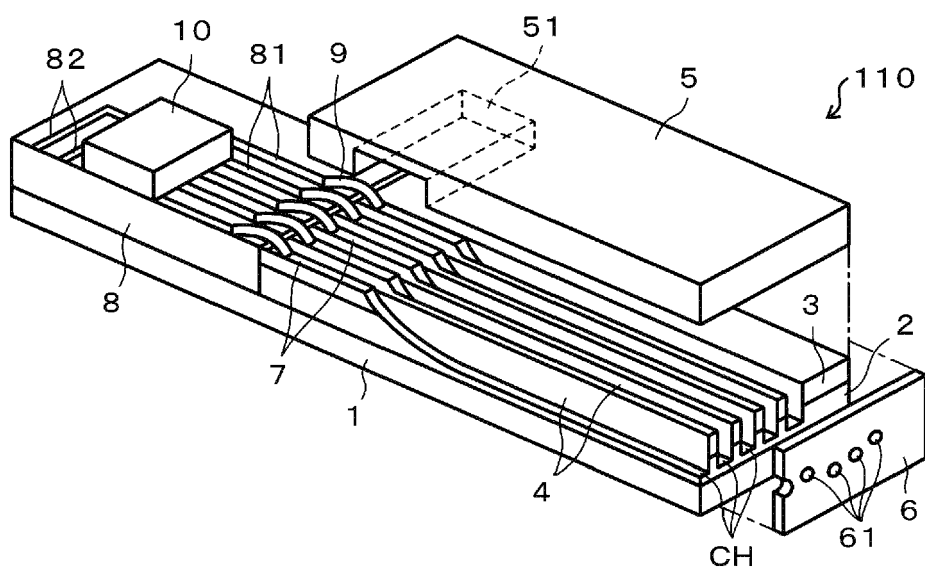


FIG. 3

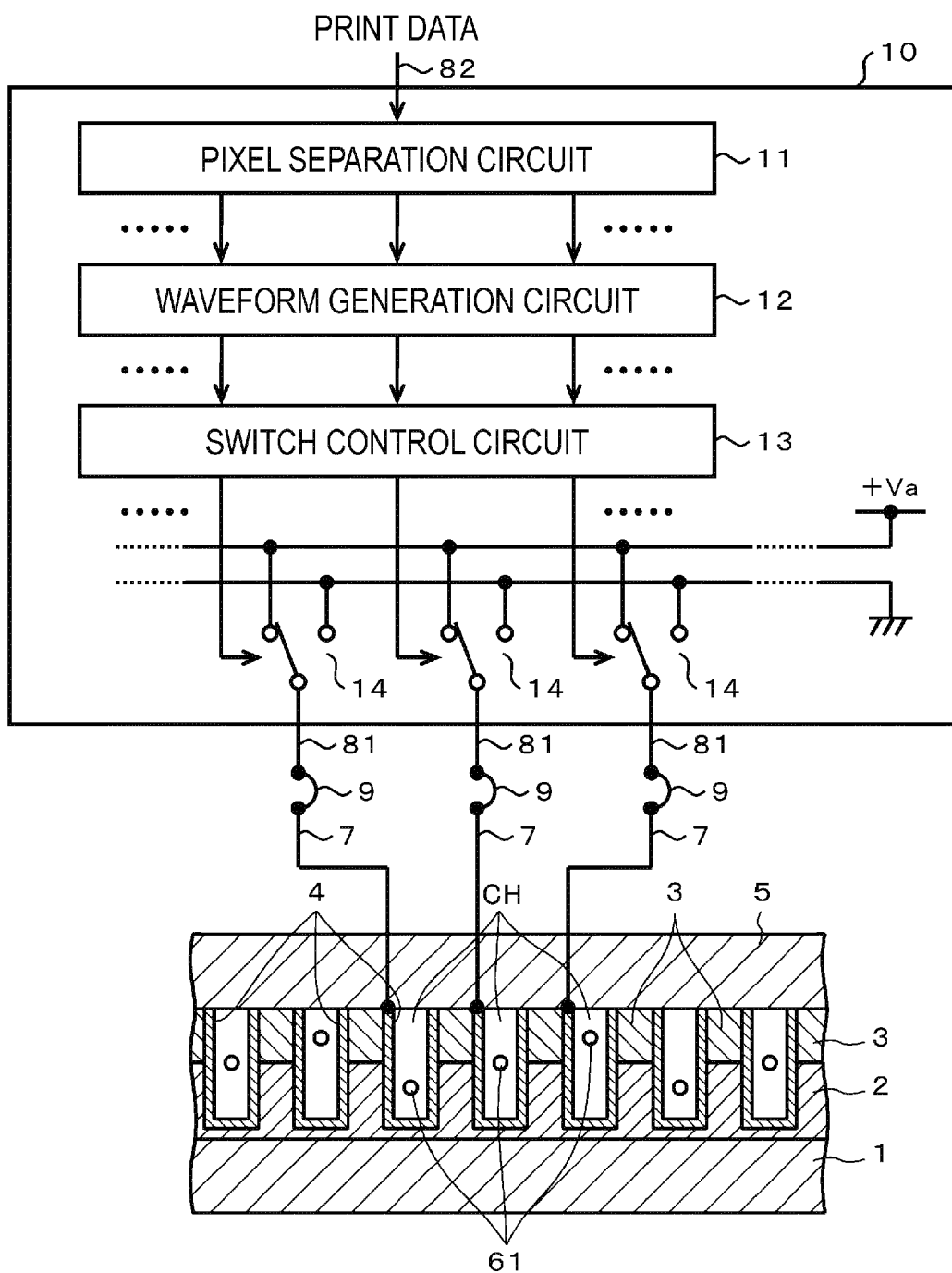


FIG. 4

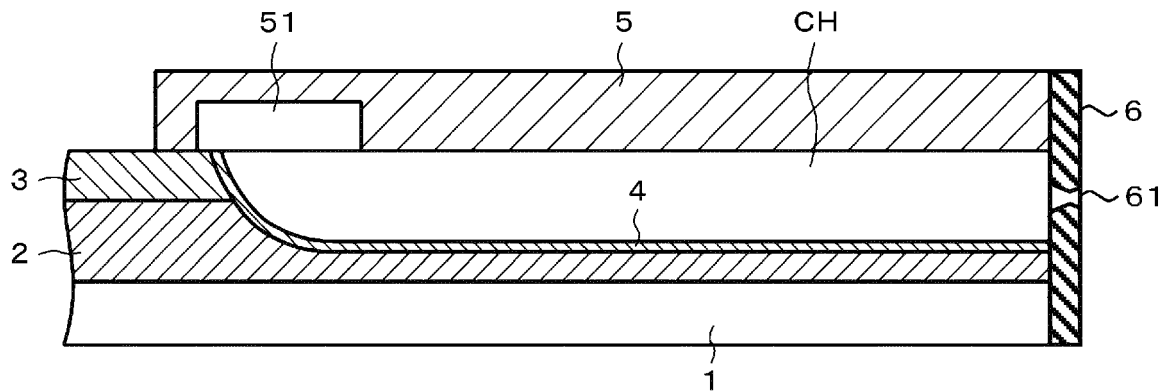


FIG. 5

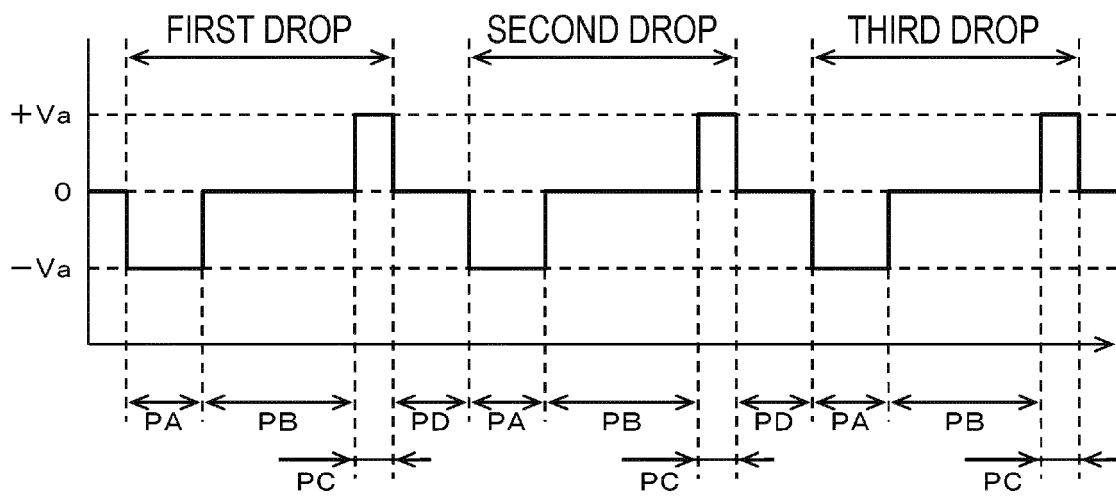


FIG. 6

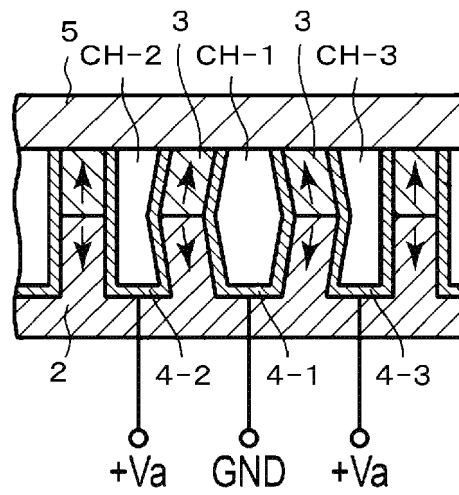


FIG. 7

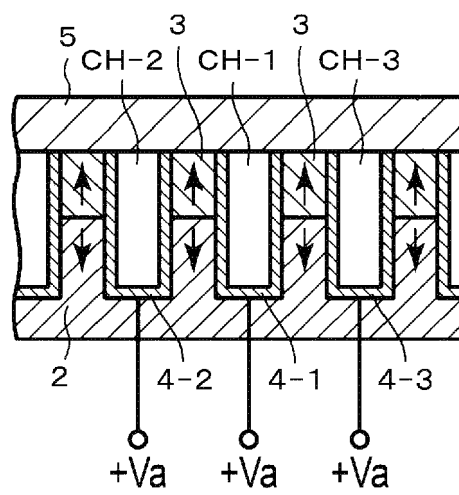


FIG. 8

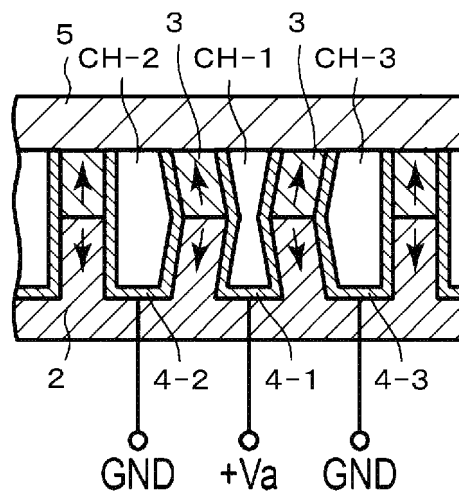


FIG. 9

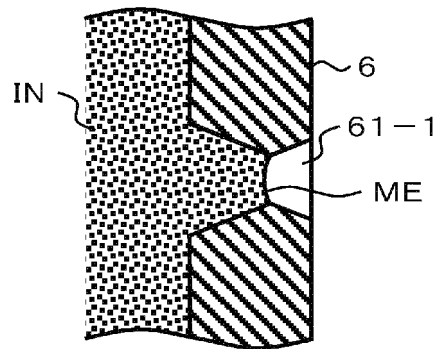


FIG. 10

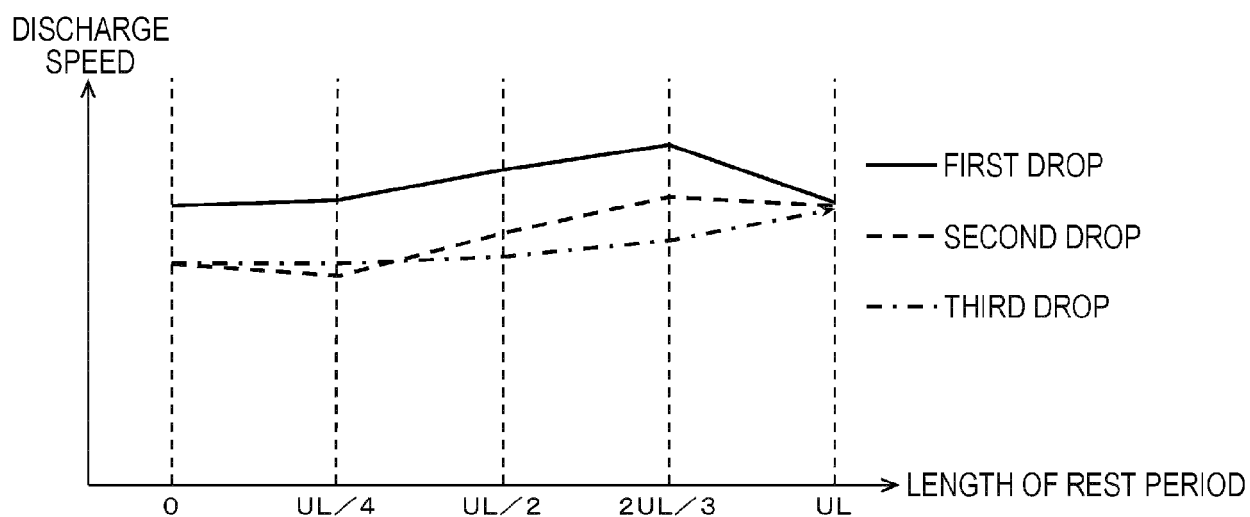


FIG. 11

LENGTH OF REST PERIOD	DISCHARGE SPEED	FLIGHT STATE	VOLTAGE
0	—	—	—
$UL/4$	NO CHANGE	GOOD	NO CHANGE
$UL/2$	BECOME FAST	GOOD	NO CHANGE
$2UL/3$	BECOME FAST	GOOD	NO CHANGE
UL	BECOME FAST	GOOD	NO CHANGE
1. $2UL$	BECOME SLOW	DOT SEPARATION OCCURRED	NO CHANGE
1. $5UL$	BECOME SLOW	DOT SEPARATION OCCURRED	NO CHANGE



EUROPEAN SEARCH REPORT

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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		29 October 2021	Loi, Alberto
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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