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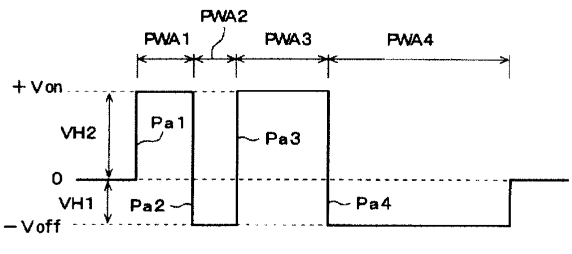
(54) INKJET HEAD DRIVING METHOD AND INKJET PRINTING APPARATUS

(57) The purpose of the present invention is to provide an inkjet head driving method and an inkjet printing apparatus that form stable large droplets efficiently with short drive cycles, limit the occurrence of satellites, and are capable of high quality image printing. A first drive signal (PA1), which is for expanding and contracting the volume of a pressure chamber to discharge at least two droplets from the same nozzle and unite same immediately after discharge to form a large droplet, comprises a first expansion pulse (Pa1) for expanding and contracting the volume of the pressure chamber, a first contraction pulse (Pa2) for contracting and expanding the volume of the pressure chamber, a second expansion pulse (Pa3) for expanding and contracting the volume of the pressure chamber, and a second contraction pulse (Pa4) for contracting and expanding the volume of the pressure chamber, in said order. A first droplet is discharged by the application of the first expansion pulse (Pa1) and the first contraction pulse (Pa2), a second droplet is discharged by application of the second expansion pulse (Pa3) and the second contraction pulse (Pa4), and the pulse width (PWA1) of the first expansion pulse (Pa1) is 0.4 AL to 2.0 AL (wherein AL is 1/2 of the acoustic resonance period of the pressure wave in the pressure chamber).

FIG.3



PA1

EP 3 127 704 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a method for driving an inkjet head and an inkjet recording apparatus and more particularly to a method for driving an inkjet head and an inkjet recording apparatus capable of stable formation in a short driving cycle when large droplets are ejected.

BACKGROUND

[0002] When pixels made of dots are to be formed by causing droplets to be ejected from a nozzle of an inkjet head to land on a media, it is known that gradation expression is made by changing a size of a dot diameter of one pixel. As a method for changing the dot diameter for gradation expression, a method of changing a number of droplets ejected from the same nozzle in 1 pixel cycle, a method of changing a driving signal in accordance with a dot size and the like are known.

[0003] Among them, the former method of changing the dot diameter has an advantage that the gradation can be expressed easily only by changing the number of driving signals to be applied within the 1 pixel cycle. However, if the number of driving signals is increased in order to form a large dot, a pixel cycle becomes longer, and there is a problem in high-frequency driving. Thus, an idea to enable stable formation of large droplets in a shorter driving cycle is in demand.

[0004] Conventional driving methods of an inkjet head include those described in Patent Documents 1 to 3.

[0005] Patent Document 1 describes that, when at least two droplets which are ejected consecutively at different speeds from the same nozzle are to be ejected, the droplet at a slower speed is ejected earlier than the droplet at a faster speed and is made to adhere by overlapping each other in one pixel so as to form one pixel.

[0006] However, in this method, since the two droplets are made to land so as to overlap on the media, there is a problem that an impact position of each of the droplets can be shifted easily.

[0007] Patent Document 2 describes that, a driving signal made of a rectangular wave, for sequentially generating a first pulse for expanding a capacity of a pressure chamber, a second pulse for contracting the capacity of the pressure chamber, a third pulse for expanding the capacity of the pressure chamber, and a fourth pulse for contracting the capacity of the pressure chamber is applied. The third pulse has a pulse width shorter than that of the first pulse, and the fourth pulse has a pulse width shorter than that of the second pulse. By determining a time difference between a pulse width center of the first pulse and the pulse width center of the third pulse as 1AL, a time difference between the pulse width center of the second pulse and the pulse width center of the fourth pulse as 1AL, a ratio of the pulse width of the first pulse to the pulse width of the third pulse, and the ratio of the pulse width of the second pulse and the pulse width of the fourth pulse in accordance with a damping rate of remaining oscillation of ink in the pressure chamber, a pressure wave generated by the first pulse and the second pulse is cancelled by the third pulse and the fourth pulse.

[0008] In this Patent Document 2, by changing the ratio of the pulse width between the first pulse and the second pulse on the basis of gradation information, an ejection volume of the ink is changed so that gradation printing is performed. However, in this method, since the third pulse and the fourth pulse are also adjusted so that the time difference from and the ratio of pulse width centers become predetermined values in accordance with the change of the pulse widths of the first pulse and the second pulse, cumbersome control should be executed, which is a problem.

[0009] On the other hand, Patent Document 3 describes that, assuming time during which the pressure wave propagates one way in an ink channel is T, a pulse width of a first injection pulse signal applied first is 0.35T to 0.65T, a pulse width of the injection pulse signals applied the second time and after is substantially T, and a time interval between the first injection pulse signal and the subsequent injection pulse signal is T, the droplet by the second injection pulse signal is injected from the nozzle before the droplet injected from the nozzle by the first injection pulse signal leaves the nozzle.

[0010] By means of each of the injection pulse signals, an actuator wall is deformed, the capacity of the ink channel increases, the actuator wall returns to a state before the deformation after certain time has elapsed, and a pressure is applied to the ink so that the ink droplet is injected, and a large droplet in which the droplet ejected by the second injection pulse signal catches up with the droplet ejected by the first injection pulse signal and both are integrated is ejected.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0011]

[Patent Document 1] Japanese Patent No. 3530717
[Patent Document 2] Japanese Patent No. 4247043

[Patent Document 3] Japanese Patent No. 3551822

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0012] The inventor paid attention to a technology of forming a large droplet by causing the same nozzle to eject a plurality of droplets and by joining them during flying immediately after the ejection in order to have as large droplets as possible efficiently ejected from the nozzle. According to this method, as compared with a case where one large droplet with the same droplet amount is ejected from the nozzle, the large droplet can be ejected while a droplet speed is suppressed, and impact position adjustment on the media is not made cumbersome.
[0013] On the other hand, the larger the droplet ejected from the nozzle becomes, or when the droplet amount is large, the faster the droplet speed becomes, the more serious the problem of occurrence of satellites or pressure wave remaining oscillation after the ejection becomes. The satellite refers to a small droplet (airborne droplet) secondarily formed behind the droplet (main droplet) ejected from the nozzle and might incur drop of an image quality.
[0014] Patent Document 3 discloses the technology for forming a large droplet by joining the plurality of droplets during flying but according to confirmation by the inventor, it was not sufficient from the viewpoint of suppression of occurrence of the satellites.
[0015] Thus, the present invention has an object to provide a method for driving an inkjet head and an inkjet recording apparatus which can form stable large droplets efficiently in a short driving cycle and can record images with high quality by suppressing occurrence of satellites.
[0016] Other object of the present invention will be made apparent from the description below.

MEANS FOR SOLVING PROBLEM

[0017] In order to realize at least one of the aforementioned objects, a method for driving an inkjet head reflecting one aspect of the present invention has the following constitution.
[0018] A method for driving an inkjet, in a method for driving an inkjet head which applies a driving signal to pressure generator for expanding or contracting a capacity of a pressure chamber, applies a pressure to a liquid in the pressure chamber by driving the pressure generator and ejects droplets from a nozzle, in which
when at least two droplets are ejected from the same nozzle and joined immediately after ejection so as to form a large droplet, a first driving signal is applied as the driving signal;
the first driving signal has a first expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, a first contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time, a second expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, and a second contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time in this order;
a first droplet is ejected from the nozzle by applying the first expansion pulse and the first contraction pulse and a second droplet is ejected by applying the second expansion pulse and the second contraction pulse; and
a pulse width of the first expansion pulse is 0.4 AL or more and 2.0 AL or less (where AL is 1/2 of an acoustic resonant period of a pressure wave in the pressure chamber).
[0019] In order to realize at least one of the aforementioned objects, an inkjet recording apparatus reflecting one aspect of the present invention has the following constitution.
[0020] In an inkjet recording apparatus including:

an inkjet head for applying a pressure for ejection of a liquid in a pressure chamber by driving of pressure generator so that a droplet is ejected from a nozzle; and
driving control means for outputting a driving signal for driving the pressure generator, in which
the driving signal includes a first driving signal for causing at least two droplets to be ejected from the same nozzle so that they are joined immediately after the ejection and form a large droplet;
the first driving signal has a first expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, a first contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time, a second expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, and a second contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time in this order;
a first droplet is ejected from the nozzle by applying the first expansion pulse and the first contraction pulse and a second droplet is ejected by applying the second expansion pulse and the second contraction pulse; and
a pulse width of the first expansion pulse is 0.4 AL or more and 2.0 AL or less (where AL is 1/2 of an acoustic

resonant period of a pressure wave in the pressure chamber).

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

[Fig. 1] Fig. 1 is a schematic configuration diagram illustrating an example of an inkjet recording apparatus according to the present invention.
[Fig. 2] Figs. 2 are views illustrating an example of an inkjet head, in which Fig. 2A is a perspective view illustrating an appearance by a section, and Fig. 2B is a sectional view when seen from a side surface.
[Fig. 3] Fig. 3 is a view for explaining a first embodiment of a first driving signal.
[Fig. 4] Figs. 4A to 4C are views for explaining an ejection operation of the inkjet head.
[Fig. 5] Fig. 5 is a conceptual view of a droplet ejected by the first driving signal.
[Fig. 6] Fig. 6 is a view for explaining a second embodiment of the first driving signal.
[Fig. 7] Fig. 7 is a view for explaining an example of a second driving signal.
[Fig. 8] Fig. 8 is a conceptual diagram of a droplet ejected by the second driving signal.
[Fig. 9] Fig. 9 is a view for explaining an example of a driving method of the inkjet head when gradation expression is made in the present invention.
[Fig. 10] Fig. 10A is a view for explaining an example of a flying state of the droplet, and Fig. 10B is a view illustrating a dot formed on a media by that.
[Fig. 11] Fig. 11A is a view for explaining another example of the flying state of the droplet, and Fig. 11B is a view illustrating a dot formed on a media by that.
[Fig. 12] Fig. 12A is a view for explaining still another example of the flying state of the droplet, and Fig. 12B is a view illustrating a dot formed on a media by that.
[Fig. 13] Figs. 13A and 13B are views for explaining another example of the first driving signal, and Fig. 13B is a view for explaining another example of the second driving signal.
[Fig. 14] Fig. 14 is a graph illustrating a change of a droplet amount when a pulse width of the first expansion pulse in the first driving signal is changed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Embodiments of the present invention will be described below by using the attached drawings.

[0023] Fig. 1 is a schematic constitution diagram illustrating an example of an inkjet recording apparatus according to the present invention.

[0024] In the inkjet recording apparatus 1, a conveying mechanism 2 sandwiches a media 7 made of paper, plastic sheets, cloth and or the like by a pair of conveying rollers 22 and conveys it by rotation of a conveying roller 21 by a conveying motor 23 in a Y-direction (sub scan direction)in the figure. An inkjet head (hereinafter referred to simply as a head) 3 is provided between the conveying roller 21 and the pair of conveying rollers 22. The head 3 is mounted on a carriage 5 so that a nozzle surface side is faced with a recording surface 71 of the media 7 and is electrically connected to a driving control unit 8 constituting driving control means in the present invention through a flexible cable 6.

[0025] The carriage 5 is provided capable of reciprocating movement in an X-X' direction (main scan direction) in the figure substantially orthogonal to the sub scan direction by driving means, not shown, along guide rails 4 extended over a width direction of the media 7. The head 3 moves the recording surface 71 of the media 7 in the main scan direction with the reciprocating movement of the carriage 5, ejects a droplet from a nozzle in the course of this movement in accordance with image data and records an inkjet image.

[0026] Fig. 2 is a view illustrating an example of the head 3, in which Fig. 2A is a perspective view illustrating an appearance by a section and Fig. 2B is a sectional view when seen from a side surface.

[0027] In the head 3, reference numeral 30 denotes a channel substrate. On the channel substrate 30, a large number of narrow-groove shaped channels 31 and partition walls 32 are juxtaposed alternately. On an upper surface of the channel substrate 30, a cover substrate 33 is provided so as to close an upper part of all the channels 31. Anozzleplate 34 is joined to end surfaces of the channel substrate 30 and the cover substrate 33. One end of each of the channels 31 communicates with an outside through a nozzle 341 formed in this nozzle plate 34.

[0028] The other end of each of the channels 31 is formed so as to be a gradually shallow groove with respect to the channel substrate 30. In the cover substrate 33, a common channel 331 common to each of the channels 31 is formed, and this common channel 331 communicates with each of the channels 31. The common channel 331 is closed by a plate 35. In the plate 35, an ink supply port 351 is formed. Through this ink supply port 351, ink is supplied from an ink supply pipe 352 into the common channel 331 and each of the channels 31.

[0029] The partition wall 32 is made of a piezoelectric element such as PZT or the like which is electro-mechanical converting means. As this partition wall 32, those formed of the piezoelectric element in which an upper wall portion 321 and a lower wall portion 322 are subjected to polarization treatment in directions opposite to each other are exemplified. However, a portion formed by the piezoelectric element in the partition wall 32 may be only the upper wall portion 321, for example. Since the partition walls 32 and the channels 31 are alternately juxtaposed, one partition wall 32 is shared by the adjacent channels 31 and 31 on both sides.

[0030] On an inner surface of the channel 31, a driving electrode (not shown in Figs. 2) is formed from wall surfaces to bottom surfaces of both partition walls 32 and 32, respectively. When a driving signal at a predetermined voltage is applied from the driving control unit 8 to the two driving electrodes arranged by sandwiching the partition wall 32, the partition wall 32 is sheared and deformed at a joint surface between the upper wall portion 321 and the lower wall portion 322 as a boundary. If the adjacent two partition walls 32 and 32 are sheared/deformed in directions opposite to each other, a capacity of the channel 31 sandwiched by the partition walls 32 and 32 is expanded or contracted, and a pressure wave is generated inside. As a result, a pressure for ejection is applied to the ink in the channel 31.

[0031] This head 3 is a shear-mode head for ejecting the ink in the channel 31 from the nozzle 341 by shear deformation of the partition wall 32 and is a preferable mode in the present invention. The shear-mode head can efficiently eject the droplet by using a rectangular wave which will be described later as the driving signal.

[0032] In this head 3, the channel 31 surrounded by the channel substrate 30, the partition wall 32, the cover substrate 33, and the nozzle plate 34 is an example of a pressure chamber in the present invention, and the partition wall 32 and the driving electrode on the surface thereof are an example of the pressure generator in the present invention.

[0033] The driving control unit 8 generates the driving signal for ejecting the droplet from the nozzle 341. The generated driving signal is output to the head 3 and is applied to each of the driving electrodes formed on the partition wall 32.

[0034] Subsequently, a first embodiment of the first driving signal will be described.

[0035] Fig. 3 is a view for explaining the first embodiment of the first driving signal in the present invention as the driving signal generated in the driving control unit 8.

[0036] A first driving signal PA1 is a driving signal for causing at least two droplets to be ejected from the same nozzle 341 and to be joined during flying immediately after the ejection so as to form a large droplet. This first driving signal PA1 has a first expansion pulse Pa1 for expanding a capacity of the channel 31 and contracting it after certain time, a first contraction pulse Pa2 for contracting the capacity of the channel 31 and expanding it after certain time, a second expansion pulse Pa3 for expanding the capacity of the channel 31 and contracting it after certain time, and a second contraction pulse Pa4 for contracting the capacity of the channel 31 and expanding it after certain time in this order.

[0037] The first expansion pulse Pa1 of the first driving signal PA1 illustrated in this embodiment is a pulse which rises from a reference potential and falls to the reference potential after certain time. The first contraction pulse Pa2 is a pulse which falls from the reference potential and rises to the reference potential after certain time. The second expansion pulse Pa3 is a pulse which rises from the reference potential and falls to the reference potential after certain time. The second contraction pulse Pa4 is a pulse which falls from the reference potential and rises to the reference potential after certain time. Here, the reference potential is assumed to be 0 potential, but that is not particularly limiting.

[0038] As described above, since the first driving signal PA1 is constituted by the expansion pulses which rise from the reference potential and fall to the reference potential after certain time and the contraction pulses which fall from the reference potential and rise to the reference potential after certain time, the driving voltage can be kept lower than the case where a single electrode pulse is used, and a circuit load and power consumption can be suppressed.

[0039] The first contraction pulse Pa2 consecutively falls without a pause period from a terminal end of falling of the first expansion pulse Pa1. Moreover, the second expansion pulse Pa3 consecutively rises without a pause period from a terminal end of rising of the first contraction pulse Pa2. Furthermore, the second contraction pulse Pa4 consecutively falls without a pause period from a terminal end of falling of the second expansion pulse Pa3.

[0040] By applying the second contraction pulse Pa2 to the driving electrode subsequent to application of the first expansion pulse Pa1, the first droplet is ejected from the nozzle 341, and by applying the second expansion pulse Pa3 and the second contraction pulse Pa4 immediately after that, the second droplet is ejected from the same nozzle 341. The ejected droplets are joined immediately after the ejection and form a large droplet and then, land onto the media 7.

[0041] In this first driving signal PA1, a pulse width PWA1 of the first expansion pulse Pa1 is set to 0.4 AL or more and 2.0 AL or less. By setting the pulse width PWA1 of the first expansion pulse Pa1 within this range, a liquid amount can be increased by the two droplets, a stable large droplet can be ejected efficiently in a short driving cycle, and occurrence of satellites accompanying the droplet can be suppressed, whereby the method for driving the inkjet head 3 and the inkjet recording apparatus 1 which can perform high quality image recording can be provided.

[0042] If the pulse width PWA1 falls under 0.4 AL, the droplet amount pushed out of the nozzle 341 by the first expansion pulse Pa1 runs short, which makes formation of a large droplet difficult. On the other hand, if the pulse width PWA1 exceeds 2.0 AL, driving efficiency deteriorates and moreover, a driving cycle becomes longer, which makes driving in a short cycle difficult.

[0043] In the present invention, the at least two droplets ejected from the same nozzle 341 by application of the first driving signal may be in a partially connected state or may be separated from each other as long as they are joined during flying immediately after the ejection and form a large droplet.

[0044] From the viewpoint of promoting validity of the aforementioned effects, a pulse width PWA2 of the first contraction pulse Pa2 is preferably set to 0.4 AL or more and 0.7 AL or less, and 0.5 AL is the most preferable. Moreover, from the similar viewpoint, a pulse width PWA3 of the second expansion pulse Pa3 is preferably set to 0.8 AL or more and 1.2 AL or less, and 1 AL is the most preferable. Furthermore, from the similar viewpoint, a pulse width PWA4 of the second contraction pulse Pa4 is preferably set to 1.8 AL or more and 2.2 AL or less, and 2 AL is the most preferable.

[0045] Here, the term AL is abbreviation of Acoustic Length and means 1/2 of an acoustic resonant period of a pressure wave in the channel 31. AL is acquired as a pulse width with which a flying speed of a droplet becomes the maximum when the pulse width of a rectangular wave is changed with a voltage value of the rectangular wave made constant by measuring the flying speed of the droplet ejected when the driving signal with the rectangular wave is applied to the driving electrode.

[0046] The pulse is a rectangular wave of a constant-voltage wave crest value and assuming that 0 V is 0%, a wave crest value voltage is 100%, and the pulse width is defined as time from rising 10% from the voltage 0 V to falling 10% from the wave crest value voltage.

[0047] Moreover, the rectangular wave refers to a waveform in which both rising time and falling time between 10% and 90% of the voltage are within 1/2 or preferably within 1/4 of AL.

[0048] Subsequently, an ejection operation of the head 3 when this first driving signal PA1 is applied will be described by using Fig. 4. Fig. 4 illustrates a part of a section when the head 3 is cut in a direction orthogonal to a length direction of the channel 31. Here, it is assumed that the droplet is ejected from a channel 31B at a center in Fig. 4. Moreover, a conceptual diagram of the droplet ejected when the first driving signal PA1 is applied is illustrated in Fig. 5.

[0049] First, when driving electrodes 36A and 36C are grounded from neutral states of partition walls 32B and 32C illustrated in Fig. 4A and the first expansion pulse Pa1 in the first driving signal PA1 is applied to a driving electrode 36B, the partition walls 32B and 32C are bent and deformed outward from each other as illustrated in Fig. 4B, and the capacity of the channel 31B sandwiched by the partition walls 32B and 32C is expanded. As a result, a negative pressure is generated in the channel 31B, and the ink flows thereinto.

[0050] The first expansion pulse Pa1 is maintained at 0.4 AL or more and 2.0 AL or less and then, application of the first expansion pulse Pa1 is finished. As a result, the capacity of the channel 31B is contracted from the expanded state, and the partition walls 32B and 32C return to the neutral state illustrated in Fig. 4A. Then, by consecutively applying the first contraction pulse Pa2 without a pause period, the capacity of the channel 31B immediately enters the contracted state illustrated in Fig. 4C. At this time, the pressure is applied to the ink in the channel 31B, and the ink is pushed out of the nozzle 341 and ejected as the first droplet.

[0051] When application of the first contraction pulse Pa2 is finished, the capacity of the channel 31B is expanded from the contracted state, and the partition walls 32B and 32C return to the neutral state illustrated in Fig. 4A. Then, by consecutively applying the second expansion pulse Pa3 without a pause period, the capacity of the channel 31B immediately enters an expanded state illustrated in Fig. 4B, and the negative pressure is generated in the channel 31. Thus, a speed of the previously ejected first droplet is suppressed. Moreover, the ink flows in again by the negative pressure generated in the channel 31B.

[0052] When application of the second expansion pulse Pa3 is finished, the capacity of the channel 31B is contracted from the expanded state, and the partition walls 32B and 32C return to the neutral state illustrated in Fig. 4A. Then, by consecutively applying the second contraction pulse Pa4 without a pause period, the capacity of the channel 31B immediately enters the contracted state illustrated in Fig. 4C. At this time, a large pressure is applied to the ink in the channel 31B, and the ink is further pushed out consecutively to the first droplet ejected by the first expansion pulse Pa1 and the first contraction pulse Pa2, and the pushed-out ink is torn off and the second droplet at a large droplet speed is ejected.

[0053] In the droplet ejected by the first driving signal PA1, as illustrated in Fig. 5, subsequent to a first droplet 101 at a smaller droplet speed by the first expansion pulse Pa1 and the first contraction pulse Pa2, a second droplet 102 at the larger droplet speed by the second expansion pulse Pa3 and the second contraction pulse Pa4 is formed. A droplet 100 at the beginning of ejection has a form in which the first droplet 101 and the second droplet 102 are connected, but since an ejection speed of the second droplet 102 is sufficiently larger than that of the first droplet 101, they are joined during flying immediately after the ejection and form one larger droplet 100.

[0054] When application of the second contraction pulse Pa4 is finished, the capacity of the channel 31B is expanded from the contracted state, and the partition walls 32B and 32C return to the neutral state in Fig. 4A.

[0055] Since the first droplet 101 at a smaller droplet speed and the second droplet 102 at the larger speed are joined, this droplet 100 has a droplet speed slower than the case where a single large droplet with the same droplet amount is ejected from the nozzle 341.

[0056] Moreover, since this droplet 100 has a slow droplet speed, a satellite amount is suppressed as compared with the case where the single droplet with the same droplet amount is ejected from the nozzle 341. That is, the satellite is generated in general when a tail formed so as to extend to the rear accompanying the ejected main droplet is separated from the main droplet. The faster the droplet speed is, the longer this tail becomes, and separation at a position away from the main droplet becomes easier. If the tail is separated at the position away from the main droplet, an impact position of the satellite is also separated largely from the main droplet, which causes a drop of the image quality. In other words, as long as the satellite is separated in the vicinity of the main droplet, the both land at substantially the same position, which rarely affect the image quality. By means of the first driving signal PA1, the droplet can be ejected at a low speed even with a larger droplet amount, a length of the tail accompanying the droplet 100 (main droplet) can be shortened, and the satellite can be separated at a position in the vicinity of the main droplet. Therefore, an influence by the satellite can be suppressed while the large droplet 100 is ejected. Thus, the problem that the satellite when the droplet 100 is ejected lowers the image quality is not caused.

[0057] The droplet speed in the present invention is calculated by recognizing the droplet on an image by a droplet observing device and by obtaining elapsed time from the ejection and a position coordinate where the droplet is present at that time. Specifically, it is calculated from a distance for which the droplet flies for 50 μs from a position away from the nozzle surface by 500 μm. The elapsed time from the ejection can be calculated by synchronizing an ejection signal of the inkjet head with strobe for observation. The position coordinate of the droplet can be calculated by image processing of a flying image.

[0058] The pulse width PWA1 of the first expansion pulse Pa1 in the first driving signal PA1 is set to 0.4 AL or more and 0.7 AL or less or more preferably to 1.3 AL or more and 1.8 AL or less. As a result, variation of the droplet speed of each droplet when the first driving signal PA1 is continuously driven in a short cycle can be suppressed while the influence of the satellite is suppressed.

[0059] Moreover, the first driving signal PA1 is preferably a rectangular wave. The first expansion pulse Pa1, the first contraction pulse Pa2, the second expansion pulse Pa3, and the second contraction pulse Pa4 constituting the first driving signal PA1 are constituted by a rectangular wave as illustrated in Fig. 3. Particularly, since the shear-mode head 3 can generate a pressure wave with a phase aligned to application of the driving signal made of a rectangular wave, the droplet can be efficiently ejected and moreover, the driving voltage can be kept lower. In general, a voltage is applied to the head 3 at all times regardless of ejection or non-ejection, and the low driving voltage is important in suppression of heat generation of the head 3 and stable ejection of the droplet.

[0060] Since the rectangular wave can be easily generated by using a simple digital circuit, circuit configuration can be simplified as compared with use of a trapezoidal wave having an inclined wave.

[0061] In the first driving signal PA1, it is preferable that a voltage value of the first expansion pulse Pa1 and a voltage value of the second expansion pulse Pa3 are equal and a voltage value of the first contraction pulse Pa2 and a voltage value of the second contraction pulse Pa4 are equal. Since at least two power supplies are sufficient, the number of power supplies can be reduced. As a result, circuit configuration of the driving control unit 8 can be simplified.

[0062] At this time, assuming that the voltage values of the first expansion pulse Pa1 and the second expansion pulse Pa3 are VH2, and the voltage values of the first contraction pulse Pa2 and the second contraction pulse Pa4 are VH1, it is preferably $|VH2|/|VH1|=2/1$. As a result, return of ink meniscus in the nozzle 341 can be promoted, whereby high-frequency driving is made possible. Moreover, stabilization of flying can be realized particularly when high viscosity ink is used.

[0063] Subsequently, a second embodiment of the first driving signal will be described.

[0064] Fig. 6 is a view for explaining the second embodiment of the first driving signal in the present invention as a driving signal generated in the driving control unit 8.

[0065] The first driving signal PA2 is a driving signal which causes at least two droplets to be ejected from the same nozzle 341 similarly to the first driving signal PA1 and joinied during flying immediately after ejection so as to form a large droplet. This first driving signal PA2 has the first expansion pulse Pa1 for expanding a capacity of the channel 31 and contracting it after certain time, the first contraction pulse Pa2 for contracting the capacity of the channel 31 and expanding it after certain time, the second expansion pulse Pa3 for expanding the capacity of the channel 31 and contracting it after certain time, the second contraction pulse Pa4 for contracting the capacity of the channel 31 and expanding it after certain time, and a third contraction pulse Pa5 for contracting the capacity of the channel 31 and expanding it after certain time in this order.

[0066] Constitution of the waveform of the first driving signal PA2 illustrated in this embodiment is different from the first driving signal PA1 only in a point that the third contraction pulse Pa5 is added at an interval from the end of application of the second contraction pulse Pa4. This third contraction pulse Pa5 is a pulse which falls from the reference potential and rises to the reference potential after certain time. The reference potential is set to 0 potential here, too, but this is not particularly limiting.

[0067] In this first driving signal PA2, too, the pulse width PWA1 of the first expansion pulse Pa1 is set to 0.4 AL or more and 2.0 AL or less. Immediately after the first droplet is ejected from the nozzle 341 by application of the first expansion pulse Pa1 and the first contraction pulse Pa2, the second expansion pulse Pa3 and the second contraction pulse Pa4 are applied so that the second droplet is ejected. Thus, the effect similar to the method for driving the inkjet head 3 and the inkjet recording apparatus 1 using the first driving signal PA1 is exerted.

[0068] Moreover, the pulse width PWA4 of the second contraction pulse Pa4 is set to 0.3 AL or more and 0.7 AL or less, the pulse width PWA5 of the third contraction pulse Pa5 is set to 0.8 AL or more and 1.2 AL or less, and it is set such that the third contraction pulse Pa5 is applied at an interval of 0.3 AL or more and 0.7 AL or less from the end of application of the second contraction pulse Pa4, that is, after a pause period PWA6. As a result, tearing-off of the tail accompanying the main droplet can be promoted, whereby the influence of the satellite can be further reduced. Moreover, the pressure wave resonant oscillation in the channel 31 can be also effectively canceled by the third contraction pulse Pa5.

[0069] In ensuring this effect, the pulse width PWA4 of the second contraction pulse Pa4 is most preferably 0.5 AL, the pulse width PWA5 of the third contraction pulse Pa5 is most preferably 1 AL, and the third contraction pulse Pa5 is most preferably applied at an interval of 0.5 AL from the end of application of the second contraction pulse Pa4.

[0070] Moreover, from the viewpoint of ensuring the aforementioned effect, the pulse width PWA2 of the first contraction pulse Pa2 and the pulse width PWA3 of the second expansion pulse Pa3 are preferably made similar to the first contraction pulse Pa2 and the second expansion pulse Pa3 in the first driving signal PA1.

[0071] Subsequently, the ejection operation of the head 3 when this first driving signal PA2 is applied will be described by using Fig. 4 similarly to the first driving signal PA1. Since from the first expansion pulse Pa1 to the second expansion pulse Pa3 are the same as the first driving signal PA1, the explanation in the first driving signal PA1 is used for explanation for them and explanation here is omitted.

[0072] When application of the second contraction pulse Pa3 in this first driving signal PA2 is finished, the capacity of the channel 31B sandwiched by the partition walls 32B and 32C is contracted from the expanded state, and the partition walls 32B and 32C return to the neutral state in Fig. 4A. Then, by consecutively applying the second contraction pulse Pa4 to the driving electrode 36B without a pause period, the capacity of the channel 31B immediately enters the contracted state illustrated in Fig. 4C. At this time, a large pressure is applied to the ink in the channel 31B, and the ink is further ejected consecutively to the ink ejected by the first expansion pulse Pa1 and the first contraction pulse Pa2, and the large droplet 100 made of the first droplet 101 and the second droplet 102 is ejected similarly to Fig. 5.

[0073] After the second contraction pulse Pa4 is maintained at 0.3 AL or more and 0.7 AL or less, the capacity of the channel 31B is expanded from the contracted state, and the partition walls 32B and 32C return to the neutral state illustrated in Fig. 4A. At this time, since the negative pressure is generated in the channel 31, the ink meniscus is withdrawn by the negative pressure generated in the channel 31 relatively earlier. Thus, the tail of the ejected ink droplet is torn off earlier, and the tail accompanying the ejected droplet 100 (main droplet) becomes short. Therefore, the influence of the satellite can be further reduced as compared with the case of the first driving signal PA1.

[0074] Moreover, after the application of the second contraction pulse Pa4 is finished, and the partition walls 32B and 32C return to the neutral state illustrated in Fig. 4A, when the third contraction pulse Pa5 is applied at an interval of 0.3 AL or more and 0.7 AL or less, the capacity of the channel 31B enters the contracted state illustrated in Fig. 4C again. Then, after 0.8 AL or more and 1.2 AL or less have elapsed, the capacity of the channel 31B is expanded while a positive pressure remains in the channel 31, and the partition walls 32B and 32C return to the neutral state illustrated in Fig. 4A again. As a result, the negative pressure is generated in the channel 31, and the pressure wave resonant oscillation is cancelled.

[0075] In this first driving signal PA2, too, for the reason similar to the first driving signal PA1, the pulse width PWA1 of the first expansion pulse Pa1 is preferably set to 0.4 AL or more and 0.7 AL or less or to 1.3 AL or more and 1.8 AL or less.

[0076] Moreover, the first driving signal PA2 is also preferably a rectangular wave for the reason similar to the first driving signal PA1. The first expansion pulse Pa1, the first contraction pulse Pa2, the second expansion pulse Pa3, the second contraction pulse Pa4, and the third contraction pulse Pa5 constituting the first driving signal PA2 are also constituted by a rectangular wave as illustrated in Fig. 6.

[0077] In the first driving signal PA2, too, it is preferable that the voltage value of the first expansion pulse Pa1 and the voltage value of the second expansion pulse Pa3 are equal and the voltage value of the first contraction pulse Pa2, the voltage value of the second contraction pulse Pa4, and the voltagevalue of the third contraction pulse Pa5 are equal for the reason similar to the first driving signal PA1.

[0078] At this time, for the reason similar to the first driving signal PA1, assuming that the voltage values of the first expansion pulse Pa1 and the second expansion pulse Pa3 are VH2, and the voltage values of the first contraction pulse Pa2, the second contraction pulse Pa4, and the third contraction pulse Pa5 are VH1, it is preferably $|VH2|/|VH1|=2/1$.

[0079] Subsequently, the case where gradation expression is made will be described.

[0080] When the droplet is to be ejected for gradation expression in the present invention, a second driving signal PB for ejecting a droplet at a relatively higher speed and smaller than the droplet 100 by the first driving signal PA1 or PA2 is joined with the aforementioned first driving signal PA1 or PA2, N pieces (N is an integer not less than 0) of the first driving signal PA1 or PA2 and the second driving signal PB at least at the end are applied within the 1 pixel cycle, and the number N is changed in accordance with image data. The 1 pixel cycle means a time interval for forming each pixel by a dot by causing the droplet to be ejected from the nozzle 341 to land onto the media 7.

[0081] Here, the second driving signal PB will be described.

[0082] Fig. 7 is a view for explaining the second driving signal in the present invention as the driving signal generated in the driving control unit 8. However, the second driving signal PB illustrated in Fig. 7 is a preferable example in the present invention and does not limit to those illustrated.

[0083] The second driving signal PB has an expansion pulse Pb1 for expanding the capacity of the channel 31 and contracting it after certain time and a contraction pulse Pb2 for contracting the capacity of the channel 31 and expanding it after certain time in this order.

[0084] The expansion pulse Pb1 of the second driving signal PB illustrated in this embodiment is a pulse which rises from the reference potential and falls to the reference potential after certain time. The contraction pulse Pb2 is a pulse which falls from the reference potential and rises to the reference potential after certain time. Here, too, the reference potential is assumed to be 0 potential, but that is not particularly limiting.

[0085] In this second driving signal PB, too, assuming that the voltage value of the expansion pulse Pb1 is VH2, and the voltage value of the contraction pulse Pb2 is VH1, it is preferably $|VH2|/|VH1|=2/1$.

[0086] In the example of this second driving signal PB, a pause period PWB3 during which the reference potential is maintained for a certain period is provided between a terminal end of falling of the expansion pulse Pb1 and a start end of falling of the contraction pulse Pb2. This is provided in order to avoid that the droplet speed becomes too fast since the capacity of the channel 31 is rapidly changed from the expanded state by the expansion pulse Pb1 to the contracted state by the contraction pulse Pb2 due to a relation with the first driving signal PA1 or PA2 and to avoid that the droplet amount of the ejected droplet becomes too large. By adjusting a length of this pause period PWB3, the speed and the droplet amount of the droplet ejected by application of the second driving signal PB can be easily adjusted in relation with the droplet ejected by the first driving signal PA1 or PA2. Thus, this pause period PWB3 is preferably provided in the second driving signal PB.

[0087] The expansion pulse Pb1 and the contraction pulse Pb2 constituting the second driving signal PB is also preferably a rectangular wave as illustrated for the reason similar to the first driving signal PA1 or PA2.

[0088] It is preferable that a pulse width PWB1 of the expansion pulse Pb1 is 0.8 AL or more and 1.2 AL or less and a pulse width PWB2 of the contraction pulse Pb2 is 1.8 AL or more and 2.2 AL or less. As a result, the droplet can be ejected efficiently. If the pause period PWB3 is too long, the ejection efficiency is largely lowered and thus, it is preferably adjusted to 1/4 AL or less.

[0089] Subsequently, the ejection operation of the head 3 when the second driving signal PB is applied will be described by using Figs. 4. Moreover, a conceptual diagram of the droplet ejected when the second driving signal PB is applied is illustrated in Figs. 8.

[0090] As illustrated in Fig. 4A, when the driving signal is not applied to any of the driving electrodes 36A, 36B, and 36C in the mutually adjacent channels 31A, 31B, 31C, the partition walls 32A, 32B, 32C, and 32D are in the neutral state without deformation. When the driving electrodes 36A and 36C are grounded and the expansion pulse Pb1 in the second driving signal PB is applied to the driving electrode 36B, an electric field is generated in a direction orthogonal to a polarization direction of the piezoelectric elements constituting the partition walls 32B and 32C. As a result, the partition walls 32B and 32C are bent and deformed outward from each other as illustrated in Fig. 4B, and the capacity of the channel 31B is expanded (Draw). As a result, the negative pressure is generated in the channel 31B, and the ink flows thereinto.

[0091] Since the pressure in the channel 31 is inverted at every AL, after this expansion pulse Pa1 is maintained for a period of 0.8 AL or more and 1.2 AL or less, the inside of the channel 31B is changed to a positive pressure. If the application of the expansion pulse Pb1 is finished and the potential is returned to the reference potential at this timing, the capacity of the channel 31B sandwiched by the partition walls 32B and 32C is contracted from the expanded state. As a result, the partition walls 32B and 32C return to the neutral state illustrated in Fig. 4A (Release). At this time, a large pressure is applied to the ink in the channel 31B, and the ink is moved to a direction in which the ink is pushed out of the nozzle 341.

[0092] By applying the contraction pulse Pb2 to the driving electrode 36B after the neutral state of the partition walls 32B and 32C is maintained only for the pause period PWB3, the partition walls 32B and 32C are bent and deformed inward to each other as illustrated in Fig. 4C, and the capacity of the channel 31B is contracted (Reinforce). As a result, the pressure is further applied to the ink in the channel 31B, and the ink having been moved in the direction of being pushed out of the nozzle 341 is further pushed out. After that, the pushed-out ink is torn off, and a single droplet 200 is ejected as illustrated in Fig. 8.

[0093] This droplet 200 is a small droplet with a droplet amount smaller than that of the droplet 100 by the aforementioned first driving signal PA1 or PA2. When this droplet 200 is ejected, satellites do not occur or is suppressed to an extremely small amount if any.

[0094] The contracted state by the contraction pulse Pb2 is returned to the original when the pressure in the channel 31 changes to positive after 1.8 A or more and 2.2 AL or less have elapsed. As a result, the capacity of the channel 31B is expanded from the contracted state, and the partition walls 32B and 32C return to the neutral state in Fig. 4A.

[0095] Fig. 9 illustrates an example of a method for driving when the gradation expression is to be made by joining the first driving signal PA1 and the second driving signal PB described above. Here, an example in which six-stage gradation expression is made from Level 0 (minimum gradation) to Level 5 (maximum gradation) by changing the number of the first driving signals PA1 to be applied in the 1 pixel cycle T from 0 (N=0) to 4 (N=4) at the maximum is illustrated. The Level 0 is a case where the driving signal is not applied at all. Though not shown, it is needless to say that the first driving signal PA2 can be also joined with the second driving signal PB similarly to the first driving signal PA1 for making the gradation expression which will be described below.

[0096] Each driving signal group expressing gradation from Level 1 to Level 5 can be stored in association with each gradation in advance in the driving control unit 8. The driving control unit 8 selects desired gradation in accordance with the image data, calls the driving signal group corresponding to that and then, applies the driving signal group to the head 3.

[0097] When the gradation expression is to be made in the present invention, by applying the second driving signal PB at least at the end of the 1 pixel cycle T except Level 0, the number of droplets ejected from the same nozzle 341 is changed. At this time, the gradation can be expressed by changing the number N in an integer not less than 0 of the first driving signals PA1 to be applied so as to form the pixel by dots made of the droplets on the media 7. If a plurality of the droplets is ejected from the same nozzle 341 within the 1 pixel cycle T, the pixel can be formed on the media 7 by dots made of the droplets joined into one by joining the plurality of the droplets during flying. Moreover, the pixel can be also formed by dots made of a collection of a plurality of the dots by causing the plurality of the droplets to land on the media 7 while overlapping each other.

[0098] The first driving signal PA1 is a driving signal for ejecting the droplet 100 relatively larger than the droplet 200 by the second driving signal PB. Thus, by applying one or more first driving signals PA1 within the 1 pixel cycle T, a large dot is mainly formed, which contributes to expression of dark gradation. Moreover, as described above, the droplet 100 has a relatively lower speed than that of the droplet 200, and the generated satellite is caught by the droplet ejected later within the same pixel cycle T. Therefore, the satellite does not make a problem of such a degree to lower the image quality.

[0099] The droplet 100 has a droplet amount larger than that of the droplet 200 and makes a large droplet. However, since a first droplet 101 at a small droplet speed and a second droplet 102 at a large droplet speed join each other, the droplet speed becomes lower than the case where one large droplet with the same droplet amount is ejected from the nozzle 341. According to this embodiment, the droplet 100 has a speed lower than that of the droplet 200.

[0100] At this time, the droplet speed of the droplet 200 is preferably adjusted to be smaller than the droplet speed of the second droplet 102 of the droplet 100. A satellite amount of the droplet 100 depends on the droplet speed of the second droplet 102, and by adjusting the droplet speed of the droplet 200 to be smaller than the droplet speed of the second droplet 102 of the droplet 100, the satellite amount of the droplet 200 can be suppressed.

[0101] When a plurality of the droplets is ejected within the 1 pixel cycle T, the satellite of the preceding droplet is caught by the droplet ejected later within the same pixel cycle T and thus, from the viewpoint of the image quality, the satellite accompanying the droplet ejected at the end within the 1 pixel cycle T makes a problem. In this embodiment, the second driving signal PB is surely applied at the end within the 1 pixel cycle T, and since the droplet 200 relatively smaller than the droplet 100 by the first driving signal PA1 is ejected and as a result, the satellite is not generated or suppressed.

[0102] Therefore, even if the first driving signal PA1 and the second driving signal PB are applied within the 1 pixel cycle T and a large dot is formed on the media 7 by ejecting a plurality of the droplets, image recording with a high quality and suppressed satellite can be performed.

[0103] In Fig. 9, reference character TA denotes a driving cycle of the first driving signal PA1 within the 1 pixel cycle T, and reference character TB denotes a driving cycle of the second driving signal PB within the 1 pixel cycle T. An example is illustrated in which the first driving signal PA1 is applied with a predetermined pause period T1 before the subsequent driving signal, and a predetermined pause period T2 is given from the end of application of the single second driving signal PB applied at the end to the start of the subsequent 1 pixel cycle T.

[0104] From the viewpoint of reduction of the influence of the satellite present among the plurality of droplets, the pause period T1 is preferably 2AL or less, and from the viewpoint of suppressing the influence of the remaining oscillation after the droplet ejection and stabilizing the subsequent droplet ejection, the pause period T2 is preferably 1.5 AL or more.

[0105] When the droplet is to be ejected for performing gradation expression, it is preferable that the single second driving signal PB is surely applied at least at the end within the 1 pixel cycle T except Level 0. Therefore, application of one or more second driving signals PB before the second driving signal PB applied at the end within the 1 pixel cycle is not limited at all. In this case, the second driving signal PB might be applied at the beginning within the 1 pixel cycle T, but impact performances are preferably improved by setting the pause period PWB3 of the second driving signal PB longer than the pause period PWB3 of the second driving signal PB applied at the end so that the speed of the droplet ejected at the beginning is slower than that of the droplet ejected at the end.

[0106] Moreover, the number N of the first driving signal PA1 may only be an integer not less than 0 and is not limited to the illustrated number but in any gradation, the second driving signal PB is surely applied at the end of the 1 pixel cycle T. Thus, whichever gradation is to be expressed, the second driving signal PB is applied. In any gradation in which the droplet is ejected, the second driving signal PB applied at the end is, as illustrated in the figure, applied so as to be at the same timing within the 1 pixel cycle T.

[0107] This second driving signal PB is preferably a driving signal for forming a smallest droplet in the plurality of the driving signals arranged in a time series within the 1 pixel cycle T. As a result, the effect of suppressing the satellite can be further improved.

[0108] Moreover, the second driving signal PB is preferably a driving signal for forming a smallest droplet and also a droplet at a fast droplet speed in the plurality of the driving signals arranged in a time series within the 1 pixel cycle T from the viewpoint of the satellite suppressing effect and the effect of suppressing the impact position deviation.

[0109] Here, it is assumed that the droplet 100 with 10 pl is ejected by the first driving signal PA1, and the droplet 200 with 6 pl is ejected by the second driving signal PB. Thus, it is Level 1=6 pl, Level 2=16 pl, Level 3=26 pl, Level 4=36 pl, and Level 5=46 pl, whereby wide gradation can be expressed while the minimum liquid amount (6 pl) by the second driving signal PB is ensured.

[0110] In general, a large droplet can be ejected also by using a driving signal made of a DRR (Draw-Release-Reinforce) waveform similar to the second driving signal PB and by extending its pulse width. However, since this makes a driving signal with a long cycle in this case, many droplets cannot be ejected in a limited period of time within the 1 pixel cycle T as in the maximum gradation is expressed. However, by using the first driving signal PA1, the droplet 100 can be ejected at a relatively low speed in a short cycle and thus, more droplets can be ejected in limited time within the 1 pixel cycle T. Therefore, by changing the number N of the first driving signal PA1 in accordance with the image data, wide gradation expression can be realized from the minimum gradation to the maximum gradation.

[0111] In the gradation expression, a diameter of the droplet 200 ejected by the second driving signal PB is preferably smaller than a diameter of the nozzle 341. By setting the diameter of the droplet 200 smaller than the diameter of the nozzle 341, the satellite suppression effect can be further improved.

[0112] Here, the diameter of the nozzle is assumed to refer to a diameter of an opening at a tip end of the nozzle in an ejection direction when its shape is circular and if it is not circular, a diameter of a circle obtained by replacing the opening with a circle with the same area.

[0113] Moreover, the diameter of the droplet is assumed to refer to a diameter when the droplet is spherical and if it is not spherical, a diameter of a ball obtained by replacing the droplet with a ball with the same volume.

[0114] On the other hand, the diameter of the droplet 100 ejected by the first driving signal PA1 or PA2 is preferably larger than the diameter of the nozzle 341. By setting the diameter of the droplet 100 larger than the diameter of the nozzle 341, the gradation can be expressed by forming a dot as large as possible on the media 7.

[0115] The diameter of the droplet 100 ejected by the first driving signal PA1 or PA2 is a diameter in a state where the first droplet 101 and the second droplet 102 are joined and form a single large droplet.

[0116] It is needless to say that the diameter of the droplet 200 ejected by the second driving signal PB is preferably smaller than the diameter of the nozzle 341 and the diameter of the droplet 100 ejected by the first driving signal PA1 or PA2 is preferably larger than the diameter of the nozzle 341.

[0117] Assuming that the droplet amount of the droplet ejected by the first driving signal PA1 or PA2 is MA, and the droplet amount of the droplet ejected by the second driving signal PB is MB, it is preferably $MA \geq MB \times 1.5$. As a result, a pixel made of dots as large as possible can be formed on the media 7 at the maximum gradation while the satellite is effectively suppressed.

[0118] In the shear-mode head 3 in which the adjacent channels 31 share the partition wall 32 in general, when the one channel 31 is driving for ejection, the both adjacent channels 31 and 31 cannot perform ejection. Thus, it is known that an independent driving type head in which the ejection channel for ejecting the droplet and a dummy channel not ejecting the droplet are arranged alternately is provided. If the head 3 is this independent driving type head, since it is likely that the ejection channel performs ejection in the whole pixel cycle T, the pixel cycles T for forming pixels continue in some cases.

[0119] At this time, the driving cycle TA of the first driving signal PA1 or PA2 within the 1 pixel cycle T and the driving cycle TB of the second driving signal PB can be $TA = TB$ for expressing the gradation on the media 7 while the satellite is suppressed, but $TA \leq TB$ is preferable. Since the large droplet 100 by the first driving signal PA1 or PA2 is at a relatively low speed, by setting $TA \leq TB$, many large droplets 100 can be created in a short cycle and at a high speed within the 1 pixel cycle T by the first driving signal PA1 or PA2 at high density gradation.

[0120] Moreover, it is preferable that the respective expansion pulses (the first expansion pulse Pa1, the second expansion pulse Pa3, the expansion pulse Pb1) of the first driving signal PA1 or PA2 and the second driving signal PB applied to the driving electrode of the channel 31 corresponding to the same nozzle 341 have constant wave crests, and the respective contraction pulses (the first contraction pulse Pa2, the second contraction pulse Pa4, the second contraction pulse Pa5, the contraction pulse Pb2) of the first driving signal PA1 or PA2 and the second driving signal PB applied to the driving electrode of the channel 31 corresponding to the same nozzle 341 have constant wave crests as illustrated in Fig. 9. Since the voltage value of +Von and the voltage value of -Voff of each of the driving signal PA1 or PA2 and PB can be made constant, constitution of the driving control unit 8 can be further simplified.

[0121] If the number N of the first driving signal PA1 or PA2 applied within the 1 pixel cycle T is N ≥ 2, the droplet 100 ejected by each of the first driving signal PA1 or PA2 may be the same speed or may be different speeds.

[0122] Figs. 10 illustrate flying states over time of the droplets 100 and 200 when each of the droplets 100 ejected from the same nozzle 341 by the plurality of the first driving signals PA1 is set to the same speed in the case of Level 4 (N = 3) illustrated in Fig. 9 and a plan view of a dot D formed on the media 7 by that as an example.

[0123] When each of the droplets 100 is set to the same speed, as illustrated in Fig. 10A, the three droplets 100 consecutively ejected within the 1 pixel cycle T fly at a constant speed. Then, when the last droplet 200 by the second driving signal PB is ejected, since the droplet 200 flies at a speed faster than the droplet 100 ejected immediately before that, it catches up with the droplet 100 and joins. Since the joined droplet flies at a speed further faster than that of the droplet 100 immediately before that, the joined droplet further catches up and joins with the droplet 100 immediately before that so that all the droplets 100 and 200 are joined together during flying. As a result, the pixel made of the dot D by the single droplet illustrated in Fig. 10B is formed on the media 7.

[0124] Moreover, the droplet speed of the droplet 100 can be adjusted by the pulse width PWA1 of the first expansion pulse Pa1. Therefore, if the droplet speed of each of the droplets 100 is to be made different, it can be realized by adjusting the pulse width PWA1 of this first expansion pulse Pa1 within the range of 0.4 AL or more and 2.0 AL or less.

[0125] At this time, the first driving signal PA1 is preferably applied in the order from the shorter pulse width PWA1 of the first expansion pulse Pa1 within the 1 pixel cycle T. As a result, in the ejected droplets 100, the later the droplet 100 is ejected, the faster its speed becomes, which is effective if each of the droplets 100 is to be reliably joined during flying.

[0126] Figs. 11 illustrate flying states over time of the droplets 100 and 200 when each of the droplets 100 ejected from the same nozzle 341 by the plurality of the first driving signals PA1 is set such that the later the droplet 100 is ejected, the faster its speed becomes in the case of Level 4 (N = 3) illustrated in Fig. 9 and a plan view of the dot D formed on the media 7 by that as an example.

[0127] In this case, as illustrated in Fig. 11A, the three droplets 100 consecutively ejected within the 1 pixel cycle T join during flying and form the joined droplet, and when the droplet 200 catches up with the joined droplet and joins it at last, all the droplets 100 and 200 are joined during flying. As a result, the dot D by the single droplet illustrated in Fig. 11B is formed on the media 7.

[0128] Moreover, the first driving signal PA1 can be applied in the order from the longer pulse width PWA1 of the first expansion pulse Pa1 of the first driving signal PA1, that is, in the order from the faster droplet speed within the 1 pixel cycle T.

[0129] Figs. 12 illustrate flying states over time of the droplets 100 and 200 when each of the droplets 100 ejected from the same nozzle 341 by the plurality of the first driving signals PA1 is set such that the earlier the droplet 100 is ejected, the faster its speed becomes in the case of Level 4 (N = 3) illustrated in Fig. 9 and a plan view of the dot D formed on the media 7 by that as an example.

[0130] In this case, as illustrated in Fig. 12, except the droplet 200 by the second driving signal PB joining with the droplet 100 ejected immediately before that so as to form the joined droplet, the pixel made of one dot D in which a plurality of the dots are overlapped on the media 7 as illustrated in Fig. 12B is formed. This is because energy of the droplet 200 ejected at last in an early stage after ejection is lost.

[0131] The dot D as illustrated in this Fig. 12B does not have an influence in an application of gaining a painted amount by using only the large dots as in the case of recording a solid image. The image quality is not largely affected in the case of the gradation expression, either, but there is a concern that the impact position might be slightly shifted each time the droplet amount is different.

[0132] When the gradation expression is to be made by changing the number of droplets to be ejected within the 1 pixel cycle T, the droplet speed is changed depending on the timing when each of the ejected droplets is joined, and the shift of the impact position at every gradation makes a problem in some cases. Particularly, if the droplet 100 ejected by the first driving signal PA1 or PA2 and the droplet 200 ejected by the second driving signal PB are joined during flying, the energy of the droplet 200 is lost, which affects the droplet speed. Therefore, there is a concern that the impact positions are slightly different between the case of ejection only of the single droplet 200 and the case of ejection of a plurality of the droplets 100 other than the droplet 200.

[0133] Assuming that the droplet speed of the droplet 100 by the first driving signal PA1 or PA2 is VA, its droplet amount is MA, the droplet speed of the droplet 200 by the second driving signal PB is VB and its droplet amount is MB, an influence at joining depends on a ratio of motion amount between a large droplet and a small droplet (MB x VB) / (MA x VA), and an influence on the impact depends on a gap to the media 7 (distance between the nozzle surface of the head 3 and the media 7) L. Moreover, if the number N of the first driving signal PA1 or PA2 increases to N ≥ 3, the number of final joining times tends to increase, and the problem of the impact position shift becomes more remarkable than the other cases.

[0134] Thus, if the number N of the first driving signal PA1 or PA2 applied within the 1 pixel cycle T is N ≥ 3, it is preferable that the droplet 200 by the second driving signal PB applied to the end of the 1 pixel cycle T and the droplet 100 by the first driving signal PA1 or PA2 applied immediately before that do not form a joined droplet at least up to a position away from the nozzle by (L x MB x VB)/(MA x VA). That is, the droplet 100 and the droplet 200 are joined after crossing the position away from the nozzle by (L x MB x VB)/(MA x VA) or land onto the media 7 so as to overlap each other.

[0135] As a result, the impact position shift at every gradation can be suppressed. Moreover, since the speed of the droplet 200 ejected at last within the 1 pixel cycle T does not have to be raised more than necessary, occurrence of the satellite can be further suppressed.

[0136] In the aforementioned explanation, a signal having the expansion pulse of +Von and the contraction pulse of -Voff is used as each of the driving signals but this is not limiting. Since deformation of the partition wall 32 is caused by a voltage difference between the two driving electrodes provided so as to sandwich the partition wall 32, if ejection is to be made by the first driving signal PA1 from the channel 31B illustrated in Fig. 4, as illustrated in Fig. 13A, by applying the first expansion pulse Pa1 and the second expansion pulse Pa3 of +Von to the driving electrode 36B in the channel 31B which is an ejection channel and by applying the first contraction pulse Pa2 of +Voff to the driving electrodes 36A and 36C of the adjacent channels 31A and 31C, the driving can be performed similarly.

[0137] Similarly, if the ejection is to be made by the first driving signal PA2 from the channel 31B illustrated in Fig. 4, as illustrated in Fig. 13B, by applying the first expansion pulse Pa1 and the second expansion pulse Pa3 of +Von to the driving electrode 36B in the channel 31B which is an ejection channel and by applying the first contraction pulse Pa2, the second contraction pulse Pa4, and the third contraction pulse Pa5 of +Voff to the driving electrodes 36A and 36C of the adjacent channels 31A and 31C, the driving can be performed similarly.

[0138] Moreover, similarly, if the ejection is to be made by the second driving signal PB from the channel 31B illustrated in Fig. 4, as illustrated in Fig. 13C, by applying the first expansion pulse Pb1 and the second expansion pulse Pb3 of +Von to the driving electrode 36B in the channel 31B which is an ejection channel and by applying the first contraction pulse Pb2 and the second contraction pulse Pb4 of +Voff to the driving electrodes 36A and 36C of the adjacent channels 31A and 31C, the driving can be performed similarly.

[0139] When the first driving signals PA1 and PA2 and the second driving signal PB illustrated in Figs. 13A to 13C are used, since each driving signal can be configured only by a positive voltage, the constitution of the driving control unit 8 can be simplified.

[0140] Moreover, in the aforementioned explanation, a head capable of shear deformation of the partition wall 32 between the adjacent channels 31 and 31 is exemplified as the head 3, but the upper wall or the lower wall of the channel may be made pressure generator constituted by the piezoelectric element such as PZT so as to shear/deform this upper wall or the lower wall.

[0141] Besides, the inkjet head in the present invention is not limited to the shear-mode at all. For example, the inkjet head may be of such a type that a wall surface of the pressure chamber is formed by a diaphragm, this diaphragm is oscillated by pressure generator constituted by the piezoelectric element such as PZT so as to apply a pressure for ejecting the ink in the pressure chamber.

EXAMPLE

[0142] Examples of the present invention will be described below but the present invention is not limited by such examples.

(Example 1)

[0143] A shear-mode inkjet head (nozzle diameter = 24 μm, AL = 3.7 μs) illustrated in Fig. 2 was prepared. For the ink, UV curable ink was used at 40°C. Viscosity of the ink at this time was 0.01 Pa·s.

[0144] The first driving signal PA1 of a rectangular wave illustrated in Fig. 3 was used as the first driving signal, and the droplet amount of a droplet ejected when the pulse width PWA1 of the first expansion pulse Pa1 was changed from 0.2 AL to 2 AL as illustrated in a graph in Fig. 14, respectively, was measured.

[0145] In any case, ejection was performed such that the pulse width PWA2 of the first contraction pulse Pa2 = 0.5 AL, the pulse width PWA3 of the second expansion pulse Pa3 = 1 AL, and the pulse width PWA4 of the second contraction pulse Pa4 = 2 AL, the driving cycle = 7AL, and the droplet speed = 6 m/s.

[0146] As a result, as illustrated in Fig. 14, by setting the pulse width PWA1 of the first expansion pulse Pa1 to 0.4 AL or more, a large droplet of approximately 10 ng or more could be ejected. However, if the pulse width PWA1 of the first expansion pulse Pa1 falls under 0.4 AL, a large droplet in which two droplets made of a first droplet and a second droplet are joined could not be formed.

(Comparative Example 1)

[0147] In the second driving signal PB illustrated in Fig. 7, the droplet was ejected similarly at the droplet speed of 6 m/s by using the driving signal made of a general DRR waveform with the pulse width PWB1 of the expansion pulse

Pb1 = 1 AL, the pulse width PWB2 of the contraction pulse Pb2 = 2 AL, and the pause period PWB3 = 0, the droplet amount was 6.7 ng.

(Example 2)

[0148] An occurrence situation of the satellite of each droplet ejected in Example 1 was observed. The occurrence situation of the satellite was evaluated such that a separation distance from the main droplet at the position having flown from the nozzle by 1.0 mm to the satellite was measured, and the length was evaluated on the basis of the following standard. The longer the separation distance is, the farther the impact position of the satellite is shifted from the main droplet, which lowers the image quality. The result is shown in Table 1.

[0149]

◎: short
○: middle
Δ slightly long
× : long

[0150] If the evaluation is any one of ◎ to Δ, it does not affect the image quality much. Therefore, if the pulse width PWA1 is 0.4 AL or more, it is known that the influence of the satellite could be suppressed.

[Table 1]

PWA1 width	Satellite evaluation result
0.2 AL	◎
0.4 AL	○
0.6 AL	○
0.8 AL	◎
1.0 AL	◎
1.2 AL	◎
1.4 AL	○
1.6 AL	○
1.8 AL	○
2.0 AL	Δ

(Example 3)

[0151] The same first driving signal PA1 as in Example 1 was used, 10 droplets were consecutively ejected at the driving cycle = 7 AL, a speed change in an ejection order of each of the 10 droplets at that time from the first droplet was acquired, and evaluation was made on the basis of the following standard.

[0152] The speed change was expressed in % of a shift of the speed of each droplet with respect to a reference speed (6 m/s). The result is shown in Table 2.

[0153]

◎: less than 10%
○: 10% or more and less than 15%
Δ: 15% or more and less than 25%
×: 25% or more

[Table 2]

PWA1 width	Ejection-order speed fluctuation evaluation result
0.4 AL	◎

(continued)

PWA1 width	Ejection-order speed fluctuation evaluation result
0.6 AL	○
0.7 AL	○
0.8 AL	Δ
0.9 AL	Δ
1.0 AL	Δ
1.1 AL	Δ
1.2 AL	Δ
1.3 AL	○
1.4 AL	○
1.6 AL	◎
1.8 AL	◎
2.0 AL	Δ

[0154] As in Table 2, if the pulse width PWA1 of the first expansion pulse Pa1 is 0.4 AL and more and 0.7 AL or less or 1.3 AL or more and 1.8 AL or less, speed fluctuation in continuous driving was suppressed.

EXPLANATIONS OF LETTERS OR NUMERALS

[0155]

1: inkjet recording apparatus
2: conveying mechanism

21: conveying roller
22: conveying roller pair
23: conveying motor

3: inkjet head
30: channel substrate
31: channel
32 partition wall

321: upper wall portion
322: lower wall portion

33: cover substrate

331: common channel

34: nozzle plate

341: nozzle

35: plate

351: ink supply port
352: ink supply pipe

4: guide rail

5: carriage
6: flexible cable
7: media

71: recording surface

8: driving control unit
100: droplet

101: first droplet
100: second droplet

200: droplet
D: dot
PA1, PA2: first driving signal

Pa1: first expansion pulse
Pa2: first contraction pulse
Pa3: second expansion pulse
Pa4: second contraction pulse
Pa5: third contraction pulse
PWA1 to PWA5: pulse width
PWA6: pause period

PB: second driving signal

Pb1: expansion pulse
Pb2: contraction pulse
PWB1, PWB2: pulse width
PWB3: pause period

T: pixel cycle

TA: driving cycle of first driving signal
TB: driving cycle of second driving signal
T1, T2: pause period

Claims

1. A method for driving an inkjet head which applies a driving signal to pressure generator for expanding or contracting a capacity of a pressure chamber, applies a pressure to a liquid in the pressure chamber by driving the pressure generator and ejects droplets from a nozzle, wherein
when at least two droplets are ejected from the same nozzle and joined immediately after ejection so as to form a large droplet, a first driving signal is applied as the driving signal;
the first driving signal has a first expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, a first contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time, a second expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, and a second contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time in this order;
a first droplet is ejected from the nozzle by applying the first expansion pulse and the first contraction pulse and a second droplet is ejected by applying the second expansion pulse and the second contraction pulse; and
a pulse width of the first expansion pulse is 0.4 AL or more and 2.0 AL or less (where AL is 1/2 of an acoustic resonant period of a pressure wave in the pressure chamber).

2. The method for driving an inkjet head according to claim 1, wherein
a pulse width of the first contraction pulse is 0.4 AL or more and 0.7 AL or less, a pulse width of the second expansion pulse is 0.8 AL or more and 1.2 AL or less, and a pulse width of the second contraction pulse is 1.8 AL or more and

2.2 AL or less in the first driving signal.

3. The method for driving an inkjet head according to claim 2, wherein a voltage value of the first expansion pulse and a voltage value of the second expansion pulse are equal and a voltage value of the first contraction pulse and a voltage value of the second contraction pulse are equal in the first driving signal.

4. The method for driving an inkjet head according to claim 3, wherein assuming that the voltage values of the first expansion pulse and the second expansion pulse are VH2, and the voltage values of the first contraction pulse and the second contraction pulse are VH1 in the first driving signal, it is |VH2|/|VH1|=2/1.

5. The method for driving an inkjet head according to claim 1, wherein
the first driving signal further has a third contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time;
the pulse width of the second contraction pulse is 0.3 AL or more and 0.7 AL or less;
the pulse width of the third contraction pulse is 0.8 AL or more and 1.2 AL or less; and
the third contraction pulse is applied at an interval of 0.3 AL or more and 0.7 AL or less from the end of application of the second contraction pulse.

6. The method for driving an inkjet head according to claim 5, wherein a pulse width of the first contraction pulse is 0.4 AL or more and 0.7 AL or less and a pulse width of the second expansion pulse is 0.8 AL or more and 1.2 AL or less in the first driving signal.

7. The method for driving an inkjet head according to claim 5 or 6, wherein voltage values of the first expansion pulse and a voltage value of the second expansion pulse are equal and a voltage value of the first contraction pulse and voltage values of the second contraction pulse and the third contraction pulse in the first driving signal are equal.

8. The method for driving an inkjet head according to claim 7, wherein assuming that the voltage values of the first expansion pulse and the second expansion pulse are VH2, and the voltage values of the first contraction pulse, the second contraction pulse, and the third contraction pulse are VH1 in first driving signal, it is |VH2|/|VH1|=2/1.

9. The method for driving an inkjet head according to any one of claims 1 to 8, wherein a pulse width of the first expansion pulse in the first driving signal is 0.4 AL or more and 0.7 AL or less or 1.3 AL or more and 1.8 AL or less.

10. The method for driving an inkjet head according to any one of claims 1 to 9, wherein the first driving signal is a rectangular wave.

11. The method for driving an inkjet head according to any one of claims 1 to 10, wherein
when a droplet at a relatively higher speed and smaller than the droplet by the first driving signal is to be formed, a second driving signal is applied as the driving signal;
the second driving signal has an expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, a contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time, and a pause period connecting the expansion pulse and the contraction pulse; and
gradation expression is made by applying N pieces (N is an integer not less than 0) of the first driving signals and the second driving signal at least at the end within 1 pixel cycle and by changing the number N in accordance with image data.

12. The method for driving an inkjet head according to claim 11, wherein a pulse width of the expansion pulse is 0.8 AL or more and 1.2 AL or less, the pulse width of the contraction pulse is 1.8 AL or more and 2.2 AL or less, and the pause period is 1/4 AL or less in the second driving signal.

13. The method for driving an inkjet head according to any one of claims 1 to 12, wherein the inkjet head is a shear-mode inkjet head.

14. An inkjet recording apparatus including an inkjet head for applying a pressure for ejection of a liquid in a pressure chamber by driving of pressure generator so that a droplet is ejected from a nozzle; and
driving controller for outputting a driving signal for driving the pressure generator, wherein
the driving signal includes a first driving signal for causing at least two droplets to be ejected from the same nozzle so that they are joined immediately after the ejection and form a large droplet;
the first driving signal has a first expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, a first contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time, a second expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, and a second contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time in this order;
a first droplet is ejected from the nozzle by applying the first expansion pulse and the first contraction pulse and a second droplet is ejected by applying the second expansion pulse and the second contraction pulse; and
a pulse width of the first expansion pulse is 0.4 AL or more and 2.0 AL or less (where AL is 1/2 of an acoustic resonant period of a pressure wave in the pressure chamber).

15. The inkjet recording apparatus according to claim 14, wherein
a pulse width of the first contraction pulse is 0.4 AL or more and 0.7 AL or less, a pulse width of the second expansion pulse is 0.8 AL or more and 1.2 AL or less, and a pulse width of the second contraction pulse is 1.8 AL or more and 2.2 AL or less in the first driving signal.

16. The inkjet recording apparatus according to claim 15, wherein
a voltage value of the first expansion pulse and a voltage value of the second expansion pulse are equal and a voltage value of the first contraction pulse and a voltage value of the second contraction pulse are equal in the first driving signal.

17. The inkjet recording apparatus according to claim 16, wherein
assuming that the voltage values of the first expansion pulse and the second expansion pulse are VH2, and the voltage values of the first contraction pulse and the second contraction pulse are VH1 in first driving signal, it is $|VH2|/|VH1|=2/1$.

18. The inkjet recording apparatus according to claim 14, wherein
the first driving signal further has a third contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time;
the pulse width of the second contraction pulse is 0.3 AL or more and 0.7 AL or less;
the pulse width of the third contraction pulse is 0.8 AL or more and 1.2 AL or less; and
the third contraction pulse is applied at an interval of 0.3 AL or more and 0.7 AL or less from the end of application of the second contraction pulse.

19. The inkjet recording apparatus according to claim 18, wherein
a pulse width of the first contraction pulse is 0.4 AL or more and 0.7 AL or less and a pulse width of the second expansion pulse is 0.8 AL or more and 1.2 AL or less in the first driving signal.

20. The inkjet recording apparatus according to claim 18 or 19, wherein
a voltage value of the first expansion pulse and a voltage value of the second expansion pulse are equal and a voltage value of the first contraction pulse and voltage values of the second contraction pulse and the third contraction pulse in the first driving signal are equal.

21. The inkjet recording apparatus according to claim 20, wherein
assuming that the voltage values of the first expansion pulse and the second expansion pulse are VH2, and the voltage values of the first contraction pulse, the second contraction pulse, and the third contraction pulse are VH1 in the first driving signal, it is $|VH2|/|VH1|=2/1$.

22. The inkjet recording apparatus according to any one of claims 14 to 21, wherein
a pulse width of the first expansion pulse in the first driving signal is 0.4 AL or more and 0.7 AL or less or 1.3 AL or more and 1.8 AL or less.

23. The inkjet recording apparatus according to any one of claims 14 to 22, wherein
the first driving signal is a rectangular wave.

24. The inkjet recording apparatus according to any one of claims 14 to 23, wherein
when a droplet at a relatively higher speed and smaller than the droplet by the first driving signal is to be formed, a second driving signal is applied as the driving signal;
the second driving signal has an expansion pulse for expanding the capacity of the pressure chamber and contracting it after certain time, a contraction pulse for contracting the capacity of the pressure chamber and expanding it after certain time, and a pause period connecting the expansion pulse and the contraction pulse; and
gradation expression is made by applying N pieces (N is an integer not less than 0) of the first driving signals and the second driving signal at least at the end are applied within 1 pixel cycle and by changing the number N in accordance with image data.

25. The inkjet recording apparatus according to claim 24, wherein
a pulse width of the expansion pulse is 0.8 AL or more and 1.2 AL or less, the pulse width of the contraction pulse is 1.8 AL or more and 2.2 AL or less, and the pause period is 1/4 AL or less in the second driving signal.

26. The inkjet recording apparatus according to any one of claims 14 to 25, wherein
the inkjet head is a shear-mode inkjet head.

FIG.1

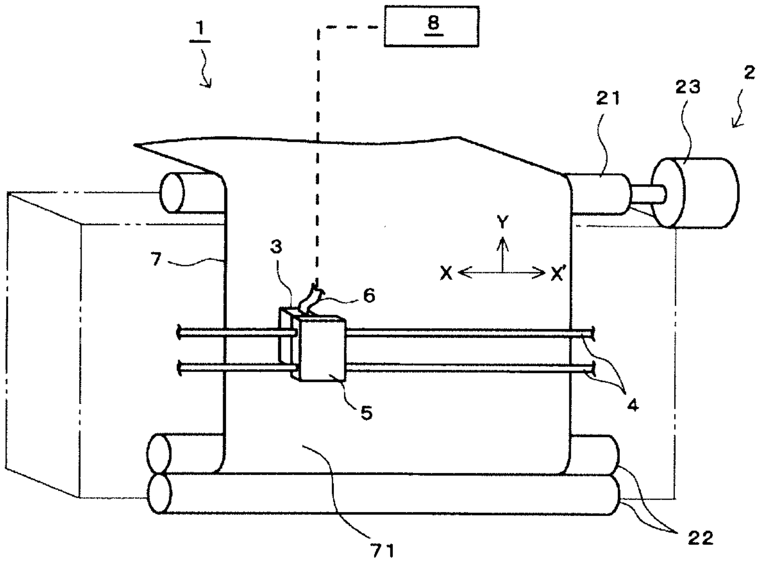


FIG.2

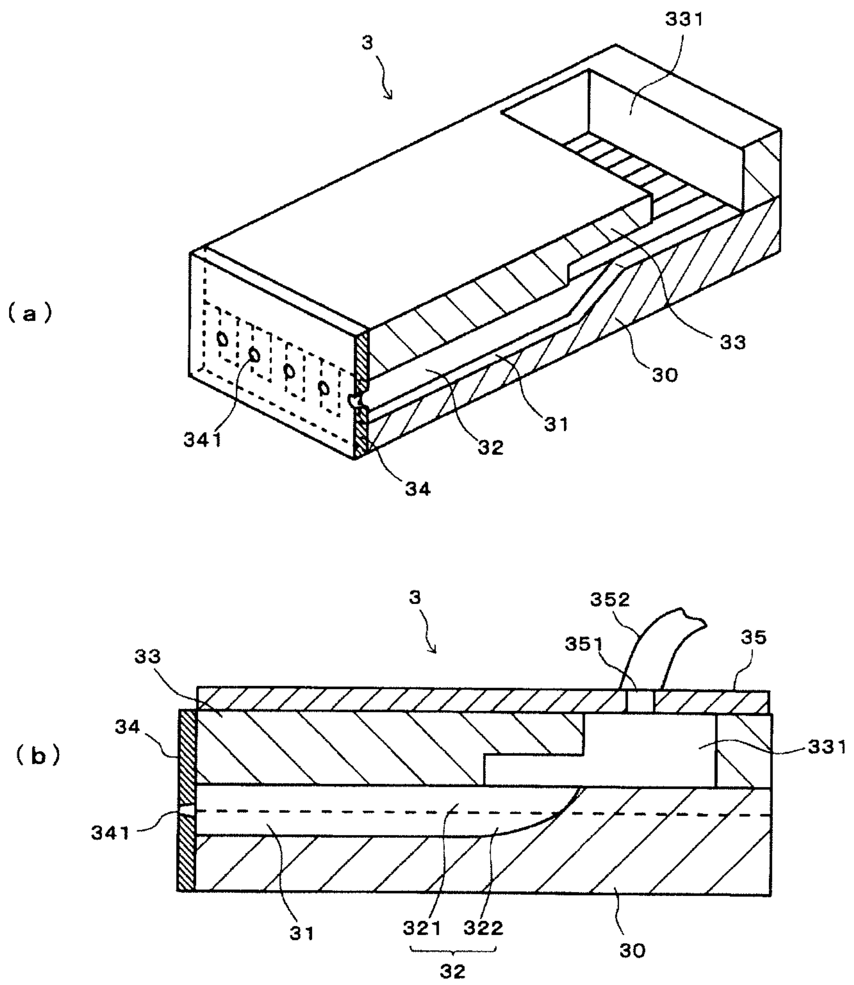
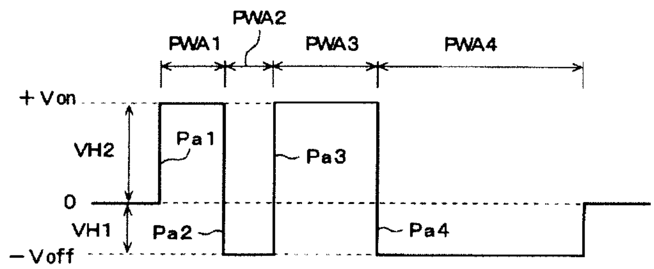
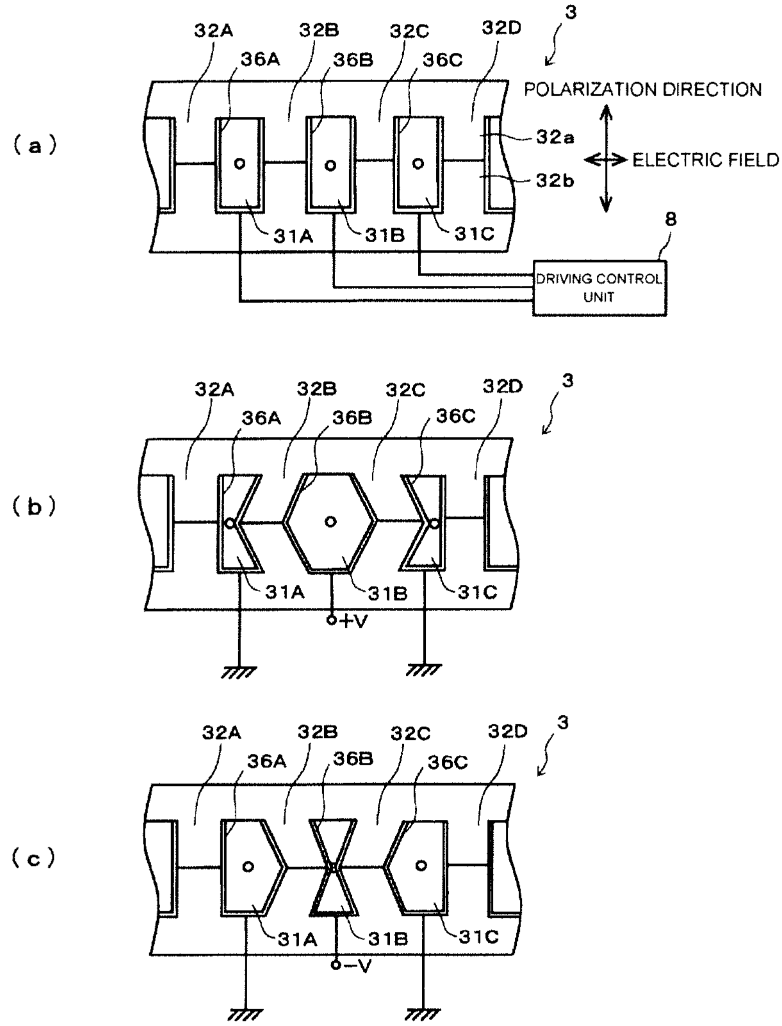


FIG.3



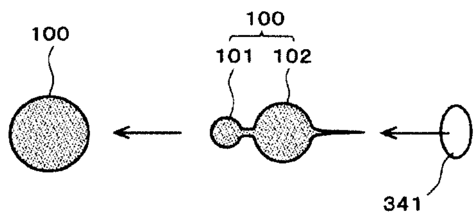
PA1

FIG.4



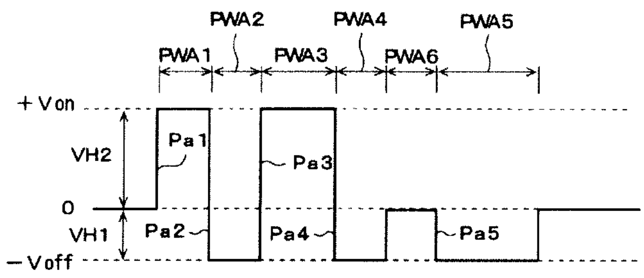
(a)
32A
32B
32C
32D
3
36A
36B
36C
POLARIZATION DIRECTION
32a
ELECTRIC FIELD
32b
31A
31B
31C
8
DRIVING CONTROL UNIT
(b)
+V
(c)
−V

FIG.5



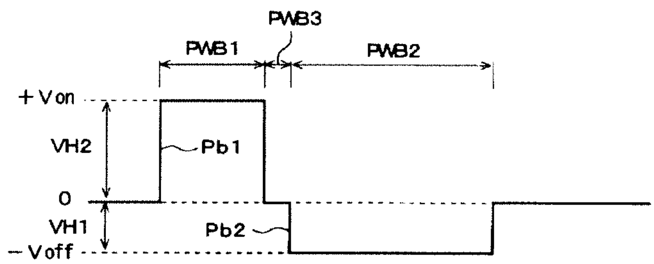
100
101
102
341

FIG.6



PA2

FIG.7



PB

FIG.8

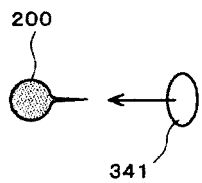


FIG. 9

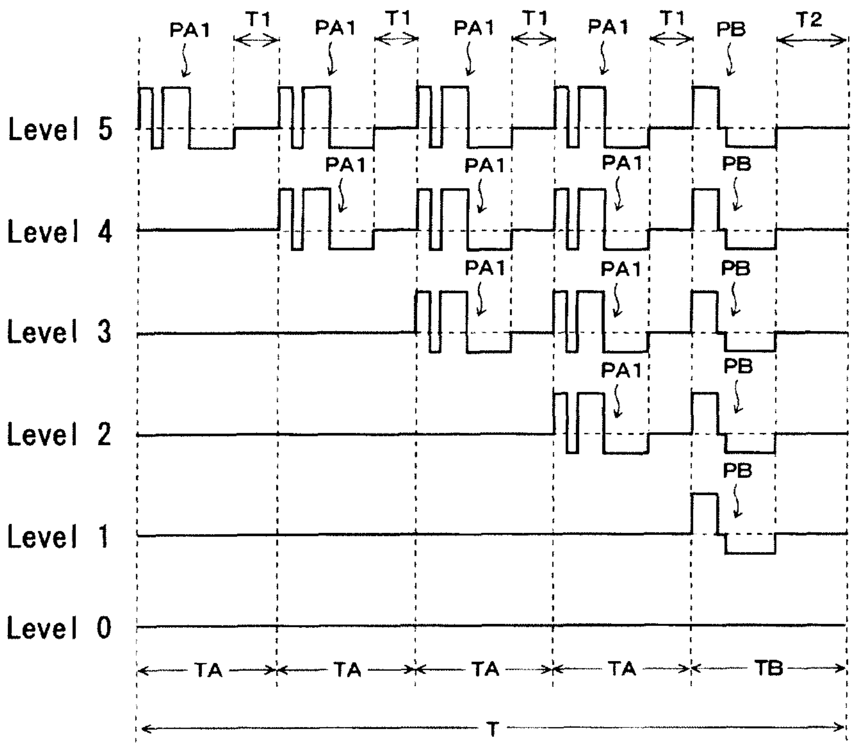

PA1
T1
PA1
T1
PA1
T1
PA1
T1
PB
T2
Level 5
PA1
PA1
PA1
PB
Level 4
PA1
PA1
PB
Level 3
PA1
PB
Level 2
PB
Level 1
Level 0
TA
TA
TA
TA
TB
T

FIG.10

(a)

(b)

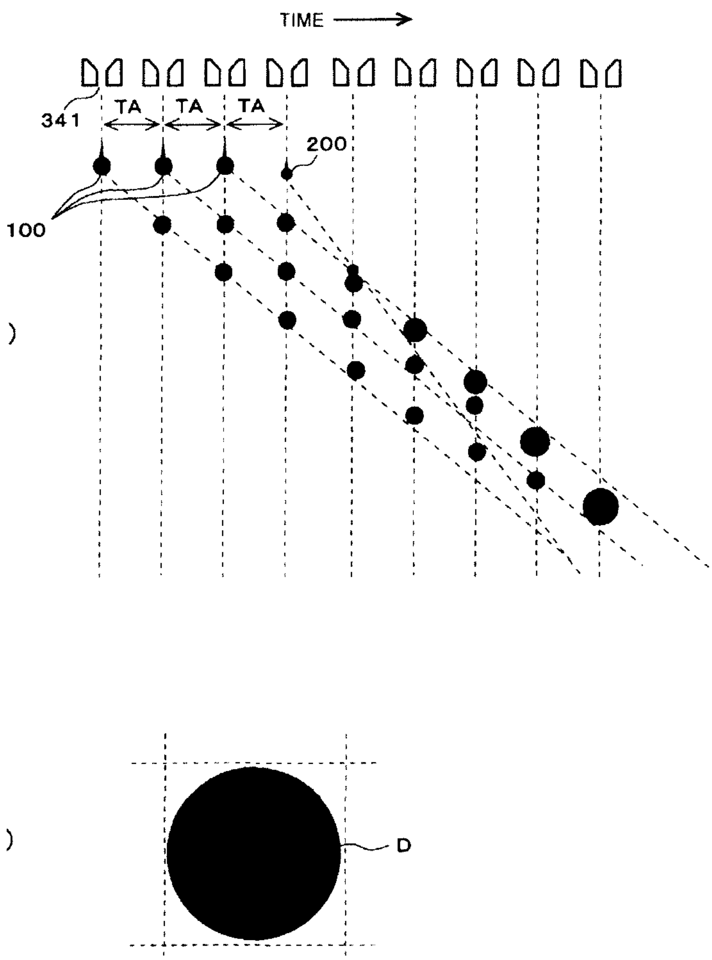
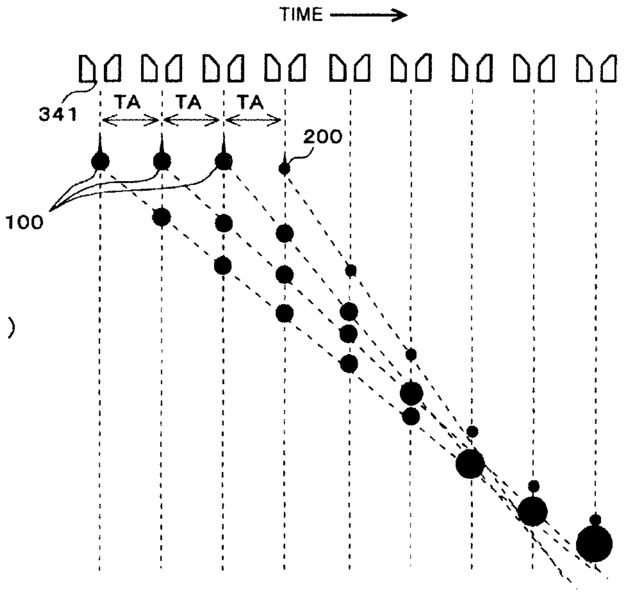


FIG.11

(a)



(b)

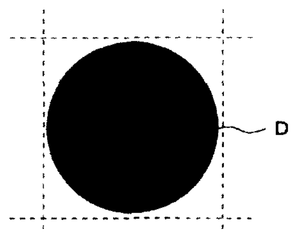
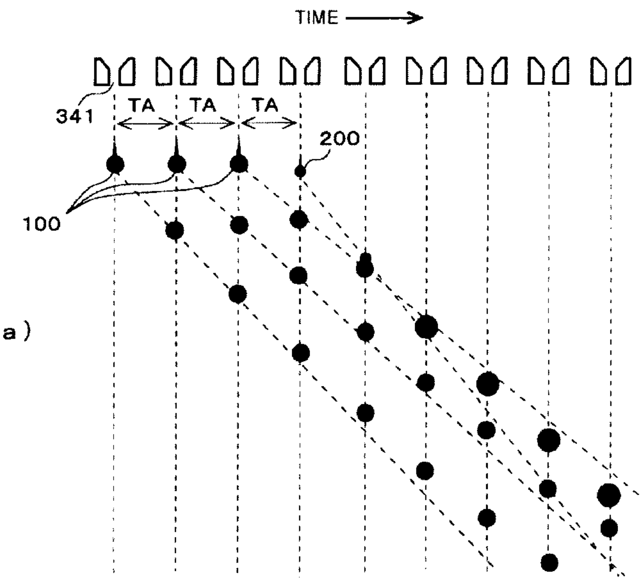


FIG.12

(a)



(b)

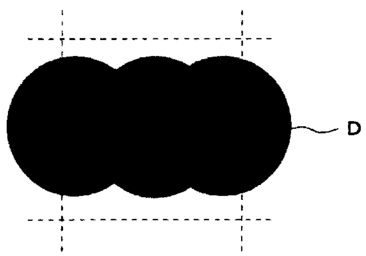


FIG.13

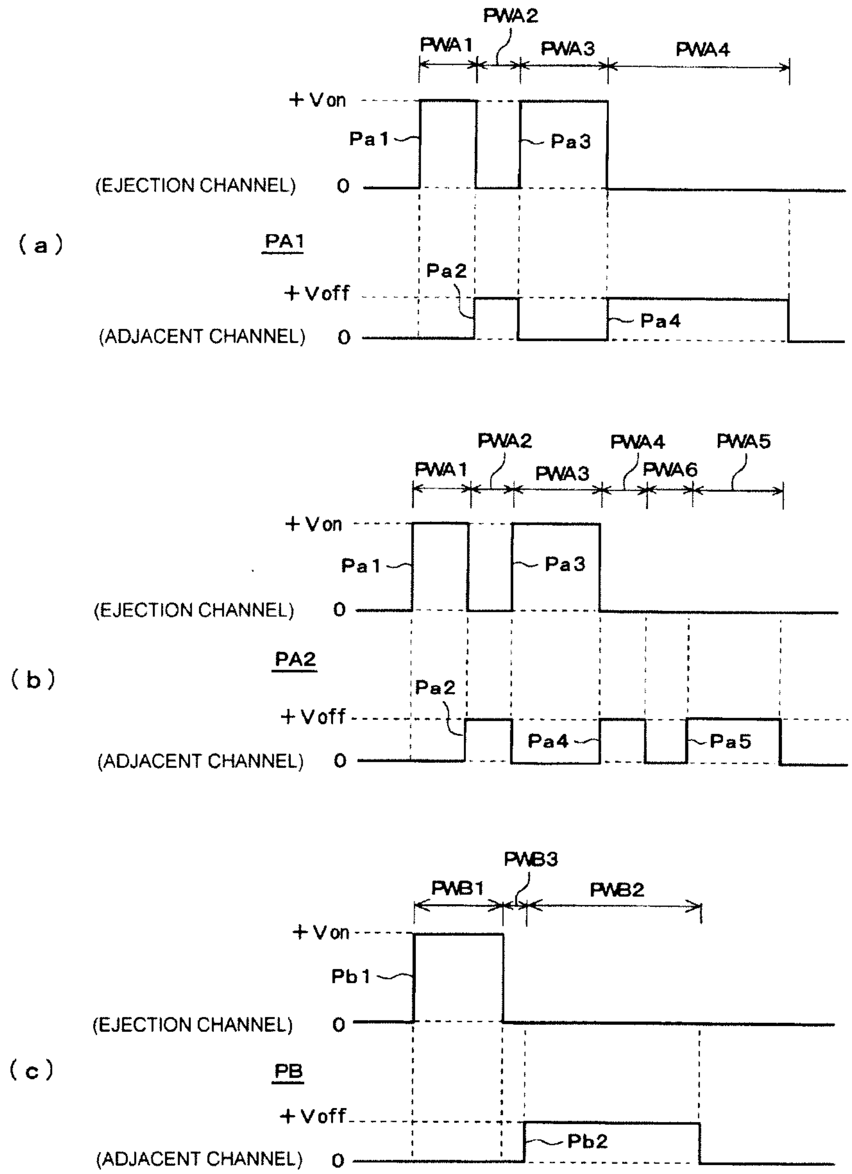
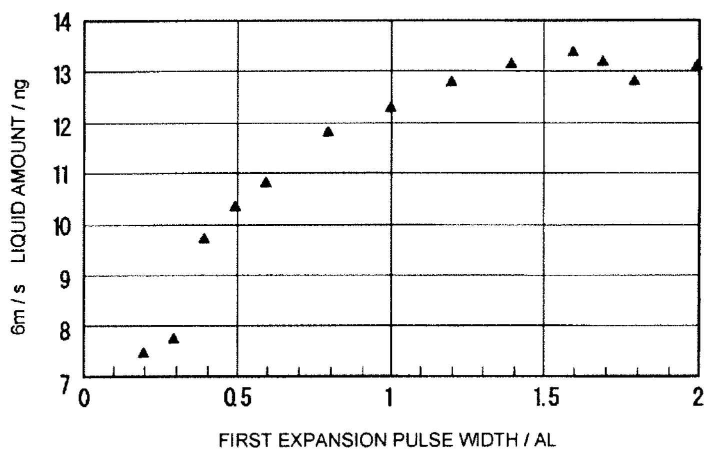

PWA1
PWA2
PWA3
PWA4
+Von
Pa1
Pa3
(EJECTION CHANNEL)
0
(a)
PA1
Pa2
+Voff
Pa4
(ADJACENT CHANNEL)
0
PWA1
PWA2
PWA3
PWA4
PWA6
PWA5
+Von
Pa1
Pa3
(EJECTION CHANNEL)
0
(b)
PA2
Pa2
+Voff
Pa4
Pa5
(ADJACENT CHANNEL)
0
PWB1
PWB3
PWB2
+Von
Pb1
(EJECTION CHANNEL)
0
(c)
PB
+Voff
Pb2
(ADJACENT CHANNEL)
0

FIG.14


14
13
12
11
10
9
8
7
6m / s LIQUID AMOUNT / ng
0
0.5
1
1.5
2
FIRST EXPANSION PULSE WIDTH / AL

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/060017

A. CLASSIFICATION OF SUBJECT MATTER
B41J2/015(2006.01)i, *B41J2/045*(2006.01)i, *B41J2/14*(2006.01)i, *B41J2/205* (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)
B41J2/015, B41J2/045, B41J2/14, B41J2/205

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	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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.
X Y A	JP 2001-301207 A (Konica Corp.), 30 October 2001 (30.10.2001), paragraphs [0027], [0038] to [0048]; fig. 9 to 10 (Family: none)	1,10,13-14, 23,26 11-12,24-25 2-9,15-22
Y	JP 2000-85158 A (Matsushita Electric Industrial Co., Ltd.), 28 March 2000 (28.03.2000), paragraphs [0036] to [0038], [0044]; fig. 9 (Family: none)	11-12,24-25
Y	JP 2011-31442 A (Riso Kagaku Corp.), 17 February 2011 (17.02.2011), paragraphs [0038] to [0043]; fig. 8 (Family: none)	11-12,24-25

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

* Special categories of cited documents:
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 June 2015 (04.06.15)	16 June 2015 (16.06.15)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2015/060017

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 2011-37260 A (Konica Minolta IJ Technologies, Inc.), 24 February 2011 (24.02.2011), entire text; all drawings & US 2010/0328381 A1 & EP 2275264 A1	1-26
A	JP 2007-152873 A (Konica Minolta Holdings, Inc.), 21 June 2007 (21.06.2007), entire text; all drawings (Family: none)	1-26
P,A	JP 2015-51585 A (Toshiba Corp.), 19 March 2015 (19.03.2015), entire text; all drawings (Family: none)	1-26

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

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- JP 3530717 B **[0011]**
- JP 4247043 B **[0011]**
- JP 3551822 B **[0011]**