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(54) Image forming apparatus

(57) An image forming apparatus uses as an image-forming agent an ink containing toner having charged particles. The recording head (1) of the image forming apparatus has an insulating substrate (4) formed with discharge electrodes (2), and an insulating upper plate (13) formed with a common electrode (14). The discharge electrodes (2) and the common electrode (14) oppose each other, and a gap serving as an ink supply passage (20) is formed between them. The supply passage (20) is connected to an ink supply/recovery mechanism (100), and the ink (6) is supplied from this mechanism to the supply passage (20). A platen roller (114) serving as a counter electrode set at the ground potential is provided ahead of the distal end of the supply passage (20). A recording medium (108) is placed on the surface of the platen roller (114) so as to face the recording head (1). A voltage is applied between the discharge electrodes (2) and the common electrode (14) to form an electric field in the supply passage (20). Thus, a toner concentration difference is formed in the ink (6) as a toner preliminary gathering process. The toner preliminary gathering process increases the toner agglomerating efficiency at discharge points (DP).

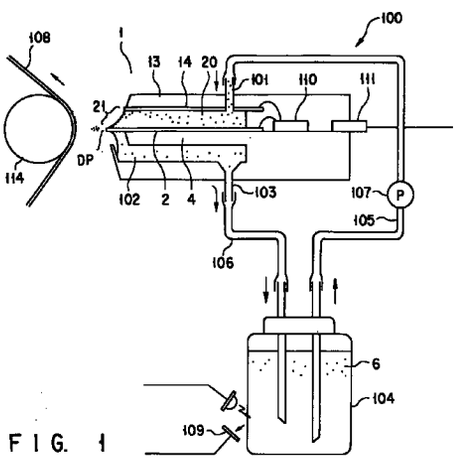

FIG. 1

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Description

The present invention relates to an image forming apparatus for forming an image on a recording medium by using, as an image-forming agent, an ink obtained by dispersing a toner consisting of charged particles and a colorant in an insulating liquid.

In recent years, ink-jet recording is widely employed in the field of personal printers. However, since a conventional ink-jet printer uses a dye as a colorant, the light-resistance, storage stability, and the like of the image are poor.

In view of this problem, WO93/1186 discloses an apparatus which enables usage of pigment particles as the colorant, thereby solving the above problems of the dye ink. This apparatus has a conductive ink supply tube which terminates into a distal end cut off at an angle of 30° with respect to the ink flowing direction. A voltage is applied between or across the ink supply tube and a counter electrode opposing this distal end. An ink containing pigment particles (to be referred to as a toner hereinafter) charged in the same polarity as that of the potential of the ink supply tube is supplied to the ink supply tube.

The charged toner in the ink is electrostatically attracted by the counter electrode at a discharge point near the distal end of the ink supply tube. Due to the surface tension of the solvent of the ink, however, the toner cannot be ejected from the ink but remains at the distal end of the ink supply tube. Thus, a large amount of toner gathers at the distal end of the ink supply tube in this manner to form an agglomerate. When the voltage across the ink supply tube and the counter electrode is further increased, the electrostatic attracting force excels the surface tension of the solvent of the ink, so that the toner agglomerate flies from the ink.

Since the image forming apparatus based on the above ejecting principle does not have a nozzle that determines the size of ejected droplets unlike in conventional ink-jet recording, it can use pigment particles. Hence, the storage stability, light-resistance, and the like of the image that pose problems in conventional ink-jet printing are improved.

However, the image forming apparatus using an ink solution containing the above conventional toner still has problems as follows.

First, it takes time for the toner in the ink at the discharge point to be agglomerated up to being ejected. When the image forming speed is increased, a toner agglomerate is not formed in time at the discharge point. Then, the image density may decrease or become non-uniform.

Second, in an image forming apparatus in which a plurality of discharge points are arranged adjacent to each other, electrostatic interference occurs between adjacent discharge points or in the toner agglomerating process. Then, the recording speed is lowered, the discharge points cannot be driven simultaneously, or the image point density becomes non-uniform.

The present invention has been made in view of the above problems of the conventional technique, and has as its object to increase, in an image forming apparatus using an ink containing a toner, the agglomerating efficiency of the toner at the discharge point.

It is another object of the present invention to prevent, in an image forming apparatus having a plurality of discharge points, mutual interference among adjacent discharge points.

According to the first aspect of the present invention, there is provided an image forming apparatus comprising:

supplying means having a discharge port arranged to oppose a recording medium, for storing an ink including colored particles therein, and for supplying the ink to the discharge port;

preliminary gathering means for preliminarily gathering the colored particles in the ink while the ink is supplied to the discharge port by the supplying means;

agglomerating means for agglomerating the colored particles, preliminarily gathered by the preliminary gathering means, in the discharge port, thereby forming an agglomerate in the ink; and

ejecting means for electrostatically ejecting the agglomerate formed by the agglomerating means from the discharge port onto the recording medium.

In the image forming apparatus according to the first aspect of the present invention, first, the colored particles in the ink are preliminarily gathered by the preliminary gathering means. An agglomerate is formed by the agglomerating means from the colored particles which are preliminarily gathered. Then, the agglomerate flies onto the recording medium due to an electrostatic Coulomb force applied by the ejecting means, thereby forming an image.

According to the second aspect of the present invention, there is provided an image forming apparatus for forming an image on a recording medium, comprising:

supplying means for storing an ink including colored particles therein, and for supplying the ink to a discharge port, arranged to oppose the recording medium, through a supply passage;

preliminary gathering means for forming a first electric field in the supply passage in order to locally distribute the colored particles in the ink to be supplied to the discharge port;

agglomerating means for forming a second electric field at a discharge point arranged in the discharge port, and agglomerating the colored particles, preliminarily gathered by the preliminary gathering means, at the discharge point, thereby forming an agglomerate in the ink; and

ejecting means for forming a third electric field more intense than the second electric field at the discharge point and ejecting the agglomerate from the discharge point onto the recording medium.

In the image forming apparatus according to the second aspect of the present invention, the colored particles are locally distributed in the ink by the operation of the

first electric field formed in the supply passage, so that a colored particles concentration difference is formed in the ink. In this state, the ink is conveyed to the discharge point, and the colored particles locally distributed in the ink are agglomerated at the discharge point by the action of the second electric field. When the more intense third electric field is formed at the discharge point, the agglomerate flies from the discharge point onto the recording medium due to the electrostatic Coulomb force, thereby forming an image.

According to the third aspect of the present invention, there is provided an image forming apparatus for forming an image on a recording medium, comprising:

supplying means for storing an ink including colored particles therein, and for supplying the ink to a discharge port, arranged to oppose the recording medium, through a supply passage;

preliminary agglomerating means for forming a first electric field at a preliminary agglomerating position arranged in the discharge port, and agglomerating the colored particles at the preliminary agglomerating position, thereby forming a preliminary agglomerate in the ink, the preliminary agglomerating position being arranged between the supply passage and a discharge point arranged in the discharge port;

agglomerating means for forming a second electric field at the discharge point, and further agglomerating the preliminary agglomerate at the discharge point, thereby forming an agglomerate in the ink; and

ejecting means for forming a third electric field more intense than the second electric field at the discharge point and ejecting the agglomerate from the discharge point onto the recording medium.

In the image forming apparatus according to the third aspect of the present invention, the colored particles in the ink are agglomerated at the preliminary agglomerating position by the action of the first electric field, thereby forming a preliminary agglomerate. The preliminary agglomerate is supplied to the discharge point together with the ink, and is further agglomerated at the discharge point by the action of the second electric field. When the more intense third electric field is formed at the discharge point, the agglomerate flies from the discharge point onto the recording medium due to the electrostatic Coulomb force, thereby forming an image.

According to the fourth aspect of the present invention, there is provided an image forming apparatus for forming an image on a recording medium, comprising:

supplying means for storing an ink including colored particles therein, and for supplying the ink to a discharge port, arranged to oppose the recording medium, through a supply passage;

preliminary gathering means for forming a first electric field in the supply passage in order to locally distribute the colored particles in the ink to be supplied to the discharge port;

preliminary agglomerating means for forming a second electric field at a preliminary agglomerating position arranged in the discharge port, and agglomerating the colored particles, preliminarily gathered by the preliminary gathering means, at the preliminary agglomerating position, thereby forming a preliminary agglomerate in the ink, the preliminary agglomerating position being arranged between the supply passage and a discharge point arranged in the discharge port;

agglomerating means for forming a third electric field at the discharge point, and further agglomerating the preliminary agglomerate at the discharge point, thereby forming an agglomerate in the ink; and

ejecting means for forming a fourth electric field more intense than the third electric field at the discharge point and ejecting the agglomerate from the discharge point onto the recording medium.

In the image forming apparatus according to the fourth aspect of the present invention, the colored particles are locally distributed in the ink by the action of the first electric field formed in the supply passage, so that a colored particles concentration difference is formed in the ink. In this state, the ink is conveyed to the preliminary agglomerating position, and the colored particles locally distributed in the ink is agglomerated at the preliminary agglomerating position by the action of the second electric field, thereby forming a preliminary agglomerate. The preliminary agglomerate is supplied to the discharge point together with the ink, and is further agglomerated at the discharge point by the action of the third electric field. When the more intense fourth electric field is formed at the discharge point, the agglomerate flies from the discharge point onto the recording medium due to the electrostatic Coulomb force, thereby forming an image.

According to the fifth aspect of the present invention, there is provided a method of forming an image, comprising:

a supplying step of supplying an ink including colored particles therein to a discharge port arranged to oppose a recording medium;

a preliminary gathering step of preliminarily gathering the colored particles in the ink while the ink is supplied to the discharge port;

an agglomerating step of agglomerating the colored particles, preliminarily gathered in the preliminary gathering step, in the discharge port, thereby forming an agglomerate in the ink; and

a ejecting step of electrostatically ejecting the agglomerate formed in the agglomerating step from the discharge port onto the recording medium.

According to the sixth aspect of the present invention, there is provided an image forming method of forming an image on a recording medium, comprising the steps of:

supplying an ink including colored particles therein to a discharge port, arranged to oppose the recording medium, through a supply passage;

forming a first electric field in the supply passage in order to locally distribute the colored particles in the ink to be supplied to the discharge port;

forming a second electric field at a discharge point

arranged in the discharge port, and agglomerating the colored particles, preliminarily gathered, at the discharge point, thereby forming an agglomerate in the ink; and

forming a third electric field more intense than the second electric field at the discharge point and ejecting the agglomerate from the discharge point onto the recording medium.

According to the seventh aspect of the present invention, there is provided an image forming method of forming an image on a recording medium, comprising the steps of:

supplying an ink including colored particles therein to a discharge port, arranged to oppose the recording medium, through a supply passage;

forming a first electric field at a preliminary agglomerating position arranged in the discharge port, and agglomerating the colored particles at the preliminary agglomerating position, thereby forming a preliminary agglomerate in the ink, the preliminary agglomerating position being arranged between the supply passage and a discharge point arranged in the discharge port;

forming a second electric field at the discharge point, and further agglomerating the preliminary agglomerate at the discharge point, thereby forming an agglomerate in the ink; and

forming a third electric field more intense than the second electric field at the discharge point and ejecting the agglomerate from the discharge point onto the recording medium.

According to the eighth aspect of the present invention, there is provided an image forming method of forming an image on a recording medium, comprising the steps of:

supplying an ink including colored particles therein to a discharge port, arranged to oppose the recording medium, through a supply passage;

forming a first electric field in the supply passage in order to locally distribute the colored particles in the ink to be supplied to the discharge port;

forming a second electric field at a preliminary agglomerating position arranged in the discharge port, and agglomerating the colored particles, preliminarily gathered, at the preliminary agglomerating position, thereby forming a preliminary agglomerate in the ink, the preliminary agglomerating position being arranged between the supply passage and a discharge point arranged in the discharge port;

forming a third electric field at the discharge point, and further agglomerating the preliminary agglomerate at the discharge point, thereby forming an agglomerate in the ink; and

forming a fourth electric field more intense than the third electric field at the discharge point and ejecting the agglomerate from the discharge point onto the recording medium.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is an explanatory diagram showing a recording head and an ink supply/recovery mechanism of an image forming apparatus according to the first embodiment of the present invention;

FIG. 2 is a schematic diagram showing the image forming apparatus using the recording head;

FIG. 3 is a block diagram showing the control unit of the image forming apparatus using the recording head;

FIGS. 4A, 4B, and 4C are a longitudinal sectional side view, a plan view, and a front view, respectively, of the main part of the image forming apparatus according to the first embodiment of the present invention, and FIG. 4D is a diagram showing the relationship between the recording head and the counter electrode of the same;

FIG. 5 is a graph showing changes over time of potentials applied to the respective electrodes of the first embodiment;

FIGS. 6A and 6B are diagrams showing the states of the toner in the ink flowing in the ink supply passage of the first embodiment;

FIG. 7 is a diagram showing agglomeration of the toner at the discharge point of the first embodiment;

FIG. 8 is a diagram showing the relationship between a plurality of discharge points and the toner distribution of the first embodiment;

FIGS. 9A, 9B, and 9C are diagrams explaining the ejecting principle of the toner at the discharge points of the first embodiment;

FIGS. 10A, 10B, and 10C are a longitudinal sectional side view, a plan view, and a front view, respectively, of the main part of an image forming apparatus according to the second embodiment of the present invention, and FIG. 10D is a diagram showing the relationship between the recording head and the counter electrode of the same;

FIG. 11 is a graph showing changes over time of potentials applied to the respective electrodes of the second embodiment;

FIG. 12 is a diagram showing the state of the toner in the ink flowing in the ink supply passage of the second embodiment;

FIG. 13 is a diagram showing the relationship between a plurality of discharge points and the toner distribution of the second embodiment;

FIGS. 14A, 14B, and 14C are a longitudinal sectional side view, a plan view, and a front view, respectively, of the main part of an image forming apparatus according to the third embodiment of the present invention, and FIG. 14D is a diagram showing the relationship between the recording head and the counter electrode of the same;

FIG. 15 is a graph showing changes over time of potentials applied to the respective electrodes of the third embodiment;

FIG. 16 is a diagram showing the state of the toner in the ink flowing in the ink supply passage of the third embodiment; and

FIG. 17 is a diagram showing the relationship between a plurality of discharge points and the toner distribution of the third embodiment.

FIG. 1 is an explanatory diagram showing a recording head 1 and an ink supply/recovery mechanism 100 of an image forming apparatus according to the first embodiment of the present invention.

The recording head 1 has an ink supply passage 20 formed between discharge electrodes 2 and a common electrode 14. A discharge port 21 is formed at the distal end of the ink supply passage 20, and a platen roller 114 serving as a support member of a recording medium (paper sheet) 108 as well as a counter electrode is arranged in front of the discharge port 21. An ink supply port 101 is connected to the ink supply passage 20, and its end portion extends to the outside of the recording head 1. An ink recovery passage 102 is formed under an insulating substrate 4 that supports the discharge electrodes 2. An ink recovery port 103 is connected to the ink recovery passage 102, and its end portion extends to the outside of the recording head 1.

An ink tank 104 is disposed outside the recording head 1. The ink tank 104 and the ink supply port 101 are connected to each other through a supply tube 105, and the ink tank 104 and the ink recovery port 103 are connected to each other through a recovery tube 106. Between the ink tank 104 and the ink supply port 101, a pump 107 is connected to the supply tube 105.

An ink 6 serving as an image-forming agent is stored in the ink tank 104. The ink 6 is obtained by dispersing a toner containing charged particles and a colorant in an insulating liquid. The ink 6 is supplied from the ink tank 104 to the ink supply passage 20 in the recording head 1 by the pump 107. The toner in the ink 6 is agglomerated in a manner to be described later, and is discharged from a discharge point DP provided to the discharge port 21 of the ink supply passage 20 toward the recording medium 108, thereby forming an image on the recording medium 108.

After passing through the discharge point DP, the ink 6 flows into the ink recovery passage 102, and is returned to the ink tank 104 through the recovery tube 106. The ink 6 is then supplied from the ink tank 104 to the recording head 1 again through the supply tube 105, and is used for image formation. Of the ink 6 circulated and used in this manner, what is consumed by image formation is mostly the toner, and most of the insulating liquid is recovered. Thus, the concentration of the toner of the ink 6 in the ink tank 104 lowers as the ink is circulated. Accordingly, a transmission type ink concentration detecting unit 109 having light-emitting and light-receiving elements is provided to the ink tank 104. The toner concentration of the ink 6 in the ink tank 104 is periodically detected by the ink concentration detecting unit 109. If the detected concentration becomes equal to or less than a predetermined value, the ink 6 is exchanged.

A drive IC 110 for driving the discharge electrodes 2 and common electrode 14 is disposed in the recording head 1. Wiring connected to the drive IC 110 extends to the outside of the recording head 1 through a connector 111.

FIG. 2 is a schematic diagram of the image forming apparatus using the recording head 1. The recording head 1 is connected to the ink supply/recovery mechanism 100, as described above. A plurality of recording media 108 are stored in a cassette 112 and are fed one by one by a paper feed roller 113. Each recording medium 108 is guided along a guide 115 and fed to a portion between the recording head 1 and the platen roller 114, and is further guided along a guide 116 and sandwiched by a convey roller pair 117. From this state, the recording medium 108 is conveyed by the convey roller pair 117 at a predetermined speed. The ink is discharged by the recording head 1 onto the recording medium 108 in synchronism with this convey speed, thereby forming an image.

FIG. 3 is a block diagram showing the control unit of the image forming apparatus using the recording head 1. The recording head 1 is connected to a head driving circuit 118 through the connector 111. A signal for controlling image data and discharge timing is sent from a head driving circuit 118 to the drive IC 110 of the recording head 1. A paper feed motor 119, a platen motor 120, and a convey roller 121 for driving the paper feed roller 113, the platen roller 114, and the convey roller pair 117 are connected to motor drivers 122, 123, and 124, respectively. The operations of the head driving circuit 118 and motor drivers 122, 123, and 124 are controlled by a CPU 125 based on a program stored in a ROM 126. External image data is transferred through an interface 127 and temporarily stored in a RAM 128. An image signal to be sent to the recording head 1 is obtained by reading and transferring image data stored in the RAM 128.

FIGS. 4A, 4B, and 4C are a longitudinal sectional side view, a plan view, and a front view, respectively, of the main part of the image forming apparatus according to the first embodiment of the present invention, and FIG. 4D is a diagram showing the relationship between the recording head and the counter electrode of the same. For the sake of illustrative convenience, the platen roller 114 serving as the support member of the recording medium 108 as well as the counter electrode is illustrated as a flat counter electrode or first electrode 9.

The recording head 1 has an insulating substrate 4 formed with the discharge electrodes or second electrodes 2, and an insulating upper plate 13 formed with the common electrode or third electrode 14. The insulating substrate 4 and the insulating upper plate 13 are arranged such that the discharge electrodes 2 and the common electrode 14 oppose each other, and a space serving as the ink supply passage 20 is formed between

the insulating substrate 4 and the insulating upper plate 13. The trailing side end (an end portion opposite the direction of an arrow A1) of the ink supply passage 20 is connected to the ink supply mechanism (see FIGS. 1 to 3), and the ink 6 serving as the image-forming agent is supplied from the ink supply mechanism to the ink supply passage 20. The discharge port 21 is formed at the distal end of the ink supply passage 20, and the counter electrode 9 set at the ground potential is disposed in front of the discharge port 21 on the distal end side. The recording medium 108 (see FIGS. 1 to 3) is placed on the recording head 1 side surface of the counter electrode 9.

The discharge electrodes 2 are obtained by forming a metal layer of, e.g., aluminum or gold, on the insulating substrate 4 by vacuum deposition and patterning the metal layer by photoetching. The discharge electrodes 2 are arranged in the lateral direction to correspond to the respective discharge points provided to the discharge port 21 such that the individual electrodes are electrically independent of each other. A portion of each discharge electrode 2 opposing the common electrode 14 has a uniform width, and the distal end portion of each discharge electrode 2 extending from the uniform-width portion is tapered narrower. The common electrode 14 is formed as one metal film electrode obtained by forming a metal layer of, e.g., aluminum or gold, on the insulating upper plate 13 by vacuum deposition. The discharge electrodes 2 and the common electrode 14 oppose each other such that the tapered distal end portions of the discharge electrodes 2 project ahead of the common electrode 14.

The discharge electrodes 2 are connected to a recording signal power supply 7 for applying potentials to the respective electrodes and a bias power supply 8a through the IC (see FIGS. 1 to 3). The common electrode 14 is connected to a bias power supply 8b. The common electrode 14 and the bias power supply 8b form a concentration difference forming means.

The ink 6 serving as the image-forming agent is obtained by dispersing a toner consisting of the charged particles and the colorant in an insulating liquid. The toner contains a colorant pigment, e.g., carbon black, contained in or attaching to the surface of a binder consisting of a resin and wax, a dispersant, a charge control agent, and the like. The toner consists of particles that are charged or can be charged in the same polarity as that of the potentials to be applied to the discharge electrodes 2 and the common electrode 14. In this embodiment, the particles of the toner are charged in positive polarity in advance.

FIG. 5 shows changes over time of potentials respectively applied to the discharge electrodes 2 and common electrode 14. The discharge electrodes 2 are biased to a potential Va in the non-recording mode and raised to a potential Vc in the recording mode, as indicated by a solid line X1. The common electrode 14 is biased to a potential Vb both in the non-recording and recording modes, as indicated by a broken line Z1. More specifically, a pulse of Vc - Va is applied to the discharge electrodes 2 in the recording mode.

The operation of the recording head shown in FIGS. 4A to 4D will be described with reference to FIGS. 6A and 6B and FIG. 7. The characteristic feature of this recording head resides in that before the ink is supplied to the discharge points provided to the discharge port 21, the toner is locally distributed in the ink as a preliminary toner gathering process.

FIG. 6A shows the state of the toner 10 in the ink 6 with no potential being applied to the discharge electrodes 2 and common electrode 14. When no external force, e.g., an electric field, is applied to the toner 10, the toner 10 is dispersed in the insulating liquid substantially uniformly by the action of the dispersant or the like and by the electrostatic repulsive force among the particles of the toner 10.

FIG. 6B shows a state wherein the bias potentials Va and Vb shown in FIG. 5 are respectively applied to the discharge electrodes 2 and common electrode 14 to cause a potential difference between the discharge electrodes 2 and common electrode 14, and an external force generated by an electric field is applied to the toner 10. The toner 10 consisting of charged particles having positive polarity moves to the lower-potential side due to electrophoresis. In the recording head 1, since the potential of the common electrode 14 is lower than that of the discharge electrodes 2, the toner 10 gathers on the common electrode 14 side.

The ink 6 is supplied from the ink supply mechanism (see FIGS. 1 to 3) to the ink supply passage 20 by a hydrostatic pressure or low-pressure pump. When the ink 6 is pushed to flow toward the distal end of the ink supply passage 20, the toner 10 locally flows on the common electrode 14 side, as shown in FIG. 6B, due to the influence of the electric field between the discharge electrodes 2 and common electrode 14. Furthermore, at a portion ahead of the distal end of the common electrode 14, the toner 10 is influenced by the counter electrode 9. For this reason, the toner 10 locally flows along the inclined open portion of the discharge port 21 at the distal end of the ink supply passage 20 formed between the distal end of the common electrode 14 and the distal ends of the discharge electrodes 2, and is supplied to the discharge points DP.

In this manner, the voltage applied across the discharge electrodes 2 and common electrode 14 serves to form a difference in concentration of the toner 10 in the direction of depth of the ink supply passage 20. Thus, the toner 10 is efficiently conveyed in the ink 6 such that it has a higher concentration on the common electrode 14 side, and is then conveyed, at the portion ahead of the distal end of the common electrode 14, to the discharge points DP such that it has a higher concentration on the surface side of the ink 6.

In the vicinities of the discharge points DP, the toner 10 is electrostatically attracted by the counter electrode 9, as shown in FIG. 7, due to the electric field concentration between the sharp distal ends of the discharge

electrodes 2 and the counter electrode 9 set at the ground potential. Thus, the toner 10 is gathered in the direction indicated by an arrow B1 in FIG. 7 from the distal ends of the discharge electrodes 2, so that the toner concentration at the discharge points DP is increased. The toner 10 gathered at the small discharge points DP form an agglomerate in which a plurality of toner particles gather.

The above-described behavior of the toner 10 in the ink 6 occurs in units of individual discharge electrodes 2, thereby forming a flow of the ink 6 containing agglomerates of the toner dispersed in accordance with the pattern of the discharge electrodes 2, as shown in FIG. 8.

The effect of agglomeration of the toner caused by the discharge electrodes 2 and the ejecting principle of the toner will be described with reference to FIGS. 9A to 9C.

FIGS. 9A to 9C show the behavior of the toner 10 in the vicinity of the distal ends of the discharge electrodes 2 serving as the discharge points DP. As the distal ends of the discharge electrodes 2 are the closest to the counter electrode 9 at the ground potential, the most intense electric field is generated at the discharge points DP in a direction perpendicular to the surface of the counter electrode 9, i.e., in the direction of an arrow B1 in FIG. 9A. Thus, the toner 10 supplied to the discharge points DP is electrostatically attracted by the counter electrode 9 and thus moves toward the counter electrode 9.

The electrostatic attracting force which acts on the toner at the discharge points DP when the bias potential Va shown in FIG. 5 is applied to the discharge electrodes 2 is set to be smaller than the surface tension of the insulating liquid serving as the solvent of the ink 6. Thus, the toner 10 cannot be ejected from the insulating liquid, i.e., from the ink 6, but remains at the discharge points at the distal ends of the discharge electrodes 2 toward the counter electrode 9. A larger amount of toner 10 is electrostatically attracted by the counter electrode 9 to move toward the discharge points DP where the toner 10 that has arrived earlier remains, and remains at the same position. Since the toner 10 that has gathered in this manner is gathered in small areas at the distal ends of the discharge electrodes 2, the distances among the respective particles of the toner 10 are decreased to such a degree that the particles can no longer be dispersed, thus forming a toner agglomerate 11, as shown in FIG. 9B.

If the potential Vc shown in FIG. 5 is applied to the discharge electrodes 2 simultaneously when the toner agglomerate 11 formed in this manner grows to have an appropriate size, the toner agglomerate 11 excels the surface tension of the insulating liquid serving as the solvent of the ink 6, and flies toward the counter electrode 9, as shown in FIG. 9C.

If a toner agglomerate 11 is to be ejected in accordance with the above ejecting principle, a large amount of toner 10 must be supplied to the discharge points DP. In the conventional technique shown in WO93/1186, as the toner concentration in the ink is maintained at a predetermined level until near the discharge points, it takes time to form a toner agglomerate having an appropriate size. In contrast to this, according to the present invention, a potential difference is formed between the discharge electrodes 2 and common electrode 14 to increase the toner concentration in the ink 6 in units of individual discharge electrodes 2. Thus, the toner 10 can be efficiently supplied to the respective discharge points DP, thereby forming toner agglomerates 11 at the respective discharge points DP faster. Therefore, the recording speed can be increased by using the recording head of the present invention.

If a toner agglomerate 11 is to be ejected in accordance with the above ejecting principle, when the toner 10 is supplied to the discharge points DP, the toner 10 should not be electrically interfered with by the adjacent discharge points DP. In the conventional technique shown in WO93/1186, the toner 10 should not be influenced by an external force but must be set at a predetermined state until near the discharge points. Thus, to prevent electrical interference by the adjacent discharge points, the distances among the discharge points must be increased. In contrast to this, according to the present invention, a mechanism for forming a toner concentration difference is provided in units of discharge electrodes 2, so that the toner 10 can be supplied to the individual discharge points DP without being influenced by the adjacent discharge points DP. Thus, the present invention is suitable for a line head in which a plurality of discharge points are present close to each other.

As described above, in the recording head 1 of the image forming apparatus according to the first embodiment, a potential difference is formed between the discharge electrodes 2 and common electrode 14 that form the ink supply passage 20. Thus, a toner concentration difference is formed in the ink 6 such that the toner 10 consisting of charged particles is locally distributed near the common electrode 14, and the ink 6 is conveyed in this state to the discharge points DP of the discharge port 21. The toner 10 locally distributed in the ink 6 is further agglomerated at the discharge points DP due to the action of the intense electric field generated by the counter electrode 9. When a higher voltage is applied across the discharge electrodes 2 and the common electrode 14, a toner agglomerate 11 flies from each discharge point onto the recording medium due to the electrostatic Coulomb force, thereby forming an image.

FIGS. 10A, 10B, and 10C are a longitudinal sectional side view, a plan view, and a front view, respectively, of the main part of an image forming apparatus according to the second embodiment of the present invention, and FIG. 10D is a diagram showing the relationship between the recording head and the counter electrode of the same. The entire basic arrangement, the ink supply/recovery mechanism, and the control unit of the image forming apparatus according to the second embodiment are substantially identical to those of the first embodiment described with reference to FIGS. 1 to 3, and a detailed description thereof will thus be omitted.

For the sake of illustrative convenience, a platen roller 114 serving as the support member of a recording medium 108 as well as the counter electrode is depicted as a flat counter electrode or first electrode 39.

A recording head 31 has an insulating substrate 34 formed with discharge electrodes or second electrodes 32, and an insulating substrate 35 formed on the insulating substrate 34 with agglomerating electrodes or third electrodes 33 serving as toner agglomerating means. An insulating upper plate 43 is arranged to oppose the agglomerating electrodes 33, and a space serving as an ink supply passage 50 is formed between the insulating upper plate 43 and the agglomerating electrodes 33. The trailing side end (an end portion opposite the direction of an arrow A2) of the ink supply passage 50 is connected to the ink supply mechanism (see FIGS. 1 to 3), and an ink 36 serving as the image-forming agent is supplied from the ink supply mechanism to the ink supply passage 50. A discharge port 51 is formed at the distal end of the ink supply passage 50, and the counter electrode 39 set at the ground potential is disposed in front of the discharge port 51 on the distal end side. The recording medium 108 (see FIGS. 1 to 3) is arranged on the recording head 31 side surface of the counter electrode 39.

The discharge electrodes 32 are obtained by forming a metal layer of, e.g., aluminum or gold, on the insulating substrate 34 by vacuum deposition and patterning the metal layer by photoetching. The discharge electrodes 32 are arranged in the lateral direction to correspond to the respective discharge points provided to the discharge port 51 such that the individual electrodes are electrically independent of each other. A portion of each discharge electrode 32 opposing the insulating upper plate 43 has a uniform width, and the distal end portion of each discharge electrode 32 extending from the uniform-width portion is tapered narrower.

The agglomerating electrodes 33 are formed by forming a metal layer of, e.g., aluminum or gold, on the insulating substrate 35 by vacuum deposition and patterning the metal layer by photoetching. The discharge electrodes 32 are arranged in the lateral direction to correspond to the respective discharge points such that the individual electrodes are electrically independent of each other. A portion of the insulating substrate 35 opposing the insulating upper plate 43 has a uniform thickness, and the distal end of the insulating substrate 35 forms an inclined portion to gradually decrease in thickness. A portion of each agglomerating electrode 33 opposing the insulating upper plate 43 has a uniform width, and a portion of each agglomerating electrode 33 corresponding to the inclined distal end of the insulating substrate 35 is tapered narrower. More specifically, the distal end of each agglomerating electrode 33 is inclined downward and tapered narrower.

The insulating substrates 34 and 35 are stacked such that the discharge electrodes 32 and the agglomerating electrodes 33 oppose each other through the insulating substrate 35. The discharge electrodes 32 and the agglomerating electrodes 33 have the same width, and the width of each discharge electrode 32 and that of the corresponding agglomerating electrode 33 are vertically aligned. The distal ends of the discharge electrodes 32 project ahead of the agglomerating electrodes 33.

The discharge electrodes 32 are connected to a recording signal power supply 37 for applying potentials to the respective electrodes and a bias power supply 38 through the IC (see FIGS. 1 to 3). The agglomerating electrodes 33 are connected to the bias power supply 38.

The ink 36 serving as the image-forming agent is obtained by dispersing a toner consisting of charged particles and a colorant in an insulating liquid. The toner contains a colorant pigment, e.g., carbon black, contained in or attaching to the surface of a binder consisting of a resin and wax, a dispersant, a charge control agent, and the like. The toner consists of particles that are charged or can be charged in the same polarity as that of the potentials to be applied to the discharge electrodes 32 and a common electrode 44. In this embodiment, the particles of the toner are charged in positive polarity in advance.

FIG. 11 shows changes over time of potentials respectively applied to the discharge electrodes 32 and agglomerating electrodes 33. The discharge electrodes 32 are biased to a potential Va in the non-recording mode and raised to a potential Vc in the recording mode, as indicated by a solid line X2. The agglomerating electrodes 33 are biased to the potential Va both in the non-recording and recording modes, as indicated by a broken line Y2. More specifically, a pulse of Vc - Va is applied to the discharge electrodes 32 in the recording mode.

The operation of the recording head shown in FIGS. 10A to 10D will be described with reference to FIGS 12 and 13. The characteristic feature of this recording head resides in that before the ink is supplied to the discharge points provided to the discharge port 51, the toner in the ink is preliminarily agglomerated as a preliminary toner gathering process.

FIG. 12 shows a state wherein the bias voltage Va shown in FIG. 11 is applied to the discharge electrodes 32 and agglomerating electrodes 33 and an external force generated by an electric field is applied to the toner 40. The ink 36 is supplied from the ink supply mechanism (see FIGS. 1 to 3) to the ink supply passage 50 by a hydrostatic pressure or low-pressure pump and pushed to flow toward the distal end of the ink supply passage 50. At this time, at the distal end of the ink supply passage 50, i.e., at the discharge port 51, the toner 40 consisting of charged particles having positive polarity is locally distributed at positions in the ink 36 corresponding to the pattern of the agglomerating electrodes 33 on the insulating upper plate 43 side in accordance with the electric field formed by the agglomerating electrodes 33 and counter electrode 39. At the inclined distal end portions of the agglomerating electrodes 33, the toner 40 is influenced by the intense electric field formed by the agglomerating electrodes 33 and counter electrode 39 to further shift to the surface of the ink 36.

Furthermore, at the distal ends of the agglomerating electrodes 33 serving as the preliminary agglomerating positions, the electric field becomes most intense between the agglomerating electrodes 33 and counter electrode 39, and the toner 40 is attracted by the electrostatic attracting force caused by the counter electrode 39 from the distal ends of the agglomerating electrodes 33 in the direction of an arrow C1 in FIG. 12. However, the toner 40 remains in the vicinities of the distal ends of the agglomerating electrodes 33 due to the surface tension of the insulating liquid serving as the solvent of the ink 36 and forms a toner agglomerate 41.

The toner agglomerate 41 formed at the distal end of each agglomerating electrode 33 grows to gradually increase its size. Since, however, a potential sufficiently large for ejecting the toner agglomerate 41 is not applied to each agglomerating electrode 33, the toner agglomerate 41 is not ejected. When the size of the toner agglomerate 41 growing at the distal end of each agglomerating electrode 33 becomes large, the surface area of the toner agglomerate 41 is also increased, so that the force applied by the flow of the ink 36 is increased. When the force applied by the flow of the ink 36 excels the electrostatic attracting force caused by the counter electrode 39, the toner agglomerate 41 at the distal end of each agglomerating electrode 33 cannot remain there but moves in the direction of the resultant force of the electrostatic attracting force and the force applied by the flow of the ink 36.

The toner agglomerate 41 that has moved from the distal end of each agglomerating electrode 33, where the electric field toward the counter electrode 39 becomes most intense, toward the corresponding discharge electrode 32 is released from the electrostatic attracting force caused by the counter electrode 39, and moves along the flow of the ink 36. In the recording head 31 shown in FIGS. 10A to 10D, the lines connecting the distal ends of the agglomerating electrodes 33 and the discharge points DP in the vicinities of the distal ends of the discharge electrodes 32 correspond to the flowing direction of the ink 36. Thus, the toner agglomerate 41 formed at the distal end of each agglomerating electrode 33 is supplied to the corresponding discharge point DP.

The toner agglomerate 41 supplied to the discharge point DP further agglomerates to form a large toner agglomerate 42 in accordance with the same principle as that explained with reference to FIGS. 9A to 9C. When the potential Vc shown in FIG. 11 is applied to each discharge electrode 32 simultaneously when the toner agglomerate 42 grows to a desired size, the toner agglomerate 42 excels the surface tension of the insulating liquid serving as the solvent of the ink 36 and flies toward the counter electrode 39.

In the recording head 31 of the present invention, because of the preliminary agglomerating process at the distal end of the agglomerating electrode 33, a toner agglomerate 42 having a desired size can be grown at the discharge point DP faster than with the conventional technique shown in WO93/1186. Therefore, a higher recording speed can be realized than with the conventional technique with which the ink is agglomerated and ejected only by the discharge points.

The behavior of the toner 40 in the ink 36 described above occurs in units of individual discharge electrodes 32, and a flow of the ink 36 containing toner agglomerates dispersed in accordance with the pattern of the discharge electrodes 32 is formed, as shown in FIG. 13. More specifically, in this embodiment, toner preliminary agglomerating mechanisms are provided in units of discharge points DP, so that the toner 40 can be supplied to the individual discharge points without being influenced by the adjacent discharge points DP. Thus, this embodiment is suitable for a line head in which a plurality of discharge points are present close to each other.

As described above, in the recording head 31 of the image forming apparatus according to the second embodiment, a potential is applied to the agglomerating electrodes 33 forming the ink supply passage 50. Thus, the toner 40 is preliminarily agglomerated at the distal ends of the agglomerating electrodes 33 where the electric field is concentrated between the counter electrode 39 and agglomerating electrodes 33. The preliminary toner agglomerate 41 is supplied to the distal end of each discharge electrode 32 together with the ink 36 to further agglomerate, thereby forming a larger toner agglomerate 42. When a higher voltage is applied across the discharge electrodes 32 and the counter electrode 39, the toner agglomerate 42 flies from each discharge point DP onto the recording medium due to the electrostatic Coulomb force, thereby forming an image.

FIGS. 14A, 14B, and 14C are a longitudinal sectional side view, a plan view, and a front view, respectively, of the main part of an image forming apparatus according to the third embodiment of the present invention, and FIG. 14D is a diagram showing the relationship between the recording head and the counter electrode of the same. The entire basic arrangement, the ink supply/recovery mechanism, and the control unit of the image forming apparatus according to the third embodiment are substantially identical to those of the first embodiment described with reference to FIGS. 1 to 3, and a detailed description thereof will thus be omitted. For the sake of illustrative convenience, a platen roller 114 serving as the support member of a recording medium 108 as well as the counter electrode is illustrated as a flat counter electrode or first electrode 69.

A recording head 61 has an insulating substrate 64 formed with discharge electrodes or second electrodes 62, an insulating substrate 65 formed on the insulating substrate 64 with agglomerating electrodes or third electrodes 63 serving as toner agglomerating means, and an insulating upper plate 73 formed with a common electrode or fourth electrode 74. The insulating substrate 65 and the insulating upper plate 73 are arranged such that the agglomerating electrodes 63 and the common electrode 74 oppose each other, and a space serving as an ink supply passage 80 is formed between the insulating substrate 65 and the insulating upper plate 73. The trail-

ing side end (an end portion opposite the direction of an arrow A3) of the ink supply passage 80 is connected to the ink supply mechanism (see FIGS. 1 to 3), and an ink 66 serving as the image-forming agent is supplied from the ink supply mechanism to the ink supply passage 80. A discharge port 81 is formed at the distal end of the ink supply passage 80, and the counter electrode 69 set at the ground potential is disposed in front of the discharge port 81 on the distal end side. The recording medium (see FIGS. 1 to 3) is arranged on the recording head 61 side surface of the counter electrode 69.

The discharge electrodes 62 are obtained by forming a metal layer of, e.g., aluminum or gold, on the insulating substrate 64 by vacuum deposition and patterning the metal layer by photoetching. The discharge electrodes 62 are arranged in the lateral direction to correspond to the respective discharge points provided to the discharge port 81 such that the individual electrodes are electrically independent of each other. A portion of each discharge electrode 62 opposing the insulating upper plate 73 has a uniform width, and the distal end portion of each discharge electrode 62 extending from the uniform-width portion is tapered narrower.

The agglomerating electrodes 63 are formed by forming a metal layer of, e.g., aluminum or gold, on the insulating substrate 65 by vacuum deposition and patterning the metal layer by photoetching. The agglomerating electrodes 63 are arranged in the lateral direction to correspond to the respective discharge points such that the individual electrodes are electrically independent of each other. A portion of the insulating substrate 65 opposing the insulating upper plate 73 has a uniform thickness, and the distal end portion of the insulating substrate 65 forms an inclined portion to gradually decrease in thickness. A portion of each agglomerating electrode 63 opposing the insulating upper plate 73 has a uniform width, and a portion of each agglomerating electrode 63 corresponding to the inclined distal end of the insulating substrate 65 is tapered narrower. More specifically, the distal end of each agglomerating electrode 63 is inclined downward and tapered narrower.

The insulating substrates 64 and 65 are stacked such that the discharge electrodes 62 and the agglomerating electrodes 63 oppose each other through the insulating substrate 65. The discharge electrodes 62 and the agglomerating electrodes 63 have the same width, and the width of each discharge electrode 62 and that of the corresponding agglomerating electrode 63 are vertically aligned. The distal ends of the discharge electrodes 62 project ahead of the agglomerating electrodes 63.

The common electrode 74 is formed as one metal film electrode obtained by forming a metal layer of, e.g., aluminum or gold, on the insulating upper plate 73 by vacuum deposition. The insulating upper plate 73 is arranged such that the inclined tapered distal end portions of the agglomerating electrodes 63 and the tapered distal end portions of the discharge electrodes 62 both below the insulating upper plate 73 project ahead of the common electrode 74.

The discharge electrodes 62 are connected to a recording signal power supply 67 for applying potentials to the respective electrodes and a bias power supply 68 through the IC (see FIGS. 1 to 3). Both the agglomerating electrodes 63 and the common electrode 74 are connected to the bias power supply 68. The agglomerating electrodes 63 are set at a higher potential than that of the common electrode 74.

The ink 66 serving as the image-forming agent is obtained by dispersing a toner consisting of charged particles and a colorant in an insulating liquid. The toner contains a colorant pigment, e.g., carbon black, contained in or attaching to the surface of a binder consisting of a resin and wax, a dispersant, a charge control agent, and the like. The toner consists of particles that are charged or can be charged in the same polarity as that of the potentials to be applied to the discharge electrodes 62, the agglomerating electrodes 63, and the common electrode 74. In this embodiment, the particles of the toner are charged in positive polarity in advance.

FIG. 15 shows changes over time of potentials respectively applied to the discharge electrodes 62, the agglomerating electrodes 63, and the common electrode 74. The discharge electrodes 62 are biased to a potential Va in the non-recording mode and raised to a potential Vc in the recording mode, as indicated by a solid line X3. The agglomerating electrodes 63 are biased to the potential Va both in the non-recording and recording modes, as indicated by a broken line Y3. The common electrode 74 is biased to a potential Vb lower than the potential Va both in the non-recording and recording modes, as indicated by a broken line Z3. More specifically, the potential difference between the agglomerating electrodes 63 and common electrode 74 is constantly Va - Vb. A pulse of Vc - Va is applied to the discharge electrodes 62 in the recording mode.

The operation of the recording head shown in FIGS. 14A to 14D will be described with reference to FIGS. 16 and 17. The characteristic feature of this recording head resides in that before the ink is supplied to the discharge points provided to the discharge port 81, the toner is locally distributed in the ink and is preliminarily agglomerated, as a preliminary toner gathering process.

FIG. 16 shows a state wherein the bias potentials Va, Vb, and Vc are respectively applied to the discharge electrodes 62, the agglomerating electrodes 63, and the common electrode 74 to cause a potential difference among the electrodes, and an external force produced by an electric field is applied to the toner 70. The toner 70 consisting of charged particles having positive polarity moves to the lower-potential side due to electrophoresis. In the recording head 61, since the potential of the common electrode 74 is lower than that of the agglomerating electrodes 63, the toner 70 gathers on the common electrode 74 side.

The ink 66 is supplied from the ink supply mechanism (see FIGS. 1 to 3) to the ink supply passage 80 by a hydrostatic pressure or low-pressure pump. When the ink 66 is pushed to flow toward the distal end of the ink

supply passage 80, the toner 70 locally flows on the common electrode 74 side, as shown in FIG. 16, due to the influence of the electric field between the agglomerating electrodes 63 and common electrode 74. In this manner, the voltage applied across the agglomerating electrodes 63 and common electrode 74 serves to form a concentration difference of the toner 70 in the direction of depth of the ink supply passage 80.

Furthermore, at a portion ahead of the distal end of the common electrode 74, the toner 70 is influenced by the counter electrode 69. For this reason, the toner 70 locally flows along the inclined open portion of the discharge port 81 at the distal end of the ink supply passage 80 formed between the distal end of the common electrode 74 and the distal ends of the agglomerating electrodes 63, and is conveyed efficiently toward the distal ends of the agglomerating electrodes 63. At the inclined distal end portions of the agglomerating electrodes 63, the toner 70 is influenced by the intense electric field formed by the agglomerating electrodes 63 and counter electrode 69 to further move to the surface of the ink 66.

Furthermore, at the distal ends of the agglomerating electrodes 63 serving as the preliminary agglomerating positions, the electric field becomes most intense between the agglomerating electrodes 63 and counter electrode 69, and the toner 70 is attracted by the electrostatic attracting force generated by the counter electrode 69 from the distal ends of the agglomerating electrodes 63 in the direction of an arrow C2 in FIG. 16. However, the toner 70 remains in the vicinities of the distal ends of the agglomerating electrodes 63 due to the surface tension of the insulating liquid serving as the solvent of the ink 66 and forms a toner agglomerate 71.

The toner agglomerate 71 formed at the distal end of each agglomerating electrode 63 grows to gradually increase its size. Since, however, a potential sufficiently large for ejecting the toner agglomerate 71 is not applied to each agglomerating electrode 63, the toner agglomerate 71 is not ejected. When the size of the toner agglomerate 71 growing at the distal end of each agglomerating electrode 63 becomes large, the surface area of the toner agglomerate 71 is also increased, so that the force applied by the flow of the ink 66 is increased. When the force applied by the flow of the ink 66 excels the electrostatic attracting fore caused by the counter electrode 69, the toner agglomerate 71 at the distal end of each agglomerating electrode 63 cannot remain there but moves in the direction of the resultant force of the electrostatic attracting force and the force applied by the flow of the ink 66.

The toner agglomerate 71 that has moved from the distal end of each agglomerating electrode 63, where the electric field toward the counter electrode 69 becomes most intense, toward the corresponding discharge electrode 62 is released from the electrostatic attracting force caused by the counter electrode 69, and moves along the flow of the ink 66. In the recording head 61 shown in FIGS. 14A to 14D, the lines connecting the distal ends of the agglomerating electrodes 63 and discharge points DP in the vicinities of the distal ends of the discharge electrodes 62 correspond to the flowing direction of the ink 66. Thus, the toner agglomerate 71 formed at the distal end of each agglomerating electrode 63 is supplied to the corresponding discharge point DP.

The toner agglomerate 71 supplied to the discharge point DP further agglomerates to form a large toner agglomerate 72 in accordance with the same principle as that explained with reference to FIGS. 9A to 9C. When the potential Vc shown in FIG. 15 is applied to each discharge electrode 62 simultaneously when the toner agglomerate 72 grows to a desired size, the toner agglomerate 72 excels the surface tension of the insulating liquid serving as the solvent of the ink 66 and flies toward the counter electrode 69.

In the recording head 61 of the present invention, because of the preliminary agglomerating process at the distal end of the agglomerating electrode 63, a toner agglomerate 72 having a desired size can be grown at the discharge point DP faster than with the conventional technique shown in WO93/1186. Furthermore, as the toner concentration of the ink 66 is increased in units of individual agglomerating electrodes 63 before the preliminary agglomerating process, the preliminary agglomerating process itself has a higher efficiency than that obtained with the recording head 31 shown in FIG. 7. Therefore, a higher recording speed can be realized than with the conventional technique with which the ink is agglomerated and ejected only by the discharge points.

The behavior of the toner 70 in the ink 66 described above occurs in units of individual discharge electrodes 62, and a flow of the ink 66 containing the toner agglomerates dispersed in accordance with the pattern of the discharge electrodes 62 is formed, as shown in FIG. 17. More specifically, in this embodiment, toner concentration difference forming mechanisms and toner preliminary agglomerating mechanisms are provided in units of discharge points DP, so that the toner 70 can be supplied to the individual discharge points without being influenced by the adjacent discharge points DP. Thus, this embodiment is suitable for a line head in which a plurality of discharge points are present close to each other.

As described above, in the recording head 71 of the image forming apparatus according to the third embodiment, a potential difference is formed between the agglomerating electrodes 63 and common electrode 74 forming the ink supply passage 80. Thus, a toner concentration difference is formed in the ink 66 such that the toner 70 consisting of charged particles are locally distributed near the surface of the common electrode 74, and in this state the ink 66 is conveyed to the distal ends of the agglomerating electrodes 63. The toner 70 is preliminarily agglomerated at the distal ends of the agglomerating electrodes 63 where the electric field is concentrated between the counter electrode 69 and agglomerating electrodes 63. The preliminary toner agglomerate 71 is supplied to the distal end of each discharge electrode 62 together with the ink 66 to further agglomerate, thereby forming a larger toner agglomerate

72. When a higher voltage is applied across the discharge electrodes 62 and the counter electrode 69, the toner agglomerate 72 flies from each discharge point onto the recording medium due to the electrostatic Coulomb force, thereby forming an image.

The effects obtained by the image forming apparatuses according to the first to third embodiments will be summarized as follows.

With the image forming apparatus according to the first embodiment, a toner concentration difference is formed in the ink and the ink is supplied in this state to the discharge point, so that the agglomerating efficiency of the toner at the discharge point can be increased. As a result, an image free from a decrease or non-uniformity in image density can be formed.

With the image forming apparatus according to the second embodiment, a toner preliminary agglomerate is formed in the ink in advance at the preliminary agglomerating position, and the ink is supplied in this state to the discharge point, so that the agglomerating efficiency of the toner at the discharge point can be increased. As a result, an image free from a decrease or non-uniformity in image density can be formed.

With the image forming apparatus according to the third embodiment, a toner concentration difference is formed in the ink and the ink is supplied in this state to the preliminary agglomerating position, so that the agglomerating efficiency of the toner at the preliminary agglomerating position can be increased. Furthermore, a toner preliminary agglomerate is formed in the ink in advance at the preliminary agglomerating position, and the ink is supplied in this state to the discharge point, so that the agglomerating efficiency of the toner at the discharge point can be increased. As a result, an image free from a decrease or non-uniformity in image density can be formed.

With the image forming apparatuses according to the first to third embodiments, when a plurality of discharge points are formed in an array, a toner flow used for forming a toner agglomerate can be formed in units of discharge points. As a result, an electrostatic interference or an interference in the toner agglomerating process will not occur among the discharge points.

Claims

1. An image forming apparatus comprising:

supplying means (100) having a discharge port (21; 51; 81) arranged to oppose a recording medium (108), for storing an ink (6; 36; 66) including colored particles (10; 40; 70) therein, and for supplying the ink to the discharge port;

preliminary gathering means (2, 14, 8a, 8b; 33, 39, 38; 63, 74, 69, 68) for preliminarily gathering the colored particles in the ink while the ink is supplied to said discharge port by the supplying means;

agglomerating means (2, 9, 8a; 32, 39, 38; 62, 69, 68) for agglomerating the colored particles, preliminarily gathered by said preliminary gathering means, in said discharge port, thereby forming an agglomerate in the ink; and

ejecting means (2, 9, 7; 32, 39, 37; 62, 69, 67) for electrostatically ejecting said agglomerate formed by said agglomerating means from said discharge port onto the recording medium.

2. An apparatus according to claim 1, characterized in that said ink (6; 36; 66) comprises an insulating liquid and said colored particles (10; 40; 70) dispersed in said insulating liquid.

3. An apparatus according to claim 1, characterized in that said colored particles include charged particles (10; 40; 70) and a colorant, and have an electric charge.

4. An apparatus according to claim 3, characterized in that said preliminary gathering means (2, 14, 8a, 8b) forms an electric field in a supply passage (20) of said supplying means (100) in order to locally distribute the colored particles (10) in the ink (6) to be supplied to said discharge port (21).

5. An apparatus according to claim 3, characterized in that said agglomerating means (2, 9, 8a; 32, 39, 38; 62, 69, 68) forms an electric field at a discharge point (DP) arranged in said discharge port (21; 51; 81) in order to form said agglomerate at said discharge point.

6. An apparatus according to claim 5, characterized in that said preliminary gathering means (33, 39, 38) forms an electric field at a preliminary agglomerating position arranged between a supply passage (50) of said supplying means (100) and said discharge point (DP), in order to agglomerate the colored particles (40) in the ink (36) at said preliminary agglomerating position, thereby forming a preliminary agglomerate.

7. An apparatus according to claim 5, characterized in that said preliminary gathering means comprises means (63, 74, 69, 68) for forming an electric field in a supply passage (80) of said supplying means (100) in order to locally distribute the colored particles (70) in the ink (66) to be supplied to said discharge port (81), and means for forming an electric field at a preliminary agglomerating position arranged between said supply passage and said discharge point (DP), in order to agglomerate the colored particles in the ink at said preliminary agglomerating position, thereby forming a preliminary agglomerate.

8. An apparatus according to claim 5, characterized in that a plurality of discharge points (DP) are arranged in an array in said discharge port (21; 51; 81).

9. An image forming apparatus for forming an image on a recording medium, comprising:

supplying means (100) for storing an ink (6) including colored particles (10) therein, and for supplying the ink to a discharge port (2), arranged to oppose the recording medium (108), through a supply passage (20);

preliminary gathering means (2, 14, 8a, 8b) for forming a first electric field in said supply passage in order to locally distribute the colored particles in the ink to be supplied to said discharge port;

agglomerating means (2, 9, 8a) for forming a second electric field at a discharge point (DP) arranged in said discharge port, and agglomerating the colored particles, preliminarily gathered by said preliminary gathering means, at said discharge point, thereby forming an agglomerate in the ink; and

ejecting means (2, 9, 7) for forming a third electric field more intense than the second electric field at said discharge point and ejecting said agglomerate from said discharge point onto the recording medium.

10. An apparatus according to claim 9, characterized in that said ink (6) comprises an insulating liquid and said colored particles (10) dispersed in said insulating liquid.

11. An apparatus according to claim 9, characterized in that said colored particles (10) include charged particles and a colorant, and have an electric charge.

12. An apparatus according to claim 11, characterized in that a first electrode (9) is disposed to oppose said discharge port (21), a second electrode (2) is disposed to oppose said first electrode through said discharge point (DP), and a third electrode (14) is disposed to oppose said second electrode through said supply passage (20).

13. An apparatus according to claim 12, characterized in that said preliminary gathering means comprises means (8a, 8b) for applying first and second bias voltages to said second and third electrodes (2, 14), respectively, in order to form said first electric field between said second and third electrodes.

14. An apparatus according to claim 12, characterized in that said agglomerating means comprises means (8a) for applying a first bias voltage to said second electrode (2), in order to form said second electric field between said first and second electrodes (9, 2).

15. An apparatus according to claim 14, characterized in that said ejecting means comprises means (7) for applying a third bias voltage greater than the first bias voltage to said second electrode (2), in order to form said third electric field between said first and second electrodes (9, 2).

16. An apparatus according to claim 12, characterized in that said first electrode (9) serves as support means for supporting the recording medium (108).

17. An apparatus according to claim 9, characterized in that a plurality of discharge points (DP) are arranged in an array at said discharge port (21).

18. An image forming apparatus for forming an image on a recording medium, comprising:

supplying means (100) for storing an ink (36) including colored particles (40) therein, and for supplying the ink to a discharge port (51), arranged to oppose the recording medium (108), through a supply passage (50);

preliminary agglomerating means (33, 39, 38) for forming a first electric field at a preliminary agglomerating position arranged in said discharge port, and agglomerating the colored particles at said preliminary agglomerating position, thereby forming a preliminary agglomerate in the ink, said preliminary agglomerating position being arranged between said supply passage and a discharge point (DP) arranged in said discharge port;

agglomerating means (32, 39, 38) for forming a second electric field at said discharge point, and further agglomerating said preliminary agglomerate at said discharge point, thereby forming an agglomerate in the ink; and

ejecting means (32, 39, 37) for forming a third electric field more intense than the second electric field at said discharge point and ejecting said agglomerate from said discharge point onto the recording medium.

19. An apparatus according to claim 18, characterized in that said ink (36) comprises an insulating liquid and said colored particles (40) dispersed in said insulating liquid.

20. An apparatus according to claim 18, characterized in that said colored particles (40) include charged particles and a colorant, and have an electric charge.

21. An apparatus according to claim 20, characterized in that a first electrode (39) is disposed to oppose said discharge port (51), a second electrode (32) is disposed to oppose said first electrode through said discharge point (DP), and a third electrode (33) is disposed to oppose said first electrode through said preliminary agglomerating position.

22. An apparatus according to claim 21, characterized in that said preliminary agglomerating means comprises means (38) for applying a first bias voltage to said third electrode (33), in order to form said first electric field between said first and third electrodes (39, 33).

23. An apparatus according to claim 21, characterized in that said agglomerating means comprises means (38) for applying a second bias voltage to said second electrode (32), in order to form said second electric field between said first and second electrodes (39, 32).

24. An apparatus according to claim 23, characterized in that said ejecting means comprises means (37) for applying a third bias voltage greater than the second bias voltage to said second electrode (32), in order to form said third electric field between said first and second electrodes (39, 32).

25. An apparatus according to claim 21, characterized in that said first electrode (39) serves as support means for supporting the recording medium (108).

26. An apparatus according to claim 18, characterized in that a plurality of discharge points (DP) are arranged in an array at said discharge port (51).

27. An image forming apparatus for forming an image on a recording medium, comprising:

supplying means (100) for storing an ink (66) including colored particles (70) therein, and for supplying the ink to a discharge port (81), arranged to oppose the recording medium (108), through a supply passage (80);

preliminary gathering means (63, 74, 68) for forming a first electric field in said supply passage in order to locally distribute the colored particles in the ink to be supplied to said discharge port;

preliminary agglomerating means (63, 69, 68) for forming a second electric field at a preliminary agglomerating position arranged in said discharge port, and agglomerating the colored particles, preliminarily gathered by said preliminary gathering means, at said preliminary agglomerating position, thereby forming a preliminary agglomerate in the ink, said preliminary agglomerating position being arranged between said supply passage and a discharge point (DP) arranged in said discharge port;

agglomerating means (62, 69, 68) for forming a third electric field at said discharge point, and further agglomerating said preliminary agglomerate at said discharge point, thereby forming an agglomerate in the ink; and

ejecting means (62, 69, 67) for forming a fourth electric field more intense than the third electric field at said discharge point and ejecting said agglomerate from said discharge point onto the recording medium.

28. An apparatus according to claim 27, characterized in that said ink (66) comprises an insulating liquid and said colored particles (70) dispersed in said insulating liquid.

29. An apparatus according to claim 27, characterized in that said colored particles (70) include charged particles and a colorant, and have an electric charge.

30. An apparatus according to claim 29, characterized in that a first electrode (69) is disposed to oppose said discharge port (81), a second electrode (62) is disposed to oppose said first electrode through said discharge point (DP), a third electrode (63) is disposed to oppose said first electrode through said preliminary agglomerating position, and a fourth electrode (74) is disposed to oppose said third electrode through said supply passage.

31. An apparatus according to claim 30, characterized in that said preliminary gathering means comprises means (68) for applying first and second bias voltages to said third and fourth electrodes (63, 74), respectively, in order to form said first electric field between said third and fourth electrodes.

32. An apparatus according to claim 30, characterized in that said preliminary agglomerating means comprises means (68) for applying a first bias voltage to said third electrode (63), in order to form said second electric field between said first and third electrodes (69, 63).

33. An apparatus according to claim 30, characterized in that said agglomerating means comprises means (68) for applying a third bias voltage to said second electrode (62), in order to form said third electric field between said first and second electrodes (69, 62).

34. An apparatus according to claim 33, characterized in that said ejecting means comprises means (67) for applying a fourth bias voltage greater than the third bias voltage to said second electrode (62), in order to form said fourth electric field between said first and second electrodes (69, 62).

35. An apparatus according to claim 30, characterized in that said first electrode (69) serves as support means for supporting the recording medium (108).

36. An apparatus according to claim 27, characterized in that a plurality of discharge points (DP) are arranged in an array at said discharge port (81).

37. A method of forming an image, comprising:

a supplying step of supplying an ink (6; 36; 66) including colored particles (10; 40; 70) therein to a discharge port (21; 51; 81) arranged to oppose a recording medium (108);

a preliminary gathering step of preliminarily gathering the colored particles in the ink while the ink is supplied to said discharge port;

an agglomerating step of agglomerating the

colored particles, preliminarily gathered in said preliminary gathering step, in said discharge port, thereby forming an agglomerate in the ink; and

a ejecting step of electrostatically ejecting said agglomerate formed in said agglomerating step from said discharge port onto the recording medium.

38. An image forming method of forming an image on a recording medium, comprising the steps of:

supplying an ink (6) including colored particles (10) therein to a discharge port (21), arranged to oppose the recording medium (108), through a supply passage (20);

forming a first electric field in said supply passage in order to locally distribute the colored particles in the ink to be supplied to said discharge port;

forming a second electric field at a discharge point (DP) arranged in said discharge port, and agglomerating the colored particles, preliminarily gathered, at said discharge point, thereby forming an agglomerate in the ink; and

forming a third electric field more intense than the second electric field at said discharge point and ejecting said agglomerate from said discharge point onto the recording medium.

39. An image forming method of forming an image on a recording medium, comprising the steps of:

supplying an ink (36) including colored particles (40) therein to a discharge port (51), arranged to oppose the recording medium (108), through a supply passage (50);

forming a first electric field at a preliminary agglomerating position arranged in said discharge port, and agglomerating the colored particles at said preliminary agglomerating position, thereby forming a preliminary agglomerate in the ink, said preliminary agglomerating position being arranged between said supply passage and a discharge point (DP) arranged in said discharge port;

forming a second electric field at said discharge point, and further agglomerating said preliminary agglomerate at said discharge point, thereby forming an agglomerate in the ink; and

forming a third electric field more intense than the second electric field at said discharge point and ejecting said agglomerate from said discharge point onto the recording medium.

40. An image forming method of forming an image on a recording medium, comprising the steps of:

supplying an ink (66) including colored particles (70) therein to a discharge port (81), arranged to oppose the recording medium (108), through a supply passage (80);

forming a first electric field in said supply passage in order to locally distribute the colored particles in the ink to be supplied to said discharge port;

forming a second electric field at a preliminary agglomerating position arranged in said discharge port, and agglomerating the colored particles, preliminarily gathered, at said preliminary agglomerating position, thereby forming a preliminary agglomerate in the ink, said preliminary agglomerating position being arranged between said supply passage and a discharge point (DP) arranged in said discharge port;

forming a third electric field at said discharge point, and further agglomerating said preliminary agglomerate at said discharge point, thereby forming an agglomerate in the ink; and

forming a fourth electric field more intense than the third electric field at said discharge point and ejecting said agglomerate from said discharge point onto the recording medium.

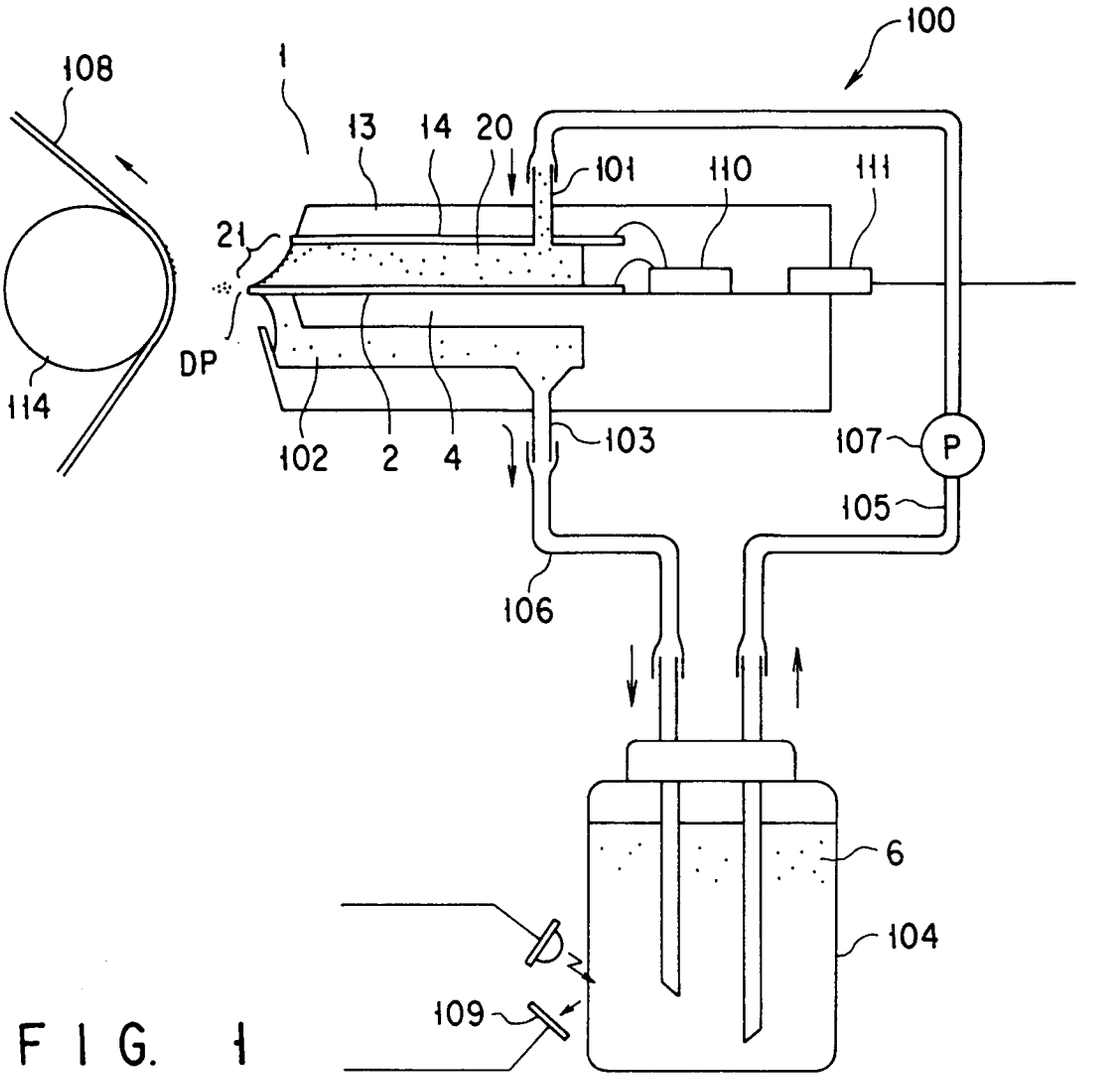

100
108
1
13
14
20
101
110
111
21
DP
114
102
2
4
103
107
P
105
106
6
104
109

FIG. 1

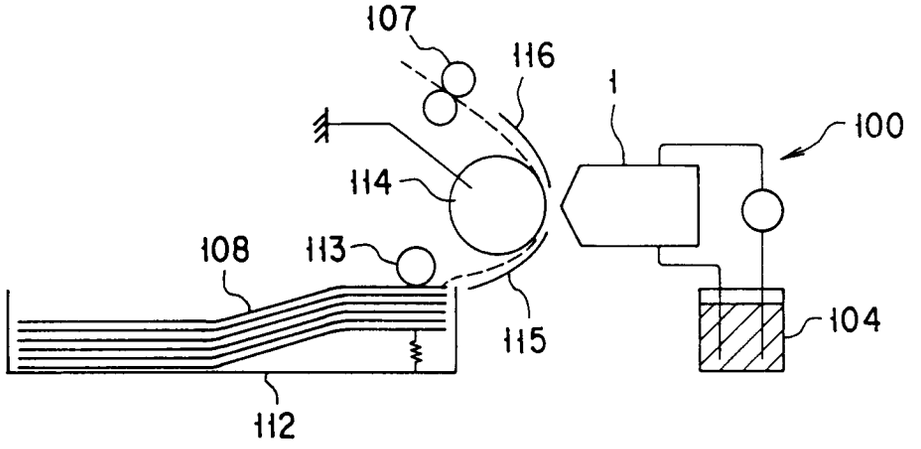

107
116
1
100
114
108
113
115
104
112

FIG. 2

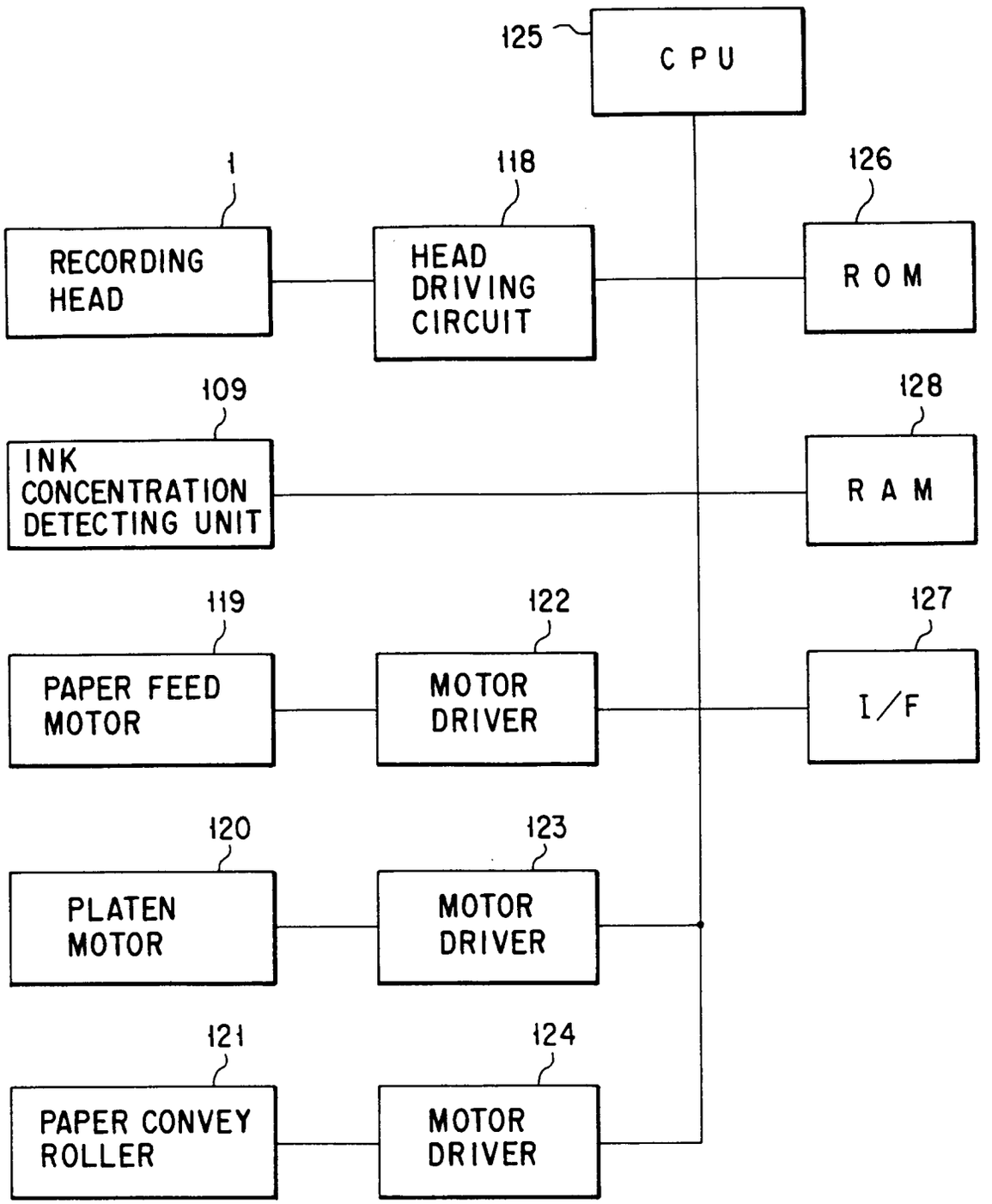

125
CPU
1
RECORDING HEAD
118
HEAD DRIVING CIRCUIT
126
ROM
109
INK CONCENTRATION DETECTING UNIT
128
RAM
119
PAPER FEED MOTOR
122
MOTOR DRIVER
127
I/F
120
PLATEN MOTOR
123
MOTOR DRIVER
121
PAPER CONVEY ROLLER
124
MOTOR DRIVER

FIG. 3

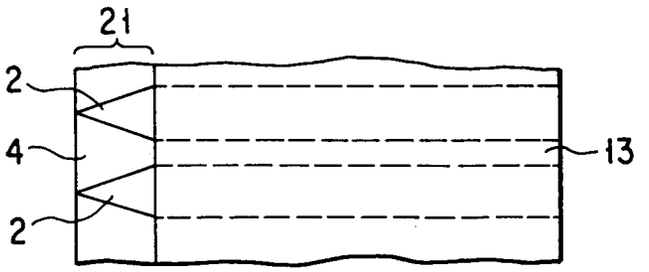


FIG. 4B

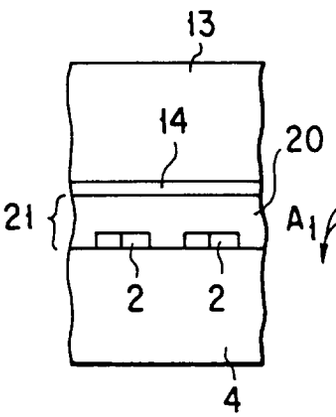


FIG. 4C

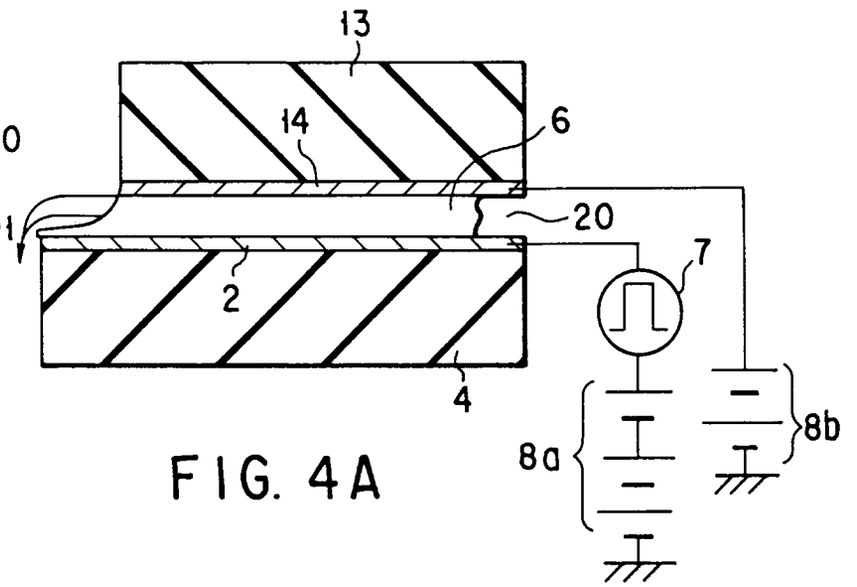


FIG. 4A

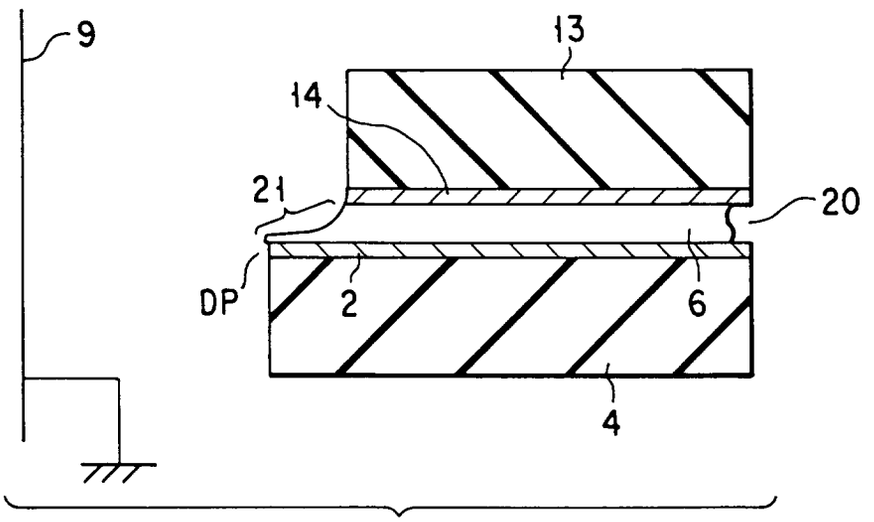


FIG. 4D

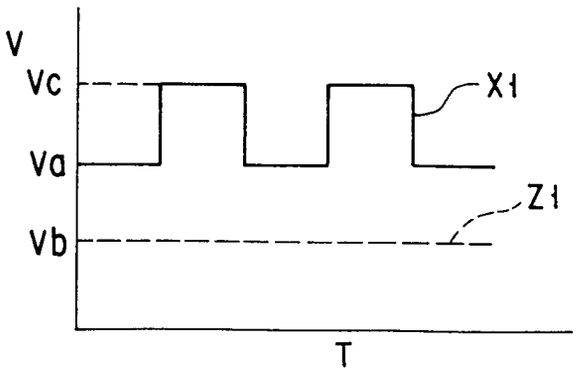


FIG. 5

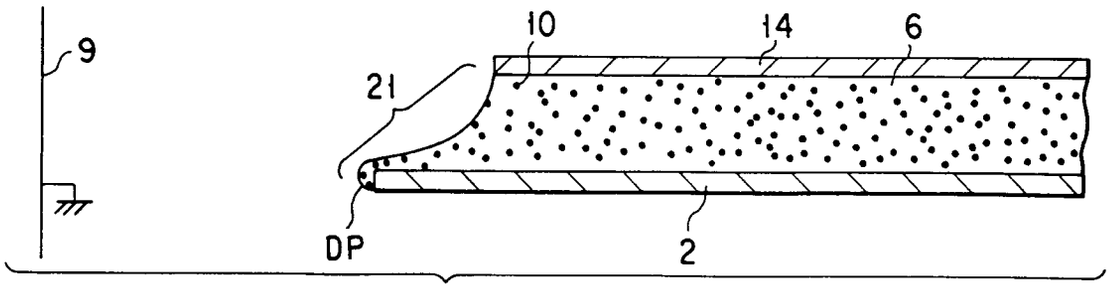


FIG. 6A

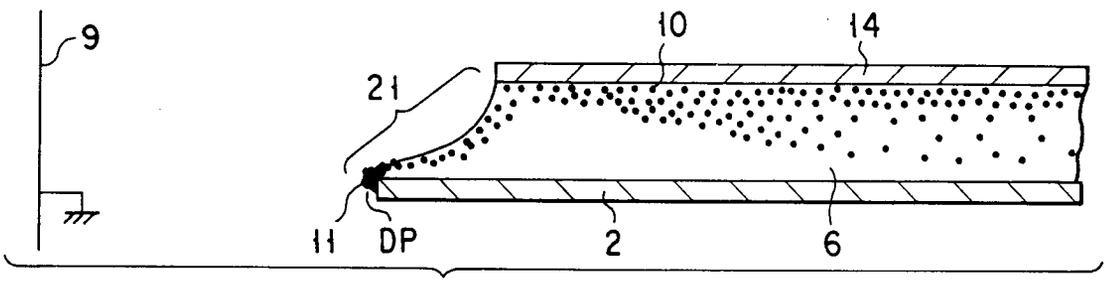


FIG. 6B

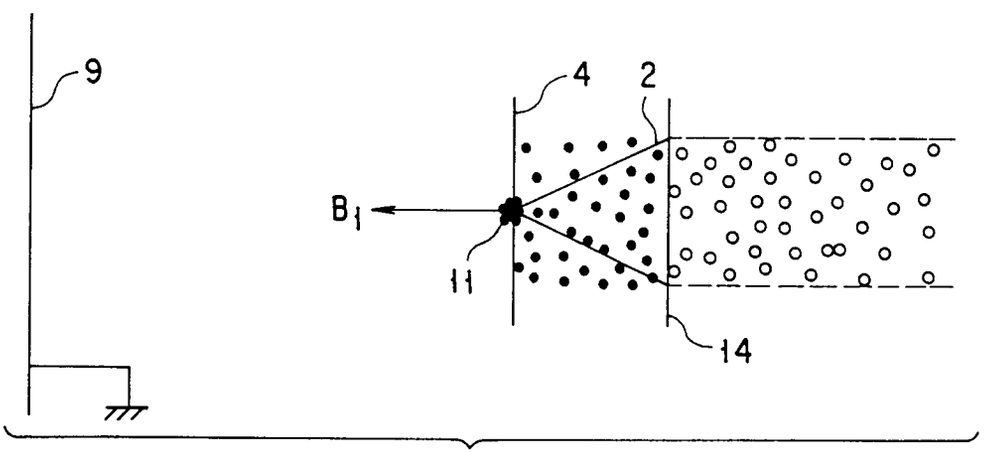


FIG. 7

FIG. 8

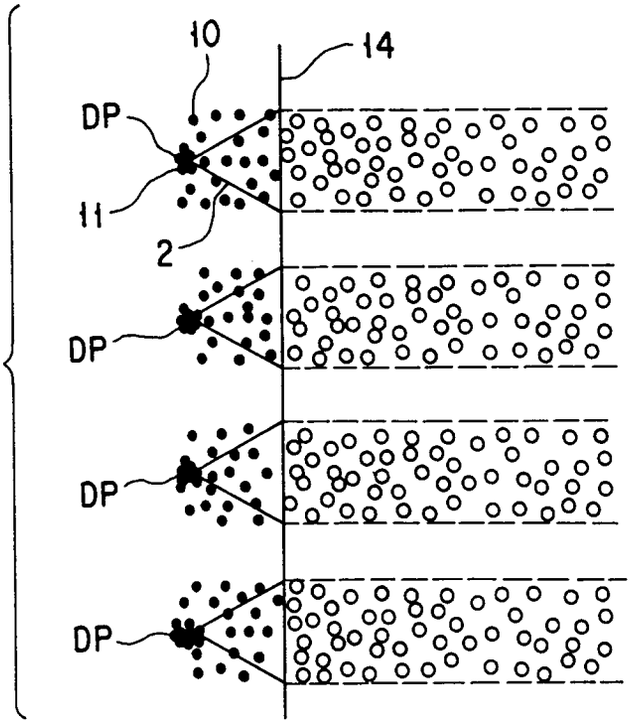


FIG. 9A

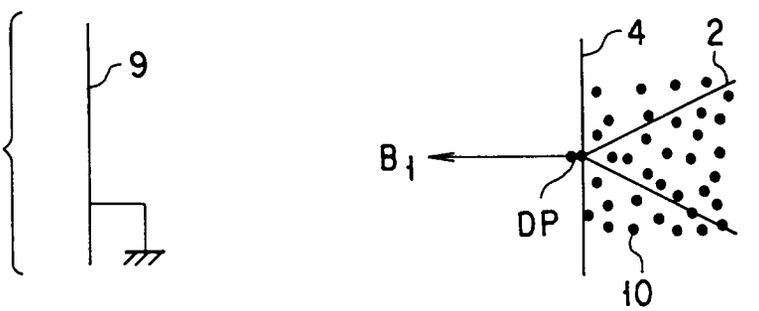


FIG. 9B

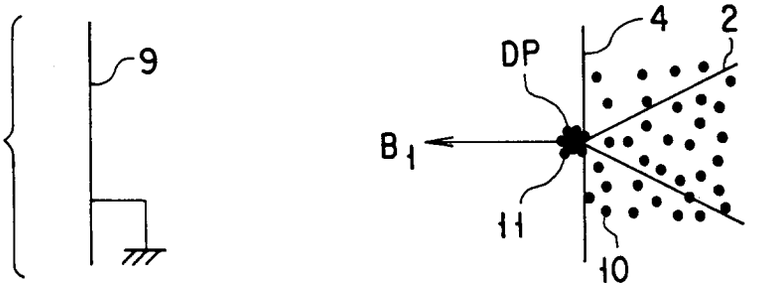
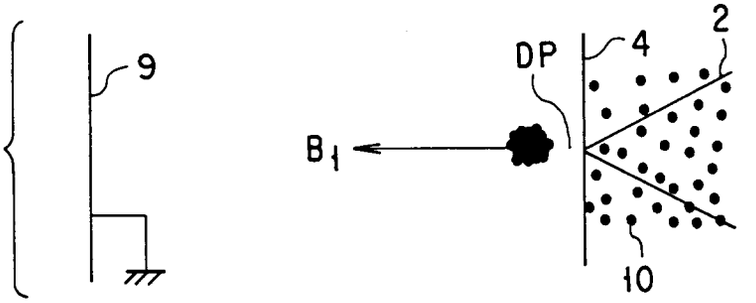


FIG. 9C



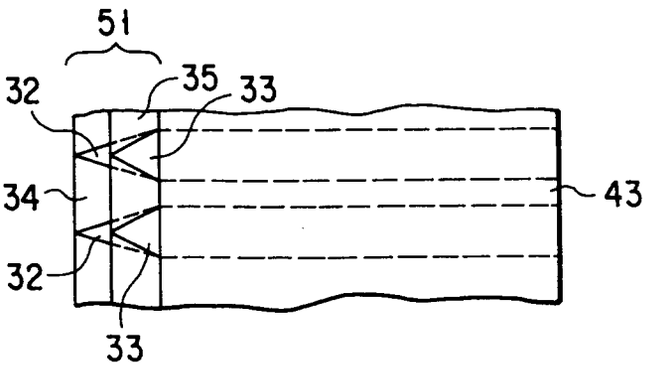


FIG. 10B

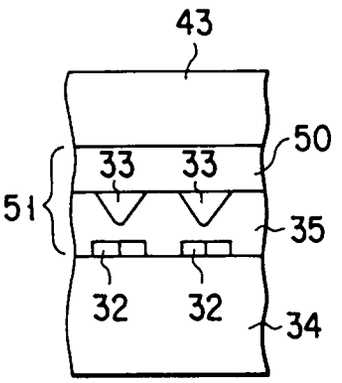


FIG. 10C

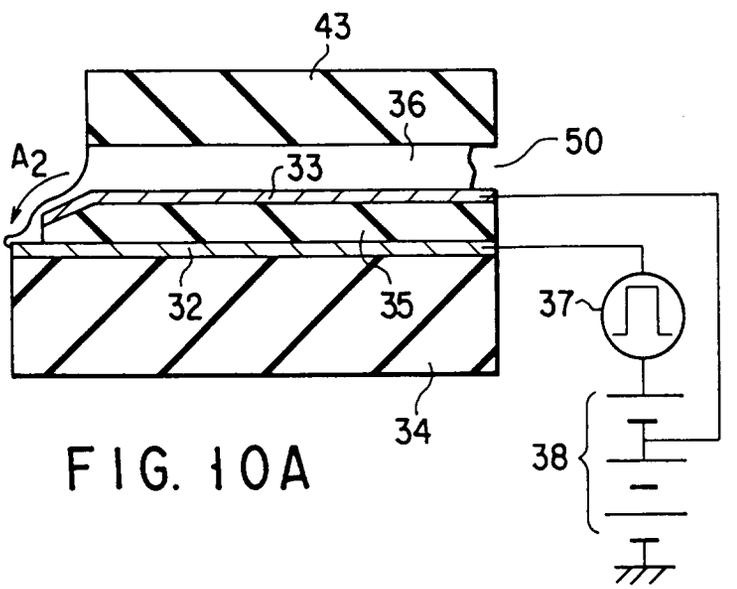


FIG. 10A

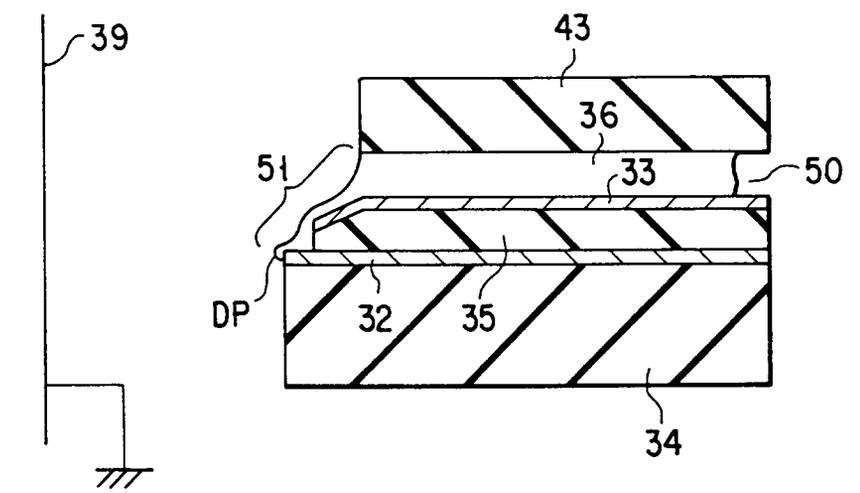


FIG. 10D

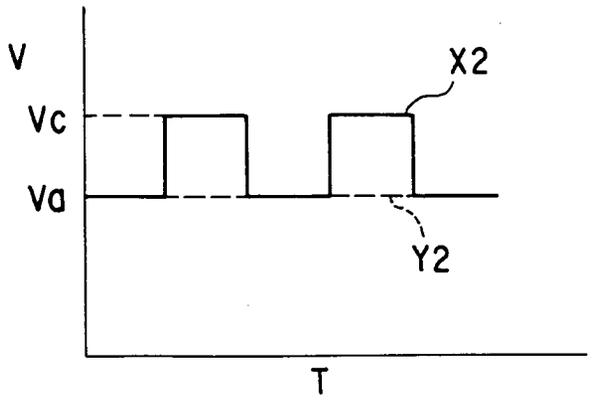


FIG. 11

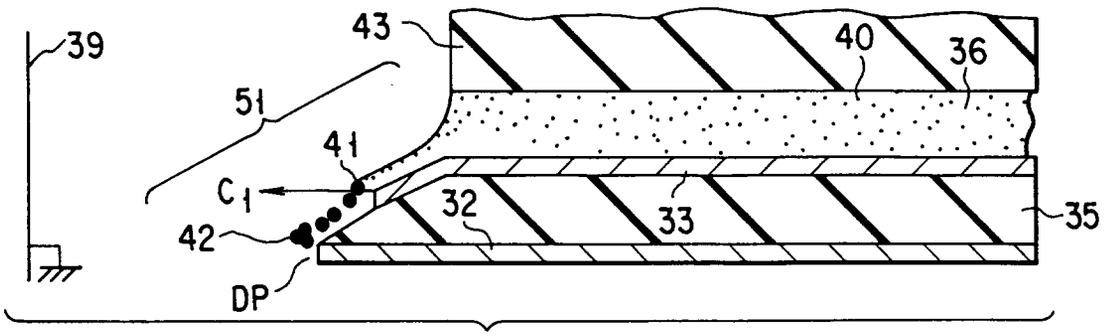


FIG. 12

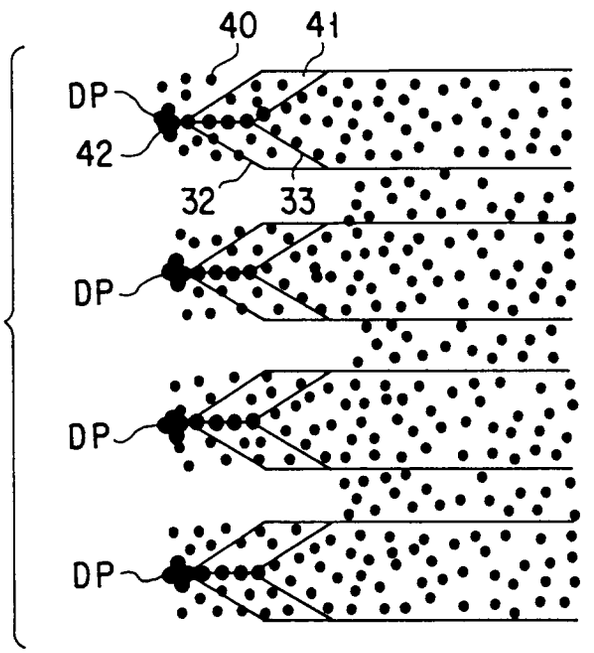


FIG. 13

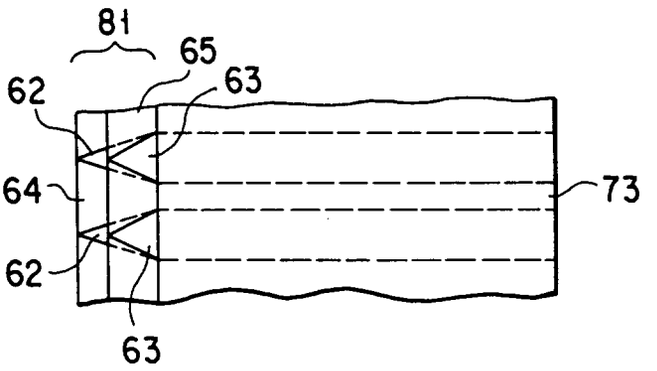


FIG. 14B

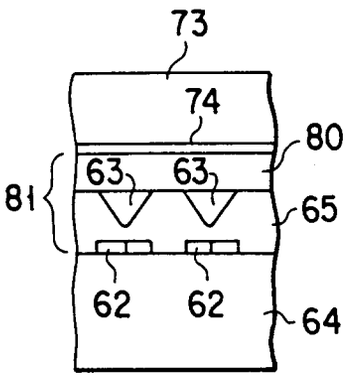


FIG. 14C

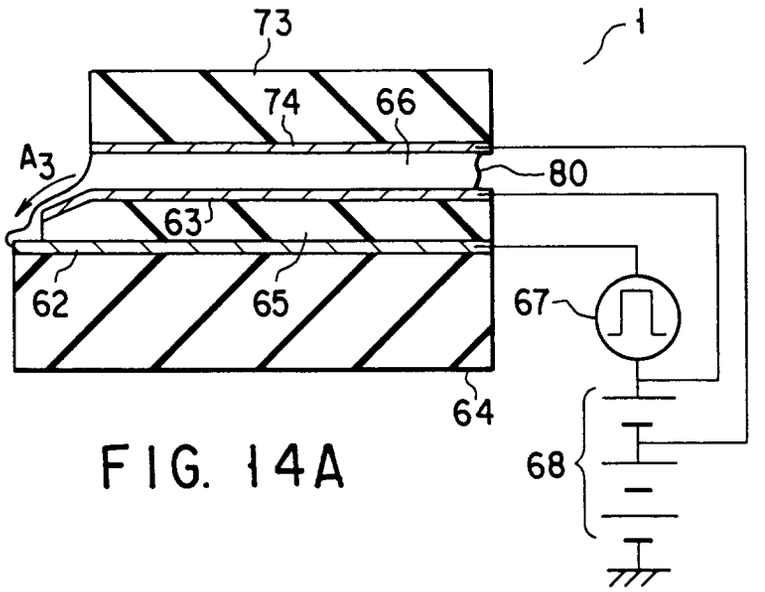


FIG. 14A

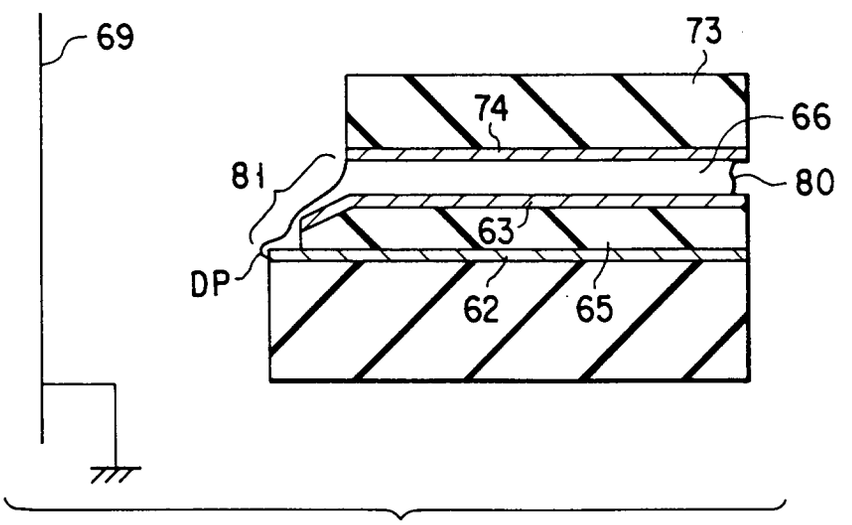


FIG. 14D

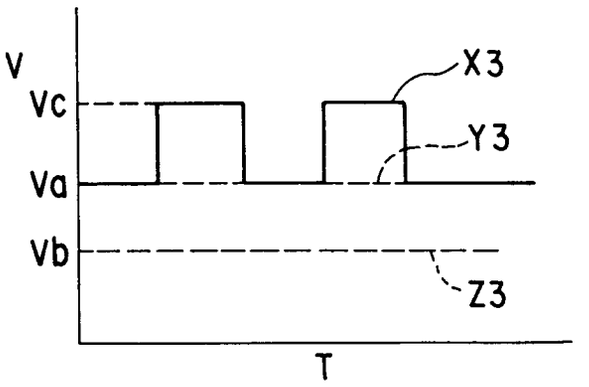


FIG. 15

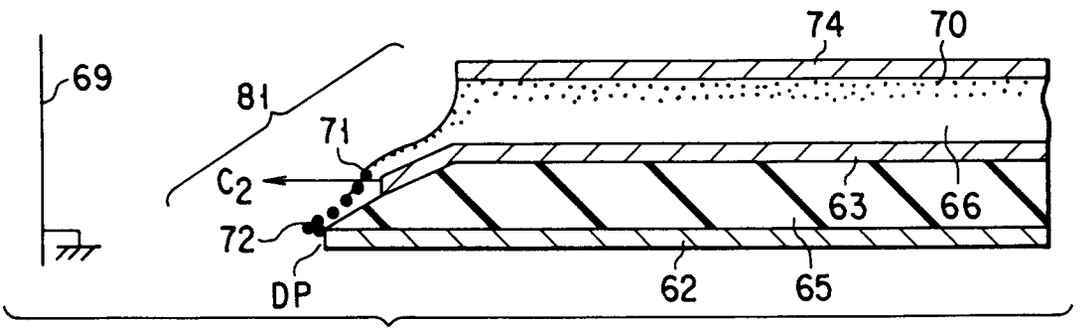


FIG. 16

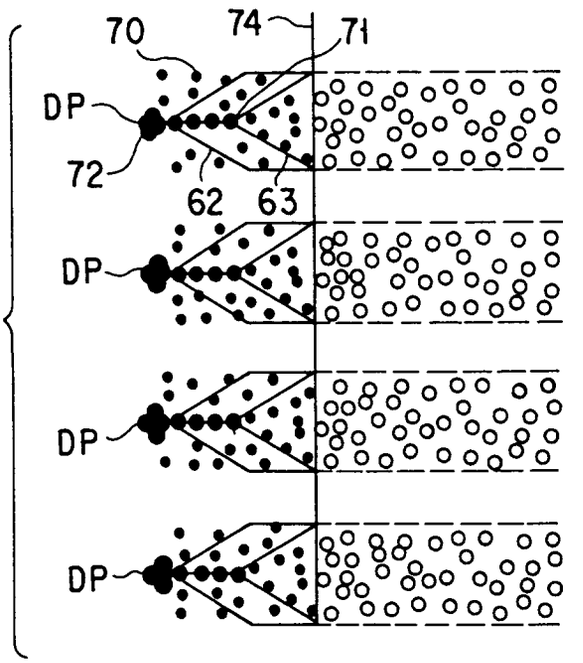


FIG. 17