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(54) Electrostatic ink jet printer and head

(57) An ink jet printing head has a protrusion member extending from an electrophoretic electrode in an ink chamber of a base plate to an orifice, and the top end of convex portion thereof protrudes passing through the orifice to the opposite electrode. Accordingly, an ink droplet of an ink always flies from the top end of the protrusion member in the orifice and the flying direction is stabilized. Further, since the top end of the convex portion of the protrusion member projects passing through the orifice, it can be prevented that the ink meniscus retracts into the orifice to form a concave portion after the flying of the ink droplet.

Further, since the protrusion member is secured to the electrophoretic electrode opposed to the orifice, the toner particles in the chamber can be moved along the protrusion member to the orifice when a biased voltage is applied to the electrophoretic electrode, and the degree of concentration of the toner particles to the orifice can be increased.

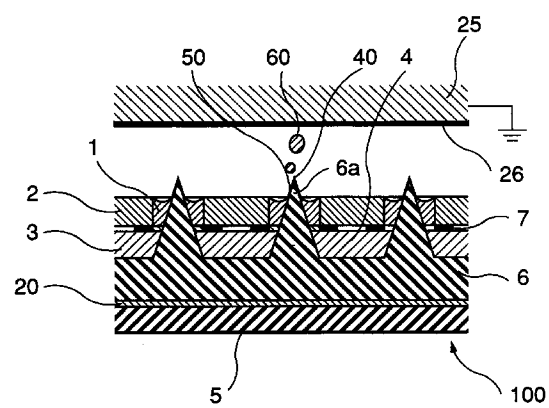

FIG.10

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Description

The present invention concerns an electrostatic ink jet recording head of depositing a charged particulate material in a liquid ink carrier to a recording medium under the effect of an electrostatic force to conduct recording and, more in particular, it relates to an electrostatic ink jet recording and a recording device head for attaining the lowing of a driving voltage.

Heretofore, an electrostatic ink jet recording device described in PCT Publication Number WO93/11866, has an electrostatic ink jet recording head and an opposite electrode. The opposite electrode is disposed at the back of a recording sheet of paper for forming an electric field with respect to the ink jet recording head. The ink jet recording head has an ink chamber for temporarily storing liquid ink supplied, for example, from an ink tank. An ejection electrode is formed at the end of the ink chamber and driven for discharging the ink. A top end of the ejection electrode is opposed to the opposite electrode. The liquid ink in the ink chamber is supplied by its surface tension as far as the top end of the ejection electrode, by which an ink meniscus is formed at the top end of the ejection electrode.

The liquid ink used for the ink jet recording head contains a charged particulate material for forming a color. The charged particulate material is hereinafter referred to as toner particles. The toner particles are charged positively by a zeta potential but the liquid ink is kept electrically neutral under the state in which no voltage is applied to the ejection electrode. The polarity of the zeta potential is determined depending on the characteristics of the toner particles.

When a voltage at a positive polarity is applied to the ejection electrode, a potential at a positive polarity of the liquid ink is increased. In this case, the toner particles move in the liquid ink to the top end of the ejection electrode by an electric field acting between the ejection electrode and the opposite electrode. The toner particles moved as far as the top end of the ejection electrode are attracted strongly to the opposite electrode by the electric field acting between the top end of the ejection electrode and the opposite electrode. If a coulomb force exerting between the toner particles collected at the top end of the ejection electrode and the opposite electrode is considerably stronger than the surface tension of the liquid ink, an agglomeration of the toner particles accompanying a small amount of liquid flies from the top end position of the ejection electrode to the opposite electrode and is deposited on the surface of the recording medium. In this way, agglomerations of the charged particulate material fly successively from the top end of the ejection electrode by the application of the voltage to the ejection electrode to conduct printing.

In the existent electrostatic ink jet recording head described above, since the distance from an ink supply port to a point at which the ink is ejected is long, the thickness of the recording head is increased.

On the other hand, Japanese Patent Laid-Open Sho 58-153661 issued on September 12, 1983 discloses an electrostatic ink jet recording head of a reduced thickness.

As shown in Fig. 1 and Fig. 2, an ink jet recording head has a base substrate 15, and a nozzle plate 10 fixed on the base substrate 15. A plurality of nozzles N11 to N5n for ejecting an ink are formed in the nozzle plate 10 in two dimensional directions X-Y. An ink chamber 12 is formed between the nozzle plate 10 and the base substrate 15. As shown in Fig. 2 and Fig. 3, the plurality of nozzles protrude cylindrically from the surface of the nozzle plate 10. Further, a plurality of first electrodes 11 in parallel with each other are formed in the nozzle plate 10 in the direction Y. The plurality of the first electrodes 11 connect nozzles N11 to N51, N12 to N52, ... , N1n to N5n in the direction Y in common respectively. One end of each of the first electrodes 11 is connected with the terminals from T1 to Tn respectively and printing signals are supplied to each of the terminals individually.

Further, second electrodes D1 to D5 are formed in the direction X on the base substrate 15. As shown in fig. 2 and Fig. 3, the second electrodes D1 to D5 are formed at the bottom of the ink chamber 12 under the nozzle plate 10.

Accordingly, the first electrodes 11 are at a common potential in the direction Y (feeding direction of recording paper), while the second electrodes D1 to D5 disposed below the first electrode 11 are common electrodes for the nozzles N11 to N5n in the direction X. A recording sheet of paper not illustrated is disposed ahead of the nozzles N11 to N5n, and an opposite electrode not illustrated is disposed at the back of the recording sheet of paper. An ink polarizing force is applied by a voltage provided between the first electrodes 11 and the second electrodes D1 to D5 to move a toner material in the ink to the nozzle, and a coulomb force is generated by the voltage between the first electrode 11 and the opposite electrode. Then, ink droplet flies from one of the nozzles N11 to N5n to the recording sheet of paper.

In this way, since the nozzle plate having a plurality of nozzles is used, the thickness of the electrostatic ink jet recording head is reduced in the ink ejecting direction.

However, since the ink is ejected through an aperture of a nozzle of a small diameter, the surface tension is large at the top end face of the nozzle and an electric field strong enough to eject the ink from the aperture overriding the surface tension has to be applied between the opposite electrode and the first electrode 11.

Further, there is a phenomenon that the ink is concaved from the top end surface of the nozzle after the ejection of the ink, which results in a drawback that the succeeding ink ejection is delayed. As a result, the operation of ejecting the ink droplet from the nozzle becomes instable to cause blotting or bleeding upon printing and incur a problem of lowering the printing quality.

An object of the present invention is to provide an electrostatic ink jet device and a recording head which has small surface tension at an ejecting portion and stabilizes the flying of toners.

In an electrostatic ink jet recording head according to the present invention, an electric field is given to an ink in which charged toner particles are dispersed and the toner particles are ejected by the electrostatic force generated from the electric field thereby conducting ink setting. The recording head has an orifice plate formed with a plurality of orifices each having a small aperture, an ejection electrode disposed to the orifice plate and located in adjacent with each of the orifices, a base plate having a chamber secured being opposed to the orifice plate for storing an ink and supplying the thus stored ink to the orifice, and an insulative protrusion member disposed in the chamber and having convex portions formed in correspondence to the orifices, with the top end of each convex portion being protruded penetrating the individual orifice.

In the present invention, since the top end of the convex portion of the protrusion member protrudes passing through the orifice, it is possible to prevent the ink meniscus from retracting into the orifices to form a concave portion after the flying of the ink droplet.

The ejection electrode may be formed on a surface of the orifice plate so as to surround the periphery of each of the orifices and may be coated with an insulation film.

Further, in the present invention, an electrophoretic electrode is formed so as to be electrically in liquid contact with the ink in the chamber on the surface opposed to a plurality of orifices of the base plate. The protrusion member extends from the electrophoretic electrode toward the orifices.

When a bias voltage is applied to the electrophoretic electrode, toner particles in the chamber move along the protrusion member to the orifices thereby enabling to increase the degree of concentration of the toner particles to the orifices. That is, the protrusion member serves as a guide for moving the toner particles into the orifices.

Fig. 1 is a plan view illustrating a conventional electrostatic ink jet printing head;

Fig. 2 is a cross sectional view taken along line S-S in Fig. 1:

Fig. 3 is a cross sectional view taken along line P-P in Fig. 2;

Fig. 4 is a schematic perspective view for a preferred embodiment of an electrostatic ink jet printing head according to the present invention;

Fig. 5A is a cross sectional view taken along line A-A in Fig. 4;

Fig. 5B is a cross sectional view taken along line B-B in Fig. 4;

Fig. 6 is an enlarged perspective view illustrating a portion T in Fig. 4:

Fig. 7 is a perspective view of an orifice plate in Fig. 6 as viewed from the rear face;

Fig. 8 is a cross sectional view taken along line C-C in Fig. 6;

Fig. 9 is a cross sectional view taken along line D-D in Fig. 6;

Fig. 10 is a cross sectional view of an electrostatic ink jet recording device as a preferred embodiment of the present invention including opposite electrodes; and

Fig. 11 is a block diagram illustrating a driving circuit.

In Fig. 4, an electrostatic ink jet printing head 100 in a preferred embodiment according to the present invention has an orifice plate 2 formed with a plurality of orifices 1 each having small apertures, and a base plate 5 opposed to and supporting the orifice plate 2. As shown in Fig. 5A, the base plate 5 supports the orifice plate 2 and has a chamber 4 which is for storing an ink 3. The portion above the chamber 4 covered with the orifice plate 2. As shown in Fig. 5A and Fig. 5B, two protrusion members 6 are secured to the bottom of the base plate 5 by way of an electrophoretic electrode 20 formed in the direction X in Fig. 4. Each of the protrusion members 6 is formed with a thin plate-like insulation material, convex portions 6a are formed at pitches identical with those of the orifices 1, and the top ends of the convex portions 6a are respectively protruded from respective orifices 1.

The orifice plate 2 is formed of a thin-sheet insulating material. The orifice 1 formed in the orifice plate 2 has a plurality of fine apertures formed at an identical interval with a desired dot pitch.

Fig. 6 is a perspective view enlarged for a portion T in Fig. 4, and Fig. 7 is a perspective view illustrating the state at the back of Fig. 6. The top end of each of the convex portion 6a of the protrusion member 6 has a shape smaller than the diameter of the orifice 1. An ejection point 40 for ejecting an ink is disposed at the top end of each convex portion 6a of the protrusion member 6 so as to protrude from each orifice 1 of the orifice plate 2 by a desired amount to the opposite electrode not illustrated in Fig. 6 (hereinafter referred to as an ejection point 40).

As shown in Fig. 7, a plurality of ejection electrodes 7 made of a metal material such as Ni or Al formed is formed as a pattern so as to surround each of the orifices 1 independent of each other, at the back of the orifice plate 2 (the surface on the side of the chamber 4 in Fig. 5A) by a thin film forming process. The ejection electrodes 7 may be formed on the surface of the orifice plate 2.

Fig. 8 is a cross sectional view taken along line C-C in Fig. 6 and Fig. 9 is a cross sectional view taken along line D-D in Fig. 6. The surface of the ejection electrode 7 formed on the rear face of the orifice plate 2 is coated with an insulative resin 9. This prevents direct contact of the ink 3 in the chamber 4 with the ejection electrode 7.

Referring again to Fig. 5A, the base plate 5 is a member made of insulating material and formed by molding or machining, and supports the orifice plate 2 from the back. Further, an ink supplying aperture 30 and ink discharging apertures 31 for circulating the ink 3 in the chamber 4 are formed to the base plate 5. Each of the protrusion members 6 is fixed between the ink supplying aperture 30 and the ink discharging apertures 31. Further, the electrophoretic electrode 20 is formed in the chamber 4 on the surface opposed to the orifice plate 2 and made of a metal material such as Cu capable of electric liquid contact with the ink 3 in the chamber 4.

The ink 3 in the chamber 4 comprises a toner ink having charged toner particles as a colorant dispersed in a liquid carrier, which is supplied from a not illustrated ink tank by way of a not illustrated pump from the ink supplying aperture 30 to the chamber 4 in the printing head and, further, recovered from the ink discharging apertures 31 to the not illustrated ink tank and then supplied again into the chamber 4 in the printing head. As described above, the ink 3 is always circulated between the ink tank and the chamber 4 in the printing head. The ink 3 supplied to the chamber 4 is maintained on each of the orifices 1 in the orifice plate 2 while forming an independent ink meniscus of a convex shape with the ejection point 40 as an apex.

Fig. 10 is a cross sectional view of an electrostatic ink jet recording device having the ink jet printing head 100 of Fig. 4. In Fig. 10, the state of the ink jet printing head 100 is identical with that in Fig. 8. An opposite electrode 25 is disposed at a position opposing the orifice plate 2 of the ink jet printing head 100 by way of a constant gap from the ejection point 40. A recording sheet of paper 26 is supplied along the opposite electrode 25 as a platen opposite electrode 25 being kept at a constant gap with respect to the ejection point 40 while being in contact with the surface of the opposite electrode 25. The opposite electrode 25 is always applied with a bias voltage at a ground level or at a polarity opposite to that of the toner particle in the ink 3, and the recording sheet of paper 26 supplied on the opposite electrode 25 is always charged to a potential identical with that for the opposite electrode 25.

Fig. 11 shows a driving circuit system for driving the electrophoretic electrode 20 and a plurality of ejection electrodes 7. In Fig. 11, a control circuit 70 controls an electrophoretic electrode driving circuit 72 and an ejection electrode driving circuit 73 based on printing data 200. The electrophoretic electrode driving circuit 72 supplies a bias voltage to the electrophoretic electrode 20 during driving. The bias voltage has a polarity identical with that of the charging polarity of the toner particles in the ink 3, by which the toner particles are repelled by the electrophoretic electrode 20 and moved toward the orifice. The ejection electrode driving circuit 73 applies a pulse voltage at a polarity identical with that of the bias voltage applied to the electrophoretic electrode 20 and higher than the voltage to the ejection electrode 7 in accordance with the printing data 200. Thus, a strong electric field is generated between the ejection electrode 7 and the opposite electrode 25 in Fig. 10.

Then, the operation of this embodiment will be explained with reference to Fig. 10 and Fig. 11.

During a recording stand-by period, a bias voltage with a polarity identical with that of the toner particles in the ink 3 at such a level as not ejecting the ink 3 from the ejection point 40 is applied to the electrophoretic electrode 20 from the electrophoretic electrode driving circuit 72, and then the ink 3 in the chamber 4 is charged to the identical potential with the electrophoretic electrode 20. Further, toner particles in the ink 3 in the chamber 4 are circulated while moving so that they are collected to the ejection point 40 by the electric field between the ink 3 and the opposite electrode 25.

During recording by the printing data 200, a pulse voltage of a polarity identical with that of the toner particles in the ink 3 (for example, +1200 V) is applied to the ejection electrode 7 surrounding the ejection point 40 corresponding to desired printing is applied from the ejection electrode driving circuit 73 to generate a strong electric field between the ejection electrode 7 and the opposite electrode 15. An electrostatic force exerts by the electric field on the toner particles in the ink 3 on the ejection point 40 and, when the electrostatic force of the toner particles overcomes the surface tension of the meniscus 50 on the ejection point 40, an ink droplet 60 containing the toner particles on the ejection point 40 is ejected to the opposite electrode 25 to conduct printing on the recording sheet of paper 26. Dots are formed in the form of depositing droplets of the toner particles on the recording sheet of paper 26, and toner particles deposited as droplets by a fixing mechanism of a heat roller or the like not illustrated are fixed on the recording sheet of paper 26.

The ink jet printing head 100 of the embodiment according to the present invention has the protrusion member 6 extending from the electrophoretic electrode 20 in the ink chamber 4 of the base plate 5 to the orifice 1, and the top end of the convex portion 6a penetrates the orifice 1 and protrudes to the opposite electrode. Accordingly, the ink droplet of the ink 3 (Fig. 10) always flies from the top end of the protrusion member 6 in the orifice 1 and the flying direction is stabilized. Further, since the top end of the convex portion 6a of the protrusion member 6 protrudes penetrating the orifice 1, the ink meniscus from retracting into the orifice 1 to form a concave portion after the flying of the ink droplet.

Further, since the protrusion member 6 extends from the electrophoretic electrode 20 toward the orifice

1, when the bias voltage is applied to the electrophoretic electrode 20, the toner particles in the chamber 4 can be moved along the protrusion member 6 to the orifice 1, and the concentration of the toner particles to the orifice 1 can be improved. That is, the protrusion member 6 serves as a guide for moving the toner particles from the chamber 4 toward the orifice 1.

In Fig. 5A, the electrophoretic electrodes 20 are connected in common with the two protrusion members 6, a plurality of the ejection electrodes 7 are disposed individually to a plurality of orifices 1 respectively, and driven individually by the ejection electrode driving circuit 73 in Fig. 11.

However, the electrophoretic electrode 20 may also be bisected corresponding to the two orifice groups in the direction X shown in Fig. 4, and the electrophoretic electrode driving circuit 72 in Fig. 11 may drive the thus bisected electrophoretic electrodes individually. Further, the ejection electrode 7 may be grouped and the ejection electrode driving circuit 73 in Fig. 11 may drive each of groups individually.

Further, a plurality of ejection electrodes 7 may be formed also as an inner layer circuit of the orifice plate 2.

Claims

1. An electrostatic ink jet printing head of an ink jet recording device of applying an electric field to an ink in which charged toner particles are dispersed and ejecting the toner particles by an electrostatic force generated by the electric field, said head comprising:

   an orifice plate formed with a plurality of orifices each having a small aperture,
   an ejection electrode disposed to the orifice plate and located in adjacent with each of the orifices,
   a base plate which is secured being opposed to the orifice plate to form a chamber for storing the ink, and
   a protrusion member disposed in said chamber and having convex portions formed corresponding to the orifices, a top end of each of the convex portions protruding by passing through each of the orifices.

2. The electrostatic ink jet printing head as defined in claim 1, wherein the ejection electrode is formed on the orifice plate so as to surround the periphery of each of the orifices, and coated at the surface thereof with an insulative film.

3. The electrostatic ink jet printing head as defined in claim 1 or 2, wherein an electrophoretic electrode is formed on the base plate to be faced to the plurality of orifices and electrically contacts with the ink in the chamber, and the protrusion members extends from the electrophoretic electrode to the orifices.

4. The electrostatic ink jet printing head as defined in claim 3, wherein the orifice plate, the base plate and the protrusion member are made of an insulative material.

5. An electrostatic ink jet recording device having an electrostatic ink jet printing head of applying an electric field to an ink in which charged toner particles are dispersed and ejecting the toner particles by an electrostatic force generated by the electric field, comprising:

   an orifice plate formed with a plurality of orifices each having a small aperture,
   an ejection electrode disposed to the orifice plate and located in adjacent with each of the orifices,
   a base plate which is secured being opposed to the orifice plate to form a chamber for storing the ink,
   an electrophoretic electrode formed on the base plate to be faced to the plurality of orifices and electrically contacting with the ink in the chamber,
   an insulativeprotrusion members extending from the electrophoretic electrode to the orifices and having convex portions formed corresponding to the orifices, a top end of each of the convex portions protruding by passing through each of the orifices,
   an opposite electrode disposed being spaced apart by a predetermined distance from the orifice plate in a direction to the top ends of the convex portions, and
   a driving circuit for driving the ejection electrode and the electrophoretic electrode to generate the electric field.

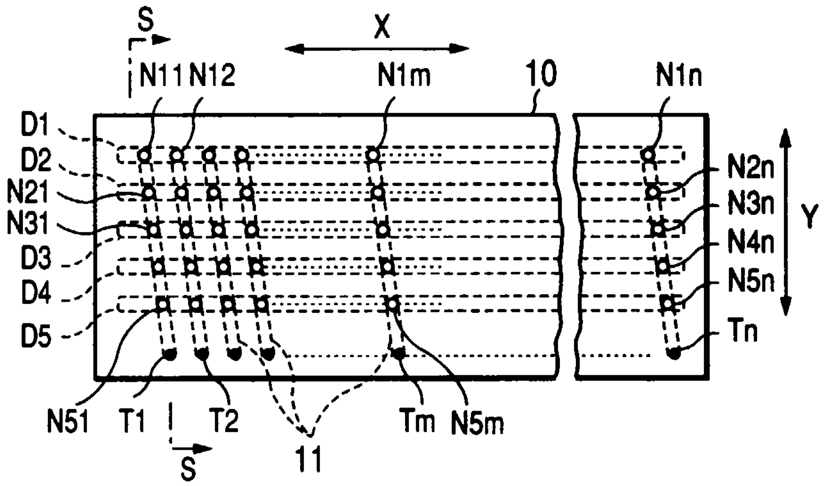

FIG.1 PRIOR ART

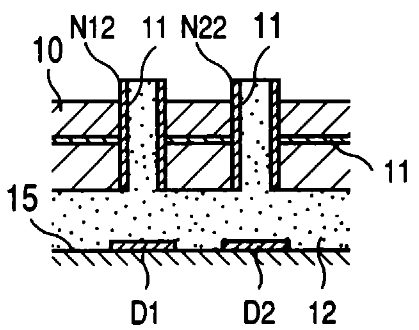

FIG.2 PRIOR ART

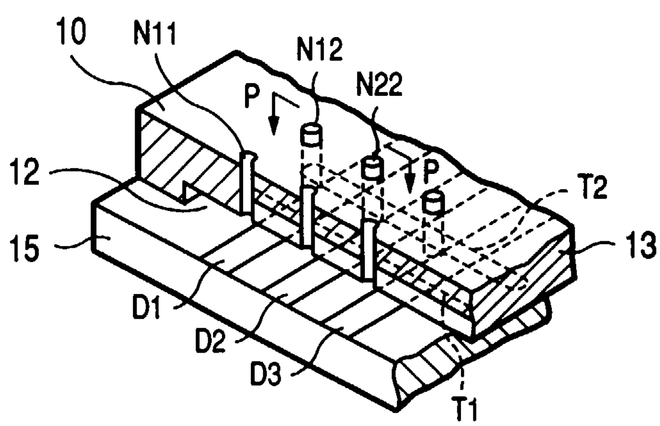

FIG.3 PRIOR ART

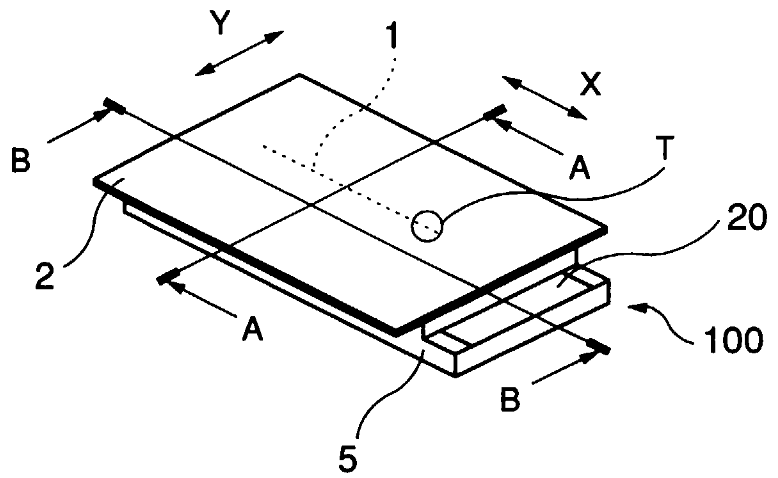

FIG.4

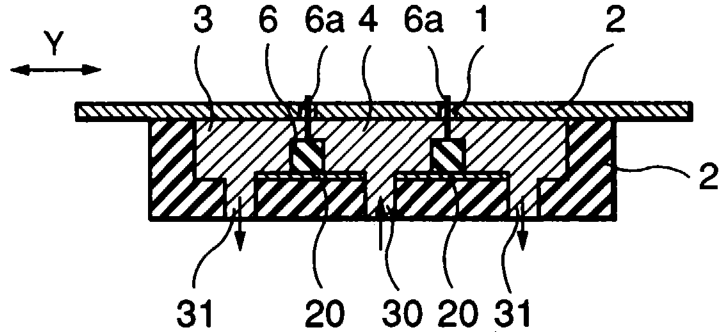

FIG.5A

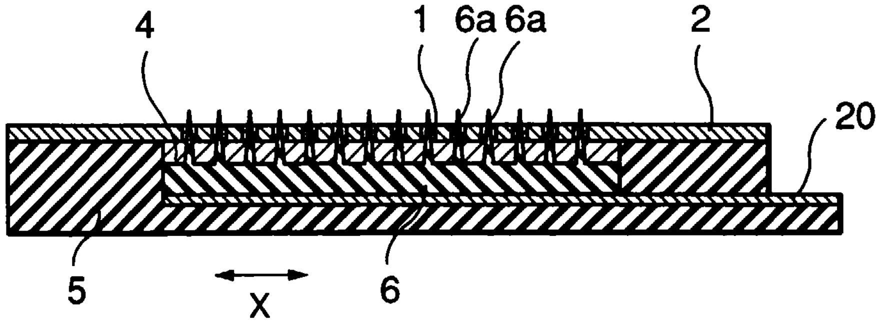

FIG.5B

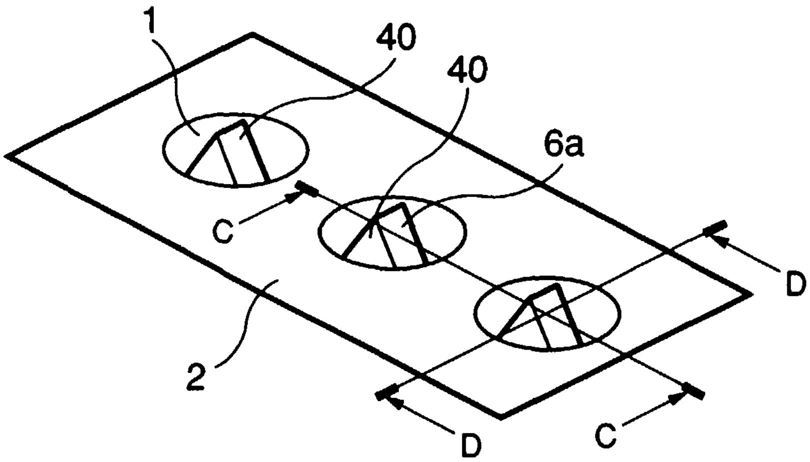

FIG.6

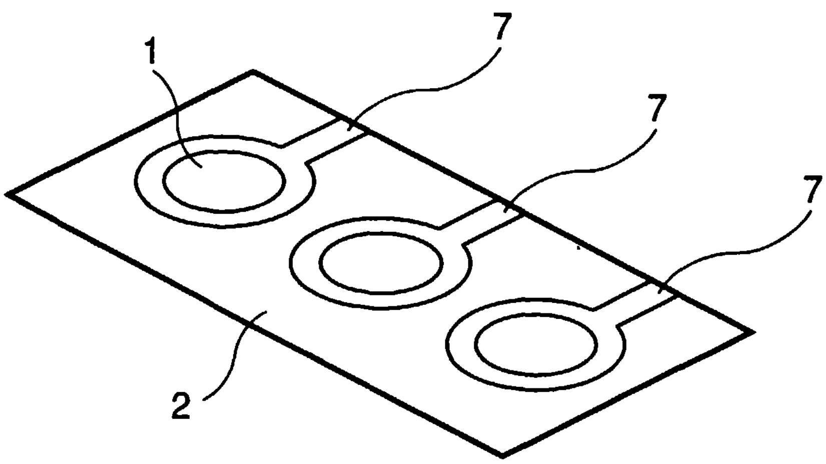

FIG.7

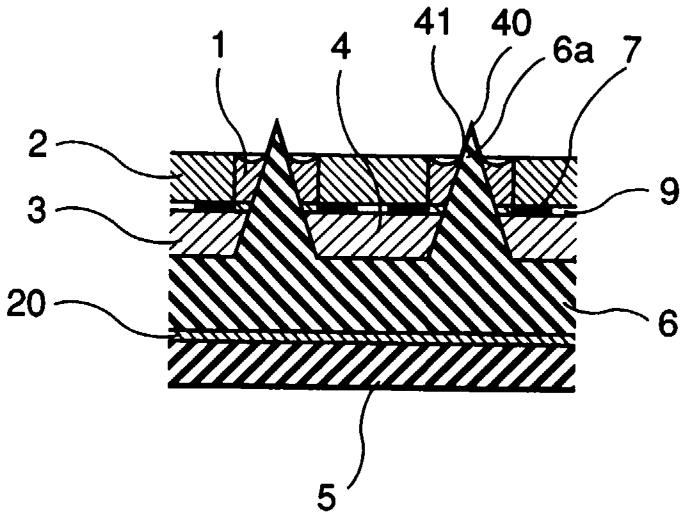

FIG.8

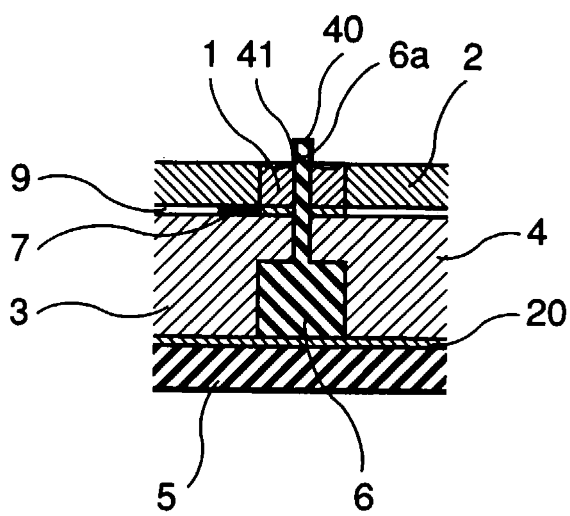

FIG.9

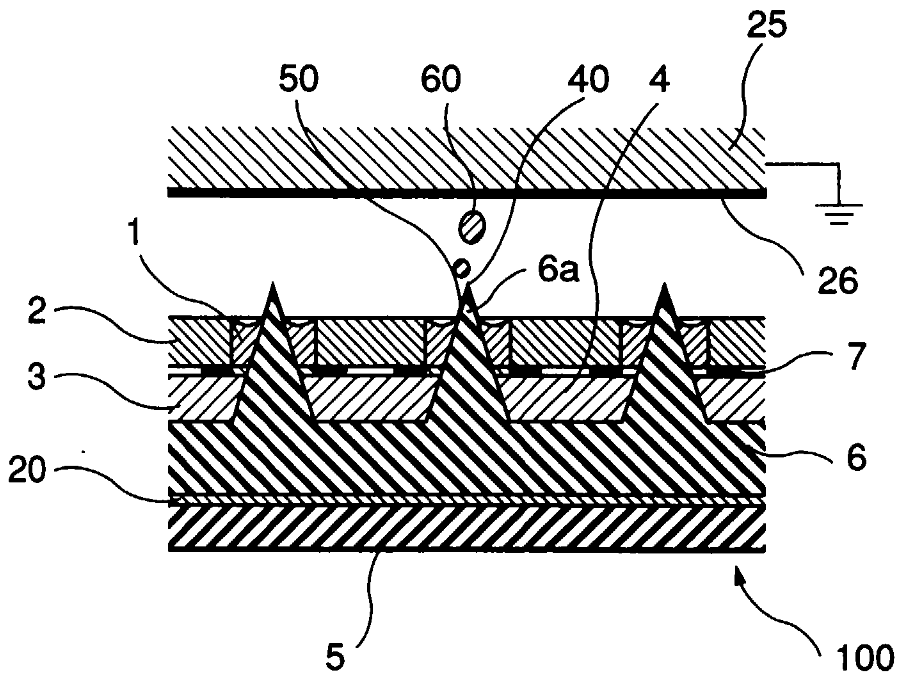
25
50
60
40
4
1
6a
2
7
3
6
20
26
5
100

FIG.10

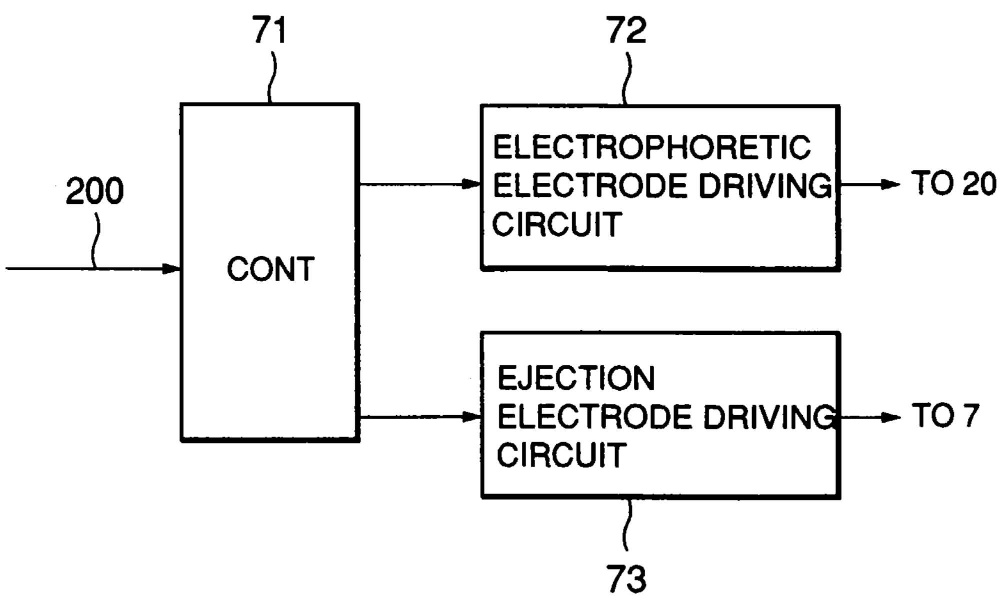
71
72
200
CONT
ELECTROPHORETIC
ELECTRODE DRIVING
CIRCUIT
TO 20
EJECTION
ELECTRODE DRIVING
CIRCUIT
TO 7
73

FIG.11