(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 813 965 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
29.12.1997 Bulletin 1997/52

(51) Int. Cl.[6]: **B41J 2/06**, B41J 2/14

(21) Application number: **97109878.5**

(22) Date of filing: **17.06.1997**

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: **17.06.1996 JP 155897/96**
31.07.1996 JP 202363/96

(71) Applicant: **NEC Corporation**
Minato-ku, Tokyo 108-01 (JP)

(72) Inventors:
- **Suetsugu, Junichi**
  Kashiwazaki-shi, Niigata (JP)
- **Minemoto, Hitoshi**
  Kashiwazaki-shi, Niigata (JP)
- **Shima, Kazuo**
  Kashiwazaki-shi, Niigata (JP)
- **Takemoto, Hitoshi**
  Kashiwazaki-shi, Niigata (JP)
- **Uematsu, Ryosuke**
  Kashiwazaki-shi, Niigata (JP)
- **Hagiwara, Yoshihiro**
  Kashiwazaki-shi, Niigata (JP)
- **Mizoguchi, Tadashi**
  Kashiwazaki-shi, Niigata (JP)
- **Yakushiji, Toru**
  Kashiwazaki-shi, Niigata (JP)

(74) Representative:
von Samson-Himmelstjerna, Friedrich R., Dipl.-Phys. et al
SAMSON & PARTNER
Widenmayerstrasse 5
80538 München (DE)

(54) Electrostatic ink jet printer having gate electrode and printing head thereof

(57) An electrostatic ink jet printer of the present invention comprises a printing head including an ink chamber for storing an ink and a plurality of ink ejection electrodes arranged in a plurality of ink ejection portions to which the ink is ejected from the ink chamber, an opposite electrode arranged oppositely to the ink ejection portions and the gate electrode arranged between the ink ejection portions of the printing head and the opposite electrode and has an opening which is maintained at a potential for attracting toner particles in the ink ejection portions by Coulomb force generated by an electric field between the ink ejection electrodes and the opposite electrode and which allow ink jetted from the ink ejection portions by Coulomb force to pass through.

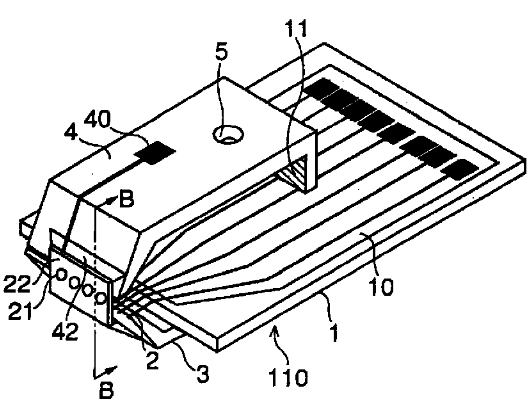

FIG.1

EP 0 813 965 A2

Description

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a printing head of an electrostatic ink jet printer for recording information on a recording medium by attracting charged particulate materials contained in ink onto the recording medium by utilizing electrostatic force and, particularly, the present invention relates to an electrostatic ink jet printer capable of reducing a drive voltage thereof, and a printing head thereof.

Description of the Prior Art

Conventionally, an electrostatic ink jet printer includes an electrostatic ink jet printing head and an opposite electrode arranged on a back surface of a recording sheet for forming an electric field between the opposite electrode and the ink jet printing head, as disclosed in PCT Publication No. WO 93/11866. The ink jet printing head includes an ink chamber for temporarily storing ink liquid supplied from an ink reservoir. Ink ejection electrodes are formed on an end portion of the ink chamber and selectively driven when the ink is to be ejected. End portions of the ink ejecting electrodes oppose to the opposite electrode. The ink liquid in the ink chamber is supplied to the end portions of the ink ejection electrodes by its surface tension, so that an ink meniscus is formed on the end portion of each ink ejection electrode.

The ink liquid used in the ink jet printing head may contain charged particulate materials for coloring the ink. The charged particulate materials will be referred to as toner particles, hereinafter. The toner particles are charged positive by zeta potential. However, the ink liquid is maintained in an electrically neutral state when no voltage is applied to the ink ejection electrodes. Polarity of the zeta potential is dependent upon properties of the toner particles.

When a positive voltage is applied to the ink ejection electrode, the positive potential of the ink liquid is increased. In such case, the toner particle in the ink liquid moves toward the end of the ink ejection electrode due to an electric field formed between the ink ejection electrode and the opposite electrode. At the end portion of the ink ejection electrode, the toner particle is strongly attracted to the opposite electrode side by the electric field between the end of the ink ejection electrode and the opposite electrode. When Coulomb force acting between the toner particles agglomerated in the end of the ink ejection electrode and the opposite electrode substantially exceeds the surface tension of the ink liquid, an agglomeration of toner particles together with a small amount of liquid is ejected from a point of the edge of the ink ejection electrode toward the opposite electrode and adhered to a front surface of the recording medium. The printing is performed by successive ejections of the agglomerations of the charged particulate material from the points of the ends of the ink ejection electrodes by the application of voltage to the ink ejection electrodes, in this manner.

Fig. 14 is a perspective view of an ink jet printing head of another conventional electrostatic ink jet printer, Fig. 15 is a partially enlarged plan view of the ink jet printing head shown in Fig. 14 and Fig. 16 is a cross section of the ink jet printing head taken along a line X-X in Fig. 14.

In Figs. 14 to 16, a substrate 51 is of an insulating material such as glass and a plurality of ink ejection electrodes 52 are formed on a surface of the substrate 1. The ink ejection electrodes 52 are formed by photolithographically patterning a film of an electrically conductive material such as chromium, which is preliminarily formed on the surface of the substrate 1 by sputtering, with a pitch of, for example, 300 dpi, that is, with an interval of about 85 μm. The ink ejection electrodes 52 are connected to respective drivers which are not shown so that they are selectively supplied with high voltage pulses when a printing is performed. Meniscus forming members 58 are formed by photolithographically patterning a photo-sensitive high molecular film laminated on the substrate 1, such that they overlap on the respective ink ejection electrodes 52 at positions of the ink ejection electrodes slightly inside the ends thereof. Thickness of the photo-sensitive high molecular film is 30 μm and width of the meniscus forming member 58 is about 30 μm. Ink meniscus 68 is formed around the meniscus forming member 58 and ends of the ink ejection electrodes 52, as shown in Figs. 15 and 16.

An upper cover 54 is mounted on the meniscus forming members 58 such that end portions of the latter are exposed. The upper cover 54 is of an electrically insulating material and is preliminarily formed with an ink supply port 55 and an ink removal port 56. Ink jet ports 57 in the form of slits and the meniscus forming members 58 are arranged alternately between the substrate 1 and the upper cover 54. Further, the meniscus forming members 58 function to support the upper cover 54 and form ink flow paths 66 as shown in Fig. 16. A portion of the meniscus forming members 58 forms a wall surface covering side portions and a rear end portion of the head and, together with the substrate 51 and the upper cover 54, constitutes an ink chamber for storing ink.

Further, in order to increase the density of toner particles in an ink liquid and supply them to the ink jet ports 57 through the ink flow paths 66, an electrophoretic electrode 61 is provided behind the ink flow paths 66, as shown in Fig. 16. An electric field is thus formed between the electrophoretic electrode 61 and an opposite electrode (not shown) provided on a back surface of a recording medium, with which toner particles in the ink are moved toward and agglomerated in the vicinity of the ink jet ports 57. Further, the agglomerations of toner particles are jetted from the top points of the ink ejection electrodes 52 toward the opposite electrode by Coulomb force and adhered to the surface of the recording medium.

Japanese Patent Application Laid-open Nos. Sho 58-153661 and Sho 58-153662 both published on September 12, 1983 disclose a conventional electrostatic ink jet printer of another type. As shown in Fig. 17, the disclosed ink jet printer includes a plurality of nozzles N each having a first electrode 11 in an inner wall of a head 100 or in the vicinity thereof, which are arranged two-dimensionally in an X and Y directions. The first electrodes 11 of the nozzles N in the Y direction (longitudinal direction of a recording sheet 50) or the X direction (width direction of the recording sheet 50) are at a common potential and second electrodes D1 and D2 arranged behind the first electrodes 11 are common in the X direction of the nozzles N. An opposite electrode 200 opposes to the first electrodes 11 through the recording sheet 50. Droplets of ink are jetted from the nozzles N to the recording sheet by providing polarizing force of ink by voltages applied between the first and second electrodes and generating Coulomb force by voltages applied between the first electrodes 11 and the opposite electrode 200.

In each of the conventional electrostatic ink jet printing heads mentioned above, toner particles are jetted in a gap between the opposite electrode provided on the back surface of the recording sheet and the ink ejection electrodes or the first electrodes of the nozzles opposite to the opposite electrode, by electrostatic power (Coulomb force) generated by a potential difference to the gap. In this case, the potential difference in the gap in the order of 0.3 to 0.5 mm must be about 1.5 to 2.5 kV. Therefore, if the ink ejection gap having a size in the order of about 1 mm which is large enough to print on a recording medium is given, the drive pulse voltage to be applied to the ink ejection electrodes becomes high, causing a manufacture of the drivers to become difficult. Further, even if a high voltage pulse drive is performed, noise may be generated which causes erroneous operations of peripheral electronic devices.

Further, there is another problem that a stable jetting of toner particles becomes difficult due to thickness variation of the recording medium and/or floating up of the running recording medium.

Further, the conventional electrostatic ink jet printer disclosed in Japanese Patent Application Laid-open Nos. Sho 58-153661 and 58-153662 have, in addition to all of the above-mentioned problems, a problem that the ink ejecting operation of droplets of ink from the nozzles becomes unstable, causing printed data to be blotted and bleeding to occur, resulting in degradation of print quality.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a reliable and low cost electrostatic ink jet printer capable of stabilizing a toner jetting by maintaining a distance between a printing electrode and a gate electrode constant, and a printing head thereof.

The electrostatic ink jet printer according to the present invention achieves the above object by providing a third electrode, that is, a gate electrode, between ink ejection electrodes of a printing head and an opposite electrode. In another aspect, the present invention provides an electrostatic ink jet printer having a printing head, the number of control circuits of which is minimized by providing a plurality of discrete gate electrode terminals in the gate electrode and performing a matrix drive by means of the gate electrode terminals and the ink ejecting electrode.

In more concrete, the electrostatic ink jet printer according to the present invention comprises a printing head including an ink chamber for storing an ink and a plurality of ink ejection electrodes arranged in a plurality of ink ejecting portions to which the ink is ejected from the ink chamber, respectively, an opposite electrode arranged oppositely to the ink ejecting portions and the gate electrode. The gate electrode is arranged between the ink ejecting portions of the printing head and the opposite electrode and has an opening portion which is maintained at a potential for attracting toner particles in the ink ejecting portions by Coulomb force generated by an electric field between the ink ejection electrodes and the opposite electrode and which allows ink jetted from the ink ejecting portions by Coulomb force to pass through. The gate electrode may be fixed to the printing head.

The printing head has the plurality of ink ejection electrodes arranged discretely in the plurality of ink ejecting portions for ejecting ink from the ink chamber, respectively. The opening portion of the gate electrode may take in the form of a plurality of holes formed in positions aligned with the respective ink ejection electrodes or may be provided as a slit extending along a direction in which the ink ejection electrodes are arranged.

Representing a diameter of the hole or width of the slit of the gate electrode by D and a distance between the gate electrode and the ink ejection electrodes by L, high stability of ink ejection is obtained when a relation $L/2 < D < L$ is established.

In the present invention, a potential difference is provided between the ink ejection electrodes and the gate electrode and agglomerations of toner particles are separated and jetted from ink meniscuses formed in the ink ejection portions by resultant Coulomb force. When the opposite electrode and the gate electrode are at the same potential, there is no electric field generated between the gate electrode and the opposite electrode. Since, therefore, agglomerations ejected by the electric field between the ejection electrodes and the gate electrode are not influenced by Coulomb force between the gate electrode and the opposite electrode, the agglomerations are jetted toward the opposite electrode while maintaining inertia provided by ink ejection as it is.

When the opposite electrode has a potential for attracting the ink passed through the opening portion of the gate electrode by Coulomb force, an electric field is generated between the opposite electrode and the gate electrode with which Coulomb force in the direction toward the opposite electrode is given to the toner particle agglomerations to enhance inertia of the agglomerations.

As described, since, in the present invention, the toner particles are ejected by means of the potential difference between the ink ejection electrodes and the gate electrode, it is possible to restrict the drive pulse voltage by reducing the distance between the ink ejection electrodes and the gate electrode. Further, since the toner particles move between the gate electrode and the opposite electrode by the inertia of the agglomerations of toner particles, it is possible to enlarge the ejection gaps between the gate electrode and the opposite electrode to the extent that the inertia is not lost.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of a printing head of an electrostatic ink jet printer according to a first embodiment of the present invention, a portion of which is cut away;

Fig. 2 is a plan view of a portion of the electrostatic ink jet printer according to the first embodiment of the present invention;

Fig. 3 is a cross section of the printing head taken along a line B-B in Fig. 1 including a recording sheet and an opposite electrode;

Fig. 4 is a block circuit diagram of a drive circuit of the electrostatic ink jet printer according to the present invention;

Fig. 5 is a graph showing a relation between potentials and positions of ink ejection electrodes, a gate electrode and an opposite electrode;

Fig. 6 is a plan view of a TAB tape from which a base film of the printing head shown in Fig. 1 is manufactured;

Fig. 7 is a perspective view of a printing head of an electrostatic ink jet printer according to a second embodiment of the present invention, a portion of which is cut away;

Fig. 8 is a plan view of a portion of the electrostatic ink jet printer according to the second embodiment of the present invention;

Fig. 9 is a timing chart showing an electrode drive pattern of the printing head shown in Fig. 7; Fig. 10 is a perspective view of a printing head

of an electrostatic ink jet printer according to a third embodiment of the present invention, a portion of which is cut away;

Fig. 11 is a perspective view of a printing head of an electrostatic ink jet printer according to a fourth embodiment of the present invention, a portion of which is cut away;

Fig. 12 is a front view of an example of a gate electrode of the printing head shown in Fig. 11;

Fig. 13 is a front view of another example of the gate electrode of the printing head shown in Fig. 11;

Fig. 14 is a perspective view of a conventional electrostatic ink jet printing head;

Fig. 15 is a plan view of a top edge portion of the conventional electrostatic ink jet printing head;

Fig. 16 is a cross section taken along a line X-X in Fig. 14; and

Fig. 17 is a cross section of another conventional electrostatic ink jet printing head.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An electrostatic ink jet printer according to a first embodiment of the present invention comprises a printing head 110 shown in Figs. 1 and 3 and an opposite electrode 23 opposing to the printing head 110 as shown in Fig. 2. A recording sheet 24 is disposed in front of the opposite electrode 23 and is transported while being printed by ink droplets containing toner particles ejected from the printing head 110.

A substrate 1 of the printing head 110 is of an insulating material such as plastics and supports a rear surface of a base film 10. The base film 10 is of an insulating material such as polyimide and is about 50 μm thick. A plurality of ink ejection electrodes 2 are formed integrally on a surface of the base film 10.

The ink ejection electrodes 2 are formed by plating the surface of the base film 10 with an electrically conductive material such as copper to a thickness of 20 to 30 μm and patterning it and extend in parallel to an ink ejecting direction with a pitch of, for example, 300 dpi, that is, with an interval of about 85 μm. Further, the ink ejection electrodes 2 protrude discretely from an end face of the base film 10 by an amount of 80 to 500 μm. As shown in Figs. 2 and 3, the ink ejection electrodes 2 are uniformly covered by an insulating coating member 17 having thickness of 10 μm or less.

In this embodiment, the printing head 110 takes in the form of a tape head having the base film 10 and the ink ejection electrodes 2 formed integrally on the base film 10 In concrete, the printing head 110 takes in the form of a TAB tape prepared by TAB (Tape Automated Bonding) technology and the insulating coating member 17 is provided by chemical vapor deposition of parylene resin.

The substrate 1 with the base film 10 formed thereon is fixed supported between an upper cover 4 and a lower cover 3. The lower and upper covers 3 and 4 are of an insulating material. In Fig. 1, the upper cover 3, the lower cover 4 and a gate electrode 22 which is later described are shown by a portion which is cut away. As shown in Fig. 3, end portions of the upper cover 4 and the lower cover 3 are bent inward such that ends thereof the opposite to both surfaces of the ink ejection electrodes 2 with spaces thereto at positions inside the end portions of the ink ejection electrodes 2. That is, the ends of the ink ejection electrodes 2 are protruded in an ink ejecting direction longer than the upper and lower covers 3 and 4.

An ink supply port 5 is preliminarily formed in the upper cover 4 as shown in Fig. 1 and an ink is supplied through the ink supply port 5 and fills spaces defined by the upper and lower covers 3 and 4 and the substrate 1. As shown in Fig. 3, spaces between the base film 10 and the upper cover 4 and between the substrate 1 and the lower cover 3 function as ink chambers as well as ink flow paths. An end portion of the ink flow path between the base film 10 and the upper cover 4 becomes an ink jet port 7. A meniscus 8 is formed from the ink jet port 7 to the ends of the ink ejection electrodes 2.

The ink jet port 7 and the meniscus 8 are also formed between the substrate 1 and the lower cover 3 and toner particles are ejected from the ink jet ports 7 along the ink ejection electrodes 2.

The printing head 110 is connected through the ink supply port 5 and a supply tube (not shown) to an ink reservoir (not shown) and the ink containing toner particles is pressurized negatively by about 1 cm H_2O and forcibly circulated by a pump (not shown). The ink is consisted of a petrochemical organic solvent (isoparaffin) dispersed with charging control agent and the so-called toner particles which are colored fine particles of thermoplastic resin and are apparently charged positively by zeta potential.

As shown in Fig. 1, an electrophoretic electrode 11 is provided within the upper cover 4 and contacts with the ink. The electrophoretic electrode 11 is applied with a voltage having the same polarity as that of the toner particle and transports the toner particles in the ink supplied from the ink supply port 5 toward the end of the ink ejection electrodes 2 by electrophoretic phenomenon caused by an electric field produced between the electrophoretic electrode 11 and the opposite electrode 23 in Fig. 2. Therefore, the toner particle density in the vicinity of the ink jet ports 7 is increased relatively to that in an upper stream of the ink chambers (on the side of the electrophoretic electrode) due to the electrophoretic transportation of the toner particles.

The gate electrode 22 is provided between the ink ejection electrodes 2 and the opposite electrode 23. The gate electrode 22 takes in the form of a plate of an electrically conductive substrate material and is fabricated by electro-forming. Surfaces of the electrode 22 is overed by an insulating film. Further, as shown in Fig. 3, the gate electrode 22 is fixed to the lower cover 3 and the upper cover 4 through respective supports 41 and 42. The gate electrode 22 has holes or orifices 21 in positions aligned with the respective printing electrodes 2. Further, the gate electrode 22 has a connection pad for connection to an external control circuit for controlling a potential of the gate electrode 22 and is connected to a gate connecting electrode 40 formed on an outer surface of the upper cover 4 as shown in Fig. 1. According to experiments conducted by the inventors, it has been found that it is preferable for stable ejection of ink to establish a relation $L/2 < D < L$ where D is a diameter of the orifice 21 of the gate electrode 22 and L is a distance between the gate electrode 22 and the ejection electrode 2. When the above relation is established, the ink can pass through the orifices 21 of the gate electrode 22 clearly.

Fig. 4 is a block circuit diagram of a drive circuit for driving the printing head 110. In Fig. 4, a control circuit 31 controls operations of an ink ejection electrode drive circuit 32, a gate electrode drive circuit 33 and an electrophoretic electrode drive circuit 34 on the basis of printing data P. The ink ejection electrode drive circuit 32, the gate electrode drive circuit 33 and the electrophoretic electrode drive circuit 34 drive the ink ejection electrodes 2, the gate electrode 22 and the electrophoretic electrode 11, respectively. The gate electrode drive circuit 33 may be removed when the gate electrode 22 is to be maintained at zero potential. Drive signals generated by the ink ejection electrode drive circuit 32 and the electrophoretic electrode drive circuit 34 have the same polarity as that of the toner particles. Therefore, the toner particles are moved toward the ends of the ink ejection electrodes 2 by electrophoresis phenomenon. In this case, the gate electrode 22 and the opposite electrode 23 are applied with voltages necessary to produce Coulomb force for ejecting the toner particles moved to the top ends of the ejection electrodes 2.

An ink ejecting operation of ink from the printing head 110 will now be described. The ink forms ink meniscuses 8 in the ink jet ports 7 by its surface tension. Since the ink in the head is under negative pressure and the ink ejection electrodes 2 protrude from the base film 10 as well as the upper cover 4 and the lower cover 3, a shape of the meniscus 8 on the side of the upper cover 4 becomes concave in vertical cross section as shown in Fig. 3 and that on the side of the lower cover 3 is symmetrical thereto. Further, since the ink ejection electrodes 2 protrude outward from the ink jet ports 7, respectively, the meniscuses 8 are formed correspondingly to the respective ink ejection electrodes 2 as shown in Fig. 2.

For example, when the gate electrode 22 is at zero potential and an arbitrary one of the ink ejection electrodes 2 is applied with a high voltage pulse from the ink ejection electrode drive circuit 32, an electric field is concentrated in the end portion of the ink meniscus protruding from the same ejection electrode. The charged toner contained in the ink is guided by the electric field generated between the gate electrode 22 and the ink ejection electrodes 2, and the charged toner is pulled out from the end of the protruded ink meniscus, becomes an agglomeration 9 of toner particles as shown in Fig. 3, passes a corresponding one of the orifices 21 of the gate electrode 22 and flies toward the opposite electrode 23 which is at the same potential as that of the gate electrode 22 or toward the recording medium 24. The toner adhered to the recording medium

24 and formed a printing dot is fixed by heating the recording medium by a heater (not shown). The mechanism for forming the printing dot will be described in more detail.

Fig. 5 shows a relation between the potentials of the ink ejection electrode 2, the gate electrode 22 and the opposite electrode 23 and the positions of these electrodes. The ink ejection electrode 2 is applied with a voltage Vp which is not lower than an ink ejection threshold voltage. The ink ejection threshold voltage means a voltage at which an ink droplet starts to fly. As shown in Fig. 3, there is a potential difference between the ink ejection electrode 2 and the gate electrode 22 for generating Coulomb force for ejecting the agglomeration 9 of toner particles, so that the toner particles are separated from the meniscus 8. The opposite electrode 23 is at a ground potential and there is no electric field generated between the gate electrode 22 and the opposite electrode 23. Therefore, since the agglomeration 9 ejected by the electric field between the ink ejection electrode 2 and the gate electrode 22 is not influenced by Coulomb force to be generated between the gate electrode 22 and the opposite electrode 23, it flies toward the opposite electrode 23 while keeping the inertia thereof given by ejection as it is.

In a case where the opposite electrode 23 is at a negative potential, it is possible to increase the inertia of the agglomeration 9 by generating an electric field between the gate electrode 22 and the opposite electrode 23 and giving the agglomeration 9 Coulomb force in the direction to the opposite electrode.

As mentioned above, since the ink ejection is performed by the potential difference between the ink ejection electrode 2 and the gate electrode 22, it is possible to restrict the drive pulse voltage by reducing the distance between the ink ejection electrode 2 and the gate electrode 22. Further, since the agglomeration 9 of the toner particles flies by inertia between the gate electrode 22 and the opposite electrode 23, it is possible to enlarge the ejection gap between the gate electrode 22 and the opposite electrode 23 to the extent that the inertia is not lost.

Fig. 6 shows a TAB tape to be used in fabricating the base film 10 (Fig. 1) of the printing head 110, schematically. A fabrication method of the base film 10 (Fig. 1) will be described in brief. A TAB tape film 12 of such as polyimide in the form of a ribbon having sprocket holes 15 on both sides thereof is flush-plated. Then, a dry film is laminated thereon and patterns of the base films 10 (Fig. 1) are formed on the TAB tape film 12 by exposing and developing the dry film. Thereafter, the base film patterns are plated with such as copper and then through-holes 14 are formed by etching with using a resist film as a mask. Thereafter, the resist film is removed, a finishing plating is performed and an insulating coating is provided on required portions of the patterns by chemical vapor deposition. In this process, inner lead portions 13 which have end portions protruding into the through-holes, become the ink ejection electrodes 2. Then, the TAB tape film is cut, resulting in the base films 10 (Fig. 1).

Fig. 7 is a perspective view of a main portion of a printing head of an electrostatic ink jet printer according to a second embodiment of the present invention and Fig. 8 is a partial cross section of the electrostatic ink jet printer. Further, Fig. 9 is a timing chart showing driving timings of an ejection electrode and a gate electrode of the printing head of the second embodiment shown in Fig. 7. In Fig. 7, a printing head 111 has the same construction as that of the printing head 110 shown in Fig. 1, except a gate electrode 220. Unlike the gate electrode 220 shown Fig. 1, the gate electrode 220 of the printing head of the second embodiment takes in the form of a plate of an insulating material and has discrete orifices 210 (Fig. 8) aligned with respective ink ejection electrodes 2. Further, electrically conductive rings 19 surrounding the respective orifices 210 are formed by such as selective sputtering of an electrically conductive material. The rings 19 constitute gate electrode terminals. The gate electrode terminals (rings) 19 are connected to gate connection electrodes 41, 42, ... formed on outer surfaces of an upper cover 4 and a lower cover 3, respectively.

The printing head 111 shown in Fig. 7 is driven by the drive circuit shown in Fig. 4. As shown in Figs. 4 and 9, a pulse signal having a constant period is supplied to the ink ejection electrodes 2 from the ejection electrode drive circuit 32. Simultaneously with the supply of the pulse signal to the ink ejection electrodes 2, the gate electrode terminal 19 corresponding to the ink ejection electrode 2 from which toner particles are to be ejected is driven. As shown in Fig. 9, voltages of the drive pulse driving the ink ejection electrodes 2 and of the gate electrode terminal 19 are commonly V1 in non-drive state and the potential of the gate electrode terminal is zero in a drive state. Thus, it is possible to control the ejection of ink droplets from the ink ejection electrodes 2 in a matrix manner by applying the drive voltage to the ink ejection electrodes 2 and the gate electrode terminals 19. Further, since electric field is generated only between the gate electrode terminal corresponding in position to the ejection of ink droplets containing toner particles and the ink jet port from which the ink droplet is jetted, it is possible to further improve the accuracy of ink ejecting direction.

Fig. 10 is a perspective view of a main portion of a printing head of an electrostatic ink jet printer according to a third embodiment of the present invention. In Fig. 10, a printing head 112 has the same construction as that of the printing head 110 shown in Fig. 1 except a gate electrode 221. The gate electrode 221 of the third embodiment takes in the form of an electrically conductive plate fabricated by such as electro-forming and is arranged between ink ejection electrodes 2 and an opposite electrode 23 such that it opposes to ink ejecting elements of the respective ink ejection electrodes 2. Further, a single slit opening 20 is formed in a portion of the gate electrode 221 which corresponds in position to the ink ejecting elements of the ink ejection electrodes. The single slit opening 20 has an area wide enough to cover all of the ink ejecting elements. Further, the gate electrode 221 has a connection pad formed on an outer surface of an upper cover 4 for connecting the gate electrode 221 to an external circuit for controlling a potential of the gate electrode 221. Therefore, unlike the gate electrode 22 of the printing head 110 shown in Fig. 1 which includes the discrete orifices, the positional alignment between the gate electrode 221 and the ink ejection electrodes 2 is facilitated.

Fig. 11 is a perspective view of a main portion of a printing head of an electrostatic ink jet printer according to a fourth embodiment of the present invention. In Fig. 11, a printing head 113 has the same construction as that of the printing head 112 shown in Fig. 10 except a gate electrode 222. The gate electrode 222 of the printing head shown in Fig. 11 takes in the form of a plate of an insulating material and has a single slit opening 20 formed in a portion of the gate electrode 222 which corresponds in position to ink ejecting elements of ink ejection electrodes 2. The single slit opening 20 has an area wide enough to cover all of the ink ejecting elements. Electrically conductive material is deposited on portions of the slit opening 20 of the gate electrode 222 which correspond in position to the respective ink ejection electrodes 2, as gate electrode terminals 19. The gate electrode terminals 19 are connected to gate connection electrodes 41 and 42 formed on an outer surface of an upper cover 4, respectively. Each gate electrode terminal 19 is divided by and fixed to the slit opening 20 such that top ends of the divided gate electrode terminal 19 oppose to each other and protrude inside from edges of the opening 20. The slit opening 20 facilitates the positional alignment between the gate electrode 222 and the ejection electrodes 2. Further, it is possible to control the ejection of ink droplets from the ink ejection electrodes 2 in a matrix manner by applying the drive voltage to the ink ejection electrodes 2 and the gate electrode terminals 19.

The gate electrode terminals 19 may be arranged in lines of the ink ejection electrodes 2, respectively, as shown in Fig. 12 or the gate electrode terminals 19 may be arranged between adjacent ones of the ink ejection electrodes 2, respectively, as shown in Fig. 13.

Further, the gate electrode terminals 19 may be provided integrally on a multi-layered TAB tape used by the TAB technology.

As described hereinbefore, since the electrostatic ink jet printer according to the present invention comprises the third electrode, that is, the gate electrode between the ink ejection electrodes and the opposite electrode, it is possible to maintain the distance between the ink ejection electrodes and the gate electrode constant and to increase the distance between the gate electrode and the opposite electrode. Therefore, it is possible to remove an influence of a variation of the distance between the ink ejection electrodes and the opposite electrode due to variation of thickness of the recording sheet and/or flattering thereof on the ink ejection and to stabilize the toner movement. Thus, it is possible to provide a reliable and low cost electrostatic ink jet printer.

Further, it is possible to perform a matrix drive of the ejection electrodes by applying suitable voltages between the ink ejection electrodes and a plurality of the discrete electrodes (gate electrode terminals) provided as the gate electrode to thereby minimize the number of control circuits and reduce the cost of the printer.

Further, since the ink ejection electrodes are provided on the base film and coated with an insulating coating member, the fabrication process is very simple and inexpensive. Further, it is possible to make a distance between the printing electrodes and the protruding amount of the electrodes stable.

In addition, since the ink ejection electrodes take in the form of a tape, it is possible to reduce the thickness and size of the head. Further, since the present invention uses the structure in which the ink passes through the gaps between the ink ejection electrodes, it is possible to forcibly drain excessive toner particles and counter ions from the region around the ejection electrodes. Therefore, a stable amount of ink is always supplied to the region around the ink ejection electrodes, resulting in a reliable ink ejection regardless of printing condition.

Claims

1. An electrostatic ink jet printer for printing a recording sheet (24) by applying an electric field to ink containing charged toner particles and flying the ink to said recording sheet (24) by Coulomb force acting on the toner particles, comprising:

   a printing head (110; 111; 112; 113) including an ink chamber for reserving the ink and at least one ink ejection electrode (2) arranged in at least one ink ejecting portion for ejecting the ink from said ink chamber;
   an opposite electrode (23) arranged in an opposite relation to said ink ejecting portion; and
   a gate electrode (22; 220; 221; 222) arranged between said ink ejecting portion and said opposite electrode (23), said gate electrode (22; 220; 221; 222) being at a potential for attracting the charged toner particles of the ink in said ink ejecting portion by Coulomb force generated by an electric field acting between said ink ejecting portion and said gate electrode (22; 220; 221; 222) and having an opening portion capable of passing the ink ejected from said ink ejecting portion therethrough.

2. The electrostatic ink jet printer as claimed in claim 1, wherein said printing head (110; 111; 112; 113) includes a plurality of said ink ejecting portions and a plurality of said ink ejection electrodes (2)

arranged in the plurality of said ink ejecting portions, respectively, and said opening portion of said gate electrode (22; 220; 221; 222) comprises a plurality of holes (21) arranged in alignment with the plurality of said ink ejecting electrodes (2).

3. The electrostatic ink jet printer as claimed in claim 2, wherein said gate electrode (22; 220; 221; 222) is constructed by a plate of an electrically conductive material.

4. The electrostatic ink jet printer as claimed in claim 2, wherein said gate electrode (22; 220; 221; 222) is constructed by a plate of an electrically insulating material having a plurality of discrete gate electrode terminals (19) formed in a periphery of said opening portion correspondingly in position to ends of said ink ejection electrodes (2), said electrostatic ink jet printer further comprises driving means for driving said discrete gate electrodes discretely.

5. The electrostatic ink jet printer as claimed in claim 2, 3 or 4, wherein a relation $L/2 < D < L$ is established, where D is a diameter of said hole (21) and L is a distance between said gate electrode (22; 220; 221; 222) and said ink ejection electrodes (2).

6. The electrostatic ink jet printer as claimed in claim 1, wherein said printing head (110; 111; 112; 113) includes a plurality of said ink ejection electrodes (2) arranged in a plurality of said ink ejecting portions, respectively, and said opening portion of said gate electrode (22; 220; 221; 222) takes in the form of a slit, said slit being formed correspondingly in position to ends of the plurality of said ink ejection electrodes (2).

7. The electrostatic ink jet printer as claimed in claim 1, wherein said opposite electrode (23) and said gate electrode (22; 220; 221; 222) are at the same potential.

8. The electrostatic ink jet printer as claimed in claim 1, wherein said opposite electrode (23) is at a potential for attracting the ink passed through said opening portion of said gate electrode (22; 220; 221; 222) by Coulomb force.

9. The electrostatic ink jet printer as claimed in claim 1, wherein said ink ejection electrodes (2) are formed on a surface of an electrically insulating base film (10) and one end portions of said ink ejection electrodes (2) form said ink ejecting portions and protrude from an edge of said base film (10).

10. The electrostatic ink jet printer as claimed in claim 9, wherein said ink ejection electrodes (2) have surface coated with an electrically insulating coating material (17).

11. The electrostatic ink jet printer as claimed in claim 10, wherein said printing head (110; 111; 112; 113) further comprises a pair of holding members provided on both surfaces of said base film (10) except end portions of said ink ejection electrodes (2), the pair of said holding members forming spaces on both sides of said base film (10) for holding the ink in between said holding members and said base film (10), and an electrophoretic electrode (11) provided in contact with the ink behind said ink ejection electrodes (2) in said spaces, for transporting the ink to regions in the vicinity of said ink ejection electrodes (2) by electrophoretic phenomenon.

12. A printing head (110; 111; 112; 113) for use in an electrostatic ink jet printer, for printing a recording medium (24) with an ink containing charged toner particles by applying an electric field to the ink containing charged toner particles and flying the ink containing charged toner particles by Coulomb force acting on the toner particles, said printing head (110; 111; 112; 113) comprising:

an ink chamber for reserving the ink;
ink ejection electrodes (2) arranged in ink ejecting portions, respectively, for ejecting the ink from said ink chamber; and
a gate electrode (22; 220; 221; 222) arranged between said ink ejecting portion and said opposite electrode (23), said gate electrode (22; 220; 221; 222) being at a potential for attracting the toner particles of said ink ejecting portion by Coulomb force generated by an electric field acting between said ink ejecting portion and said gate electrode (22; 220; 221; 222) and having an opening portion capable of passing the ink ejected from said ink ejecting portion.

13. The printing head (110; 111; 112; 113) as claimed in claim 12, further comprising a supporting member for supporting said gate electrode (22; 220; 221; 222) to said ink chamber.

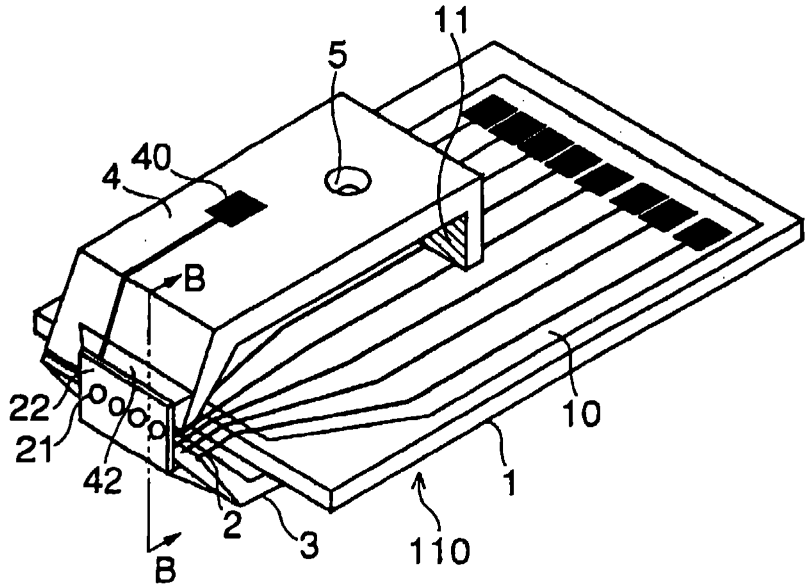

FIG.1

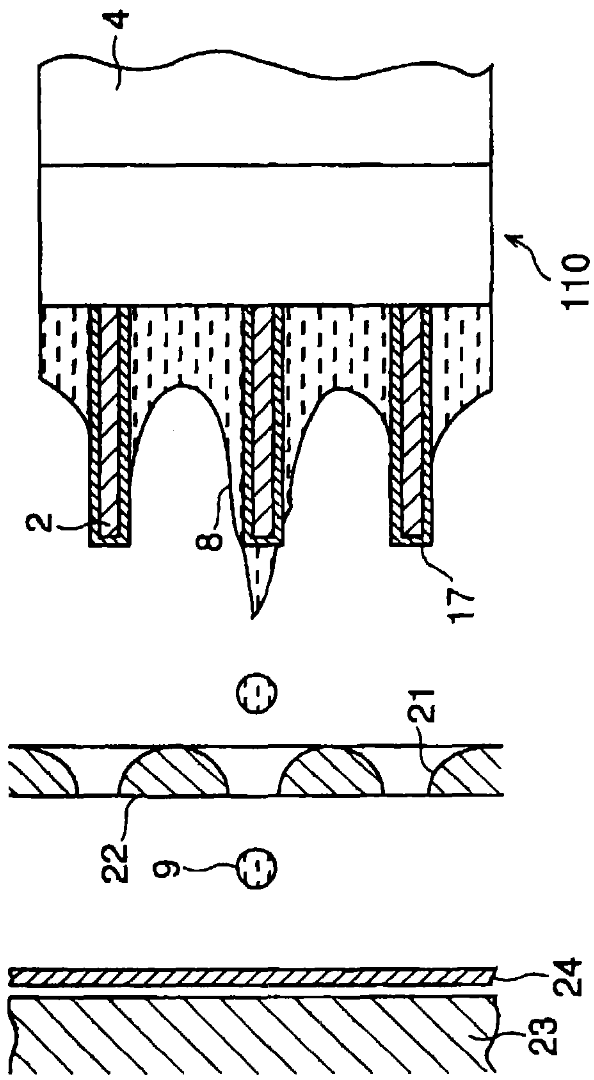

FIG.2

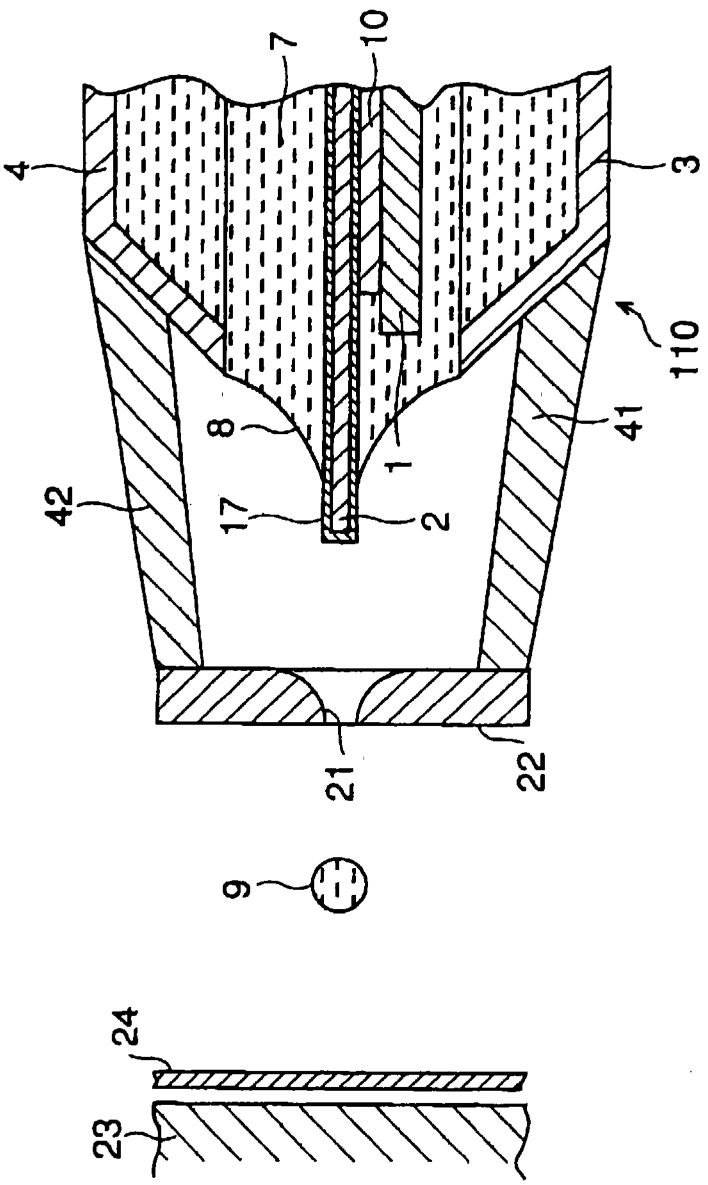

FIG.3

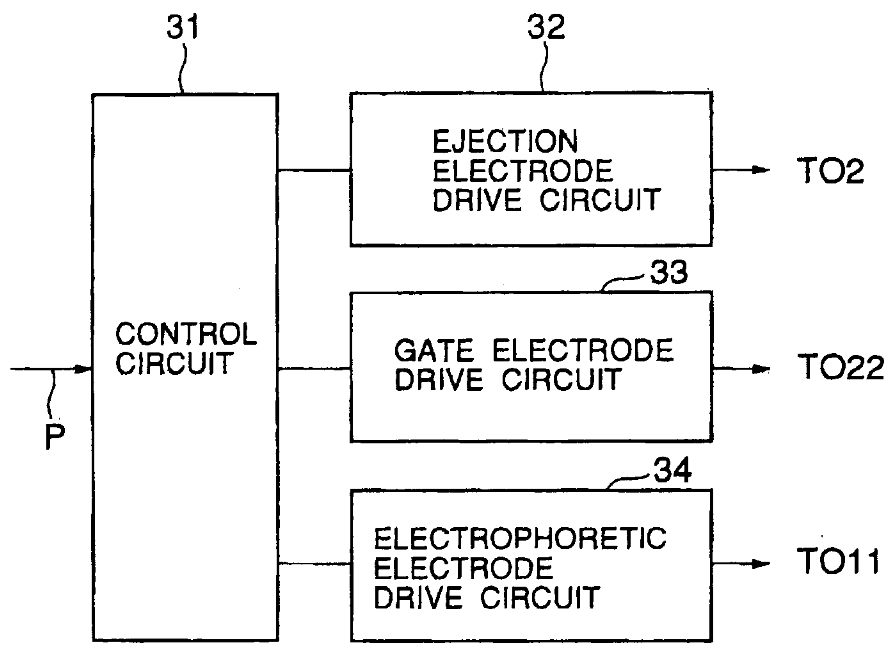
31
32
EJECTION
ELECTRODE
DRIVE CIRCUIT
TO2
33
CONTROL
CIRCUIT
GATE ELECTRODE
DRIVE CIRCUIT
TO22
P
34
ELECTROPHORETIC
ELECTRODE
DRIVE CIRCUIT
TO11

FIG.4

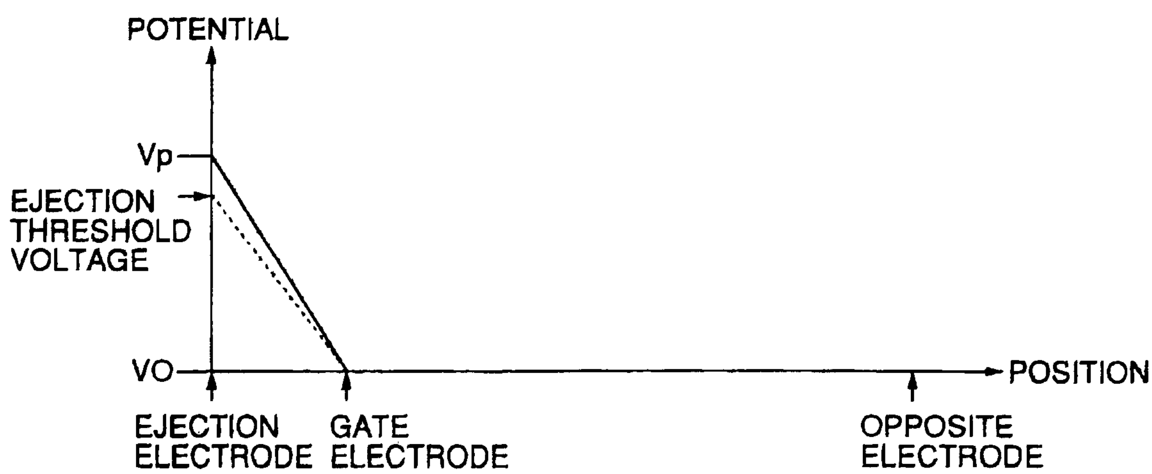
POTENTIAL
Vp
EJECTION
THRESHOLD
VOLTAGE
VO
POSITION
EJECTION
ELECTRODE
GATE
ELECTRODE
OPPOSITE
ELECTRODE

FIG.5

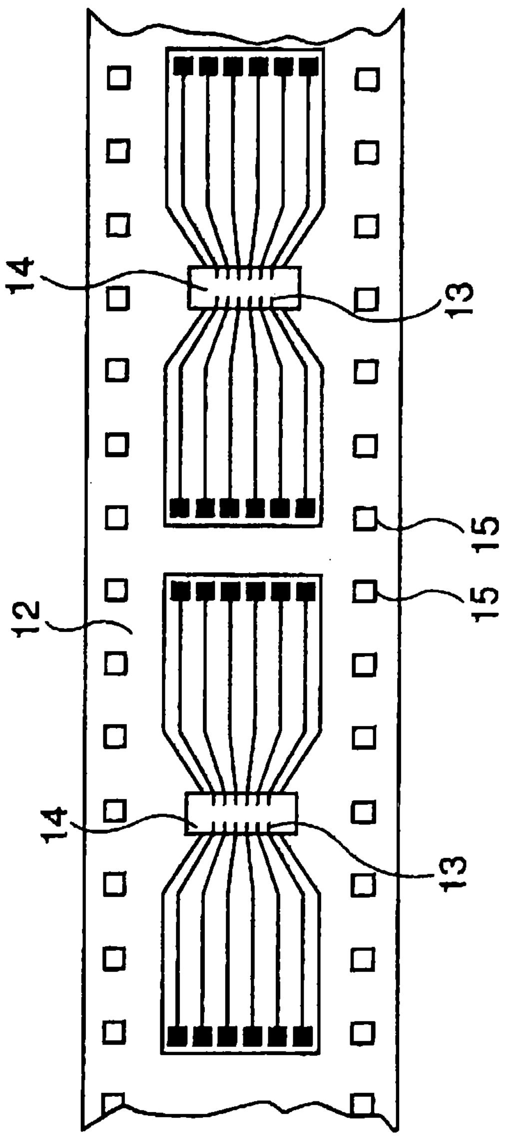

FIG.6

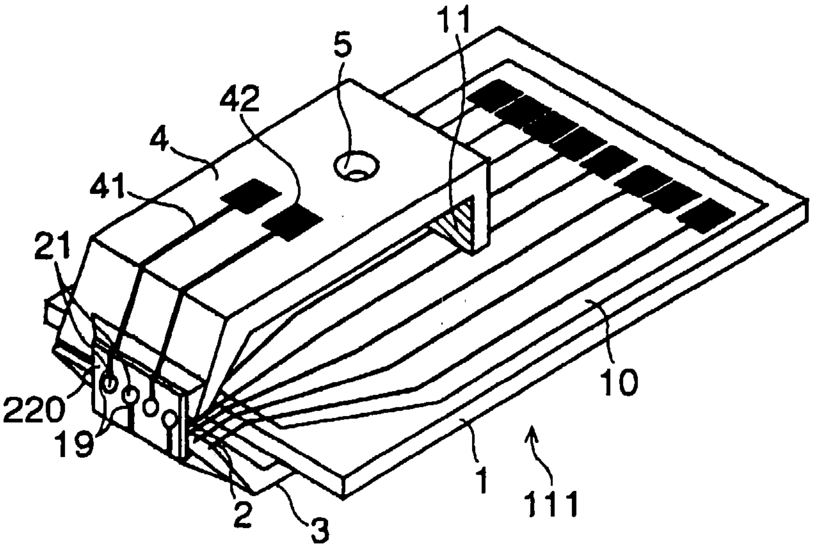

FIG.7

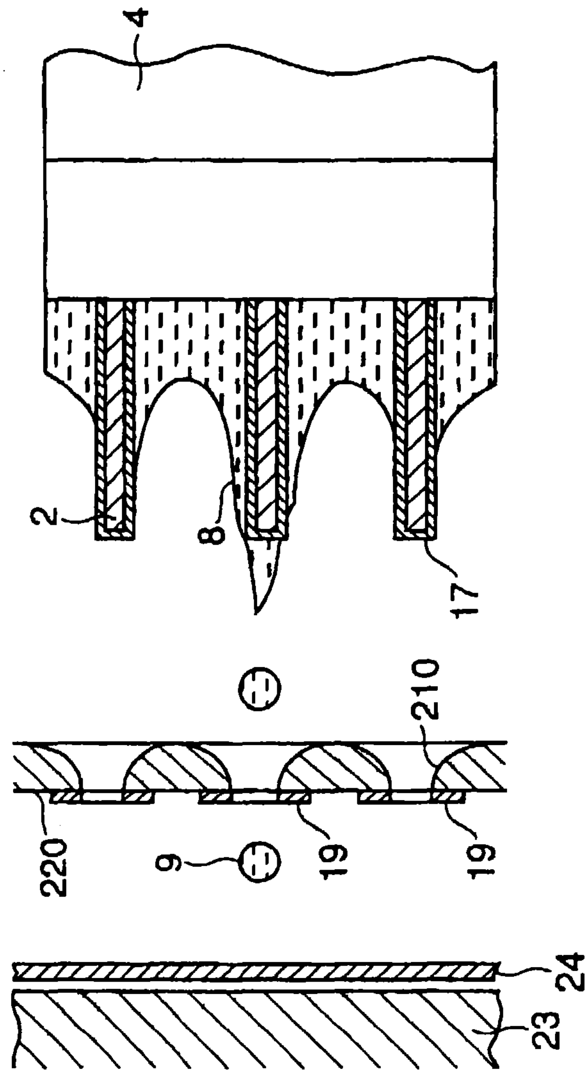

FIG.8

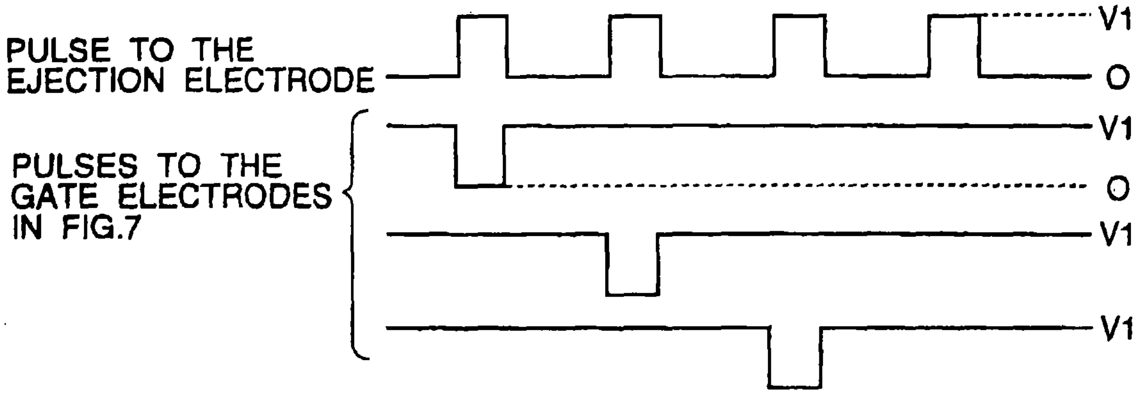
PULSE TO THE
EJECTION ELECTRODE
PULSES TO THE
GATE ELECTRODES
IN FIG.7
V1
O
V1
O
V1
V1

FIG.9

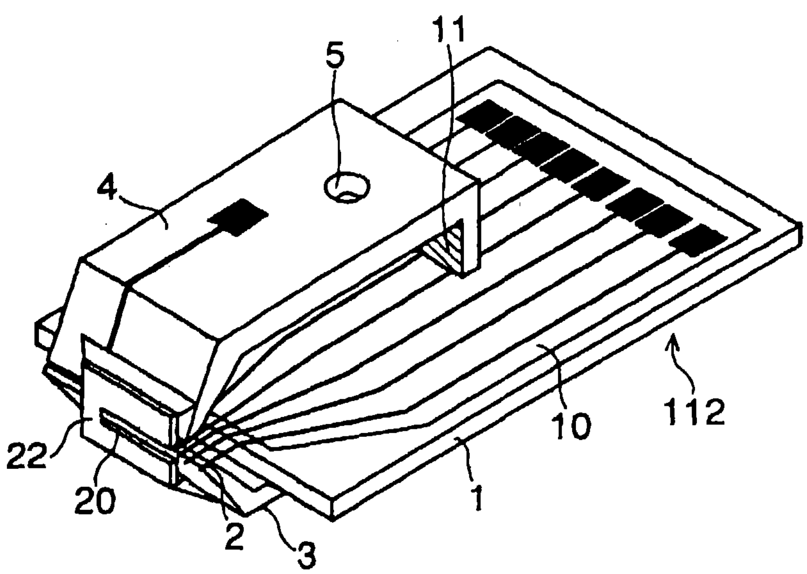
11
5
4
22
20
2
3
1
10
112

FIG.10

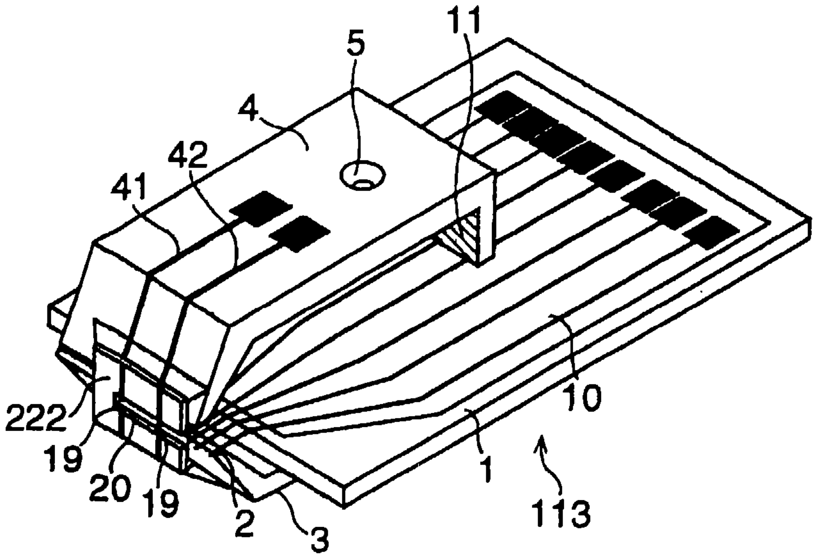

FIG.11

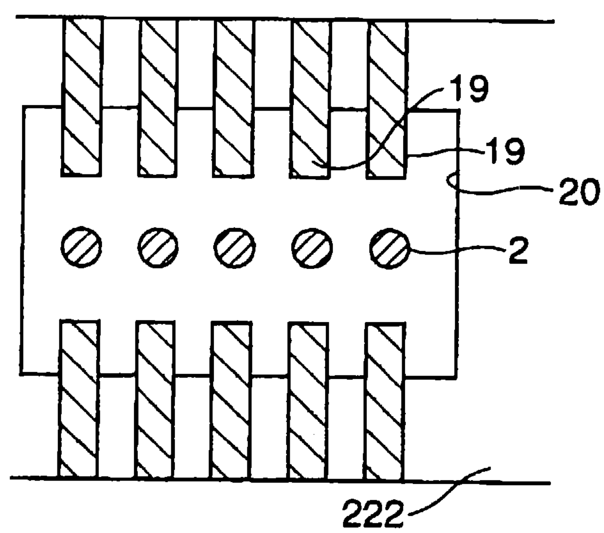

FIG.12

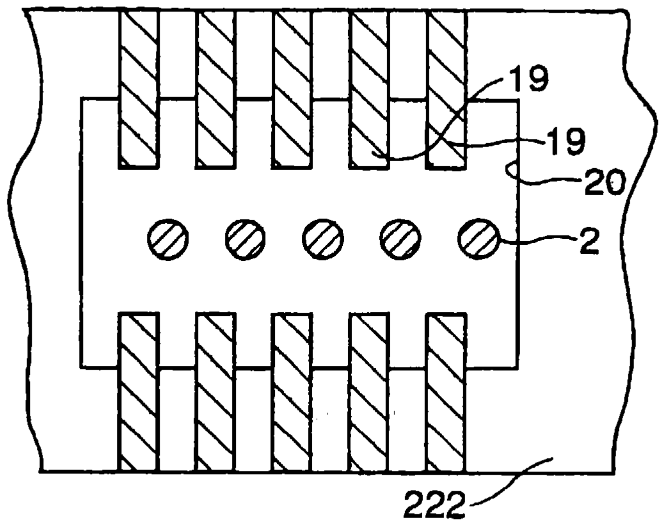

FIG.13

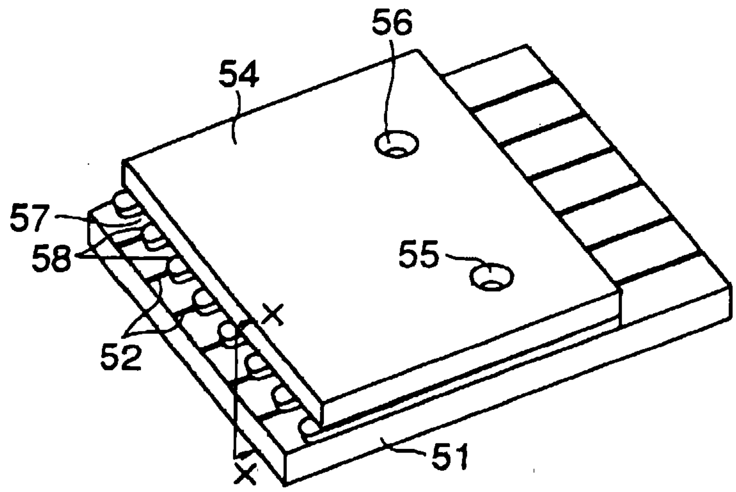

FIG.14

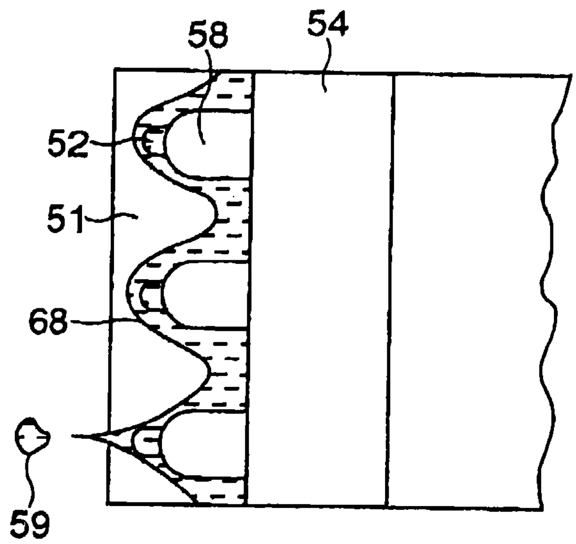

FIG.15

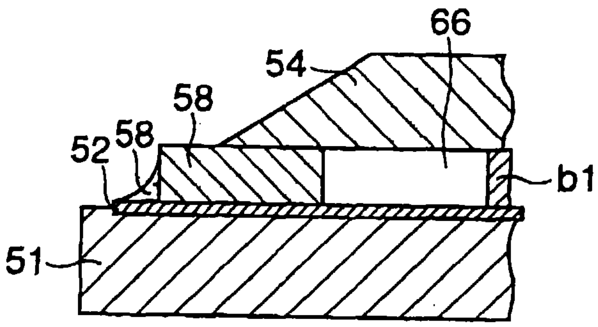

FIG.16

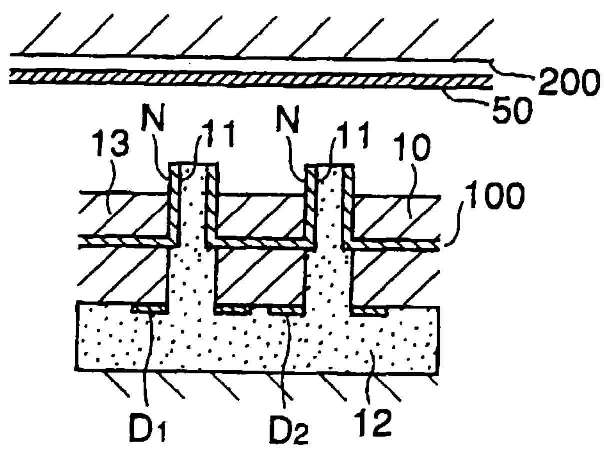

FIG.17