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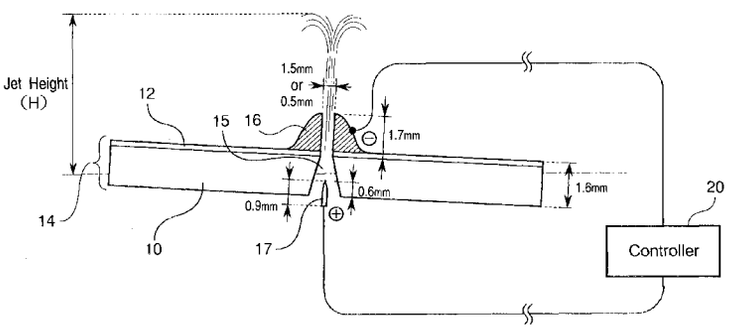
(54) Recording methods using electro-sensitive movable fluids, and recording apparatuses

(57) In the method of using an ink-jet recording ink composition and the recording apparatus according to the invention, by the application of a voltage between one or plural ink jet electrodes (16) and one or plural source electrodes (17) which are provided in the vicinity of bottom ends of the ink jet electrodes and are electrically insulated from the ink jet electrodes, an ink-jet recording ink composition comprising an electrosensitive movable fluid and a colorant dissolved or dispersed in the fluid is moved in the direction of the source electrodes to the ink jet electrodes and is jetted from tips of the ink jet electrodes. An ink attraction electrode may be further arranged in the present invention, whereby the ink composition jetted from the ink jet electrodes can be attracted by the ink attraction electrode and thereby more precise printing can be carried out. A gate electrode may be furthermore arranged between the ink attraction electrode and the ink jet electrode, whereby printing can be carried out with controlling the jet line of the ink composition.

Fig. 1



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Description

[0001] The present invention relates to methods of using ink-jet recording ink compositions containing electro-sensitive movable fluids (also called "Electro-Conjugated Fluids (ECF)" by the present inventors) and to recording apparatuses (e.g., printers) using the ink-jet recording ink compositions.

[0002] Information machines such as personal computers have been amazingly rapidly and widely spread recently. With such spread, printers of various types for recording information have come into the market.

[0003] The printers are broadly divided into wire dot printers, heat-sensitive transfer printers, ink jet printers and laser printers based on the recording system. Of these various printers, the ink jet printers are relatively small and lightweight, and besides they are capable of performing multi-color printing. Therefore, the ink jet printers have been broadly employed. Examples of recording systems adopted in the ink jet printers include a bubble jet system, in which ink is heated to produce bubbles and the ink is jetted by the action of the bubbles, and an ink jet system using a piezo element.

[0004] In the bubble jet system, ink is repeatedly heated. Therefore, heat deterioration of ink easily takes place and power consumption is high. In the system using a piezo element, high voltage is necessary to drive the system and power consumption is high.

[0005] In these ink jet systems, it is difficult to prepare large-scale printer heads because of their complicated structures, and the power consumption is high. Therefore, plural large-sized printer heads cannot be arranged in practice, and small-sized printer heads must be moved in the right or left direction. As a result, motors to move the printer heads need to be provided. The provision of motors causes not only a problem of noise of motor driving but also a problem of slow printing. In the bubble jet system or the ink jet system using a piezo element, further, ink jet of only one time is feasible per one application of a voltage (application of a pulse voltage), and continuous ink jet is infeasible. In these systems, furthermore, a pump chamber needs to be provided per one dot in order to perform ink jetting, and besides the pump chamber must be connected to an ink tank by a capillary in order to prevent back-flow of the ink caused by pressurizing the pump chamber. By the provision of the pump chamber, the structure of the ink jet means becomes complicated. Moreover, agglomeration of ink occasionally takes place in the capillary, and it may be difficult to stably feed ink for a long period of time.

[0006] Separately from the above systems, a drop-on-demand type ink-jet recording system is known. As the ink used for this system, there has been proposed an ink composition (ER ink composition) having electrorheological (ER) properties such that the composition is increased in its viscosity (the composition becomes non-fluid according to circumstances) when a voltage is applied from the external electric field (see Japanese Patent Laid-Open Publications No. 117663/1980 and No. 172746/1990, Japanese Printing Institute Bulletin Vol. 27, No. 3, P. 283).

[0007] The ER ink composition comprises a dielectric fluid and ER particles dispersed in the fluid. In the drop-on-demand type ink-jet recording system, the ink jet mechanism is as follows. When a voltage is applied to the ER ink composition filled between electrodes facing each other, the ER particles dispersed in the ER ink composition are polarized by the action of an electric field generated between the electrodes. By virtue of the electrostatic attractive force based on the polarization, the ER particles are coordination linked to each other in the direction of the electric field and thereby become a resistance to the external shear flow. This resistance stops jetting of the ink composition (off-state is formed). Contrariwise, when no voltage is applied, the ink composition is allowed to exhibit fluidity inherent in the composition, and due to the external shear flow, the ink composition is jetted (on-state is formed). Thus, the jetting of the ink composition is controlled. In this mechanism, the ER effect is utilized as a resistance to the external shear flow which is produced by the coordination linkage of the ER particles in the ER ink composition upon application of a voltage. That is, the ER effect is utilized as a source of generating a force to allow the ER particles to functions as a stop valve for controlling jetting of the ER ink composition.

[0008] As the ER particles for use in the conventional ER ink composition, there have been proposed particles comprising cores of a polymer material having a specific gravity of not more than 1.2 and a hydrophilic compound with which the cores are covered (see Japanese Patent Laid-Open Publication No. 162494/1991). An ER ink composition using such particles is also known (see Japanese Patent Laid-Open Publication No. 257485/1992).

[0009] In a printer using the conventional ER ink composition, the ER ink composition is always under pressure (in the external shear flow state), and in order to allow the ER particles in the ER ink composition under pressure to function as a stop valve, a voltage is applied to the ER ink composition to coordination link the ER particles to one another. In the use of the printer, therefore, it is necessary to continuously apply a voltage to the ER ink composition except an extremely short period of time for jetting the ER ink composition. Further, in order to coordination link the ER particles and thereby allow them to have a sufficient function as a stop valve, a considerably high voltage must be applied. That is, in the drop-on-demand type ink-jet recording system, a considerably high voltage is necessary to allow the ER particles in the ER ink composition to have a sufficient function as a stop valve, and besides the high voltage must be continuously applied throughout driving of the printer except an extremely short period of time for jetting the ER ink composition. Therefore, the power consumption becomes considerably high.

[0010] In the drop-on-demand type ink-jet recording system, the voltage applied to one nozzle is high as described

above. Therefore, the number of the nozzles employable for one printer is limited, and the limited number of nozzles must be moved to perform recording. Further, the nozzles are driven by a driving means such as a motor, and hence a problem of noise of the driving means takes place.

[0011] The ER ink composition contains the ER particles. When the ER ink composition is jetted, the ER particles are brought into contact with the electrode to which a voltage is applied and which is provided on the ink jet nozzle, and with the wall of the orifice. The ER particles are inorganic particles as described above, and therefore the inner surface of the nozzle wall is considerably abraded by the contact with the ER particles. If the abrasion powder is introduced into the ER ink composition, ER properties of the ER ink composition are altered, and this may cause extraordinary current between the electrodes.

[0012] The ER ink composition is a dispersion of the ER particles in a dielectric fluid, and the ER particles have a problem of dispersion stability in the ER ink composition. That is, when the ER ink composition is stored for a long period of time, the ER particles may be sedimented. In the ER ink composition containing the sedimented ER particles, the function as a stop valve due to the coordination linkage of the ER particles is not sufficiently exhibited even if a voltage is applied.

[0013] It is an object of the present invention to provide a novel method of using an ink-jet recording ink composition, which is used for an ink jet printer, and to provide a recording apparatus utilizing the method. More particularly, the invention provides a method wherein an ink-jet recording ink composition is jetted utilizing a jet flow of an electro-sensitive movable fluid produced by application of a voltage between electrodes, and provides a recording apparatus utilizing the method.

[0014] It is another object of the invention to provide a method of precisely jetting an ink-jet recording ink composition containing the above-mentioned electro-sensitive movable fluid and to provide a recording apparatus utilizing the method.

[0015] It is a further object of the invention to provide a novel ink-jet recording ink composition for use in the above-mentioned methods and recording apparatuses.

[0016] From a first aspect, the invention provides a method of using an ink-jet recording ink composition, said method comprising:

arranging one or plural ink jet electrodes and one or plural source electrodes in the vicinity of bottom ends of the ink jet electrodes, said source electrodes being electrically insulated from the ink jet electrodes, and
applying a voltage between the ink jet electrodes and the source electrodes to jet an ink-jet recording ink composition from tips of the ink jet electrodes,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0017] The method of using an ink-jet recording ink composition preferably comprises:

arranging one or plural ink jet electrodes and an ink attraction electrode for attracting an ink-jet recording ink composition jetted from the ink jet electrodes,
energizing the ink composition so that it can be jetted from the ink jet electrodes, and
applying a voltage between the ink jet electrodes and the ink attraction electrode to jet the ink composition from tips of the ink jet electrodes toward the ink attraction electrode,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0018] The method of using an ink-jet recording ink composition preferably comprises:

arranging one or plural ink jet electrodes, one or plural source electrodes in the vicinity of bottom ends of the ink jet electrodes, said source electrodes being electrically insulated from the ink jet electrodes, and an ink attraction electrode for attracting an ink-jet recording ink composition jetted from the ink jet electrodes, and
applying a voltage between the ink jet electrodes and the source electrodes and between the ink jet electrodes and the ink attraction electrode to jet the ink composition from tips of the ink jet electrodes toward the ink attraction electrode,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0019] The method of using an ink-jet recording ink composition preferably comprises:

arranging one or plural ink jet electrodes, one or plural source electrodes in the vicinity of bottom ends of the ink

jet electrodes, said source electrodes being electrically insulated from the ink jet electrodes, an ink attraction electrode for attracting an ink-jet recording ink composition jetted from the ink jet electrodes, and a gate electrode between the ink jet electrodes and the ink attraction electrode, and

applying a voltage between the ink jet electrodes and the source electrodes and between the ink jet electrodes and the ink attraction electrode to jet the ink composition from tips of the ink jet electrodes toward the ink attraction electrode, with controlling a voltage applied to the gate electrode and thereby controlling the direction of the jetted ink composition,

said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0020] The method of using an ink-jet recording ink composition preferably comprises:

arranging one or plural ink jet electrodes, one or plural source electrodes in the vicinity of bottom ends of the ink jet electrodes, said source electrodes being electrically insulated from the ink jet electrodes, a pair of ink attraction electrodes for attracting an ink-jet recording ink composition jetted from the ink jet electrodes in the jet direction of the ink-jet recording ink composition, said pair of ink attraction electrodes being electrically insulated from each other, and a baffle with an ink-passing hole between the ink jet electrodes and the ink attraction electrodes,

applying a voltage between the ink jet electrodes and the source electrodes and between the ink jet electrodes and one of the ink attraction electrodes to continuously jet the ink-jet recording ink composition from tips of the ink jet electrodes toward the baffle, and

decreasing or stopping power supply to the voltage-applied ink attraction electrode and simultaneously increasing or applying a voltage to the other ink attraction electrode to allow the ink composition to pass through the ink-passing hole of the baffle,

said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0021] From a second aspect, the invention provides a recording apparatus of printing mechanism, including an ink jet means having a hole through which an ink-jet recording ink composition is jetted correspondingly to printing signals.

wherein the ink jet means comprises one or plural ink jet electrodes and one or plural source electrodes which are provided in the vicinity of bottom ends of the ink jet electrodes and are electrically insulated from the ink jet electrodes; and the ink composition can be jetted from tips of the ink jet electrodes by applying a voltage between the ink jet electrodes and the source electrodes,

said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0022] The recording apparatus of the invention is a recording apparatus of printing mechanism, including an ink jet means having a hole through which an ink-jet recording ink composition is jetted correspondingly to printing signals,

wherein the ink-jet recording ink composition is fed to the ink jet means; the ink jet means comprises one or plural ink jet electrodes for jetting the ink composition and an ink attraction electrode for attracting the ink composition jetted from the ink jet electrodes, said ink attraction electrode being arranged in the vicinity of the arrival point of the jetted ink composition; and the ink composition is jetted from tips of the ink jet electrodes toward the ink attraction electrode by applying a voltage between the ink jet electrodes and the ink attraction electrode,

said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid and being energized so that it can be jetted from the ink jet electrodes.

[0023] The recording apparatus preferably comprises an ink jet means having a hole through which an ink-jet recording ink composition is jetted correspondingly to printing signals,
correspondingly to printing signals,

wherein the ink-jet recording ink composition is fed to the ink jet means; the ink jet means comprises one or plural ink jet electrodes for jetting the ink composition, one or plural source electrodes which are provided in the vicinity of bottom ends of the ink jet electrodes and are electrically insulated from the ink jet electrodes, and an ink attraction electrode for attracting the ink composition jetted from the ink jet electrodes, said ink attraction electrode being arranged in the vicinity of the arrival point of the jetted ink composition; and the ink composition is jetted from tips of the ink jet electrodes toward the ink jet electrode by applying a voltage between the source electrodes and the ink jet electrode and between the ink attraction electrode and the ink jet electrodes,

said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0024] The recording apparatus preferably comprises an ink jet means having a hole through which an ink-jet recording ink composition is jetted correspondingly to printing signals,

wherein the ink-jet recording ink composition is fed to the ink jet means; the ink jet means comprises one or plural ink jet electrodes for jetting the ink composition, one or plural source electrodes which are provided in the vicinity of bottom ends of the ink jet electrodes and are electrically insulated from the ink jet electrodes, an ink attraction electrode for attracting the ink composition jetted from the ink jet electrodes, said ink attraction electrode being arranged in the vicinity of the arrival point of the jetted ink composition, and a gate electrode provided between the ink jet electrode and the ink attraction electrode; and the ink composition is jetted from tips of the ink jet electrodes toward the ink attraction electrode by applying a voltage between the ink jet electrodes and the source electrodes and between the ink jet electrodes and the ink jet electrode, with controlling a voltage applied to the gate electrode and thereby controlling the direction of the jetted ink composition,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0025] The recording apparatus preferably comprises an ink jet means having a hole through which an ink-jet recording ink composition is jetted correspondingly to printing signals,
correspondingly to printing signals,

wherein the ink-jet recording ink composition is fed to the ink jet means; the ink jet means comprises one or plural ink jet electrodes for jetting the ink composition, one or plural source electrodes which are provided in the vicinity of bottom ends of the ink jet electrodes and are electrically insulated from the ink jet electrodes, at least one pair of ink attraction electrodes which are electrically insulated from each other and arranged in the jet direction of the ink composition, and a baffle which has an ink-passing hole and is provided between the ink jet electrodes and the ink attraction electrodes; the ink composition is continuously jetted from tips of the ink jet electrodes toward the baffle by applying a voltage between the ink jet electrodes and the source electrodes and between the ink jet electrodes and one of the ink attraction electrodes; and the ink composition is allowed to pass through the ink-passing hole of the baffle to reach a recording material by stopping power supply to the voltage-applied ink attraction electrode and simultaneously applying a voltage to the other ink attraction electrode, to thereby change the direction of the jetted ink composition,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0026] The recording apparatus preferably comprises an ink jet means having a hole through which an ink-jet recording ink composition is jetted correspondingly to printing signals,
correspondingly to printing signals,

wherein the ink-jet recording ink composition is fed to the ink jet means; the ink jet means comprises one or plural ink jet electrodes for jetting the ink composition, and at least one pair of ink attraction electrodes which are electrically insulated from the ink jet electrodes and arranged in the jet direction of the ink composition; and at least one through-hole through which the ink composition jetted from the ink jet electrodes toward the ink attraction electrodes passes is provided to the ink attraction electrodes; and the ink composition is allowed to pass through the through-hole of the ink attraction electrodes to reach a recording material,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

[0027] Preferably, the ink-jet recording ink composition comprises an electro-sensitive movable fluid, which is capable of producing a jet flow according to the applied voltage, and a colorant dissolved or dispersed in the fluid. The electro-sensitive movable fluid for forming the ink composition comprises a compound having a conductivity σ and a viscosity η located on or inside a triangle in a graph showing a relation between a conductivity σ, plotted as abscissa, and a viscosity η, plotted as ordinate, of a fluid at the working temperature and the working pressure, said triangle having, as vertexes, a point P indicated by the conductivity $\sigma = 4 \times 10^{-10}$ S/m (preferably 5×10^{-10} S/m) and the viscosity $\eta = 1 \times 10^{0}$ Pa·s, (preferably 8×10^{-1} Pa·s), a point Q indicated by the conductivity $\sigma = 4 \times 10^{-10}$ S/m (preferably 5×10^{-10} S/m), and the viscosity $\eta = 1 \times 10^{-4}$ Pa·s (preferably 2×10^{-4} Pa·s), and a point R indicated by the conductivity $\sigma = 5 \times 10^{-6}$ S/m (preferably 2.5×10^{-6} S/m), and the viscosity $\eta = 1 \times 10^{-4}$ Pa·s (preferably 2×10^{-4} Pa·s), or

comprises a mixture of two or more compounds, said mixture being adjusted to have a conductivity σ and a viscosity η located on or inside said triangle.

[0028] When a certain dielectric fluid (i.e., "electro-sensitive movable fluid" referred to herein) is subjected to an electric field, an electric force is generated in the fluid owing to the ununiformity of electric conductivity and dielectric constant. In the direct-current electric field, the Coulomb force acting on free charge dominates rather than the dielectrophoretic force. This Coulomb force causes hydrodynamic instability, resulting in occurrence of convection of the electro-sensitive movable fluid or a secondary motion of the fluid. These phenomena are called "electrohydrodynamic (EHD) effects".

[0029] The present inventors have found that an ink composition prepared by dissolving or dispersing a colorant in the electro-sensitive movable fluid can be vigorously jetted from a nozzle by applying a voltage to the composition. The present inventors consider that the jet phenomenon of the ink composition is owing to the EHD effects. Utilization of the EHD effects in the ink-jet recording type printers has been never known hitherto. The present inventors consider that the motion of the ink-jet recording ink composition in the present invention is probably-by virtue of the EHD effects, but they do not conclude that the phenomenon occurring in the invention is owing to the "EHD effects".

[0030] Some preferred embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings, in which:

[0031] Fig. 1 is a view to explain jetting principles of an ink composition for use in the present invention.

[0032] Fig. 2 is a view to explain jetting principles of an ink composition for use in the present invention.

[0033] Fig. 3 is a view schematically showing an embodiment of the recording apparatus according to the present invention.

[0034] Fig. 4 is a graph showing a relation between a conductivity σ and a viscosity η of an electro-sensitive movable fluid at 25 °C.

[0035] Fig. 5 is a view showing a height of jetted dibutyl decanedioate (DBD) and a current between the electrodes given when the applied voltage is changed in the range of 0 to 12 kV.

[0036] Figs. 6(A), 6(B) and 6(C) are each a view showing another embodiment of the electrode employable in the present invention.

[0037] Figs. 7(A), 7(B) and 7(C) are each a view schematically showing plural nozzles which are together used to form one dot.

[0038] Figs. 8(a), 8(b), 8(c), 8(d) and 8(e) and Fig. 9 are each a view to explain a method of applying a voltage to a recording apparatus using an ink attraction electrode.

[0039] Fig. 10, Fig. 11, Fig. 12, Fig. 13 and Fig. 24 are each a view schematically showing a nozzle of a recording apparatus including a gate electrode.

[0040] Fig. 14 is a view schematically showing deviation of a jet line of an ink composition.

[0041] Fig. 15, Fig. 16, Fig. 17 and Fig. 18 are each a view showing deviation correction of a jet line of an ink composition by the use of plural nozzles.

[0042] Fig. 19, Fig. 20, Fig. 21 and Fig. 22 are each a view showing another embodiment of the source electrode used in the recording apparatus of the present invention.

[0043] Fig. 23 is a view schematically showing a nozzle used in Example 10.

[0044] Fig. 25 is a view schematically showing the other embodiment of the recording apparatus according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0045] The methods of using an ink-jet recording ink composition and the recording apparatuses using an ink-jet recording ink composition according to the invention are described in detail hereinafter.

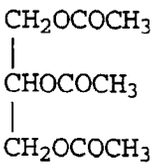
[0046] The ink-jet recording ink composition for use in the invention comprises an electro-sensitive movable fluid, which is capable of forming a jet flow between the electrodes correspondingly to the applied voltage, and a colorant dissolved or dispersed in the fluid (, or which is colored).

[0047] The electro-sensitive movable fluid used herein is an organic compound which is liquid at working temperatures at which a jet flow of the compound can be produced between the electrodes correspondingly to the applied voltage. This organic compound is substantially dielectric.

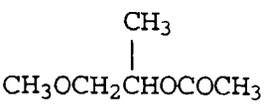
[0048] Listed below are examples of compounds exhibiting the above properties and employable as the electro-sensitive movable fluids in the invention.

(1) Dibutyl adipate (DBA)
(2) Tributyl citrate (TBC)
(3) Monobutyl maleate (MBM)
(4) Diallyl maleate (DAM)

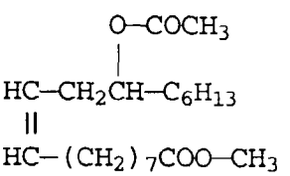
(5) Dimethyl phthalate (DMP)
(6) Triacetin



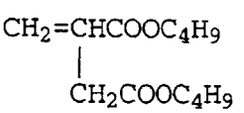
(7) Ethyl cellosolve acetate
(8) 2-(2-Ethoxyethoxy)ethyl acetate
(9) 1,2-Diacetoxyethane
(10) Triethylene glycol diacetate
(11) Butyl cellosolve acetate
(12) Butyl carbitol acetate
(13) 3-Methoxy-3-methylbutyl acetate
(trade name: Solfit AC)
(14) Dibutyl fumarate (DBF)
(15) 2-Ethylhexyl benzyl phthalate
(trade name: Placizer B-8)
(17) Propylene glycol methyl ether acetate (PMA)



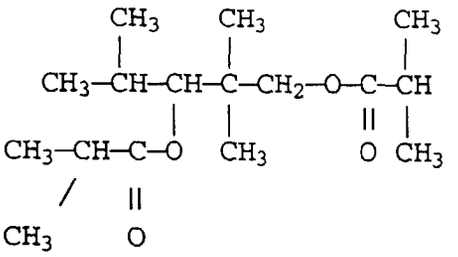
(18) Methyl acetyl ricinoleate (MAR-N)



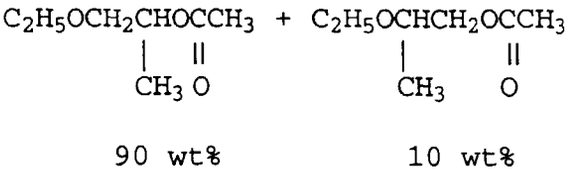
(19) 2-Ethylhexyl palmitate
(trade name: Exepal EH-P)
(20) Dibutyl itaconate (DBI)



(21) Polyethylene glycol monooleate
(trade name: Emanone 4110)
(22) Butyl stearate
(trade name: Exepal BS)
(23) 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate
(trade name: Kyowanol D)

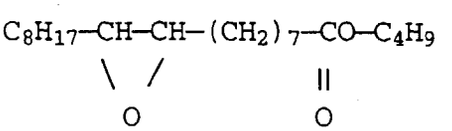


(24) 2,2,4-Trimethyl-1,3-pentanediol monoisobutyrate
(trade name: Kyowanol M)
(25) Propylene glycol monoethyl ether
(26) Propylene glycol ethyl ether acetate
(trade name: BP-Ethoxypropyl Acetate)

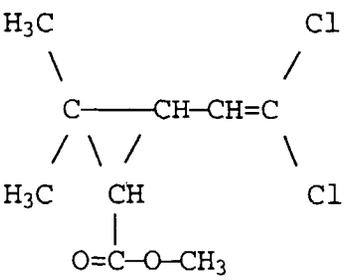


90 wt% 10 wt%

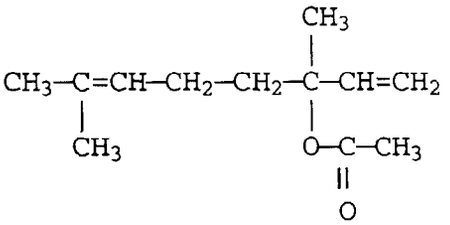
(27) 9,10-Epoxy butyl stearate
(trade name: Sansocizer E-4030)



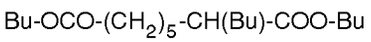
(28) Tetrahydrophthalic acid dioctyl ester
(trade name: Sansocizer DOTP)
(29) Tributyl phosphate (TBP)
(30) Tributoxyethyl phosphate (TBXP)
(31) Tris(chloroethyl) phosphate (CLP)
(32) Ethyl 2-methylacetoacetate
(33) 1-Ethoxy-2-acetoxypropane
(34) 2-(2,2-Dichlorovinyl)-3,3-dimethylcyclopropane carboxylic acid methyl ester (DCM-40)



(35) Linalyl acetate



(36) Dibutyl decanedioate
(37) Mixture of Kyowanol M and Exepal EH-P in a mixing ratio of 1:4 by weight
Kyowanol M (trade name) : 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate
Exepanl EH-P (trade name): 2-ethylhexyl palmitate
(38) Mixture of DAM and Exepal BS in a mixing ratio of 1 : 4 by weight
DAM: diallyl maleate
Exepal BS (trade name): butyl stearate
(39) Dibutyl dodecanedioate (DBDD)



[0049] The compounds mentioned above can be used singly or in combination.

[0050] The conductivity and the viscosity of the above compounds, as measured at 25 °C, are set forth in Table 1.

Table 1

Compound (™: trade name)	Conductivity (S/m)	Viscosity (Pa·s)
(1) DBA	3.01×10^{-9}	3.5×10^{-3}
(2) TBC	5.71×10^{-7}	2.0×10^{-2}
(3) MBM	2.60×10^{-5}	2.0×10^{-2}
(4) DAM	7.80×10^{-7}	2.5×10^{-3}
(5) DMP	3.90×10^{-7}	1.2×10^{-2}
(6) Triacetin™	3.64×10^{-9}	1.4×10^{-2}
(7) Ethyl cellosolve acetate	7.30×10^{-5}	9.0×10^{-4}
(8) 2-(2-Ethoxyethoxy)ethyl acetate	6.24×10^{-7}	1.4×10^{-2}
(9) 1,2-Diacetoxyethane	2.00×10^{-6}	1.5×10^{-3}
(10) Triethylene glyocl acetate	5.20×10^{-7}	8.1×10^{-3}
(11) Butyl cellosolve acetate	2.10×10^{-8}	7.0×10^{-4}
(12) Butyl carbitol acetate	5.20×10^{-8}	1.7×10^{-3}
(13) Solfit AC™	8.30×10^{-8}	6.0×10^{-4}
(14) DBF	2.65×10^{-9}	3.5×10^{-3}
(15) Placizer B-8™	1.10×10^{-8}	7.8×10^{-2}
(17) PMA	1.56×10^{-7}	6.0×10^{-4}
(18) MAR-N™	1.30×10^{-8}	1.3×10^{-2}
(19) Exepal EH-P™	2.60×10^{-10}	9.5×10^{-3}
(20) DBI	1.46×10^{-8}	3.5×10^{-3}
(21) Emanone 4110™	3.75×10^{-7}	8.0×10^{-2}
(22) Expal BS™	3.10×10^{-10}	8.5×10^{-3}

Table 1 (continued)

Compound (™: trade name)	Conductivity (S/m)	Viscosity (Pa·s)
(23) Kyowanol D™	6.24×10^{-9}	4.0×10^{-3}
(24) Kyowanol M™	6.80×10^{-8}	1.2×10^{-2}
(25) MP-Ethoxypropanol™	6.24×10^{-5}	8.0×10^{-4}
(26) BP-Ethoxypropyl Acetate™	3.10×10^{-8}	6.0×10^{-4}
(27) Sansocizer E-4030™	5.46×10^{-9}	2.0×10^{-2}
(28) Sansocizer DOTP™	6.20×10^{-10}	4.0×10^{-2}
(29) TBP	2.20×10^{-6}	2.2×10^{-3}
(30) TBXP	1.10×10^{-5}	9.0×10^{-3}
(31) CLP	7.80×10^{-6}	3.0×10^{-2}
(32) Ethyl 2-methylacetoacetate	1.00×10^{-4}	5.0×10^{-4}
(33) 1-Ethoxy-2-acetoxypropane	4.41×10^{-7}	4.0×10^{-4}
(34) DCM-40™	2.60×10^{-5}	5.5×10^{-3}
(35) Linalyl acetate	1.82×10^{-9}	1.3×10^{-3}
(36) Dibutyl decanedioate	1.40×10^{-9}	7.0×10^{-3}
(39) Dibutyl dodecanedioate	5.2×10^{-9}	9.3×10^{-3}

[0051] The electro-sensitive movable fluid for the ink-jet recording ink composition employable in the invention is preferably a compound or a mixture each having the following specific conductivity and the following specific viscosity at the working temperature.

[0052] That is, when the conductivity σ and the viscosity η of the "dielectric fluids" including the above compounds are measured under the conditions of an electric field intensity of 2 $kVmm^{-1}$ and a temperature of 25 °C, the dielectric fluids are distributed as shown in Fig. 4.

[0053] The compound used as the electro-sensitive movable fluid in the ink composition for use in the invention is preferably a compound having, at its working temperature, a conductivity σ and a viscosity η located on or inside a triangle in a graph (Fig. 4) wherein the conductivity σ is plotted as abscissa and the viscosity η is plotted as ordinate, said triangle having the following points P, Q and R as vertexes. When a mixture of two or more kinds of compounds is used as the electro-sensitive movable fluid, the mixture is preferably such a mixture as adjusted to have a conductivity σ and a viscosity η located inside the above triangle.

Table 2

	Conductivity (σ)	Viscosity (η)
Point P	4×10^{-10} S/m	1×10^{0} Pa·S
(Point P^0)	preferably 5×10^{-10} S/m	preferably 8×10^{-1} Pa·S
Point Q	4×10^{-10} S/m	1×10^{-4} Pa·S
(Point Q^0)	preferably 5×10^{-10} S/m	preferably 2×10^{-4} Pa·S
Point R	5×10^{-6} S/m	1×10^{-4} Pa·S
(Point R^0)	preferably 2.5×10^{-6} S/m	preferably 2×10^{-4} Pa·S

[0054] In Table 2, the points P^0, Q^0 and R^0 are particularly preferable points as the vertexes of the triangle wherein the electro-sensitive movable fluid of the invention is located.

[0055] Some examples of the compounds preferably used as the electro-sensitive movable fluids in the ink composition for use in the invention are given below.

(1) Dibutyl adipate (DBA)

($\sigma = 3.01 \times 10^{-9}$ S/m, $\eta = 3.5 \times 10^{-3}$ Pa·s)

(6) Triacetin

($\sigma = 3.64 \times 10^{-9}$ S/m, $\eta = 1.4 \times 10^{-2}$ Pa·s)

(11) Butyl cellosolve acetate

($\sigma = 2.10 \times 10^{-8}$ S/m, $\eta = 7.0 \times 10^{-4}$ Pa·s)

(12) Butyl carbitol acetate

($\sigma = 5.20 \times 10^{-8}$ S/m, $\eta = 1.7 \times 10^{-3}$ Pa·s)

(13) 3-Methoxy-3-methylbutyl acetate (Solfit AC)

($\sigma = 8.30 \times 10^{-8}$ S/m, $\eta = 6.0 \times 10^{-4}$ Pa·s)

(14) Dibutyl fumarate (DBF)

($\sigma = 2.65 \times 10^{-9}$ S/m, $\eta = 3.5 \times 10^{-3}$ Pa·s)

(17) Propylene glycol methyl ether acetate (PMA)

($\sigma = 1.56 \times 10^{-7}$ S/m, $\eta = 6.0 \times 10^{-4}$ Pa·s)

(18) Methyl acetyl ricinoleate (MAR-N)

($\sigma = 1.30 \times 10^{-8}$ S/m, $\eta = 1.3 \times 10^{-2}$ Pa·s)

(20) Dibutyl itaconate (DBI)

($\sigma = 1.46 \times 10^{-8}$ S/m, $\eta = 3.5 \times 10^{-3}$ Pa·s)

(23) 2,2,4-Trimethyl-1,3-pentanediol diisobutyrate
(trade name: Kyowanol D)

($\sigma = 6.24 \times 10^{-9}$ S/m, $\eta = 4.0 \times 10^{-3}$ Pa·s)

(26) Propylene glycol ethyl ether acetate
(trade name: BP-Ethoxypropyl Acetate)

($\sigma = 3.10 \times 10^{-8}$ S/m, $\eta = 6.0 \times 10^{-4}$ Pa·s)

(27) 9,10-Epoxy butyl stearate
(trade name: Sansocizer E-4030)

($\sigma = 5.46 \times 10^{-9}$ S/m, $\eta = 2.0 \times 10^{-2}$ Pa·s)

(28) Tetrahydrophthalic acid dioctyl ester
(trade name: Sansocizer DOTP)

($\sigma = 6.20 \times 10^{-10}$ S/m, $\eta = 4.0 \times 10^{-2}$ Pa·s)

(33) 1-Ethoxy-2-acetoxypropane

($\sigma = 4.41 \times 10^{-7}$ S/m, $\eta = 4.0 \times 10^{-4}$ Pa·s)

(35) Linalyl acetate

($\sigma = 1.82 \times 10^{-9}$ S/m, $\eta = 1.3 \times 10^{-3}$ Pa·s)

(36) Dibutyl decanedioate

($\sigma = 1.40 \times 10^{-9}$ S/m, $\eta = 7.0 \times 10^{-3}$ Pa·s)

(39) Dibutyl dodecanedioate (DBDD)

($\sigma = 5.2 \times 10^{-9}$ S/m, $\eta = 9.3 \times 10^{-3}$ Pa·s)

[0056] When a mixture of plural compounds is used as the electro-sensitive movable fluid in the invention, the conductivity and the viscosity of the mixture are made to be located on or inside the triangle defined by the points P, Q and R shown in Fig. 4, whereby the mixture can be preferably used in the invention.

[0057] In other words, even if each of compounds has a conductivity and/or a viscosity out of the above range, a mixture of the compounds can be favorably used as the electro-sensitive movable fluid in the invention, as far as the conductivity and the viscosity of the mixture are within the above range, respectively.

[0058] For example, a mixture ($\sigma = 2.60 \times 10^{-9}$ S/m, $\eta = 9.8 \times 10^{-3}$ Pa·s) of 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate (trade name: Kyowanol M, $\sigma = 6.80 \times 10^{-8}$ S/m, $\eta = 1.2 \times 10^{-2}$ Pa·s) and 2-ethylhexyl palmitate (trade name: Exepal EH-P, $\sigma = 2.60 \times 10^{-10}$ S/m, $\eta = 9.5 \times 10^{-3}$ Pa·s) in a mixing ratio of 1:4 by weight, each having a conductivity and a viscosity out of the above range, can be favorably used as the electro-sensitive movable fluid for forming the ink composition for use in the invention. Also, a mixture ($\sigma = 4.17 \times 10^{-9}$ S/m, $\eta = 5.0 \times 10^{-3}$ Pa·s) of DAM (diallyl maleate, $\sigma = 7.8 \times 10^{-7}$ S/m, $\eta = 2.5 \times 10^{-3}$ Pa·s) and butyl stearate (trade name: Exepal BS, $\sigma = 3.1 \times 10^{-10}$ S/m, $\eta = 8.5 \times 10^{-3}$ Pa·s) in a mixing ratio of 1:4 by weight, each having a conductivity and a viscosity out of the above range, can be favorably used as the electro-sensitive movable fluid for forming the ink composition for use in the invention.

[0059] The requisite of the electro-sensitive movable fluid is that the movable fluid has the above-defined conductivity and viscosity at the temperature at which the ink composition is used. That is, even the compounds having a conductivity and a viscosity out of the above range at 25 °C are employable as the electro-sensitive movable fluids, as far as the conductivity and the viscosity of the compounds are within the above range at the working temperature of the ink composition when the ink composition is used under heating.

[0060] In the ink-jet recording ink composition for use in the invention, a colorant is dissolved or dispersed in the electro-sensitive movable fluid.

[0061] Colorants generally include dyes and pigments, and in the invention, conventional dyes and pigments are both employable.

[0062] Examples of the dyes employable as the colorants in the invention include azo dyes, anthraquinone dyes, indigoid dyes, phthalocyanine dyes, carbonium ion dyes, nitro dyes, quinacrine dyes and naphthoquinone dyes.

[0063] Examples of the pigments employable as the colorants in the invention include inorganic pigments and organic pigments.

[0064] Particular examples of the inorganic pigments include white pigments, such as zinc oxide, lithopone and

titanium oxide; yellow pigments, such as chromium yellow, cadmium yellow and nickel titanium yellow; red pigments, such as red iron oxide, cadmium red and molybdenum orange; blue pigments, such as Prussian blue and ultramarine blue; and carbon black. Particular examples of the organic pigments include azo pigments, phthalocyanine pigments, metal complex salt pigments, triphenylmethane pigments, vat dyes, quinacridone pigments and isoindolinone pigments.

[0065] The colorants mentioned above can be used singly or in combination.

[0066] The content of the colorant in the ink composition can be appropriately determined.

[0067] To the ink composition for use in the invention, additives, such as stabilizer, dispersant, surface active agent, viscosity increasing agent, rheological property adjusting agent, ink fixation improver, volatility adjusting agent, antiseptic agent, mildew-proofing agent, color tone adjusting agent and gloss adjusting agent, can be generally added according to necessity.

[0068] The stabilizer employable herein is, for example, an ultraviolet light absorber. Examples of the ultraviolet light absorbers include benzophenone derivatives, such as 2,2'-dihydroxy-4-methoxybenzophenone, benzotriazole derivatives, substituted acrylonitrile derivatives, aromatic ester derivatives and triazine derivatives.

[0069] Examples of the high-molecular dispersants and the surface active agents employable herein include anionic surface active agents, such as alkyl sulfonate, alkylaryl sulfonate and sulfosuccinic ester; cationic surface active agents, such as tertiary amine salt, quaternary ammonium salt, tertiary sulfonium salt and alkylpyridinium salt; and nonionic surface active agents, such as polyhydric alcohol derivatives.

[0070] The additives can be added in amounts not detrimental to the properties of the ink composition. In general, the additived are used in amounts of not more than 30 % by weight based on the total of the electro-sensitive movable fluid and the colorant.

[0071] The ink-jet recording ink composition for use in the invention can be prepared by mixing the electro-sensitive movable fluid, the colorant (dyes or pigments), and if necessary, additives.

[0072] In the present invention, the ink composition can be jetted from the ink jet means utilizing such properties of the electro-sensitive movable fluid that a jet flow of the fluid is produced when a voltage is applied to the fluid.

[0073] Fig. 1 and Fig. 2 are each a view to explain jetting principles of the ink composition. In Fig. 1, a needle electrode is used as the electrode, and in Fig. 2, a linear electrode is used as the electrode.

[0074] As shown in Fig. 1 and Fig. 2, a nozzle base 14 consisting of a substrate 10 made of an insulating material (e.g., plastic) and a conductive metal 12 (e.g., gold, silver or copper) adhesion bonded to the substrate is prepared. The nozzle base 14 is provided with a through-hole 15. The through-hole 15 shown in Fig. 1 and Fig. 2 is in the form of a truncated cone (taper), in which the bottom diameter is larger than the top diameter (diameter on the metal 12 side). The through-hole 15 is connected to a through-hole of a nozzle-like electrode 16 (ink jet electrode) provided on the conductive metal 12. The diameter of the through-hole of the nozzle-like electrode 16 is equal to the top diameter of the truncated conical through-hole. The nozzle-like electrode 16 serves not only as an electrode but also as a jet guide of the ink composition from the through-hole 15. An additional ink jet guide means may be provided at the upper part of the nozzle-like electrode 16 to control distance, direction, diffusion, etc. of the jetted ink composition.

[0075] In the vicinity of the bottom of the through-hole 15, a source electrode is arranged. As the source electrode, a needle electrode 17 is arranged in Fig. 1, and a linear electrode 18 is arranged in Fig. 2. As the source electrode, the needle electrode is described below in detail, but for example, a linear electrode may be provided concentrically with the ink jet electrode so that the bottom end of the ink jet electrode is surrounded with the linear electrode, or a network electrode formed of plural linear electrodes may be provided in such a manner that the bottom end of the ink jet electrode is covered with the network electrode. Details of various source electrodes other than the needle electrode will be described later.

[0076] In Fig. 1, the needle electrode 17 is arranged in such a manner that the tip thereof partly enters the through-hole 15 at almost the center of the through-hole. However, an ununiform electric field can be generated even if the tip of the needle electrode 17 does not enter the through-hole. In Fig. 2, a linear electrode 18 extended along the diameter of the through-hole is arranged on the bottom end side of the through-hole 15.

[0077] The needle electrode 17 or the linear electrode 18 is connected to a controller 20, and also the nozzle-like electrode 16, i.e., ink jet electrode, is connected to the controller 20.

[0078] By virtue of the controller 20, a direct-current-voltage is applied between the needle electrode 17 and the nozzle-like electrode 16 or between the linear electrode 18 and the nozzle-like electrode 16.

[0079] The ink jet means having the above structure is arranged on the liquid level of the ink composition. In Fig. 1 and Fig. 2, the nozzle base 14 is inclined (by 20° in these figures) to the liquid level of the ink composition to facilitate measurement of a jet height (H) of the ink composition.

[0080] When a voltage such as a pulse voltage, a rectangular voltage or a continuous voltage is applied between the needle electrode 17 and the nozzle-like electrode 16 or between the linear electrode 18 and the nozzle-like electrode 16 from the controller 20, a jet flow of the ink composition is produced in the direction of the needle electrode 17 or the linear electrode 18 to the nozzle-like electrode 16, and the ink composition is jetted from the tip of the through-hole of the nozzle-like electrode 16. The jet height (H) of the ink composition is determined according to the applied voltage

and the type of the electro-sensitive movable fluid for forming the ink composition, provided that the same nozzle is used.

[0081] Fig. 5 shows a jet height of dibutyl decanedioate (DBD) and a current between electrodes given when the voltage applied between the nozzle-like electrode 16 having a through-hole top diameter of 1.5 mm and the needle electrode is changed in the range of 0 to 12 kV.

[0082] In case of DBD mentioned above, jetting of DBD is observed at an applied voltage of 3.35 kV or higher. When the voltage exceeds about 6 kV, the jet height of DBD increases in proportion of the applied voltage, and for example, at an applied voltage of 12 kV, the jet height (H) reaches 50 mm. The current (I) given at this instant is extremely small, and the electrical energy required for jetting the ink composition is very low. Though the ink jet electrode is explained herein by exemplifying the nozzle-like electrode, the ink jet electrode is not limited to an electrode in the cylindrical shape such as a nozzle, and as a matter of course, ink jet electrodes of variously modified shapes, e.g., ink jet electrode consisting of two flat plates facing each other, are available.

[0083] The method of using the ink composition according to the invention is a method wherein the ink composition comprising the electro-sensitive movable fluid (e.g., DBD) and the colorant dissolved or dispersed in the fluid is jetted from the ink jet means utilizing such properties of the electro-sensitive movable fluid that a jet flow of the fluid is produced by application of a voltage.

[0084] The voltage applied between the electrodes is a direct-current-voltage producing a potential difference of usually 50 V to 30 kV, preferably 100 V to 15 kV. There is no specific limitation on the magnitude of the applied voltage. In case of a potential difference of, for example, 10 kV, it is possible to apply a voltage of +5 kV to the positive electrode and to apply a voltage of -5 kV to the negative electrode. There is no specific limitation also on the type of the applied voltage, and any of a pulse voltage, a rectangular voltage and a continuous voltage is available. The jet quantity of the ink composition can be controlled by the applied voltage and the voltage application time.

[0085] In the method of the invention, it is possible to set the needle electrode 17 (or the linear electrode 18) as a positive electrode and the ink jet electrode as a negative electrode, or to set the needle electrode 17 (or the linear electrode 18) as a negative electrode and the ink jet electrode as a positive electrode.

[0086] As is apparent from Fig. 5. the current given by application of a voltage is very small. Therefore, heat generation of the ink jet means associated with jetting of the ink composition is not usually observed.

[0087] The recording apparatus of the invention is a recording apparatus including an ink jet means having a hole through which an ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid is jetted correspondingly to the printing signals (i.e., applied voltage); wherein the ink jet means comprises one or plural ink jet electrodes and one or plural source electrodes which are provided in the vicinity of bottom ends of the ink jet electrodes and are electrically insulated from the ink jet electrodes, and a jet flow of the ink composition is produced by applying a voltage between the ink jet electrodes and the source electrodes and thereby the ink composition can be jetted from tips of the ink jet electrodes.

[0088] Fig. 3 schematically shows an embodiment of the recording apparatus of the invention. In the embodiment shown in Fig. 3, nozzle-like electrodes are used as the ink jet electrodes.

[0089] Referring to Fig. 3, plural nozzle-like electrodes 31 are provided as the ink jet electrodes in an ink jet means 50. In the ink jet means 50, plural source electrodes 37 are arranged correspondingly to the plural nozzle-like electrodes 31. In Fig. 3, the source electrodes 37 are each a needle electrode. The nozzle-like electrode 31 (ink jet electrode) is provided with a through-hole, and this through-hole is generally connected to a tapered through-hole 35 provided in an insulating substrate 30 and in a conductive metallic foil 32 placed on the substrate 30, whereby an ink composition 39 can be jetted out.

[0090] The jet direction of the ink composition 39 is determined by the nozzle-like electrode 31. A voltage is applied to the ink composition, and the applied voltage can be controlled by, for example, a personal computer 40 or a control means 41.

[0091] In the recording apparatus wherein the ink jet electrodes 31 are negative electrodes and the source electrodes 37 (needle electrode) are positive electrodes as shown in Fig. 3, if a voltage is applied to the specific source electrodes 37, the ink composition 39 can be selectively jetted from only the corresponding specific nozzles.

[0092] The quantity of electricity required for jetting the ink composition is extremely small, and besides heat generation of the ink jet means does not take place even if a voltage is applied. In the recording apparatus, therefore, a large number of nozzles (ink jet electrodes) can be arranged in parallel to a roll 45 and in conformity with a width of a printing material (printing medium) 46 such as paper, and therefore, the nozzles do not need to be moved. Accordingly, the quantity of electricity for driving the recording apparatus of the invention is markedly smaller than that of the conventional ink jet printers, and the recording apparatus of the invention is noiseless because of few driving means. Further, high-speed printing is feasible because the nozzles do not need to be moved.

[0093] In the recording apparatus of the invention, moreover, a large number of nozzles can be arranged not only in the crosswise direction as described above but also in the lengthwise direction to perform simultaneous multi-color printing.

[0094] By the use of the ink-jet recording ink composition and by the arrangement of a large number of nozzles, a

printer having no driving means for moving the nozzles can be manufactured. In the recording apparatus of the invention, however, the nozzles may be moved to perform printing.

[0095] The recording apparatus of the invention has a function of jetting the ink composition from the nozzle upon application of a voltage between the ink jet electrode and the source electrode as described above, and therefore the recording apparatus can be variously modified as far as the apparatus has such a function.

[0096] Especially, the shapes of the nozzle, the ink jet electrode and the source electrode can be variously modified.

[0097] Fig. 6 schematically shows a multi-step electrode which is another embodiment of the ink jet electrode.

[0098] The multi-step electrode shown in Fig. 6 consists of a cylinder and plural unit electrodes which are made of a conductive material and disposed in the cylinder. The unit electrode has a hollow cylindrical body made of, for example, a metal, and the hollow portion serves as an ink flow path. At the tip of the cylindrical body, a protrusion electrically connected to the cylindrical body is provided. Plural unit electrodes having such structure are disposed in series in the cylinder made of an insulating material in such a manner that each protrusion points to the nozzle opening (i.e., downstream side of the ink flow). When a voltage is applied in such a manner that the units electrodes of the multi-step electrode are of high voltage and low voltage alternately, the ink composition of the invention moves toward the nozzle opening at the first unit electrode, that is, a jet flow of the ink composition is produced. This jet flow is accelerated at the next unit electrode. Thus, the jet flow is successively accelerated and finally comes out from the nozzle. For example, if a multi-step electrode having four unit electrodes is arranged at an angle of 30° to the liquid level of the ink composition and if a voltage of 12 kV is applied, the jet distance of the ink composition reaches 200 mm. In case of 15 kV, the jet distance reaches 300 mm. By the arrangement of plural unit electrodes, an ununiform electric field favorable for producing a jet flow of the ink composition can be generated.

[0099] The shape of the unit electrode is not limited to the cylindrical one mentioned above, and the unit electrode may have various shapes such a shape of square flat plate and a shape of circular plate each of which has an ink flow path at the center or thereabout. Also, the protrusion may have various shapes such as a needle shape, a multi-needle shape and a linear shape.

[0100] In the recording apparatus of the invention, plural ink jet electrodes can be so arranged that they together form one ink dot, as shown in Fig. 7. In Fig. 7(A), four ink jet electrodes are arranged correspondingly to the needle electrodes. A voltage can be applied to the ink jet electrodes independently, and one ink dot can be printed by these four ink jet electrodes. The ink jet electrode may be in the shape of a flat plate, as shown in Fig. 7(B). As shown in Fig. 7(C), the source electrode corresponding to the ink jet electrode may consist of plural needles. The source electrode may be a point electrode or a conical electrode manufactured by utilizing printed wiring technique.

[0101] In the recording apparatus, the ink jet means comprises the source electrode (needle electrode) and the ink jet electrode, and the ink composition is pushed (jetted) out from the tip of the ink jet electrode by means of the needle electrode and the ink jet electrode. In the recording apparatus, an ink attraction electrode may be further provided to jet the ink composition more efficiently. If the ink attraction electrode is provided to attract the ink composition jetted from the ink jet electrode, the ink composition can be fed to the recording material more finely and more stably.

[0102] Fig. 8(a) schematically shows a recording system using the ink attraction electrode. Referring to Fig. 8, numeral 71 designates an ink attraction electrode, numeral 73 designates an ink jet electrode, and numeral 75 designates a needle electrode serving as a source electrode.

[0103] In Fig. 8(a), an ink composition 77 comprising the electro-sensitive movable fluid and the colorant is filled in an ink case 79. The ink composition is fed to the ink case 79 from the outside, and no air is present between the needle electrode 75 and the ink jet electrode 73. The needle electrode 75 is in the shape of a needle, and the tip of the needle points to the hole of the ink jet electrode 73. An ununiform electric field is generated in the ink composition present between the needle electrode 75 and the ink jet electrode 73.

[0104] The ink attraction electrode 71 has only to be designed so as to attract the ink composition jetted from the ink jet electrode 73, and the shape of the ink attraction electrode 71 is not specifically limited. However, a plane electrode or a linear electrode is preferable. In Fig. 8(a), a plane ink attraction electrode 71 is shown. The ink attraction electrode 71 is generally arranged on the back surface side of a recording material 81 (paper in Fig 8(a)) on which the ink composition jetted from the ink jet electrode 73 impinges.

[0105] The recording system using the needle electrode 75, the ink jet electrode 73 and the ink attraction electrode 71 includes three types, namely, type A, type B and type C, as shown in Fig. 8(a).

[0106] Voltages applied to the needle electrode 75, the ink jet electrode 73 and the ink attraction electrode 71 are represented by symbols V_S, V_D and V_P, respectively. In the type A, a relation of V_S, $V_P >> V_D$ is formed among the voltages applied to those electrodes, whereby the ink composition is jetted. That is, the ink jet electrode is grounded to make V_D be 0 V, and a direct-current plus voltage (V_S) generating such a potential difference between V_S and V_D as is incapable of jetting the ink composition is applied to the needle electrode. For example, when the plus voltage is in the range of usually +3 kV to +6 kV, preferably +4 kV to +5 kV, the ink composition is not jetted from the ink jet electrode 73. In this state, if the voltage applied to the ink attraction electrode is changed from 0 V (GND) to +4 kV or +5 kV, the ink composition is jetted from the ink jet electrode 73 toward the ink attraction electrode 71. In this recording

system, the voltage V_S applied to the needle electrode and the voltage V_D applied to the ink jet electrode are kept constant, and only the voltage V_P applied to the ink attraction electrode is changed, whereby a relation of V_S, $V_P >> V_D$ is formed among the voltages applied to the three electrodes. The ink composition thus jetted impinges on a recording material (e.g., paper) placed between the ink jet electrode 73 and the ink attraction electrode 71 to perform recording.

[0107] In the type B and the type C, a relation of V_S, $V_P << V_D$ is formed among the voltages applied to the above three electrodes, whereby the ink composition is jetted. In the type C, for example, a direct-current minus voltage (V_S) generating such a potential difference between V_S and V_D as is incapable of jetting the ink composition is applied to the needle electrode. For example, when the minus voltage is in the range of usually -3 kV to -6 kV, preferably -4 kV to -5 kV, the ink composition is not jetted from the ink jet electrode 73. In this state, if the voltage applied to the ink attraction electrode is changed from 0 V (GND) to -4 kV or -5 kV, the ink composition is jetted from the ink jet electrode 73 toward the ink attraction electrode 71. In this recording system, the voltage V_S applied to the needle electrode and the voltage V_D applied to the ink jet electrode are kept constant, and only the voltage V_P applied to the ink attraction electrode is changed, whereby a relation of V_S, $V_P << V_D$ is formed among the voltages applied to the three electrodes. The ink composition thus jetted is received by the recording material placed between the ink jet electrode 73 and the ink attraction electrode 71 to perform recording. In the type B, the voltage V_S applied to the needle electrode is set to 0 V (GND), and a direct-current plus voltage is applied between the needle electrode and the ink jet electrode. For example, when the plus voltage is in the range of usually +3 kV to +6 kV, preferably +4 kV to +5 kV, the ink composition is not jetted from the ink jet electrode 73. In this state, if the voltage applied to the ink attraction electrode is changed from +4 kV or +5 kV to 0 V (GND), the ink composition is jetted from the ink jet electrode 73 toward the ink attraction electrode 71. In this recording system, the voltage V_S applied to the needle electrode and the voltage V_D applied to the ink jet electrode are kept constant, and only the voltage V_P applied to the ink attraction electrode is changed, whereby a relation of V_S, $V_P << V_D$ is formed among the voltages applied to the three electrodes. The ink composition thus jetted is received by the recording material placed between the ink jet electrode 73 and the ink attraction electrode 71 to preform recording.

[0108] By virtue of such a voltage change, switching can be carried out for an extremely short period of time even when a conventional high-voltage circuit such as Cockcroft Walton circuit is used.

[0109] As shown in Fig. 8(b), a flow resistance member 76 may be provided at the hole portion of the ink jet electrode 73. The flow resistance member 76 not only prevents the ink composition, which has been energized by pressure application or the like, from leaking from the tip of the ink jet electrode but also removes dust or the like contained in the ink composition 77 to inhibit clogging of the nozzle. Besides, the flow resistance member 76 prevents drying of the ink composition. The flow resistance member 76 is preferably a filter-like one. Control of the flow rate of the ink composition can be also effected by the flow resistance member 76.

[0110] Owing to the flow resistance member 76, the diameter of a pillar of the jetted ink composition becomes small. When the hole of the ink jet electrode is sufficiently small, enough resistance can be obtained even if the flow resistance member is not especially provided. The feed rate of the ink composition 77 jetted from the ink case 79 is restricted by the resistance, and the pillar of the ink composition is attracted by the external ink attraction electrode 71. Therefore, the pillar of the ink composition naturally becomes fine (slender). Though the pillar of the ink composition is fine, it can be kept by a balance of the jet action and the attraction action. That is, jetting of a fine pillar of the ink composition can be favorably carried out. By virtue of the fine pillar of the ink composition, a minute ink line can be drawn on the recording material. Therefore, the present invention is suitable for precise recording.

[0111] Fig. 8(c) shows another embodiment of the on-demand type ink jet head.

[0112] By the change of the voltages V_S, V_D and V_P applied to the electrodes of the ink-jet recording system shown in Fig. 8(c), on-demand recording can be realized.

[0113] Referring to Fig. 8(c), in the type A, the voltage V_S applied to the needle electrode 75 is changed from a low level to a high level to obtain a relation of V_S, $V_P >> V_D$ for jetting the ink composition. For example, in the type A shown in Fig. 8(c), V_S is changed from GND to V_H, whereby the ink composition is jetted.

[0114] In the type B, the voltage Vs is changed from a high level to a low level to obtain a relation of V_S, $V_P << V_D$ for jetting the ink composition. For example, V_S is changed from V_H to GND as shown in Fig. 8(c), whereby the ink composition is jetted.

[0115] In the type C, the voltage V_S is changed from a high level to a low level to obtain a relation of V_S, $V_P << V_D$ for jetting the ink composition. For example, V_S is changed from GND to $-V_H$ as shown in Fig. 8(c), whereby the ink composition is jetted.

[0116] Referring to Fig. 8(d), in the type A, the voltage V_D applied to the ink jet electrode 73 is changed from a high level to a low level to obtain a relation of V_S, $V_P >> V_D$ for jetting the ink composition. For example, in the type A shown in Fig. 8(d), V_D is changed from V_H to GND, whereby the ink composition is jetted.

[0117] In the type B, the voltage V_D is changed from a low level to a high level to obtain a relation of V_S, $V_P << V_D$ for jetting the ink composition. For example, V_D is changed from GND to V_H as shown in Fig. 8(d), whereby the ink

composition is jetted.

[0118] In the type C, the voltage V_D is changed from a low level to a high level to obtain a relation of V_S, $V_P << V_D$ for jetting the ink composition. For example, V_D is changed from $-V_H$ to GND as shown in Fig. 8(d), whereby the ink composition is jetted.

[0119] Referring to Fig. 8(e), in the type A, the voltage V_p of the ink attraction electrode 71 is changed from a low level to a high level to obtain a relation of V_S, $V_P >> V_D$ for jetting the ink composition. For example, in the type A shown in Fig. 8(e), V_P is changed from GND to V_H, whereby the ink composition is jetted.

[0120] In the type B, the voltage V_P is changed from a high level to a low level to obtain a relation of V_S, $V_P << V_D$ for jetting the ink composition. For example, V_P is changed from V_H to GND as shown in Fig. 8(e), whereby the ink composition is jetted.

[0121] In the type C, the voltage V_P is changed from a high level to a low level to obtain a relation of V_S, $V_P << V_D$ for jetting the ink composition. For example, V_P is changed from GND to $-V_H$ as shown in Fig. 8(e), whereby the ink composition is jetted.

[0122] The voltage change value to jet the ink composition in the above-mentioned system is an absolute value, and is usually 3 kV to 6 kV, preferably 4 kV to 5 kV.

[0123] The above-mentioned relations for jetting the ink composition may be formed as shown in Fig. 9. For example, in the type A, the voltage V_P applied to the ink attraction electrode 71 is set lower than the high voltage V_H by ΔV (ΔV is a value sufficiently smaller than V_H). Likewise, the voltage V_S applied to the needle electrode 75 is set lower than the high voltage V_H by ΔV. That is, each of V_S and V_P is decreased by ΔV to form a relation of V_S, $V_P > V_D$. In order to jet the ink composition, V_D is decreased by ΔV with maintaining V_S and V_P as they are, to form a relation of V_S, $V_P >> V_D$ for jetting the ink composition, whereby the ink composition can be jetted.

[0124] Also in the type B and the type C, a relation of V_S, $V_P < V_D$ is first formed, and then a relation of V_S, $V_P << V_D$ is formed, whereby the ink composition can be jetted.

[0125] In other words, a relation of V_S, $V_P > V_D$ among the voltages applied to the electrodes is first formed in the type A. In this state, the ink composition is not jetted, but at the ink jet electrode 73, the ink composition comes near being jetted. Then, V_D is decreased by ΔV. As a result, a relation of V_S, $V_P >> V_D$ is formed among the applied voltages, and the ink composition is jetted from the ink jet electrode 73. The ΔV value needs only to be considerably smaller than the V_H value, and is for example usually about 1/5 to 1/3 of the V_H value. Specifically, the ΔV value is about 1 kV to 1.2 kV.

[0126] In the type B, the applied voltages before and during jetting of the ink composition are as follows.

Before jetting

[0127]

$$V_P = GND + \Delta V$$

$$V_D = V_H$$

$$V_S = GND + \Delta V$$

During jetting

[0128]

$$V_P = GND + \Delta V \text{ (unchanged)}$$

$$V_D = V_H + \Delta V$$

$$V_S = GND + \Delta V \text{ (unchanged)}$$

[0129] As described above, V_P and V_S are beforehand set higher than GND by ΔV, and in order to jet the ink com-

position, V_D is set higher than the prescribed applied voltage V_H by ΔV, whereby V_S, V_P and V_D satisfy the condition of V_S, $V_P << V_D$ for jetting the ink composition, and the ink composition can be jetted.

[0130] In other words, a relation of V_S, $V_P < V_D$ among the voltages applied to the electrodes is first formed. In this state, the ink composition is not jetted, but at the ink jet electrode 73, the ink composition comes near being jetted. Then, V_D is increased by ΔV. As a result, a relation of V_S, $V_P << V_D$ is formed among the applied voltages, and the ink composition is jetted from the ink jet electrode 73. The meaning of ΔV is the same as described above.

[0131] In the type C, the ink composition can be jetted in the same manner as in the type B except that V_H in the type B is changed to $-V_H$.

[0132] The ΔV value is an absolute value, and is usually 0.8 kV to 1.5 kV, preferably 1 kV to 1.2 kV.

[0133] In the above method, jetting of the ink composition can be controlled by controlling a voltage ΔV of low level. Moreover, since the ink composition has come near being jetted, the ink composition can be jetted by a slight change of ΔV with a good response. That is, according to this method, the response time can be shortened.

[0134] The method described above is a method to jet the ink composition correspondingly to the printing signals. In the present invention, printing can be controlled by continuously jetting the ink composition and changing the jet flow (i.e., by allowing a pillar of the ink composition to reach the recording material such as paper), or by blocking the pillar.

[0135] The pillar of the ink composition is controlled by a gate electrode. As shown in Fig. 10, a voltage is constantly applied to the needle electrode, the ink jet electrode and the ink attraction electrode to continuously form a pillar of the ink composition, while a voltage for printing (printing signal) is applied to the gate electrode 99(a).

[0136] The ink composition 77 is jetted to form a pillar of the composition in the direction of the ink jet electrode 73 to the ink attraction electrode 71 by means of the needle electrode 75, the ink jet electrode 73 and the ink attration electrode 71. Between the ink jet electrode 73 and the ink attraction electrode 71, a baffle 83 is arranged. The baffle is provided with an ink-passing hole 98 at such position that the pillar of the ink composition passes through it when a voltage is applied to the gate electrode 99(a) but the pillar of the ink composition impinges on the baffle so as not to reach the recording material 81 when no voltage is applied to the gate electrode 99(a). The ink-passing hole 98 may be a circular hole as shown in the baffle 83a of Fig. 10(a), or may be a slit as shown in the baffle 83b of Fig. 10(a). The ink composition blocked by the baffle is collected and recycled or discarded.

[0137] When recording is not performed, the pillar of the ink composition formed by continuous jetting impinges on the baffle 83 as indicated by numeral 1 or 3, followed by collecting the ink composition. When recording is performed, the pillar of the ink composition passes through the circular hole or slit 98 as indicated by numeral 2 and reaches the recording material 81.

[0138] In the above cases, application of voltage is carried out in three ways, namely, type A: V_S, $V_P >> V_D$, type B: V_S, $V_P << V_D$, and type C: V_S, $V_P << V_D$, as previously described, and the voltage applied to each electrode is high enough for jetting the ink composition 77.

[0139] To the gate electrode 99, a voltage V_G is applied. The pillar of ink composition passes through the ink jet electrode and is jetted from its tip opening. At this time, the pillar of the ink composition is charged with the same polarity as that of the ink jet electrode. If the gate electrode voltage V_G is brought close to the ink jet electrode voltage V_D, the pillar of the ink composition and the gate electrode repels each other owing to the Coulomb force, and the pillar of the ink composition moves from numeral 1 to numerals 2, 3, as shown in Fig. 10. In this instance, the gate electrode is connected to the ink jet electrode through a switch (SW_1), and the gate electrode voltage V_G is equal to the ink jet electrode voltage V_D.

[0140] If a voltage is applied to such an apparatus as mentioned above to form a pillar of the ink composition, the pillar stands upright in the SW_1-off condition as indicated by numeral 1. Then, if a voltage is applied to the gate electrode, the pillar is changed as indicated by numerals 2, 3. Only the pillar indicated by numeral 2 passes through the circular hole or slit 98 of the baffle 83, then is attracted by the ink attraction electrode 71 and arrives at the recording material 81 to form a dot on the recording material 81. The ink composition, which has been jetted as indicated by numeral 1 or 3 and has not reached the recording material 81, is collected and recycled or discarded.

[0141] By the application of a voltage to the gate electrode, the pillar (jet line) of the ink composition can be changed as indicated by 1→2→3 or 1→2 shown in Fig. 10. After the jet line of the ink composition (sometimes referred to as "ink jet line" hereinafter) is changed as indicated by 1→2→3, the ink jet line returns to the initial position as indicated by 3→2→1 when the gate electrode voltage V_G is decayed. In this recording system, therefore, the ink jet line indicated by numeral 2 is formed twice, and as a result printing is carried out twice.

[0142] Fig. 11 shows a modification of the recording system shown in Fig. 10.

[0143] In Fig. 11, an embodiment wherein the gate electrode is located near the ink attraction electrode is shown. In a preferred embodiment, the gate electrode 99b and the ink attraction electrode 71 may be combined into one body. In Fig. 11, the gate electrode 99b is connected to the ink attraction electrode 71 through a switch SW_2.

[0144] By virtue of the above connection, the difference between the voltage V_G of the gate electrode 99b and the voltage V_D of the ink jet electrode 73 (i.e., voltage of the pillar of the ink composition) becomes large, and the gate

electrode 99b pulls the pillar of the ink composition. As a result, the ink jet line is changed as indicated by 1→2→3. When the switch SW_2 is turned off to apply no voltage to the gate electrode 99b, the ink jet line is changed as indicated by 3→2→1, and the pillar of the ink composition returns to the initial position. Other operations are the same as those described with respect to Fig. 10.

[0145] Fig. 12 shows a modification of the recording system shown in Fig. 11.

[0146] Referring to Fig. 12(a), a baffle 83 and a gate electrode 85 are combined into one body. Though the gate electrode 85 can be connected to an ink jet electrode 73, it is preferable that the gate electrode 85 is connected to an ink attraction electrode 71 through a switch SW_3 as shown in Fig. 12. By the connection between the ink attraction electrode 71 and the gate electrode 85, the ink jet line is changed as indicated by 1→2→3. The ink jet line indicated by numeral 2 passes through a slit 92 and reaches a recording material 81. When the switch SW_3 is turned off, the ink jet line is changed as indicated by 3→2→1.

[0147] Fig. 13 shows an embodiment wherein a baffle 90 and gate electrodes 91a, 91b are combined into one body. As shown in Fig. 13(a), an ink attraction electrode, the baffle and the gate electrode can be combined into one body.

[0148] In Fig. 13, the ink attraction electrode is divided into two parts 91a, 91b each of which is allowed to have a function of a gate electrode.

[0149] When a switch SW_4 is turned off to bring the voltage V_{P1} close to the voltage V_S, the pillar of the ink composition is attracted by the ink attraction electrode 91a and stands upright as indicated by numeral 1. Then, if the switch SW_4 is turned off and if a switch SW_5 is turned on to bring the voltage V_{P2} close to the voltage V_S, the ink jet line is changed as indicated by 1→2→3. The ink jet line indicated by numeral 2 passes through a slit 92 to perform printing (recording) on a recording material 81. In this recording system, since the recording material 81 is arranged on the back side of the ink attraction electrode, the ink composition having passed through the slit 92 is not jetted up so high. Therefore, the recording material 81 should be arranged at the position not so far from the back surface of the ink attraction electrodes 91a, 91b.

[0150] Fig. 24 shows another embodiment of the invention. Referring to Fig. 24, an ink case 79 is provided with a needle electrode 75 and an ink jet electrode 73, and an ununiform electric field is generated in an ink composition 77 filled in the ink case 79. In this embodiment, a baffle 83 having an ink-passing hole 92, a recording material 81 and a pair of ink attraction electrodes 191a, 191b electrically insulated from each other are arranged in this order in the ink jet direction of the ink composition from the tip of the ink jet electrode 73. For example, a switch SW_6 is turned on to apply a plus voltage to the ink attraction electrode 191a, and at the same time, a minus voltage is applied to the ink jet electrode 73. As a result, the ink composition 77 is jetted from the tip of the ink jet electrode 73 toward the ink attraction electrode 191a, but because of the baffle 83 located between the ink jet electrode 73 and the ink attraction electrode 191a, the pillar of the jetted ink composition impinges on the baffle 83 as indicated by numeral 1 and does not reach the recording material 81.

[0151] Then, a switch SW_6 is turned off, and at the same time, a switch SW_7 is turned on to apply a plus voltage to the ink attraction electrode 191b, whereby the pillar of the ink composition is attracted by the ink attraction electrode 191b and moves as indicated by numerals 2, 3. The pillar of the ink composition having passed through a slit 92 reaches the recording material 81 to perform printing on the recording material.

[0152] The needle electrode, the ink jet electrode, the ink attraction electrode, and if desired, the gate electrode and the baffle are provided as described above, and the recording material 81 is moved relatively to the ink jet electrode with applying a voltage to each electrode, whereby the ink composition 77 can be jetted onto the surface the recording material correspondingly to the applied voltage.

[0153] In the recording apparatus of the invention, one or more nozzles (electrode group) having the above structure are arranged to jet the ink composition 77 onto the surface of the recording material 81, and thereby a desired ink pattern is formed.

[0154] Fig. 14 shows an embodiment wherein two ink jet openings 101 are arranged side by side. When the ink composition is jetted from the thus arranged two ink jet openings at the same time, the pillars of the ink composition jetted from the ink jet openings 101 repels each other and deviate outward to form ink jet lines a' and b' each of which is positioned on the outer side as compared with the ink jet line a or b formed when only one ink jet opening is arranged. The deviation of the ink jet line is presumably caused by the Coulomb force.

[0155] In order to correct the deviation of the ink jet line in the recording apparatus of the invention, the ink composition is not jetted from the adjacent nozzles of the nozzles 101a, 101b, 101c and 101d at the same time but jetted from the nozzles with a time log, namely, at the time t_1, t_2, t_3 and t_4. The deviation of the ink jet line is caused by the Coulomb force generated between the ink jet lines, and therefore, as the distance between the ink jet lines becomes wider, the deviation becomes smaller. In general, the deviation rarely takes place if the ink composition is not jetted from the adjacent nozzles at the same time. Accordingly, if the ink composition is jetted from one nozzle at one time as shown in Fig. 15, the deviation of the ink jet line can be inhibited. In order to jet the ink composition from plural nozzles at once, the distance between the nozzles used for jetting is sufficiently widened as shown in Fig. 16. As a result, the ink composition can be jetted from plural nozzles at the same time. In this case, the nozzle distance at which deviation of

the ink jet line does not substantially take place is usually 3 to 6 mm, preferably 4 to 5 mm.

[0156] In Fig. 15 and Fig. 16, nozzles 101a to 101d are arranged one-dimensionally. In Fig. 17, nozzles 101a to 101c, nozzles 102a to 102c and nozzles 103a to 103c are arranged two-dimensionally to widen the distance between the nozzles. That is, the nozzles are arranged in zigzag to form a nozzle line composed of the nozzles 101a to 101c and a nozzle line composed of the nozzles 102a to 102c as shown in the plan view of Fig. 17. In this case, if the nozzles on one line are positioned obliquely by 45° from the nozzles on the next line and if the distance between the adjacent nozzles on one line is expressed by a symbol L, the pitch between the nozzles becomes $L/\sqrt{2}$, and hence printing of higher resolution can be carried out. That is, by the two-dimensional arrangement of nozzles, the nozzle distance can be widened, and therefore deviation of the ink jet line can be reduced even if the recording apparatus has the same resolution.

[0157] As shown in Fig. 18, dummy nozzles can be arranged on the periphery of plural nozzles to reduce deviation of the jet lines of the ink composition jetted from the nozzles positioned between the dummy nozzles. When the dummy nozzles are arranged at the periphery to jet the ink composition, deviation of the ink jet lines (a) and (e) from the dummy nozzles arranged on the outermost side becomes largest. With respect to the ink jet lines (b), (c) and (d) from the nozzles positioned between the dummy nozzles (a) and (e), as the position of the nozzle comes inner, deviation of the jet line becomes smaller. On the inner side of the dummy nozzles (a) and (e), such deviation of the ink jet line as is a trouble in practical use is hardly observed. Accordingly, a recording apparatus substantially free from deviation of ink jet line can be manufactured by effectively arranging dummy electrodes on the periphery of plural nozzles. The dummy nozzles are useful for both of one-dimensional nozzle arrangement and two-dimensional nozzle arrangement.

[0158] The method of using an ink-jet recording ink composition and the recording apparatus according to the invention can be variously modified.

[0159] Though the source electrode is explaind above exemplifying a needle electrode, the source electrode is not limited to the needle electrode, and an electrode of any type is available as far as it can form, together with the ink jet electrode, an ununiform electric field in the ink composition containing the electro-sensitive movable fluid. For example, as shown in Fig. 19, a conductive material electrically insulated from an ink jet electrode 173 is arranged on the bottom of an ink case 179 provided with the ink jet electrode 173 to form a flat plate source electrode 174. The shape, area, etc. of the flat plate electrode can be varied to form various electrodes such as dot electrode, linear electrode, plane electrode and network electrode. By the use of such electrodes, the size of the ink case 179 of the recording apparatus can be made small. A foil, a line and a dot serving as such source electrodes can be formed by utilizing, for example, printed wiring technique. Likewise, the ink jet electrode can be manufactured by utilizing printed wiring technique. Specifically, a through-hole having a trapezoid section is formed in a printed-wiring board, and a conductive film is deposited on the edge portion of the through-hole by means of plating such as electroless plating.

[0160] As shown in Fig. 20, on the periphery of an ink jet electrode 173 provided on the top of an ink case 179, a circularly holed flat plate electrode 180 electrically insulated from the ink jet electrode 173 may be formed to generate an ununiform electric field in an ink composition 177, and thereby the ink composition 177 can be jetted from the tip of the ink jet electrode 173. As shown in Fig. 21, a network electrode 181 may be arranged in an ink case 179 having an ink jet electrode 173 to generate an ununiform electric field in an ink composition 177, and thereby the ink composition 177 can be jetted from the ink jet electrode 173. The ink composition can be jetted without providing any source electrode, as shown in Fig. 22. That is, an ink composition 177 is energized (for example, continuously pressurized) with controlling jetting of the ink composition 177 from the tip of an ink jet electrode 173 by means of a flow resistance member or the like, whereby such condition that the ink composition comes near being jetted by application of a voltage between the source electrode and the ink jet electrode is formed. Then, the potential of the ink attraction electrode is changed, and as a result, the ink composition can be jetted even if no source electrode is provided. Also in case of providing a source electrode, the ink composition can be jetted similarly to the above by applying a low voltage to the source electrode so as to restrict its function or by allowing the source electrode to have no function as an electrode.

[0161] In order to efficiently jet the ink composition in the method and the recording apparatus according to the invention, it is preferable that, with applying a voltage to the source electrode and the ink attraction electrode, a voltage is applied to the ink jet electrode so as to increase a potential difference between the source electrode and the ink jet electrode and between the ink jet electrode and the ink attraction electrode.

[0162] In the present invention, while such a voltage as is incapable of jetting the ink composition in the direction of the ink attraction electrode is applied between the source electrodes and the ink jet electrodes, a voltage corresponding to printing signals may be applied to the ink attraction electrode to jet the ink composition in the direction of the ink attraction electrode. Similarly, while such a voltage as is incapable of jetting the ink composition in the direction of the ink attraction electrode is applied between the source electrodes and the ink jet electrodes, a voltage corresponding to printing signals may be applied to the ink source electrode to jet the ink composition in the direction of the ink attraction electrode.

[0163] In the method and the recording apparatus according to the invention, though the shape of each electrode can be appropriately determined, it is preferable that the ratio between the inner diameter of the tip of the ink jet

electrode and the outer diameter thereof is in the range of 1:1.00 to 1:3.00. In such an ink jet electrode, the ratio between the outer diameter of the tip of the ink jet electrode and the length of a flow path in the ink jet electrode (length of a path provided in the ink jet electrode through which the ink composition flows) is preferably in the range of 1:3 to 1:20. If the ink jet electrode is formed as described above, the ink composition can be more efficiently jetted.

[0164] The present invention is described hereinbefore with reference to the embodiments wherein the ink composition is jetted upward against the gravity. However, a recording apparatus wherein the ink composition is jetted in the horizontal direction (i.e., laterally) or the vertical direction (i.e., downward) can be also manufactured. Though an embodiment that ink jet electrodes are formed in a linear form is only described hereinbefore, the ink jet electrodes may be in the other form, such as a bent-in-right-angle form.

[0165] Further, as shown by Fig. 25, the recording apparatus of the invention may contain the following ink jet means.

[0166] That is, the ink jet means comprises one or plural ink jet electrodes for jetting the ink composition, and at least one pair of ink attraction electrodes which are electrically insulated from the ink jet electrodes and arranged in the jet direction of the ink composition, and at least one through-hole through which the ink composition jetted from the ink jet electrodes toward the ink attraction electrodes passes may be provided to the ink attraction electrodes. The ink composition is allowed to pass through the through-hole of the ink attraction electrodes to reach a recording material, so that printing is performed correspondinly to printing signals. In the above recording apparatus the ink jet electrodes are preferably provided on the side wall or the bottom of ink-keeping unit disposed in the ink jet means. In this case the ink composition is jetted in a horizontal or downward direction from the ink jet electrodes. In the above system of the recording apparatus, no source electrode is needed as a liquid pressure is produced. In general, the voltage of -0.5 kV is applied to the ink attraction electrodes, and the voltage at the nozzle electrode turns to 0V. When jetting the ink composition, the voltage of +1.4 kV is applied to the nozzle electrodes, so that the ink composition may be jetted.

[0167] The action occurring between the source electrode and the ink jet electrode, namely, ink jet action, can be brought about by utilizing gravity or by externally applying a pressure to the ink composition. In the horizontal jet action, a hydraulic pressure of the ink composition depending on the position of the nozzle in the ink tank can be utilized as a part of the jet power. The vertical jet action of the ink composition can be brought about by utilizing a pressure given by pressurizing a closed ink tank.

[0168] The jet action of the ink composition can be brought about without using application of a voltage between the source electrode and the ink jet electrode, as previously described. In detail, the jet power is beforehand controlled so that the ink composition comes near being jetted from the nozzle tip (and that leakage is prevented), and a voltage is applied between the ink jet electrode and the ink attraction electrode to jet the ink composition toward the ink attraction electrode. In this method, the source electrode is unnecessary, and hence high effect in the manufacturing cost is obtained. However, this method is occasionally unsuitable for a system wherein the ink jet properties are precisely controlled based on each nozzle.

[0169] As a matter of course, use of the source electrode and use of gravity of the ink composition itself or external force given by pressurizing the ink tank may be combined to bring about the ink jet action. In this combination type, the voltage applied to the source electrode can be reduced correspondingly to the external force used, and besides the ink jet properties of each nozzle can be controlled by adjusting the source electrode. As a result, the voltage applied to the source electrode can be lowered, and the switching control can be easily made.

EFFECT OF THE INVENTION

[0170] The ink-jet recording ink composition employable in the invention comprises an electro-sensitive movable fluid, which is capable of producing a jet flow upon application of a voltage, and a colorant dissolved or dispersed in the fluid. This ink composition can be jetted from a nozzle by applying a voltage to the composition. In the present invention, therefore, heating of the ink composition as in the bubble jet system is unnecessary, and consumption of high electric power as in the ink jet system using piezo element is unnecessary.

[0171] The ink composition for use in the invention utilizes such properties of the electro-sensitive movable fluid that a jet flow of the fluid is produced upon application of a voltage to the fluid. The ink composition generates no heat even when a voltage is applied, and the electrical energy required for jetting the ink composition is extremely small. Therefore, a printer using the ink composition has the following advantages. A large number of nozzles can be arranged because a pump chamber is unnecessary. Differently from the conventional ink jet printers, the nozzles do not need to be moved, and driving means for moving the nozzles is unnecessary. Therefore, a high-speed and low-noise printer can be provided. Even when a large number of nozzles are arranged, the electric power consumed by each nozzle is extremely low, and hence the electrical energy consumed by the whole printer becomes conspicuously small. The recording apparatus of the invention can be easily miniaturized because nozzles do not need to be moved.

[0172] In the recording apparatus, further, application of pressure to the ink composition is not always necessary differently from the bubble jet recording apparatus or the recording apparatus using piezo element. Therefore, no pump chamber needs to be provided, and the structure in the vicinity of the nozzles become extremely simple, so that the

recording apparatus of the invention is suitable as a large-sized recording apparatus. Moreover, the ink composition can be stably supplied for a long period of time because it is unnecessary to connect the apparatus to the ink tank by a capillary tube.

[0173] In the method of the invention, the ink composition can be continuously jetted by continuously applying a voltage to the electrodes. In the method of the invention, further, digital control of the applied voltage is not always necessary. Even when the applied voltage is analogically controlled, the ink composition can be jetted correspondingly to the applied voltage, and fine printing is feasible.

[0174] In the method of the invention, an ink attraction electrode may be provided in addition to the ink jet electrode and the source electrode. In this case, the ink composition can be jetted toward the ink attraction electrode by beforehand applying a prescribed voltage to the ink jet electrode and to the source electrode and then merely changing the voltage applied to the ink attraction electrode. The voltage applied to the ink attraction electrode serves as a voltage to control jetting of the ink composition. In the method and the recording apparatus according to the invention, a high voltage is required as a whole to jet the ink composition. For example, it is difficult to perform instantaneous switching at a direct-current-voltage of 5 kV order. However, the ink composition can be efficiently jetted by beforehand applying a voltage of such a low level that the ink composition is not jetted to the ink attraction electrode and to the source electrode and then applying a relatively low voltage to the ink jet electrode. According to this method, the voltage required for switching is relatively low, though the applied voltage is high as a whole. Therefore, a recording apparatus having an extremely simple structure and easy controllability can be provided by modifying a commercially available switching element.

EXAMPLE

[0175] The present invention is further described with reference to the following examples, but it should be construed that the invention is in no way limited to those examples.

Example 1

[0176] A copper foil was adhesion bonded to a phenolic plate having a thickness of 1.5 mm, and a conductive metal having a height of 1.7 mm was fusion bonded to the copper foil, as shown in Fig. 1. The phenolic plate had a tapered through-hole (bottom diameter: 3.0 mm, top diameter: 1.5 mm), and each of the copper foil and the conductive metal had a hole (diameter: 1.5 mm) serving as a jet guide and a nozzle-like electrode. In the above bonding, these three holes were connected to each other to form a nozzle.

[0177] Then, a needle electrode (diameter: 0.9 mm) was arranged near the bottom end of the tapered through-hole of the phenolic plate in such a manner that the tip of the needle electrode entered the tapered through-hole by 0.6 mm and that the needle electrode was not in contact with the phenolic plate.

[0178] Separately, 99.97 % by weight of dibutyl decanedioate (DBD) was mixed with 0.03 % by weight of a red dye (Kayaset Red D, available from Nippon Kayaku Co., Ltd.) to dissolve the red dye in dibutyl decanedioate. Thus, an ink-jet recording red ink composition was prepared. The dibutyl decanedioate had a conductivity of 1.40×10^{-9} S/m and a viscosity of 7.0×10^{-3} Pa·s at 25 °C.

[0179] The above-obtained nozzle equipped with an electrode was arranged on the liquid level of the ink-jet recording red ink composition at an inclination of 20° to the liquid level of the ink composition.

[0180] The needle electrode and the nozzle-like electrode were set as a positive electrode and a negative electrode, respectively, and a voltage of 6 to 12 kV shown in Table 3 was applied between the needle electrode and the nozzle-like electrode to measure a jet height of the ink composition comprising dibutyl decanedioate and the red dye. The current in the ink composition was also measured.

[0181] The results are set forth in Table 3.

[0182] In the examples, the viscosity and the conductivity (electrical resistance) of the electro-sensitive movable fluid were measured in the following manner by the use of a rheometer (Rheo-Stress RS100, manufactured by HAAKE Co.). The compound (electro-sensitive movable fluid) was interposed between two discs (diameter: 3.5 cm), and a direct-current-voltage of 2 kV was applied to measure a conductivity (S/m at 2 kV/mm) of the compound. Then, one of the discs was rotated to measure a viscosity of the compound. The temperature in the measurements was 25 °C, unless otherwise noted.

Table 3

Voltage (kV)	6.0	7.0	9.0	10.5	12.0
Jet height (mm)	7	15	27	37	48

Table 3 (continued)

Current (μA)	4.7	7.5	10.0	14.0	18.0

Example 2

[0183] An ink-jet recording ink composition was prepared in the same manner as in Example 1, except that dibutyl dodecanedioate having a branched chain (Bu-OCO-$(CH_2)_5$-CH(Bu)-COO-Bu, abbreviated to "DBDD" hereinafter) was used in place of DBD. Then, the jet height and the current were measured in the same manner as in Example 1, except that the above-prepared ink composition was used. The DBDD had a conductivity of 5.2 x 10^{-9} S/m and a viscosity of 9.3 × 10^{-3} Pa·s at 25 °C. The results are set forth in Table 4.

Table 4

Voltage (kV)	6.0	7.0	9.0	10.5	12.0
Jet height (mm)	7	17	30	41	53
Current (μA)	5.0	8.2	12.0	16.0	19.0

Example 3

[0184] An ink-jet recording ink composition was prepared in the same manner as in Example 1, except that linalyl acetate was used in place of DBD. Then, the jet height and the current were measured in the same manner as in Example 1, except that the above-prepared ink composition was used, the diameters of the holes (top diameter of the tapered through-hole of the phenolic plate, diameters of the holes of the copper foil and the conductive metal) were changed to 0.5 mm, and the applied voltage was changed in the range of 4 and 12 kV. The linalyl acetate had a conductivity of 1.82 × 10^{-9} S/m and a viscosity of 1.3 × 10^{-3} Pa·s at 25 °C. The results are set forth in Table 5.

Table 5

Voltage (kV)	4.0	6.0	7.5	9.0	10.5	12.0
Jet height (mm)	3	5	10	13	15	20
Current (μm)	0.7	2.0	2.9	4.5	6.8	7.8

Example 4

[0185] An ink-jet recording white ink composition was prepared in the same manner as in Example 1, except that 2.0 % by weight of a titanium oxide powder as a white pigment was homogeneously dispersed in 98 % by weight of DBD. Then, the jet height and the current were measured in the same manner as in Example 1, except that the above-prepared ink composition was used. The results are set forth in Table 6.

Table 6

Voltage (kV)	6.0	7.0	9.0	10.5	12.0
Jet height (mm)	6	12	25	40	49
Current (μA)	5.0	8.2	11	16	22

Example 5

[0186] An ink-jet recording blue ink composition was prepared in the same manner as in Example 1, except that 1.0 % by weight of phthalocyanine blue as a blue pigment and 0.04 % by weight of 2,2'-dihydroxy-4-methoxybenzophenone were homogeneously dispersed in 98.96 % by weight of DBD. Then, the jet height and the current were measured in the same manner as in Example 1, except that the above-prepared ink composition was used in place of the red ink composition. The results are set forth in Table 7.

Table 7

Voltage (kV)	6.0	7.0	9.0	10.5	12.0

Table 7 (continued)

Jet height (mm)	5	10	19	35	42
Current (μA)	6.4	8.7	12	15	19

Example 6

[0187] An ink-jet recording blue ink composition was prepared in the same manner as in Example 1, except that 1.0 % by weight of phthalocyanine blue as a blue pigment and 0.04 % by weight of 2,2'-dihydroxy-4-methoxybenzophenone were homogeneously dissolved in 98.96 % by weight of linalyl acetate. Then, the jet height and the current were measured in the same manner as in Example 1, except that the above-prepared blue ink composition was used in place of the red ink composition using DBD, the diameters of the holes (top diameter of the tapered through-hole of the phenolic plate, diameters of the holes of the copper foil and the conductive metal) were changed to 0.5 mm, and the applied voltage was changed in the range of 4 and 12 kV. The results are set forth in Table 8.

Table 8

Voltage (kV)	4.0	6.0	7.5	9.0	10.5	12.0
Jet height (mm)	4	7	11	13	16	22
Current (μm)	1.0	2.3	3.0	5.5	7.2	8.2

Example 7

[0188] A copper foil was adhesion bonded to a phenolic plate having a thickness of 1.5 mm, and a conductive metal having a height of 1.7 mm was fusion bonded to the copper foil, as shown in Fig. 3. The phenolic plate had a tapered through-hole (bottom diameter: 3.0 mm, top diameter: 1.5 mm), and each of the copper foil and the conductive metal had a hole (diameter: 1.5 mm) serving as a jet guide and a nozzle-like electrode. In the above bonding, these three holes were connected to each other to form a nozzle.

[0189] Then, a linear electrode (diameter: 0.2 mm) was placed below the phenolic plate and along the bottom diameter of the tapered through-hole of the phenolic plate. This linear electrode was set as a positive electrode.

[0190] Separately, an ink-jet recording red ink composition was prepared in the same manner as in Example 1.

[0191] The above-obtained nozzle equipped with an electrode was arranged on the liquid level of the ink-jet recording red ink composition at an inclination of 20° to the liquid level of the ink composition.

[0192] The linear electrode and the nozzle-like electrode were set as a positive electrode and a negative electrode, respectively, and a voltage of 6 to 12 kV shown in Table 9 was applied between the linear electrode and the nozzle-like electrode to measure a jet height of the ink composition comprising dibutyl decanedioate and the red dye. The current in the ink composition was also measured.

[0193] The results are set forth in Table 9.

Table 9

Voltaqe (kV)	6.0	7.0	9.0	10.5	12.0
Jet height (mm)	3	9	25	32	40
Current (μA)	3.0	5.8	7.2	10	13

Example 8

[0194] The jet height of the ink composition and the current in the ink composition were measured in the same manner as in Example 1, except that the needle electrode and the nozzle-like electrode were set as a negative electrode and a positive electrode, respectively.

[0195] The results are set forth in Table 10.

Table 10

Voltage (kV)	6.0	7.0	9.0	10.5	12.0
Jet height (mm)	2	7	23	30	38

Table 10 (continued)

Current (μA)	3.0	7.2	9.7	13	18

Example 9

[0196] The jet height of the ink composition and the current in the ink composition were measured in the same manner as in Example 1, except that a multi-step electrode shown in Fig. 6 was used as the electrode. The multi-step electrode had four unit electrodes, and each of the unit electrodes had a cylindrical body (length: 10 mm, inner diameter: 3 mm) and a protrusion (length: 5 mm). The distance between the tip of the protrusion and the lower end of the next unit electrode was 1.5 mm.

[0197] The results are set forth in Table 11.

Table 11

Voltage (kV)	6.0	7.0	9.0	10.5	12.0
Jet height (mm)	10	21	41	53	71
Current (μA)	11	18	28	36	19

Example 10

[0198] To 97 g of dibutyl decanedioate, 3.0 g of a black dye (Kayaset Black 151-H, available from Nippon Kayaku Co., Ltd.) was introduced, and the mixture was sufficiently stirred and filtered to obtain a filtrate as a black ink composition. The black ink composition had a conductivity a of 3.0×10^{-9} S/m and a viscosity η of 8×10^{-3} Pa·s at 2 kV/mm and 25 °C.

[0199] Then, a needle electrode and an ink jet electrode were immersed in the black ink composition, and an ink attraction electrode was arranged above the ink jet electrode, as shown in Fig. 23. The distance between the ink jet electrode and the ink attraction electrode was 10 mm, and the diameter of the nozzle tip of the ink jet electrode was 0.6 mm. The ink jet electrode was in the form of a cylinder having a diameter of 0.6 mm and a length of 10 mm. The distance between the tip of the needle electrode and the bottom of the ink jet electrode was 2 mm.

[0200] In the following two cases, a voltage required for jetting the black ink composition was measured.

Case A: The ink attraction electrode, the ink jet electrode and the needle electrode were set as a positive electrode, a negative electrode and a positive electrode, respectively, and a direct-current-voltage was applied to each electrode. Then, a voltage required for intermittently jetting the black ink composition and a voltage required for continuously jetting the black ink composition were measured.

Case B: The ink attraction electrode, the ink jet electrode and the needle electrode were set as a negative electrode, a positive electrode and a negative electrode, respectively, and a direct-current-voltage was applied to each electrode. Then, a voltage required for intermittently jetting the black ink composition and a voltage required for continuously jetting the black ink composition were measured.

[0201] The results are set forth in Table 12.

Table 12

	Case A	Case B
Voltage required for intermittent jetting	5.5 kV	5.5 kV
Voltage required for continuous jetting	6.5 kV	7.0 kV

Claims

1. A recording apparatus of printing mechanism, including one or more ink jet means having a hole through which an ink-jet recording ink composition can be jetted corresponding to printing signals,

   wherein the ink jet means comprises one or more ink jet electrodes and one or more source electrodes which are provided in the vicinity of bottom ends of the ink jet electrodes and are electrically insulated from the ink

jet electrodes; and the ink composition can be jetted from tips of the ink jet electrodes by applying a voltage between the ink jet electrodes and the source electrodes,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

2. A recording apparatus of printing mechanism, including an ink jet means having a hole through which an ink-jet recording ink composition can be jetted corresponding to printing signals,

wherein in use the ink-jet recording ink composition is fed to the ink jet means; the ink jet means comprises one or more ink jet electrodes for jetting the ink composition and an ink attraction electrode for attracting the ink composition jetted from the ink jet electrodes, said ink attraction electrode being arranged in the vicinity of the arrival point of the jetted ink composition; and in use the ink composition is jetted from tips of the ink jet electrodes toward the ink attraction electrode by applying a voltage between the ink jet electrodes and the ink attraction electrode,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid and being energized so that it can be jetted from the ink jet electrodes.

3. The recording apparatus as claimed in claim 2, wherein one or more source electrodes are provided in the vicinity of bottom ends of a part of the ink jet electrodes, said source electrodes being electrically insulated from the ink jet electrodes.

4. A recording apparatus of printing mechanism, comprising an ink jet means having a hole through which an ink-jet recording ink composition can be jetted corresponding to printing signals,

wherein in use the ink-jet recording ink composition is fed to the ink jet means; the ink jet means comprises one or more ink jet electrodes for jetting the ink composition, one or more source electrodes which are provided in the vicinity of bottom ends of the ink jet electrodes and are electrically insulated from the ink jet electrodes, and an ink attraction electrode for attracting the ink composition jetted from the ink jet electrodes, said ink attraction electrode being arranged in the vicinity of the arrival point of the jetted ink composition; and in use the ink composition is jetted from tips of the ink jet electrodes toward the ink attraction electrode by applying a voltage between the source electrodes and the ink jet electrode and between the ink attraction electrode and the ink jet electrodes,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

5. A recording apparatus of printing mechanism as claimed in claim 4, further comprising at least one pair of ink attraction electrodes which are electrically insulated from each other and arranged in the jet direction of the ink composition, and a baffle which has an ink-passing hole and is provided between the ink jet electrodes and the ink attraction electrodes; in use the ink composition is continuously jetted from tips of the ink jet electrodes toward the baffle by applying a voltage between the ink jet electrodes and the source electrodes and between the ink jet electrodes and one of the ink attraction electrodes; and the ink composition is allowed to pass through the ink-passing hole of the baffle to reach a recording material by stopping power supply to the voltage-applied ink attraction electrode and simultaneously applying a voltage to the other ink attraction electrode, to thereby change the direction of the jetted ink compositions.

6. A recording apparatus of printing mechanism, including an ink jet means having a hole through which an ink-jet recording ink composition can be jetted corresponding to printing signals,

wherein the ink-jet recording ink composition is fed to the ink jet means; the ink jet means comprises one or more ink jet electrodes for jetting the ink composition, and at least one pair of ink attraction electrodes which are electrically insulated from the ink jet electrodes and arranged in the jet direction of the ink composition; and at least one through-hole through which the ink composition jetted from the ink jet electrodes toward the ink attraction electrodes passes is provided to the ink attraction electrodes; and the ink composition is allowed to pass through the through-hole of the ink attraction electrodes to reach a recording material,
said ink-jet recording ink composition comprising an electro-sensitive movable fluid and a colorant dissolved or dispersed in the fluid.

7. A recording apparatus of printing mechanism as claimed in claim 4, further comprising a gate electrode provided

between the ink jet electrode and the ink attraction electrode; wherein the ink composition is jetted in use from tips of the ink jet electrodes toward the ink attraction electrode by applying a voltage between the ink jet electrodes and the source electrodes and between the ink jet electrodes and the ink attraction electrode, with a controlling voltage applied to the gate electrode, thereby controlling the direction of the jetted ink composition.

8. The recording apparatus as claimed in claim 7, wherein a baffle with an ink-passing hole is provided between the gate electrode and the ink attraction electrode.

9. The recording apparatus as claimed in claim 7 or 8, wherein the gate electrode and the baffle with an ink-passing hole are combined into one body.

10. The recording apparatus as claimed in claim 9, wherein the gate electrode and the baffle with an ink-passing-hole are combined into one body, the gate electrode comprises a pair of electrodes insulated from each other by a boundary of the ink-passing hole, and the gate electrode serves also as the ink attraction electrode.

11. The recording apparatus as claimed in any preceding claim, wherein the source electrode, where provided, is at least one of an electrode selected from the group consisting of a linear electrode, a flat plate electrode, a needle electrode and a circularly holed flat plate electrode.

12. The recording apparatus as claimed in any preceding claim, wherein the ratio between an inner diameter of the tip of the ink jet electrode and an outer diameter thereof is in the range of 1:1 to 1:3, and the ratio between an outer diameter of the tip of the ink jet electrode and a length of a flow path of the ink jet electrode is in the range of 1:3 to 1:20.

13. The recording apparatus as claimed in any preceding claim, wherein the ink-jet recording ink composition is pressurized.

14. The recording apparatus as claimed in any preceding claim, wherein no source electrode is provided or the source electrodes do not function as electrodes, and the ink-jet recording ink composition is energized or pressurized with controlling a flow rate of the ink composition and leakage thereof by a flow resistance member.

15. The recording apparatus as claimed in any preceding claim, wherein the peripheral electrodes from among the plural ink jet electrodes are dummy electrodes, and a voltage can be applied to the dummy electrodes to correct the direction of the jetted ink composition.

16. The recording apparatus as claimed in any preceding claim, wherein the ink jet electrodes are arranged in plural lines so that the plural ink jet electrodes in one line and the plural ink jet electrodes in the next line together take a zigzag configuration.

17. The recording apparatus as claimed in any of claims 3-16, wherein a voltage is applied in use to the ink jet electrodes with applying a voltage to the source electrodes and the ink attraction electrode so as to increase potential difference between the ink jet electrodes and the source electrodes and between the ink jet electrodes and the ink attraction electrode.

18. The recording apparatus as claimed in any of claims 3-17, wherein while such a voltage as is incapable of jetting the ink composition in the direction of the ink attraction electrode is applied between the source electrodes and the ink jet electrodes, a voltage corresponding to printing signals is applied to the ink attraction electrode to jet the ink composition in the direction of the ink attraction electrode.

19. The recording apparatus as claimed in any of claims 3-17, wherein while such a voltage as is incapable of jetting the ink composition in the direction of the ink attraction electrode is applied between the source electrodes and the ink jet electrodes, a voltage corresponding to printing signals is applied to the ink source electrode to jet the ink composition in the direction of the ink attraction electrode.

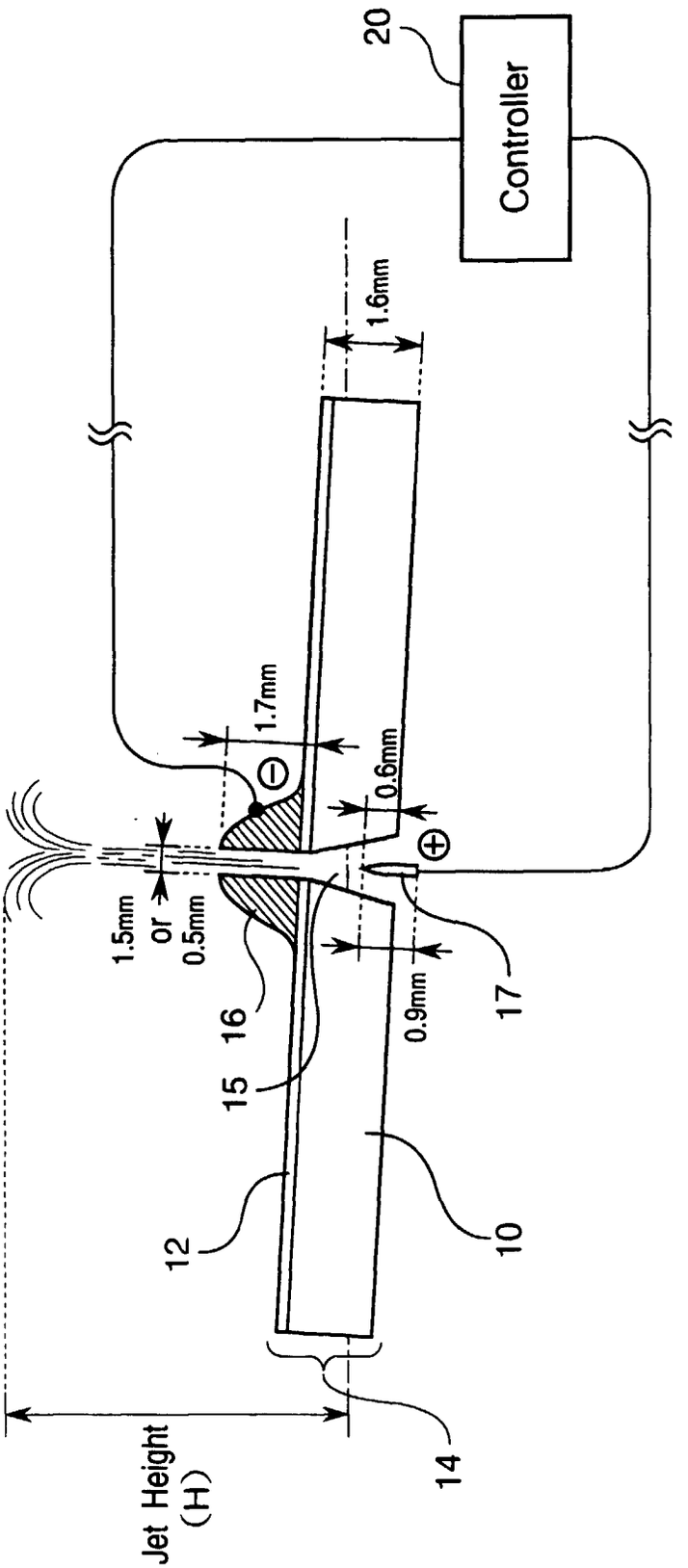
20. The recording apparatus as claimed in any preceding claim, wherein the ink jet electrode is a multi-step electrode comprising plural unit electrodes each having an ink flow path and a protrusion which is positioned at the tip of the ink flow path and is electrically connected to the periphery of the ink flow path, said plural unit electrodes being disposed in series in such a manner that each protrusion points upstream and is close to the ink flow path of the

next unit electrode but not in contact with the next unit electrode, said multi-step electrode being designed so that a high voltage and a low voltage can be applied to the plural unit electrodes alternately.

21. The recording apparatus as claimed in any preceding claim, wherein the ink jet electrodes are provided on the side wall or the bottom of ink-keeping unit disposed in the ink jet means, and wherein the ink composition is jetted in a horizontal or downward direction from the ink jet electrodes.

22. The recording apparatus as claimed in any preceding claim 36, wherein the electro-sensitive movable fluid comprises a compound having a conductivity σ and a viscosity η located on or inside a triangle in a graph showing a relation between a conductivity σ, plotted as abscissa, and a viscosity η, plotted as ordinate, of a fluid at the working temperature and the working pressure, said triangle having, as vertices, a point P indicated by the conductivity $\sigma = 4 \times 10^{-10}$ S/m and the viscosity $\eta = 1 \times 10^{0}$ Pa.s, a point Q indicated by the conductivity a = 4×10^{-10} S/m and the viscosity $\eta = 1 \times 10^{-4}$ Pa.s, and a point R indicated by the conductivity σ = 5 x 10-6 S/m and the viscosity η = 1×10^{-4} Pa.s, or comprises a mixture of two or more compounds, said mixture being adjusted to have a conductivity a and a viscosity η located on or inside said triangle.

Fig. 1


20
Controller
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1.7mm
0.6mm
1.5mm
or
0.5mm
0.9mm
16
15
17
12
10
14
Jet Height
(H)

Fig. 2

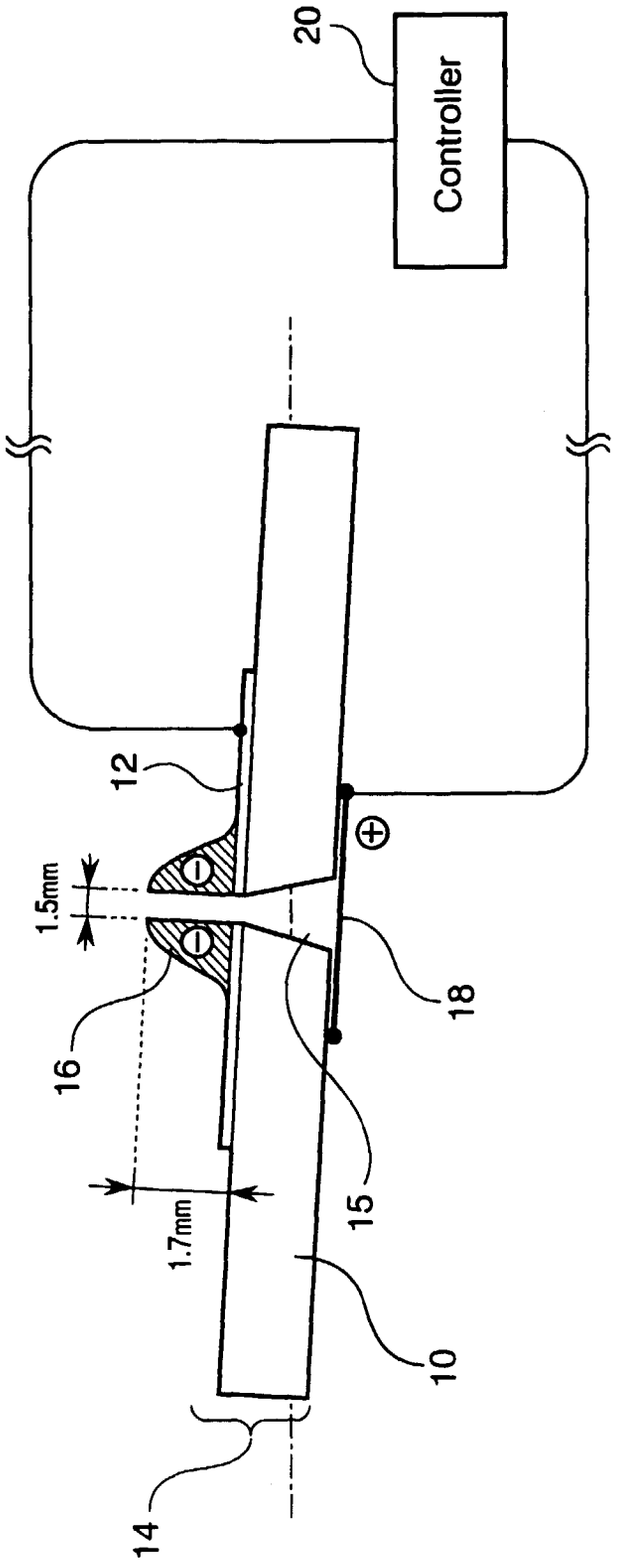
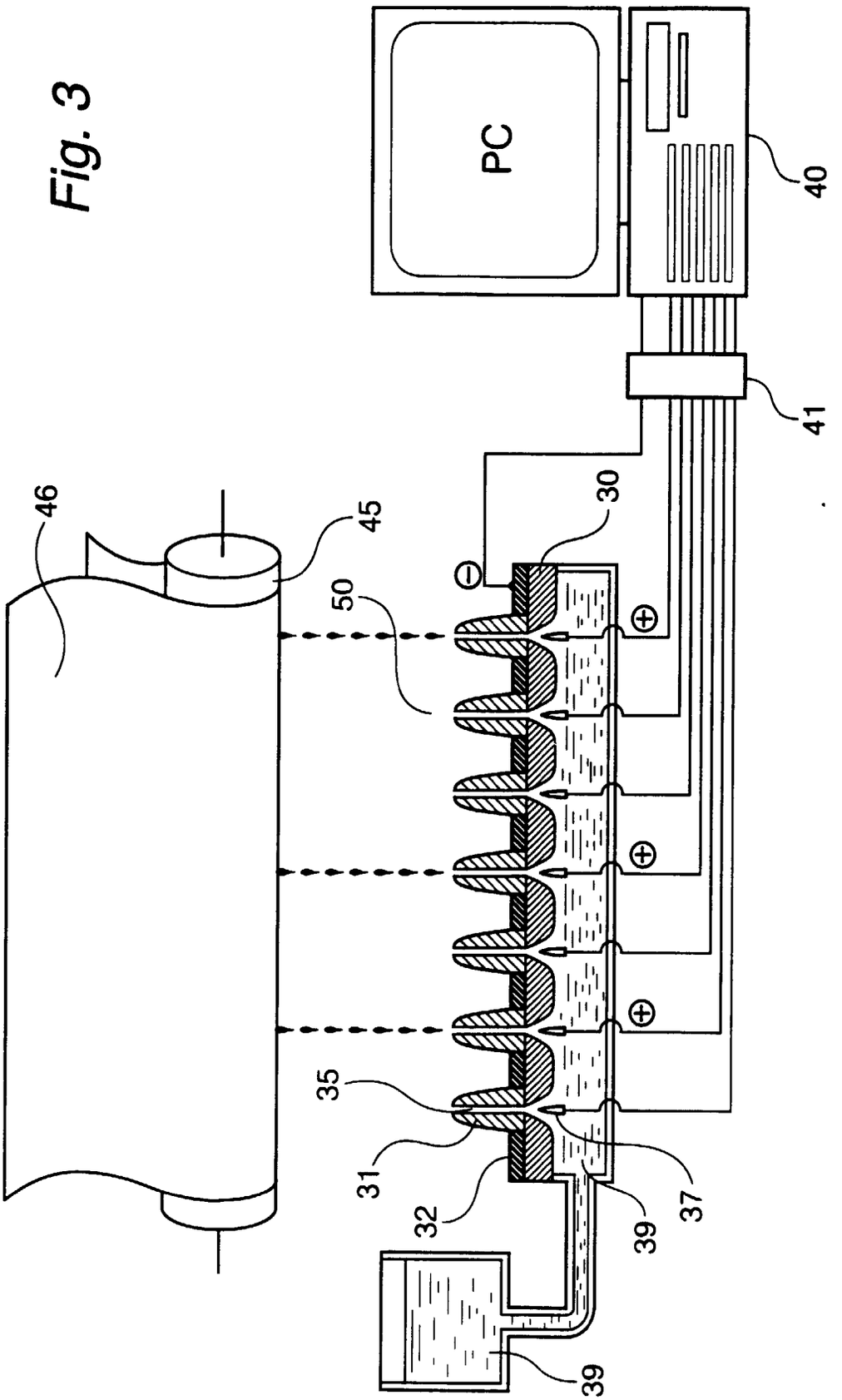
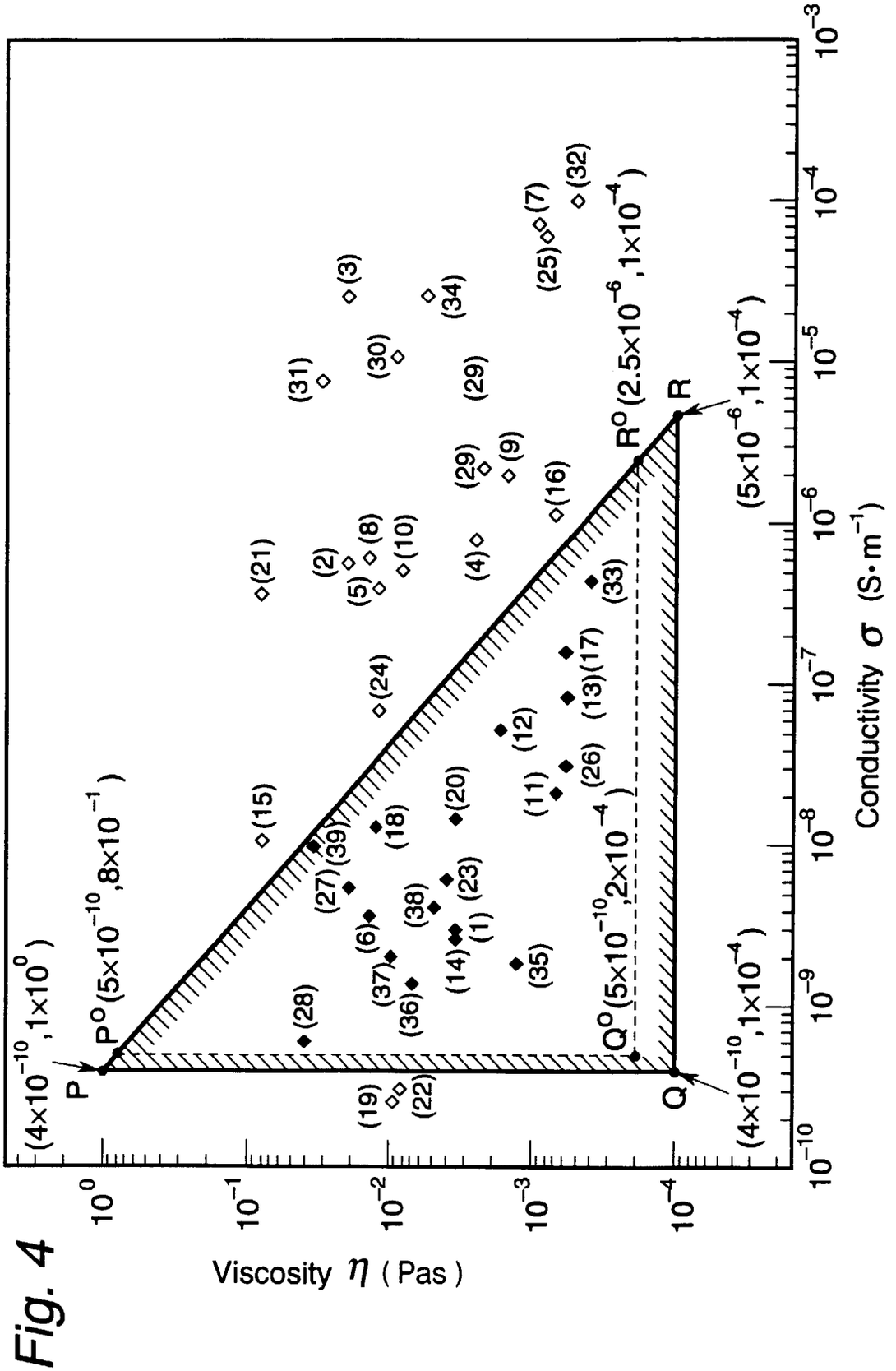


Fig. 3

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$(4\times10^{-10},1\times10^{-4})$
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$(5\times10^{-6},1\times10^{-4})$
Viscosity η (Pas)
Conductivity σ $(S\cdot m^{-1})$
10^{0} 10^{-1} 10^{-2} 10^{-3} 10^{-4}
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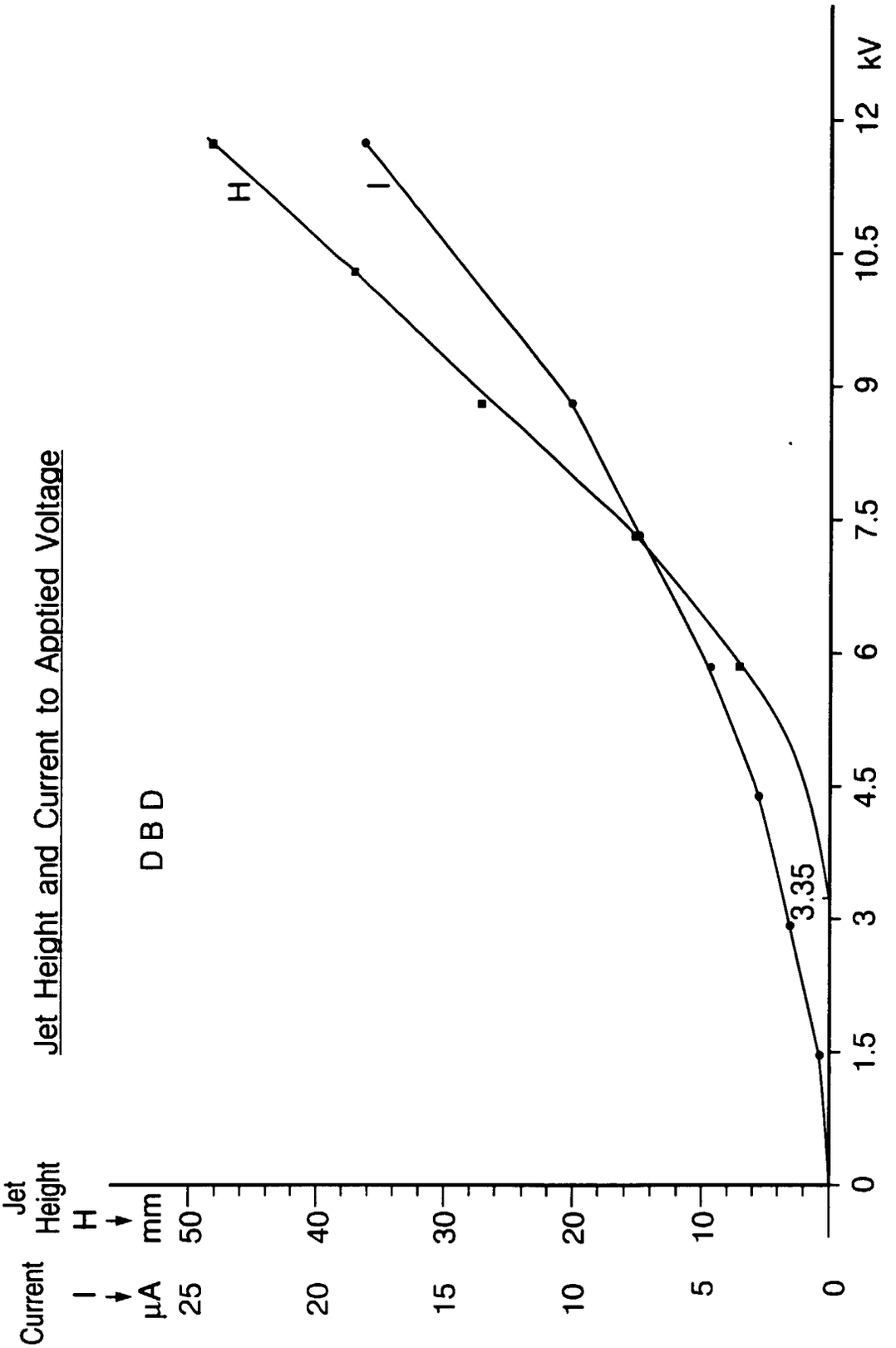
Fig. 4

Fig. 5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15
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5
0
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40
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20
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kV

Fig. 6

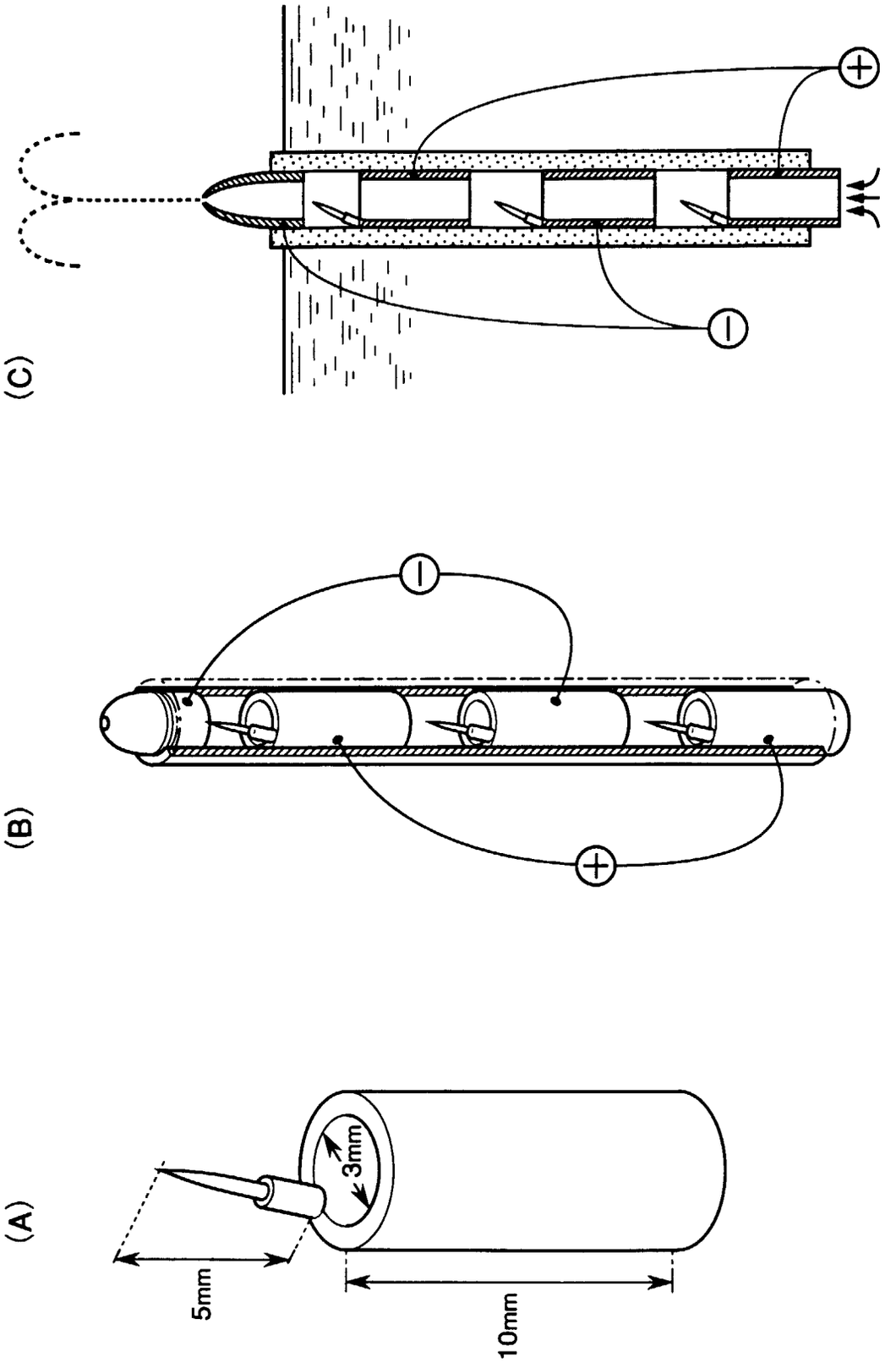


Fig. 7

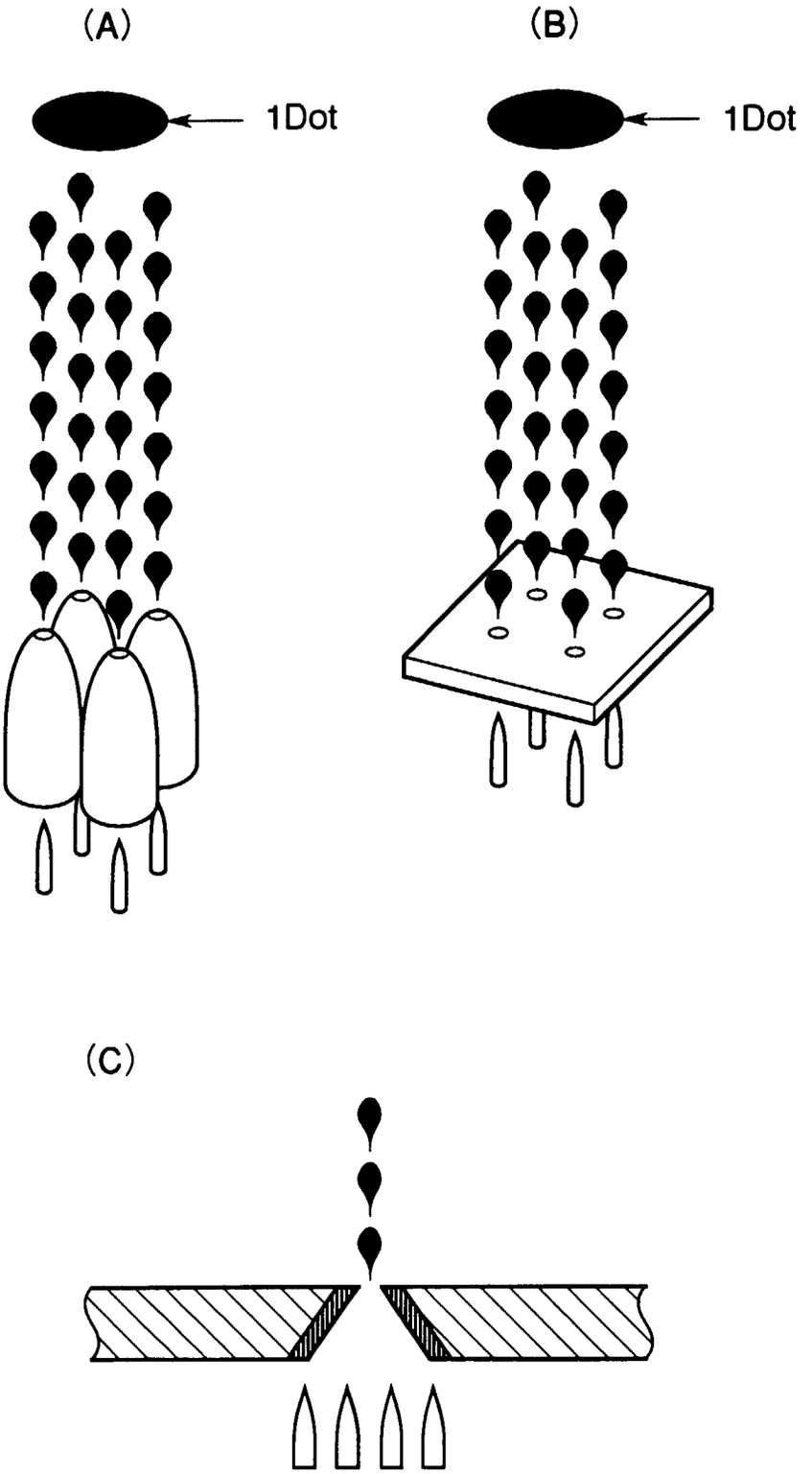
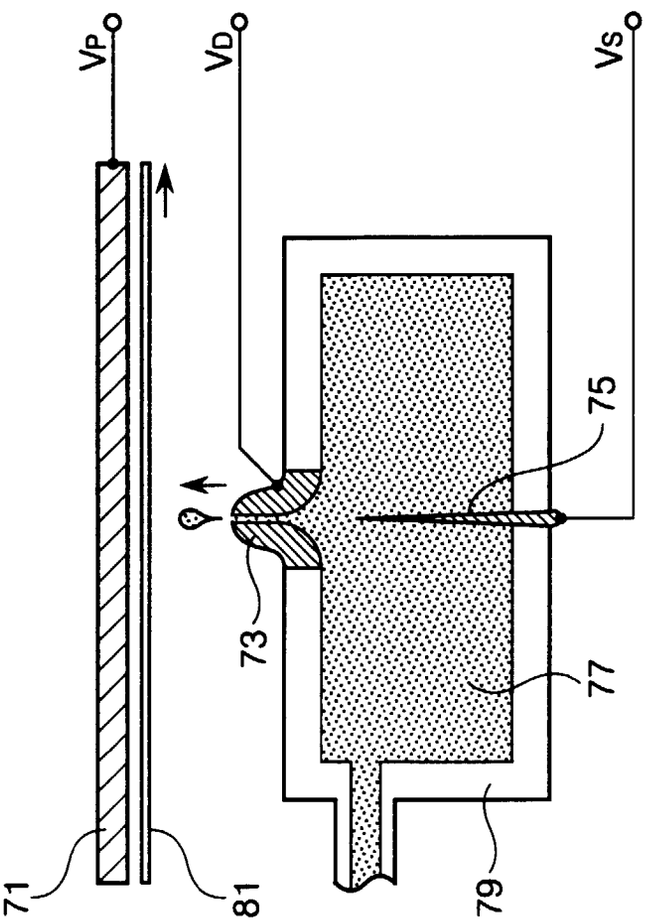


Fig. 8 (a)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GND
VH
Type B
(VS, VP << VD)
VH → GND
VH
GND
Type C
(VS, VP << VD)
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−VH
VP
VD
VS
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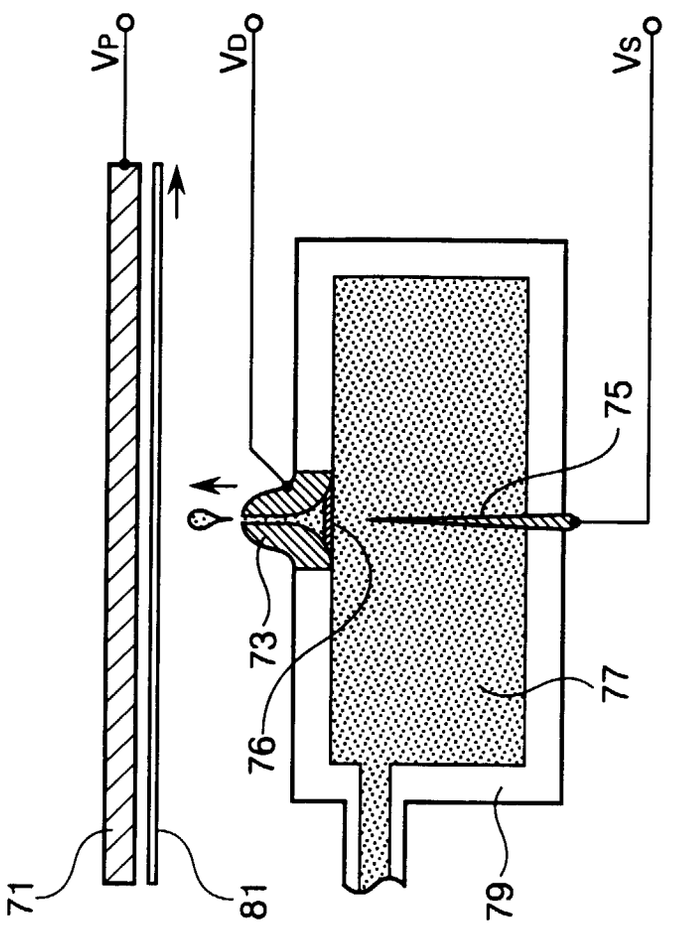
81
73
75
77
79

Fig. 8 (b)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VH→GND
VH
GND
Type C
(VS,VP<< VD)
GND→-VH
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-VH
VP
VD
VS
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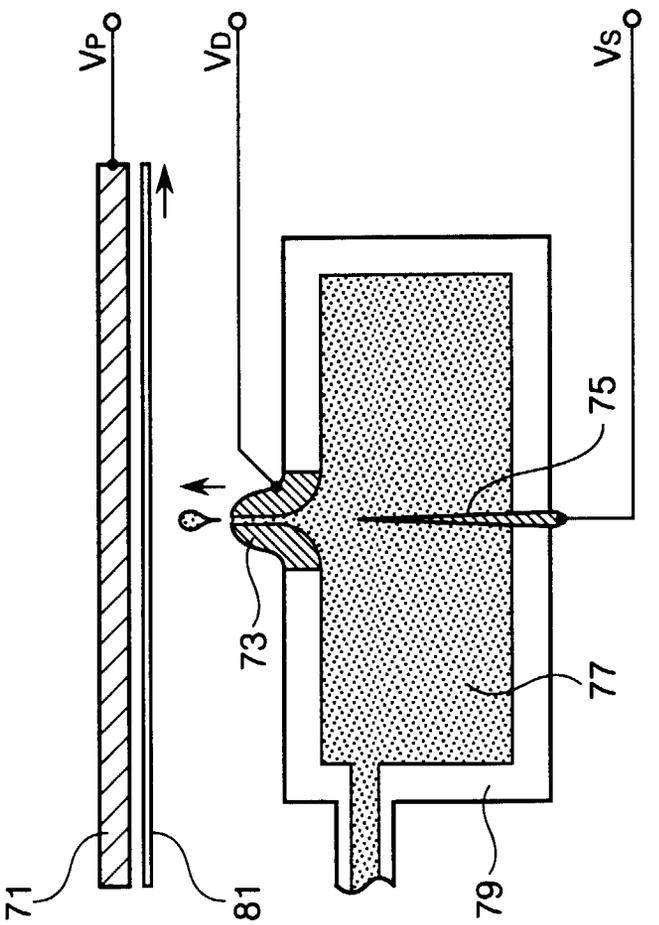
81
73
76
75
77
79

Fig. 8 (c)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Type B
(VS,VP<< VD)
Type C
(VS,VP<< VD)
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GND
VH
GND
GND→+VH
VH→GND
GND→–VH
VP
VD
VS
71
81
73
75
77
79

Fig. 8 (d)

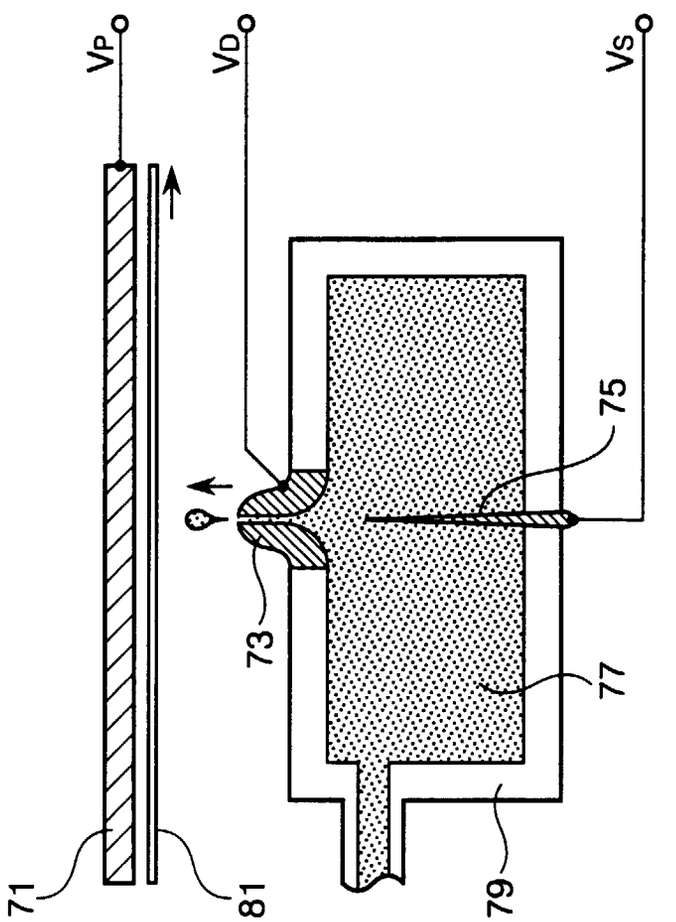

Type A
(VS,VP>>VD)
Type B
(VS,VP<<VD)
Type C
(VS,VP<<VD)
VH
GND
−VH
VH→GND
GND→+VH
−VH→GND
VH
GND
−VH
VP
VD
VS
71
81
73
75
77
79

Fig. 8 (e)

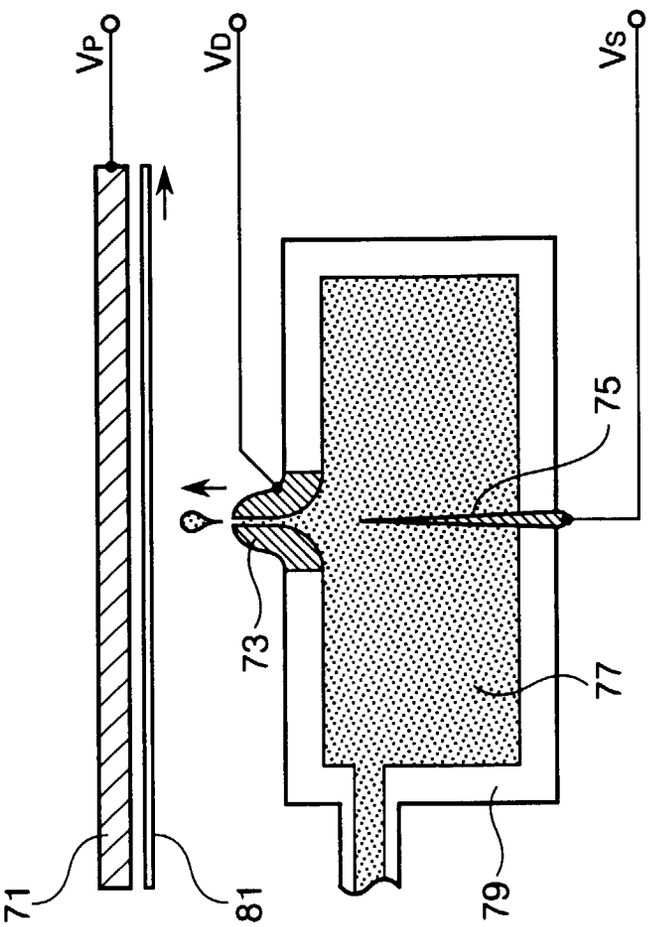

Type A
(VS,VP>>VD)
GND→+VH
GND
VH
Type B
(VS,VP<<VD)
VH→GND
VH
GND
Type C
(VS,VP<<VD)
GND→−VH
GND
−VH
VP
VD
VS
71
81
73
75
77
79

Fig. 9

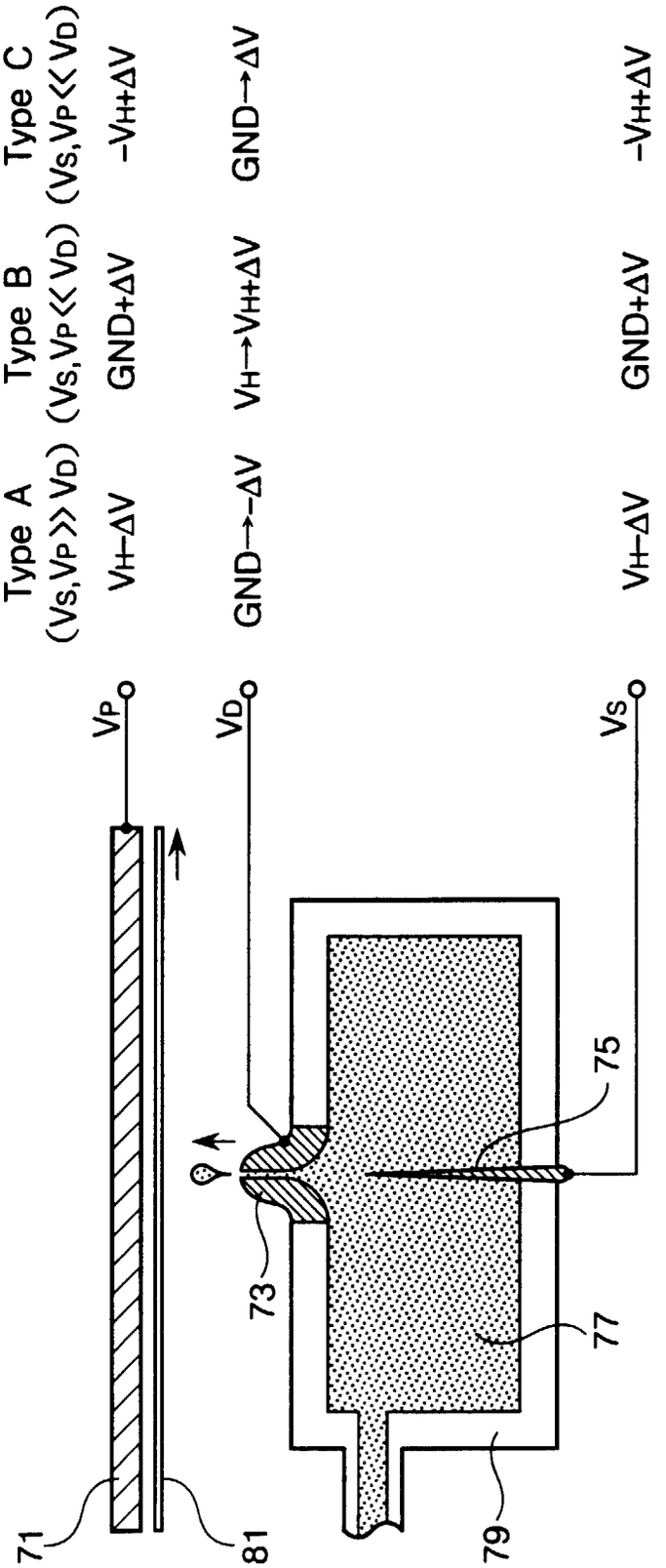
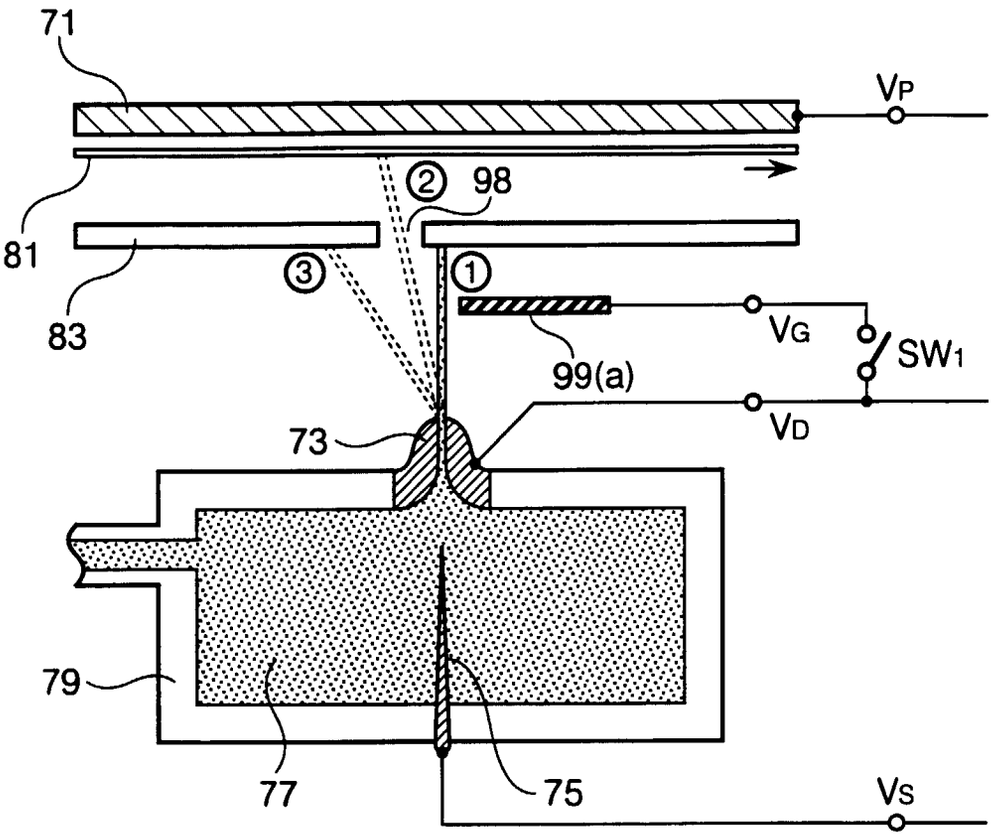

Type A
(VS,VP>>VD)
VH−ΔV
GND→−ΔV
VH−ΔV
Type B
(VS,VP<<VD)
GND+ΔV
VH→VH+ΔV
GND+ΔV
Type C
(VS,VP<<VD)
−VH+ΔV
GND→ΔV
−VH+ΔV
VP
VD
VS
71
73
75
77
79
81

Fig. 10



(a)

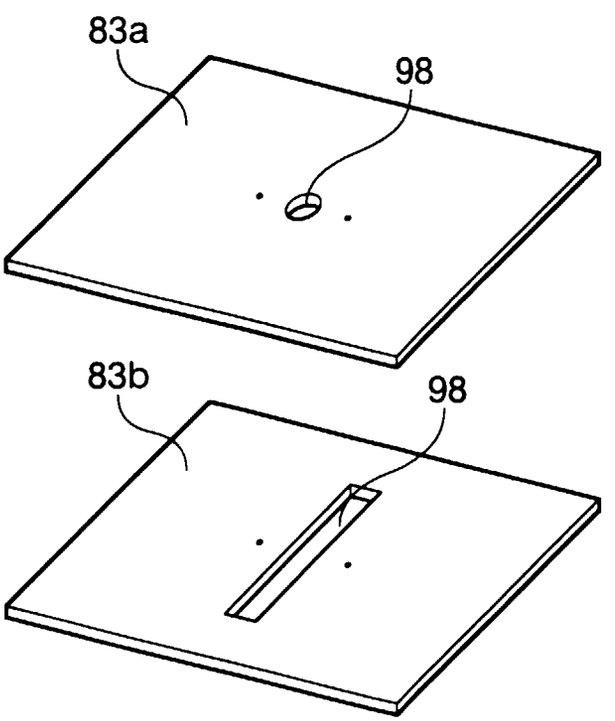


Fig. 11

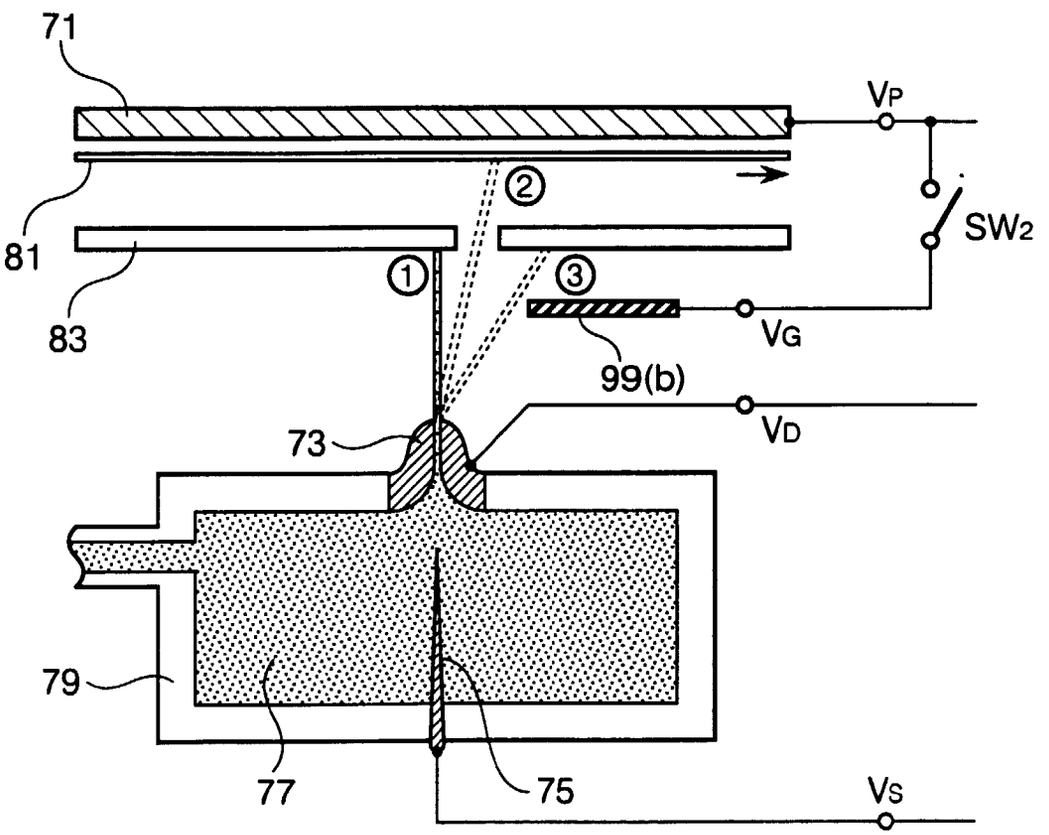
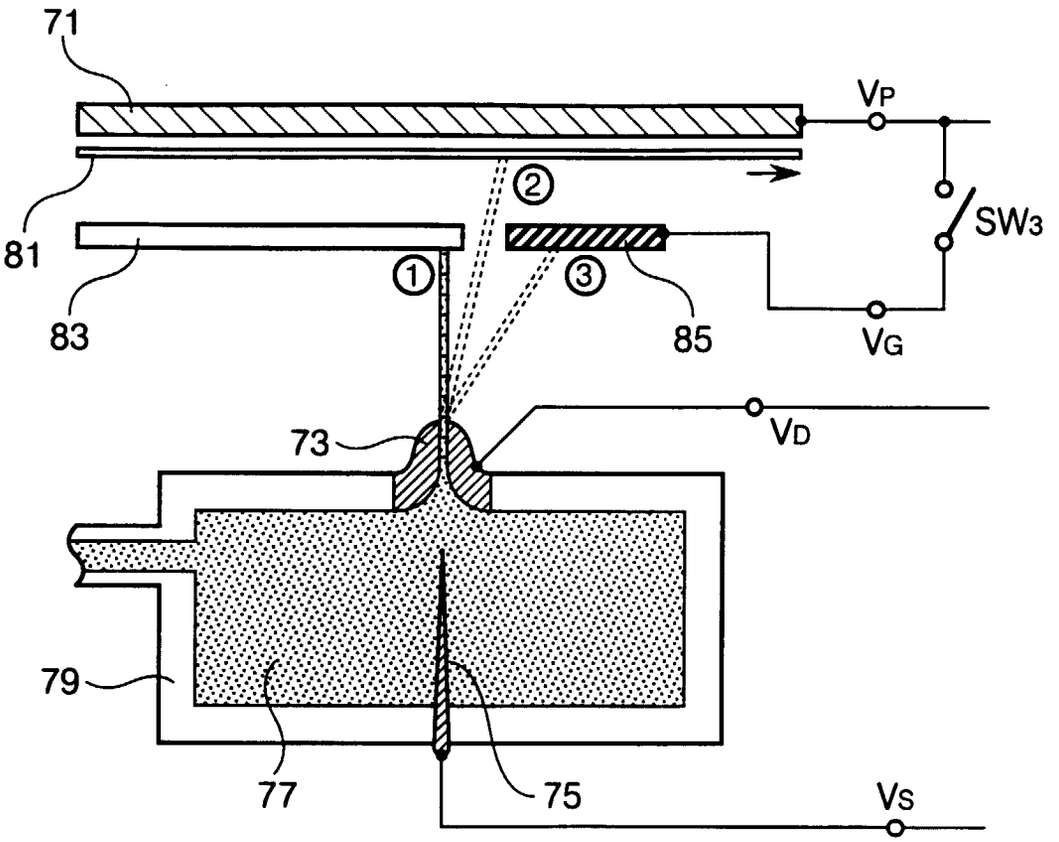


Fig. 12



(a)

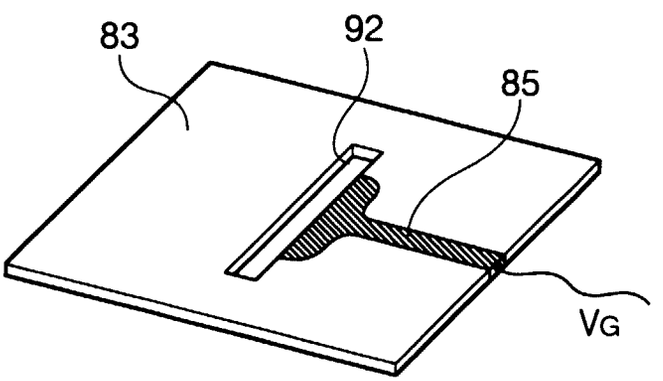
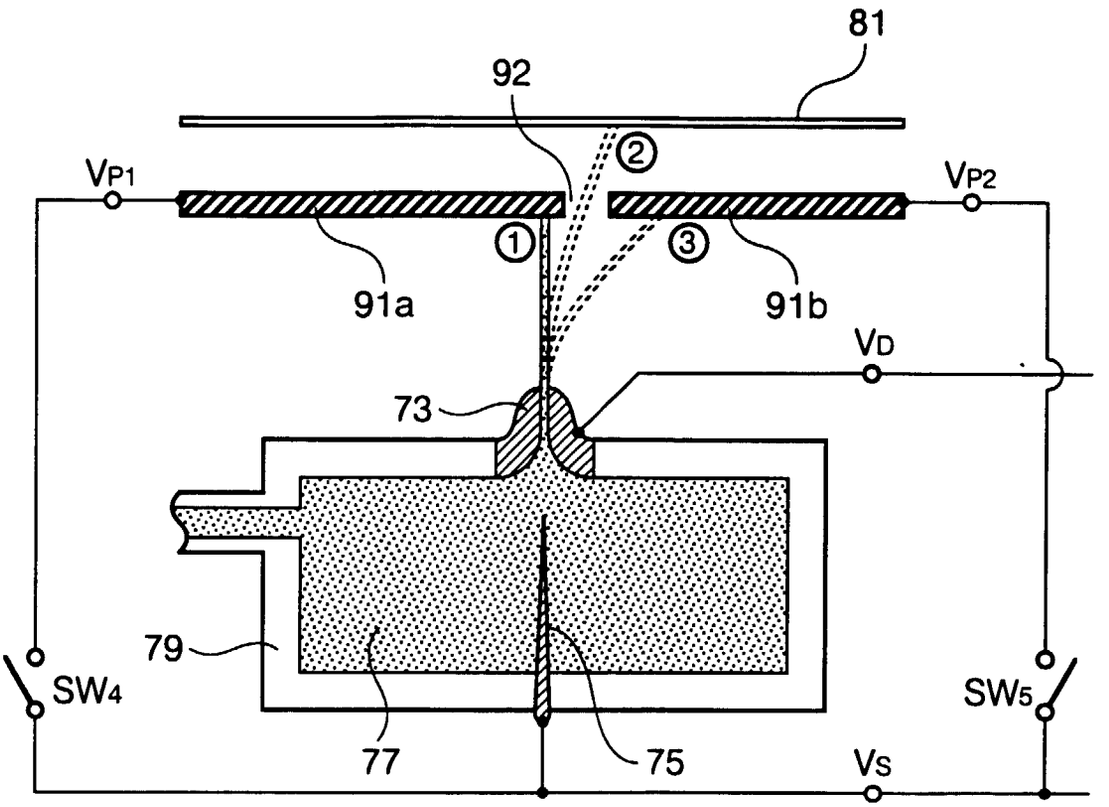


Fig. 13


81
92
②
VP1
VP2
①
③
91a
91b
VD
73
79
SW4
SW5
77
75
VS

(a)

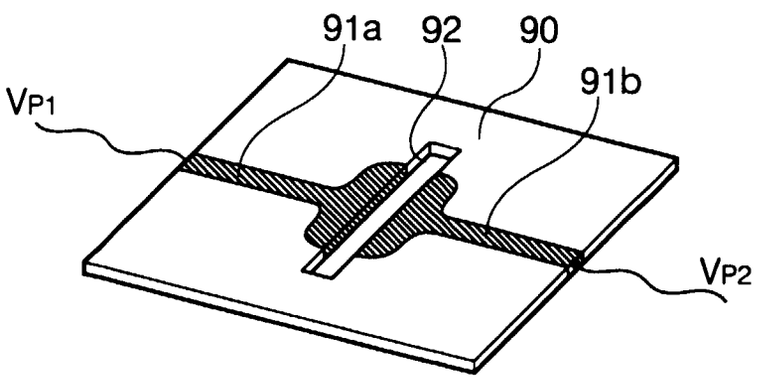

91a
92
90
91b
VP1
VP2

Fig. 14

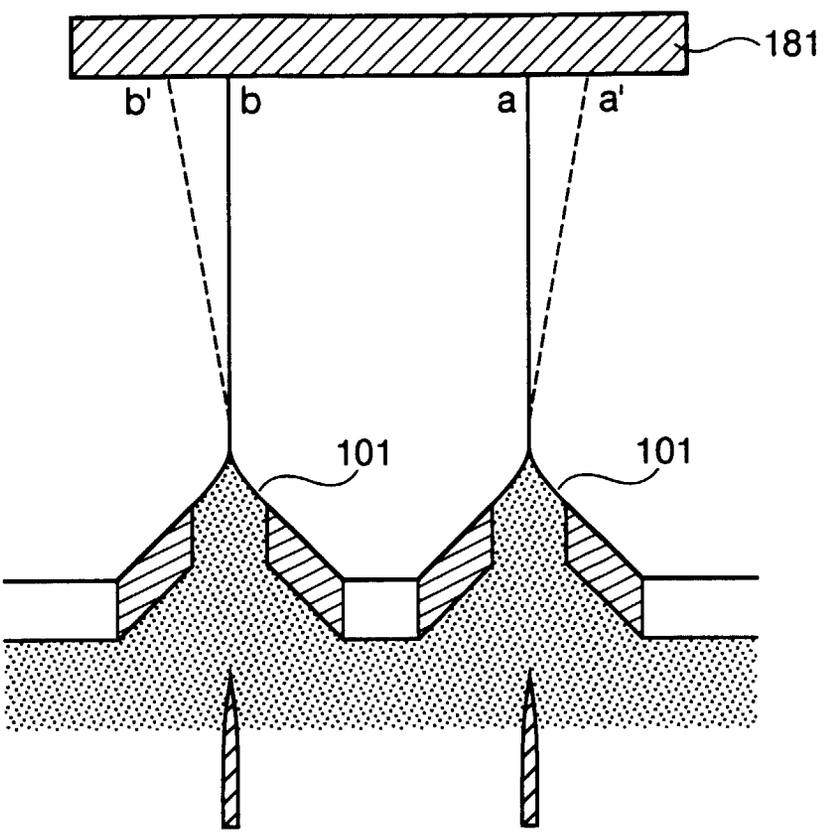


Fig. 15

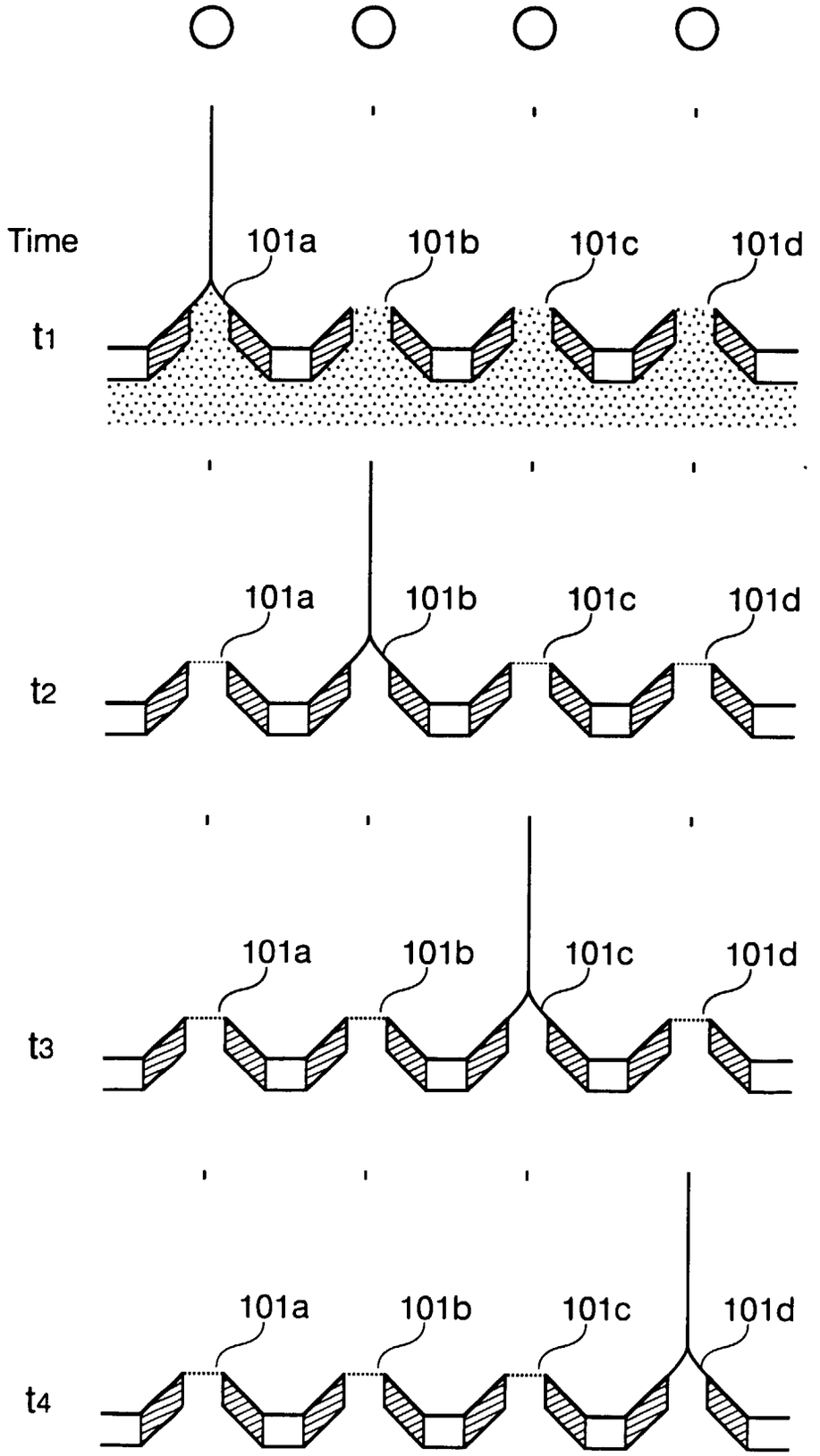

Time
101a
101b
101c
101d
t1
101a
101b
101c
101d
t2
101a
101b
101c
101d
t3
101a
101b
101c
101d
t4

Fig. 16

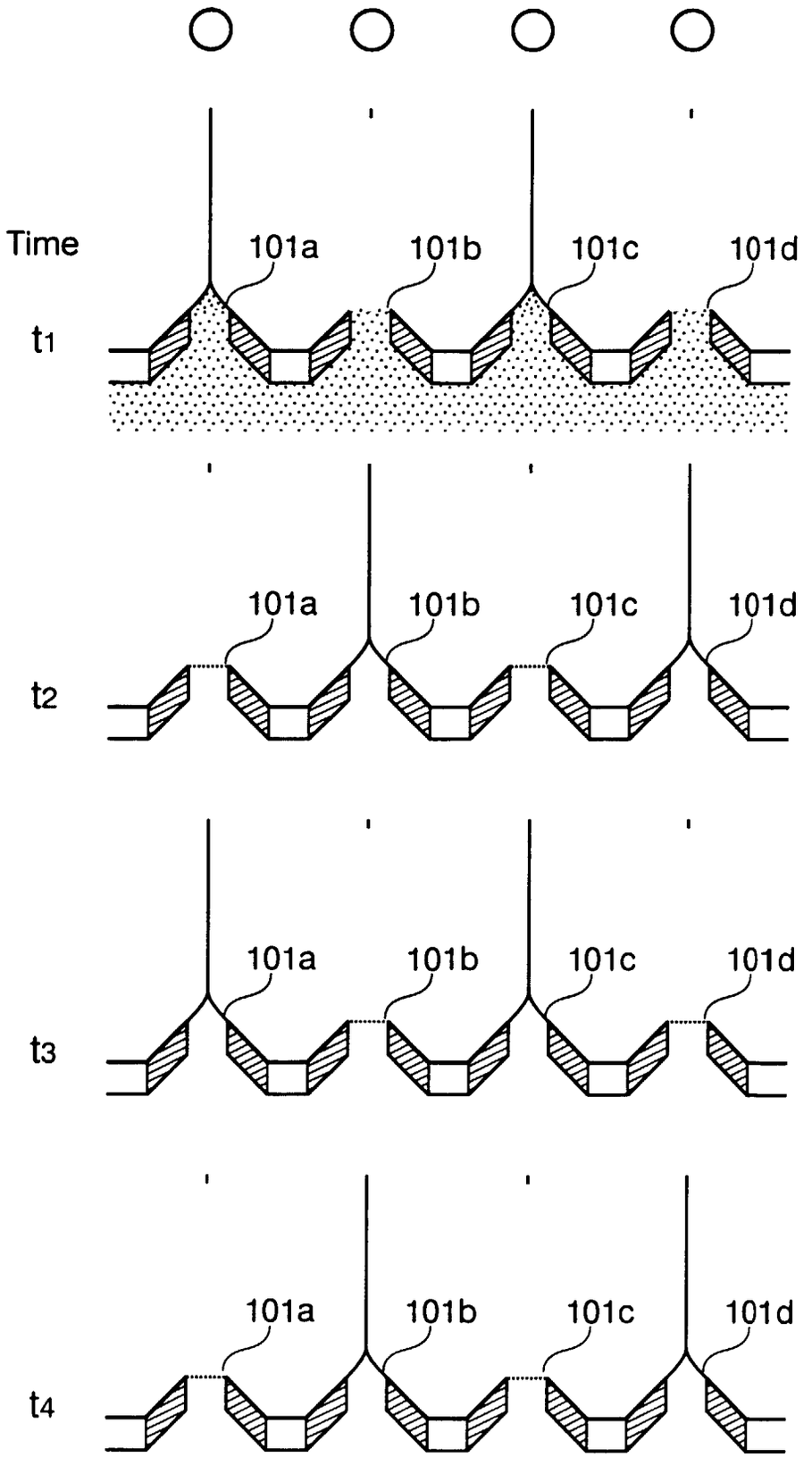
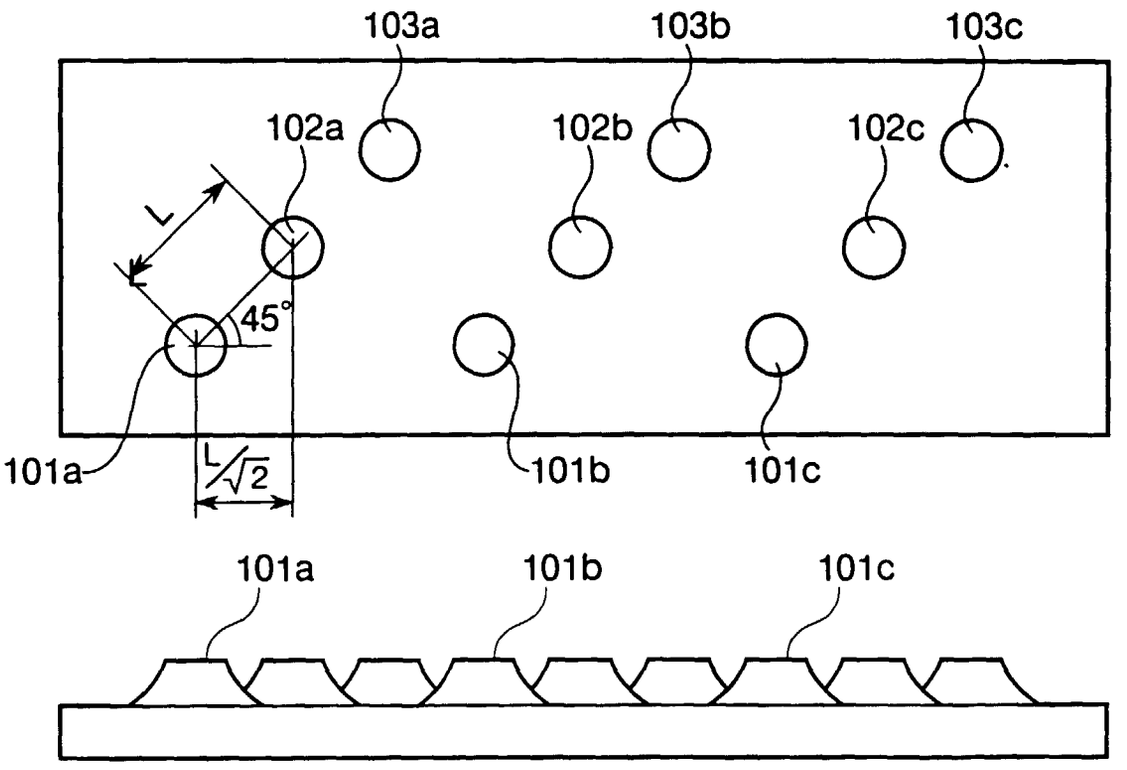

Time
101a
101b
101c
101d
t1
101a
101b
101c
101d
t2
101a
101b
101c
101d
t3
101a
101b
101c
101d
t4

Fig. 17


103a
103b
103c
102a
102b
102c
L
45°
101a
L/√2
101b
101c
101a
101b
101c

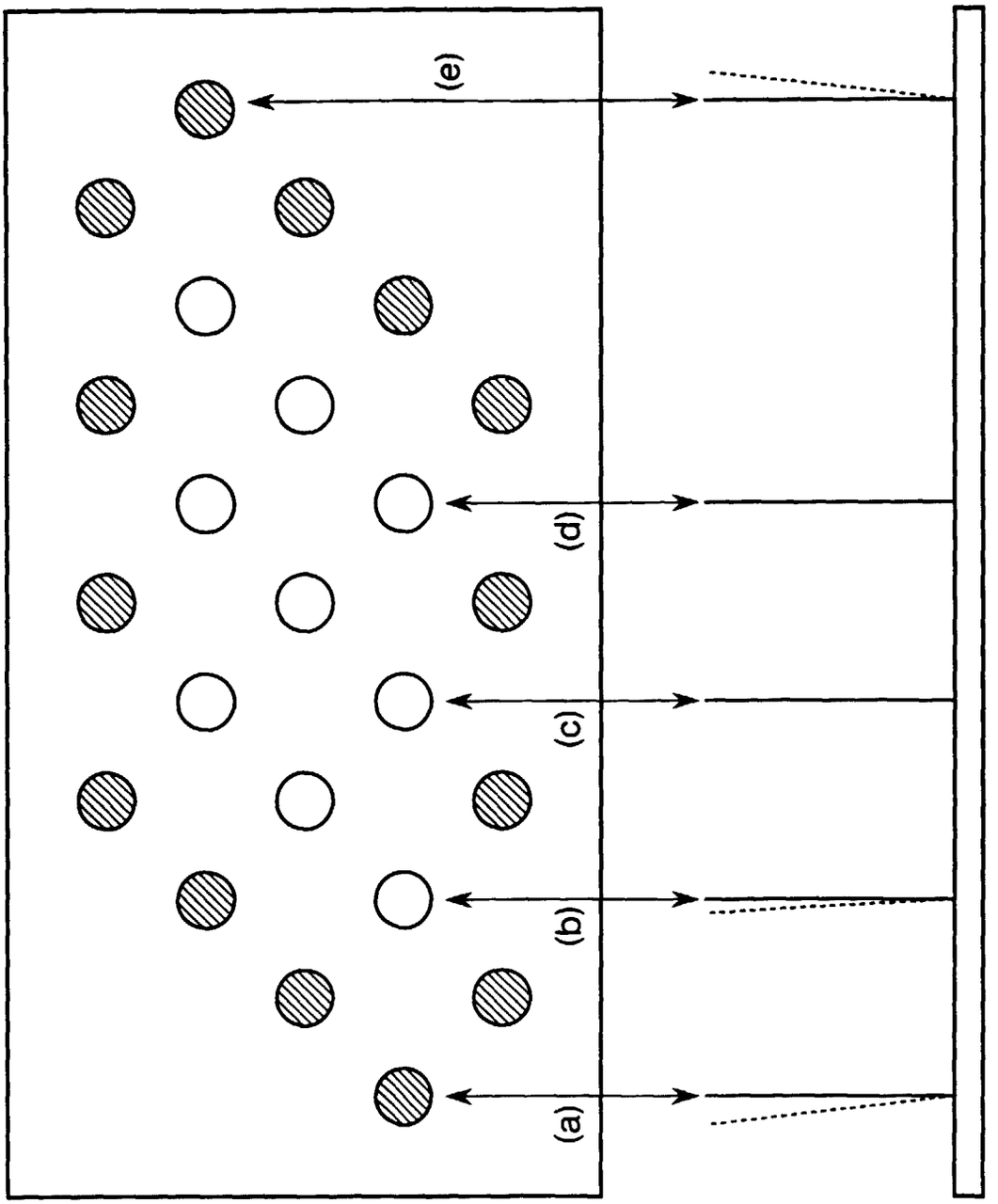


Fig. 18

Fig. 19

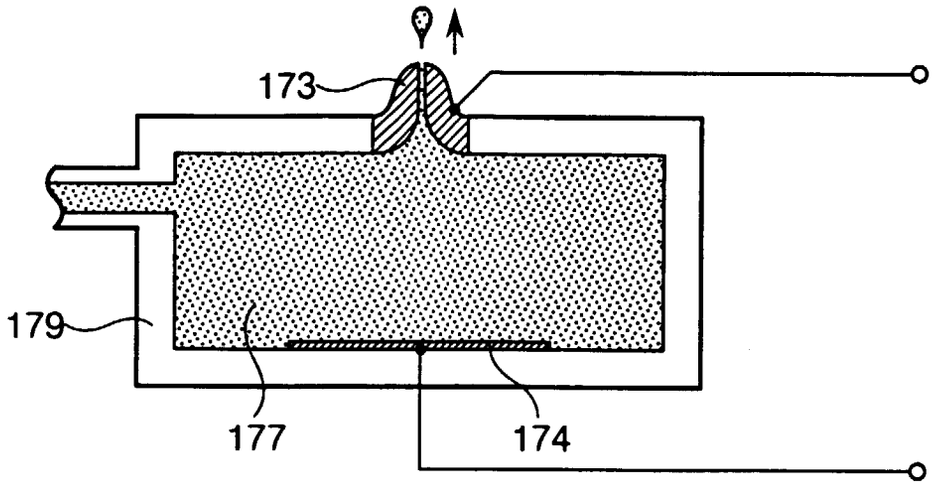


Fig. 20

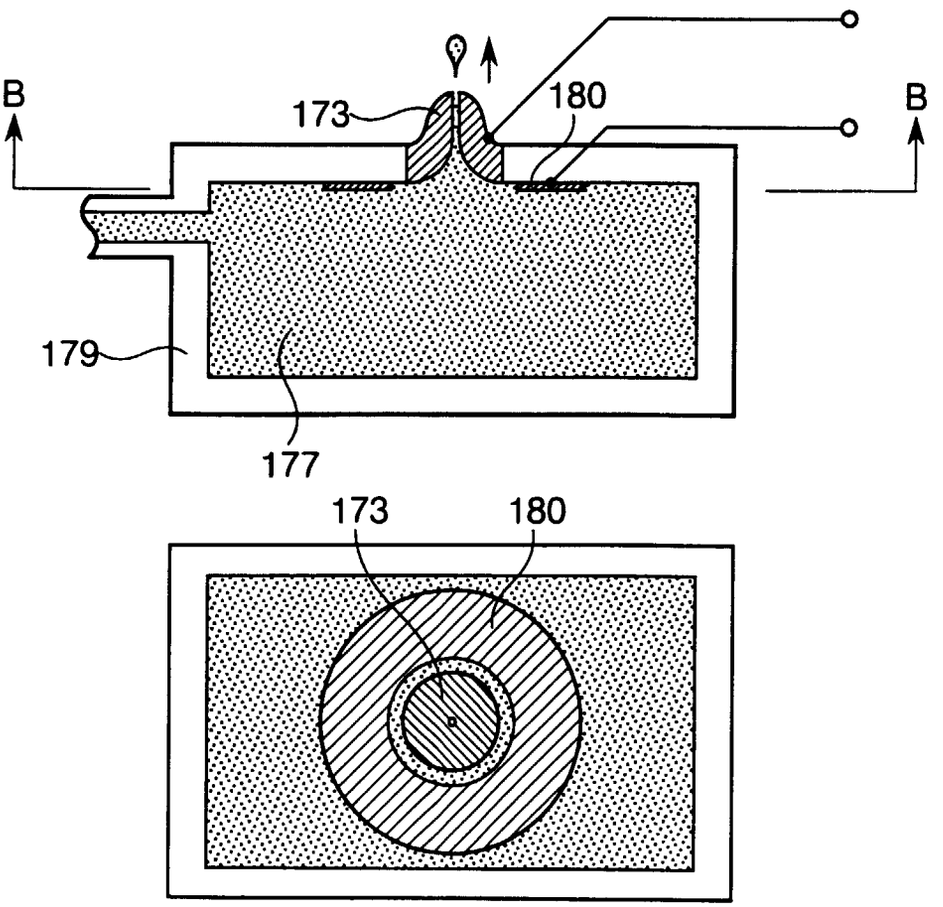


Fig. 21

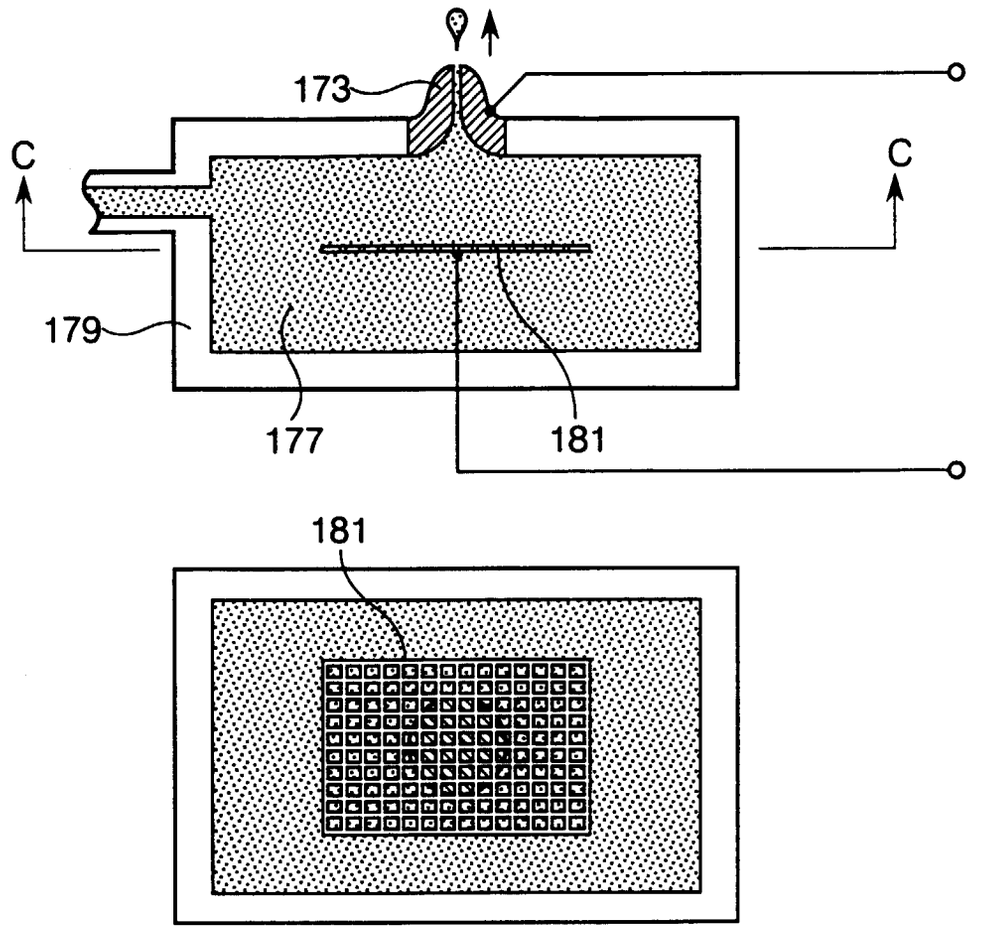


Fig. 22

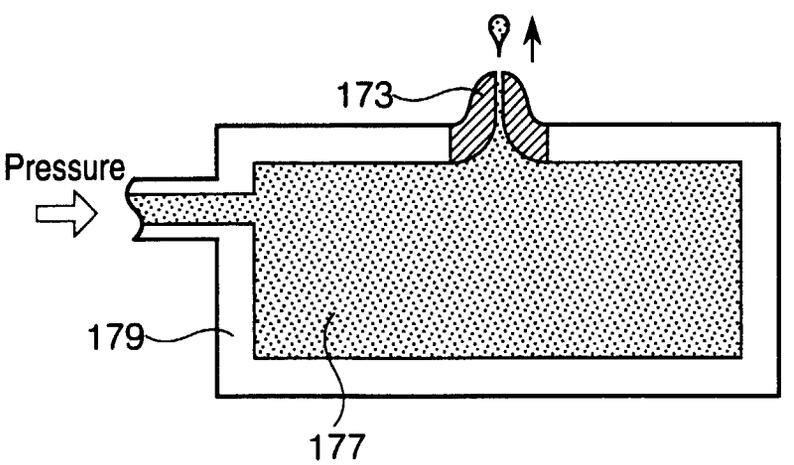


Fig. 23

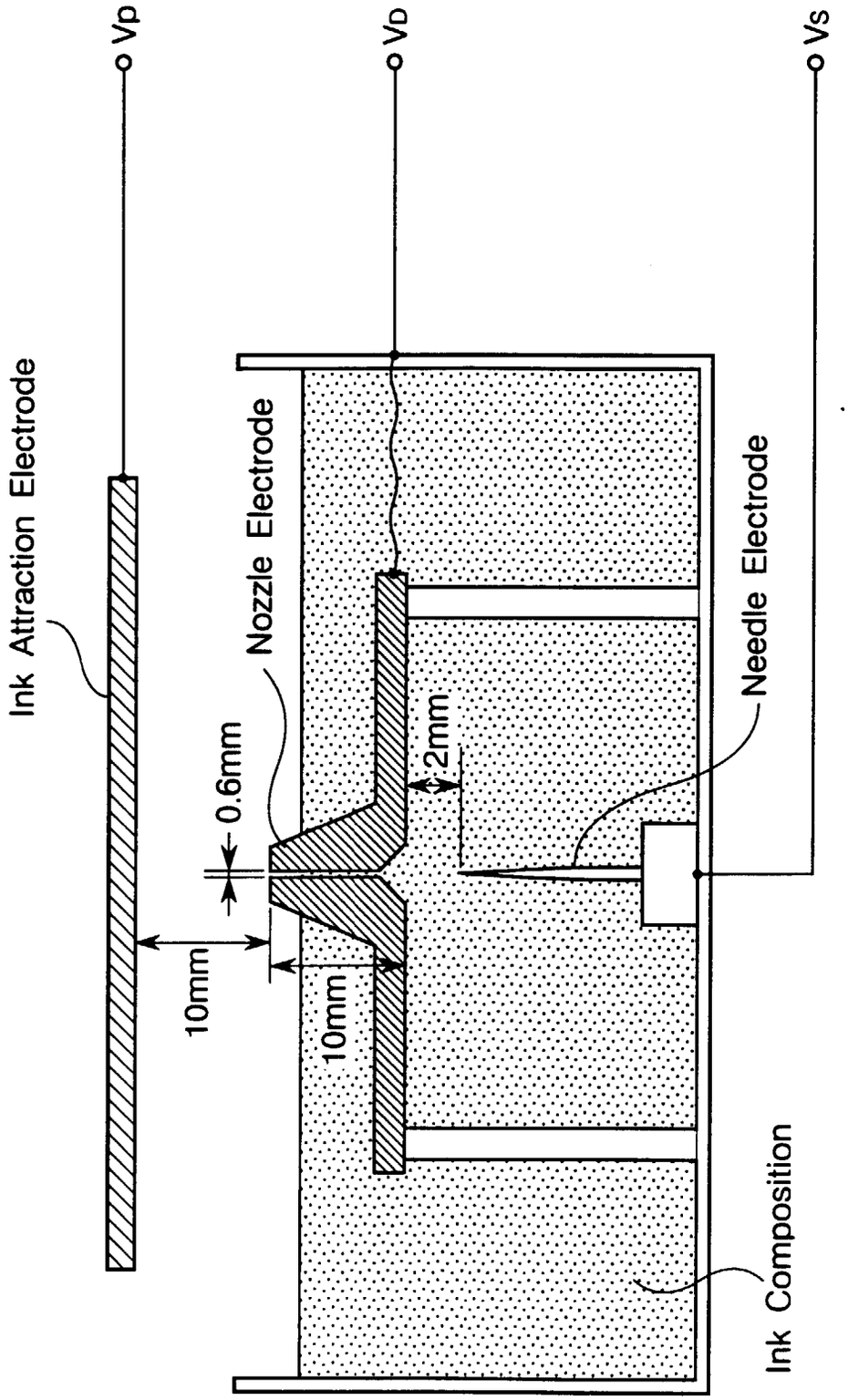

Vp
VD
Vs
Ink Attraction Electrode
Nozzle Electrode
Needle Electrode
0.6mm
2mm
10mm
10mm
Ink Composition

Fig. 24

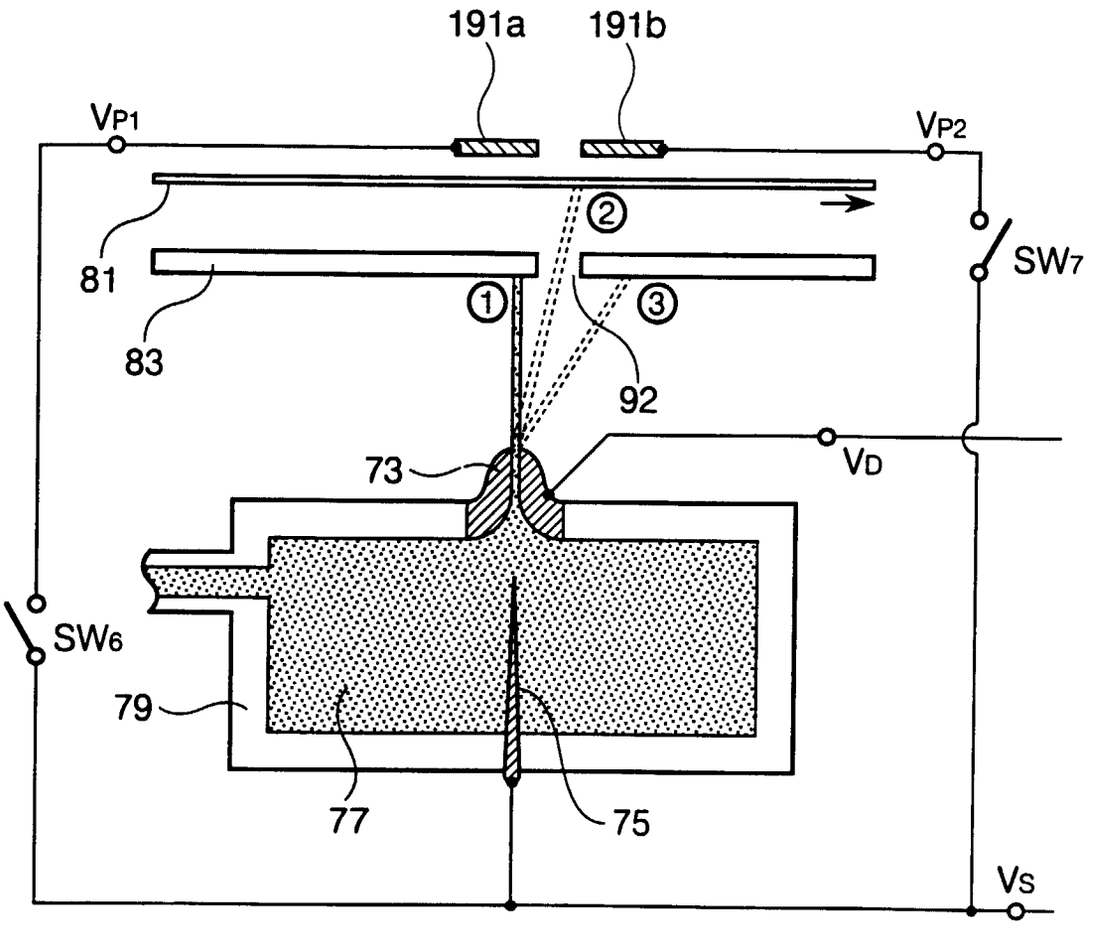
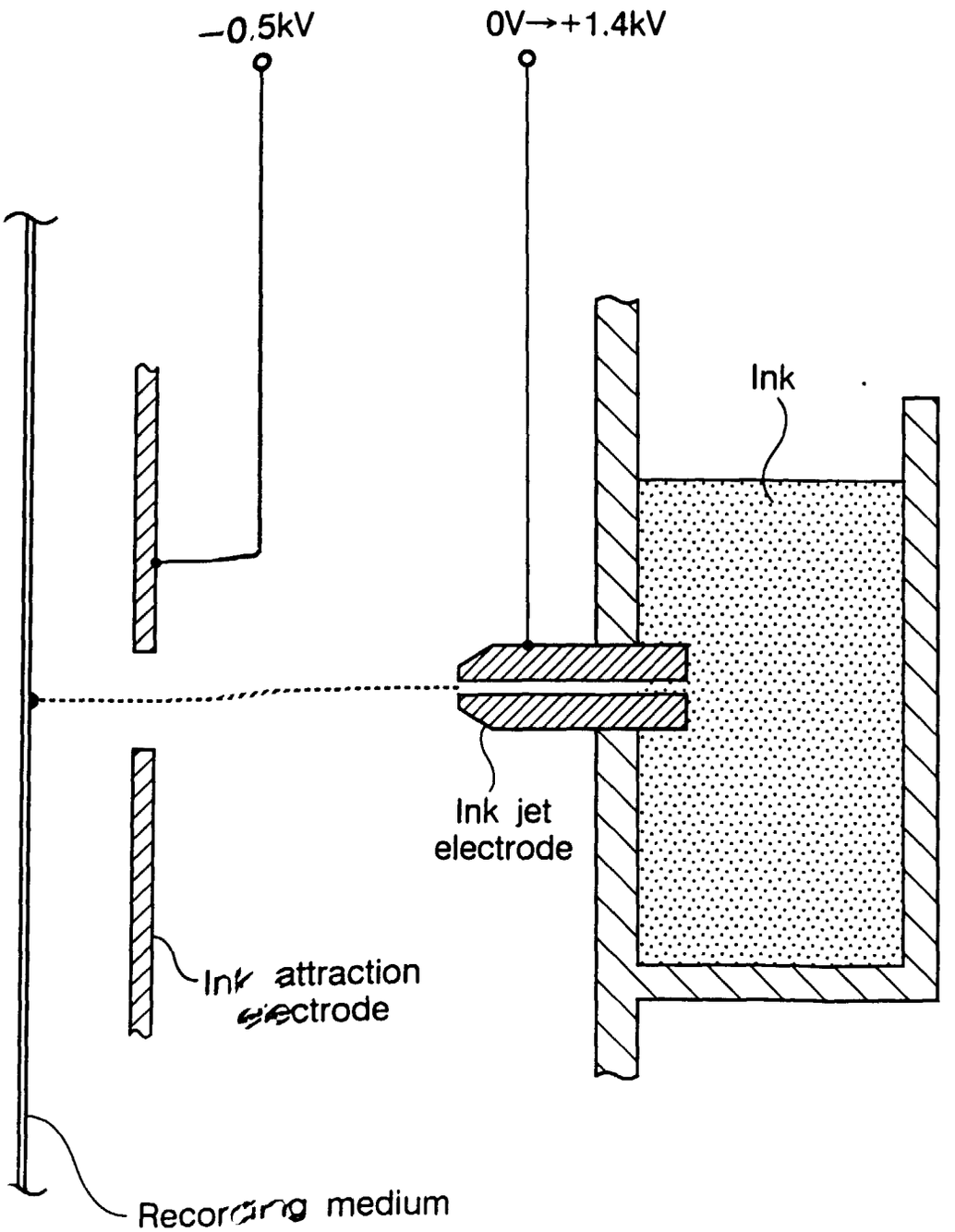


Fig. 25


−0.5kV
0V→+1.4kV
Ink
Ink jet electrode
Ink attraction electrode
Recording medium