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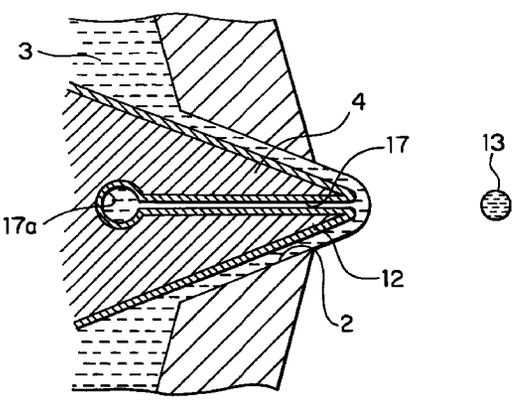
(54) Electrostatic ink jet recording head

(57) An electrostatic ink jet recording head has an ejection electrode (4) which enables a printing of an excellent quality and a high accuracy. The recording head has a head body (100) defining an ink chamber (1) for receiving liquid ink containing charged toner particles. A set of electrodes including an electrophoretic electrode (5a, 5B), a plurality of ejection electrodes (4) and an opposing electrode (6) are provided for ejecting the toner particles substantially without an insulating solvent. The ejection electrode (4) has a tip of a sharp edge protruding from the ejection opening (2) of the ink chamber (1). The ejection electrode (4) has a capillary slit (17) for introducing the ink toner therethrough and for forming an excellent meniscus by a capillary action.

FIG. 5



EP 0 780 229 A1

Description

BACKGROUND OF THE INVENTION

(a) Field of the Invention:

The invention relates to an electrostatic ink jet recording head and, in particular, to an electrostatic recording head using a liquid ink containing charged, colored toner particles dispersed in an insulating solvent.

(b) Description of the Related Art:

An electrostatic ink jet recording head is known in which charged toner particles in the ink chamber are subject to an electric field to be ejected from the ink chamber for recording.

A conventional static ink jet recording head has a problem in that liquid ink deposited on a recording medium produces blots or mottles, preventing a printing of high accuracy and excellent quality. In addition, it further has a problem in that the liquid ink is dissolved to run out when the printed recording medium is wetted by water.

SUMMARY OF THE INVENTION

It is an object of the invention to solve the problems as described above, by providing an electrostatic ink jet recording head which is capable of achieving a printing of an excellent quality and high accuracy.

According to the present invention, there is provided an electrostatic ink jet recording head comprising a head body defining an ink chamber for receiving liquid ink containing charged toner particles, the ink chamber having an ejection opening at a front end thereof for ejecting the toner particles therethrough; and

a set of electrodes, for ejecting the toner particles, including an electrophoretic electrode, disposed in operable relationship with the ink chamber, for providing an electric field for migrating the charged toner particles toward the ejection opening, at least one ejection electrode, disposed in operable relationship with the ejection opening, for forming an ink meniscus of the liquid ink, and an opposing electrode disposed outside the ink chamber in operable relationship with the ejection electrode, the ejection electrode having a tip formed with a capillary slit extending in a direction from the tip toward a rear end of the ink chamber, the capillary slit introducing the liquid ink within the ejection electrode.

In accordance with an embodiment of the invention, a voltage of the same polarity as the toner particles dispersed in the liquid ink is applied to an electrophoretic electrode, whereupon the toner particles are subject to an electrophoresis within the ink chamber and are collected or concentrated at the ejection opening, forming convex ink meniscuses at the tips of the ejection electrode. When a driving voltage pulse of a certain magnitude and of the same polarity as the toner particles is applied to the ejection electrode, the toner particles are ejected as a cluster from the tip of the ejection electrode toward the opposing electrode. The ejected toner particles are deposited on a recording medium to produce a dot record on a recording medium disposed in front of the opposing electrode. The toner particles thus dissipated at the ejection electrode are replenished at any time by the potential difference between the electrophoretic electrode and ejection electrode.

The ink contained within the ink chamber is effectively supplied to the tip of the ejection electrode through the capillary slit formed in the tip of the ejection electrode, whereby an ink meniscus of a convex shape is formed and maintained at the tip of the ejection electrode.

Since the ink droplet ejected from the ejection opening is substantially composed only of toner particles, the problem of an ink blotting or the like can be eliminated which is encountered in a conventional ink jet recording head of the type in which liquid ink including the toner and solvent is ejected. The record obtained by the ink droplets composed substantially only of the toner particles is scarcely dissolved by water, achieving a high printing quality comparable to the record achieved by an electrophotography. The capillary slit formed in the tip of the ejection electrode allows the ink to be supplied to the tip of the ejection electrode by the capillary action thereof, and accordingly an effective ink meniscus can be maintained at the tip of the ejection electrode, enabling a stabilized ink ejection.

The above and other objects, features and advantages of the present invention will be more apparent from the following description, referring to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an elevational view, partly broken, of an electrostatic ink jet recording head according to an embodiment of the invention;

Fig. 2 is a bottom view, partly broken, of the ink jet recording head shown in Fig. 1;

Fig. 3 is a side view , partly removed, of the ink jet recording head shown in Fig. 1 as viewed from the opposing electrode;

Fig. 4 is an equivalent circuit diagram of the ink jet recording head shown in Fig. 1;

Fig. 5 is a schematic enlarged view of the tip of the ejection electrode shown in Fig. 1; and

Fig. 6 is a schematic enlarged view of the tip of the ejection electrode in a comparative example of a conventional ink jet recording head.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the invention will now be described. The general arrangement of an electrostatic ink jet recording head according to the embodiment is

shown in Figs. 1 to 3, wherein a side elevational view, a bottom view and a side view as observed from the opposing electrode are shown in the respective drawings.

The electrostatic ink jet recording head includes a head body 100 having an ink chamber 1 for receiving a liquid ink 3 containing therein charged toner particles, an ejection opening 2 formed at the front end of the ink chamber 1, an ejection electrode 4 having a sharp-edged tip projecting slightly through the ejection opening 2, and two electrophoretic electrodes 5A and 5B disposed at the rear end of the ink chamber 1 and disposed on the outer surface of the head body for surrounding the ink chamber 1 except for the front end of the ink chamber 1. It is to be noted that a plurality of ejection electrodes are generally arranged in the direction perpendicular to the plane of Fig. 1, and that in this embodiment only a single ejection electrode 4 is depicted in the drawings for a simplification purpose.

An opposing electrode 6 is disposed in opposing relationship with the tip of the ejection electrode 4 with a recording medium 7 interposed therebetween. The electrophoretic electrodes 5A and 5B are associated with an electrophoretic voltage source 9 which applies the electrophoretic electrodes 5A and 5b with an electrophoretic voltage Vep. Similarly, the ejection electrode 4 is associated with an ejection voltage source 8 which applies driving voltage pulse Vp to the ejection electrode 4.

Referring next to Fig. 5 showing the detail of the tip of the ejection electrode 4, the ejection electrode 4 is covered by an insulating film coating 12 made of a hydrophilic resin. The ejection electrode 4 protrudes from the ejection opening 2 and extends through the rear end of the ink chamber 1. The ejection electrode 4 includes a sharp-edged tip formed by a taper at each of the top surface and a bottom surface of the ejection electrode 4. In addition, a horizontal, capillary slit 17 is formed in the tip of the ejection electrode 4 and extends within the ejection electrode 4 toward the interior of the ink chamber 1. It will be noted that the tip of the ejection electrode 4 has a shape similar to a pen point as viewed in Fig. 5, and the inner end of the capillary slit 17 is of a round shape for effectively introducing the liquid ink 3.

In Figs. 1, 2 and 3, the ink chamber 1 is defined by a bottom plate 14, side-wall plate 15 and a top plate 16, all of a dielectric material. The ejection opening 2 is a microscopic gap formed in one of the side-walls 15 located at the front end of the ink chamber 1, receiving an ink meniscus formed at the tip of the ejection electrode 4.

The liquid ink 3 contains colored toner particles apparently charged by zeta-potential and dispersed in a solvent, which may be isoparaffin, i.e., petroleum derived organic material. The liquid ink 3 received in the ink chamber 1 is applied with a back pressure by a pump (not shown) to circulate through an ink inlet port 10 and ink outlet port 11. The ink inlet port 10 and an ink outlet port 11 are connected with an ink reservoir through tubes (not shown).

The ejection electrode 4 is electroformed from an electrically conductive material such as Cu, Ni or the like and has a width on the order of 50 microns, extending from the front end of the ink chamber toward the rear edge of the head body passing through the rear end of the ink chamber 1. As mentioned above, the ejection electrode 4 is covered by an insulating film coating 12 at the portion thereof where the ejection electrode 4 is in contact with the liquid ink 3, and thus is insulated from the ink 3. The insulating film coating 12 is made of a hydrophilic material which is selected to improve the affinity between the surface of the ejection electrode 4 and the ink 3. The ejection electrode 4 has a sharp edge at its tip which protrudes from the ejection opening by a length of approximately 80 to 100 microns. The inner surface of the capillary slit 17 is also covered by the insulating film 12. The capillary slit 17 has a space which is small enough to produce a capillary action.

The opposing electrode 6 is formed of an electrically conductive material such as a metal. The opposing electrode 6 is connected to the ground through a resistor to prevent a large leakage current from flowing between the opposing electrode and the ejection electrode. It is to be noted that the opposing electrode 6 also serves as a platen with respect to the recording medium 7.

The ejection voltage source 8 applies a high voltage pulse Vp of the same polarity as the toner particles dispersed in the ink 3 to the ejection electrode 4 at a given timing which depends on a recording signal received from an external circuit. On the other hand, the electrophoretic voltage source 9 applies a constant high voltage Vep of the same polarity as the toner particles to the electrophoretic electrode 4.

Before operation, charged toner particles are received within the ink chamber 1. In this state, the ink 3 is equivalent to a conductor having a certain resistance connected in parallel with a capacitor, as shown in Fig. 4. The insulating film 12 coating the ejection electrode 4 forms a capacitor 14 having electrodes formed by the ejection electrode 4 and the ink 3.

During a standby mode before printing, the electrophoretic voltage pulse Vep is applied from the voltage source 9 to the electrophoretic electrode 5 including inner and outer electrodes 5A and 5B. In this state, no voltage is applied or only a small bias voltage is applied from the voltage source 8 to the ejection electrode 4, the bias voltage being lower than the electrophoretic voltage Vep, whereby a potential difference is produced between the electrophoretic electrode 5 and ejection electrode 4. The potential difference produces an apparent charged state of the toner particles dispersed in the ink 3, whereby a sufficient amount of toner particles, which equalizes the potential of the ink 3 to the electrophoretic voltage Vep, are accumulated on the surface of the insulating film 12 coating the ejection electrode 4.

During a recording mode, an ejection voltage pulse

Vp is applied to the ink 3 on the insulating film of the ejection electrode 4, the ink 3 being maintained at equipotential with the electrophoretic voltage Vep. When a potential difference between the potentials of the ejection electrode 4 and the opposing electrode 6 exceeds a threshold voltage, the resulting electrostatic force exerts Coulomb force upon the ink 3 containing toner particles and surrounding the ejection electrode 4 to overcome the surface tension by the ink meniscus, whereby an ink droplet 13 is ejected toward the opposing electrode from the ink meniscus. The ejected ink droplet 13 is deposited on the recording medium 7 disposed in front of the opposing electrode 6 to form a dot record.

Subsequent to the recording operation, the amount of toner particles which is sufficient to replenish the wanting amount of electric charge is supplied onto the surface of the insulating film 12. Specifically, since the recording operation is conducted by dissipating the toner particles dispersed in the ink 3, the toner concentration will be reduced in the vicinity of the ejection electrode 4 immediately after the ejection of the toner particles. In this state, a high voltage applied to the electrophoretic electrode 5 drives the toner particles within the ink chamber 1 by an electrophoresis to migrate toward the tip of the ejection electrode 4, thereby replenishing the toner particles in the vicinity of the ejection electrode 4. In particular, since the ejection electrode 4 is insulated from the ink 3, after the charged toner particles migrate toward the tip of the ejection electrode 4 to provide a steady state of the potential distribution within the ink chamber 1, the toner particles stop to migrate any further, thereby restoring an initial state of the ink. The high voltage pulse Vp applied to the ejection electrode 4 is controlled in accordance with an image to be recorded.

By repeating the described recording operation, a desired image is recorded. Subsequently, the recording medium 7 on which a record is made is conveyed to a fixing unit (not shown) where it is thermally fixed.

Thus, since the printing operation is conducted by ejection and deposition substantially only of the toner particles onto the recording medium 7, a blotting of the ink, which has been experienced with a conventional ink jet recording technique in which a liquid ink is directly injected to produce a record, can be eliminated, achieving a high quality printing which is comparable to that achieved with the electrophotography.

The advantage of the configuration of the tip of the ejection electrode will be described hereinafter. Fig. 6 shows a comparative example having a conventional flat tip and shown for comparison with the tip of Fig. 5. Since the ink 3 received within the ink chamber is maintained under a back pressure, it is impossible for the ink meniscus to maintain a convex form in Fig. 6 so as to cover the tip of the ejection electrode 54, resulting in a difficulty that the ink 3 cannot be sufficiently supplied to the tip of the ejection electrode 54 where the electric field is most concentrated.

By contrast, the provision of the capillary slit 17 in the tip portion of the ejection electrode 4, which protrudes from the ink chamber 1, supplies a sufficient amount of ink by a capillary action, allowing an effective ink meniscus to be maintained at the tip of the ejection electrode 4, which in turn enables a stabilized ink ejection.

The configuration in which the capillary slit 17 extends into the interior of the ink chamber 1 provides a sufficient amount of ink supply to the tip of the ejection electrode 4. In addition, the ink inlet space 17a having a diameter which is slightly greater than the space of other portion of the cut-out 17 and formed at the inner end of the capillary slit 17 assures a smooth supply of the ink to the tip of ejection electrode 4.

Finally, since the ejection electrode 4 is disposed so that its tip protrudes beyond the ejection slit 2 by a length on the order of 80 to 100 microns, as shown in Fig. 5, this allows to provide a convex figure of the ink meniscus at the tip of the ejection electrode 4 where the electric field is most concentrated, thereby achieving a satisfactory concentration of the electric field to provide a stabilized ink ejection.

Although the present invention is described with reference to a preferred embodiment thereof, the present invention is not limited thereto and it will be apparent from those skilled in the art that various modifications or alterations can be easily made from the embodiment without departing from the scope of the present invention.

Claims

1. An electrostatic ink jet recording head comprising:

   a head body (100) defining an ink chamber (1) for receiving liquid ink (3) containing charged toner particles, said ink chamber (1) having an ejection slit (2)at a front end thereof for ejecting the toner particles therethrough; and
   a set of electrode, for ejecting said toner particles, including an electrophoretic electrode (5, 5a, 5b), disposed in operable relationship with said ink chamber (1), for providing an electric field for migrating said charged toner particles toward said ejection opening (2), at least one ejection electrode (4), disposed in operable relationship with said ejection opening (2), for forming an ink meniscus of the liquid ink, and an opposing electrode (6) disposed outside said ink chamber (1) in operable relationship with said ejection electrode (4), characterized in that
   said ejection electrode (4) has a tip formed with a capillary slit (17) extending in a direction from the tip toward a rear end of said ink chamber (1), said capillary slit (17) introducing the liquid ink within said ejection electrode (4).

2. An electrostatic ink jet recording head as defined in

Claim 1 wherein the tip of said ejection electrode (4) is of a sharp edge protruding from said ejection opening (2).

3. An electrostatic ink jet recording head as defined in Claim 1 wherein the tip of said ejection electrode (4) protrudes from said ejection opening (2) by approximately 80 to 100 microns.

4. An electrostatic ink jet recording head as defined in Claim 1 wherein said capillary slit (17) has an inner end (17a) within said ejection electrode (4), said inner end (17a) having a space for introducing the liquid ink (3) larger than a space of an outer end of said capillary slit (17).

5. An electrostatic ink jet recording head as defined in Claim 4 wherein said inner end has a round shape as viewed in a direction perpendicular to the extending direction of the capillary slit.

FIG. 1

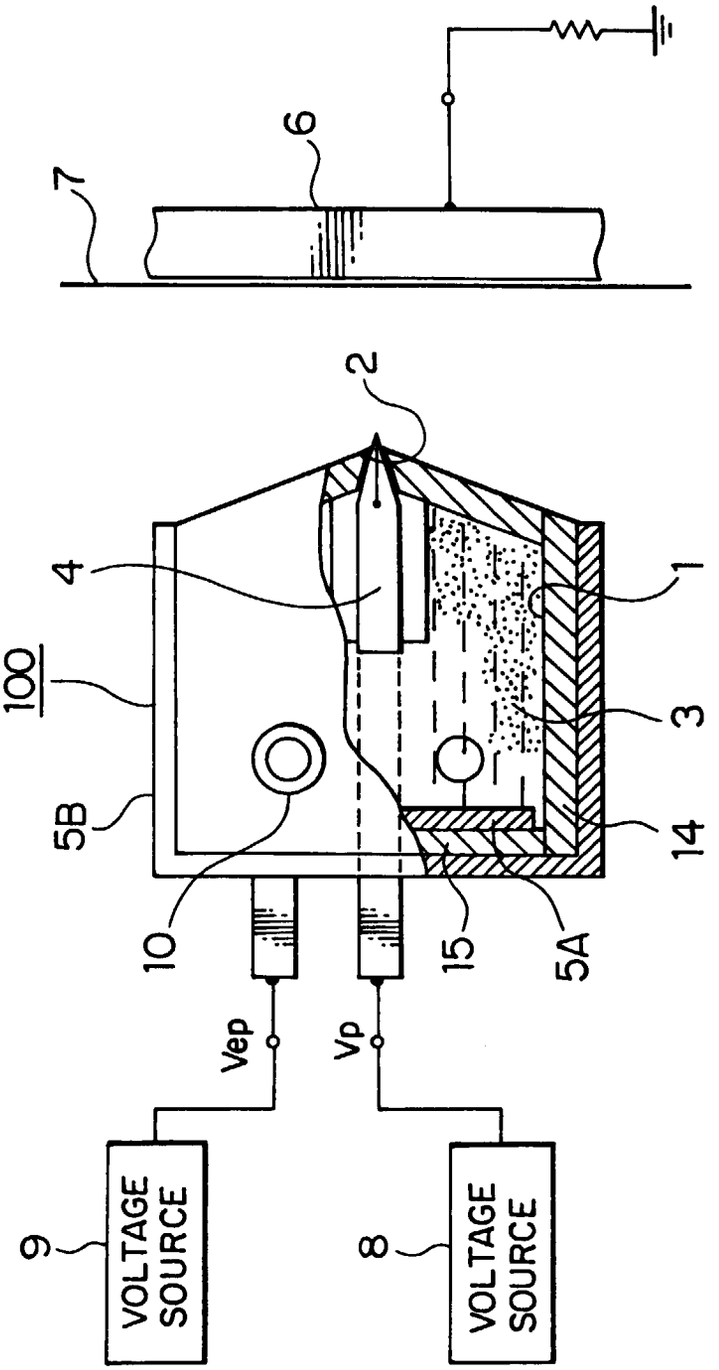

6
7
2
4
1
100
3
5B
14
10
15
5A
Vep
Vp
9
VOLTAGE SOURCE
8
VOLTAGE SOURCE

FIG. 2

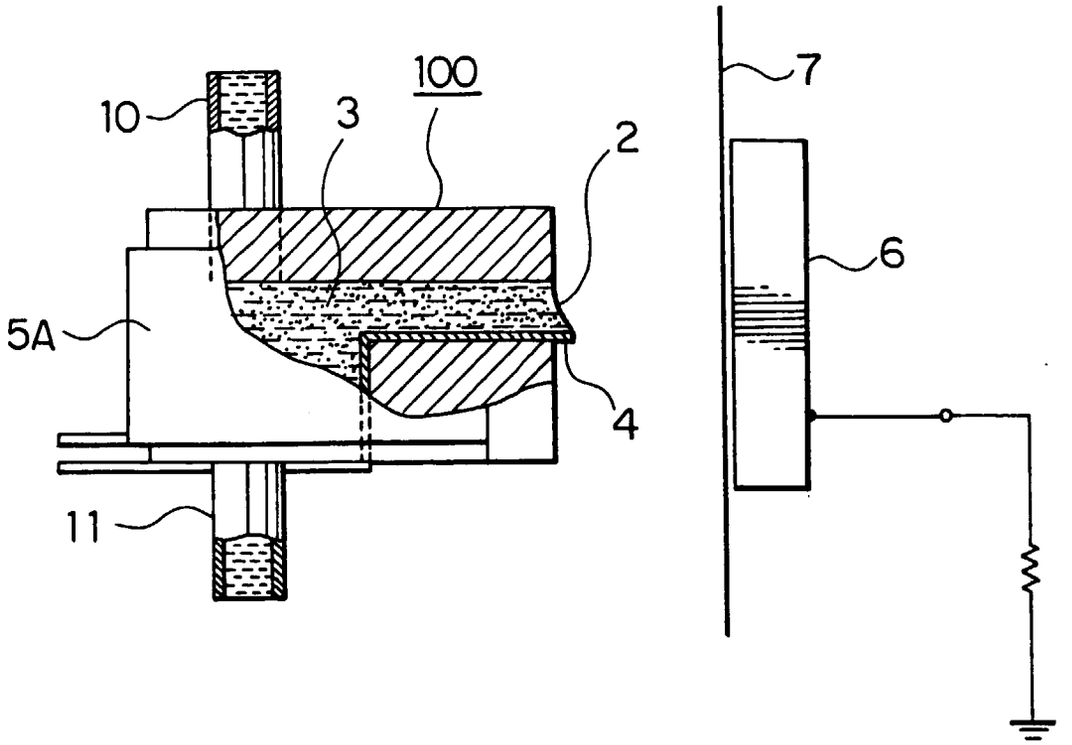


FIG. 3

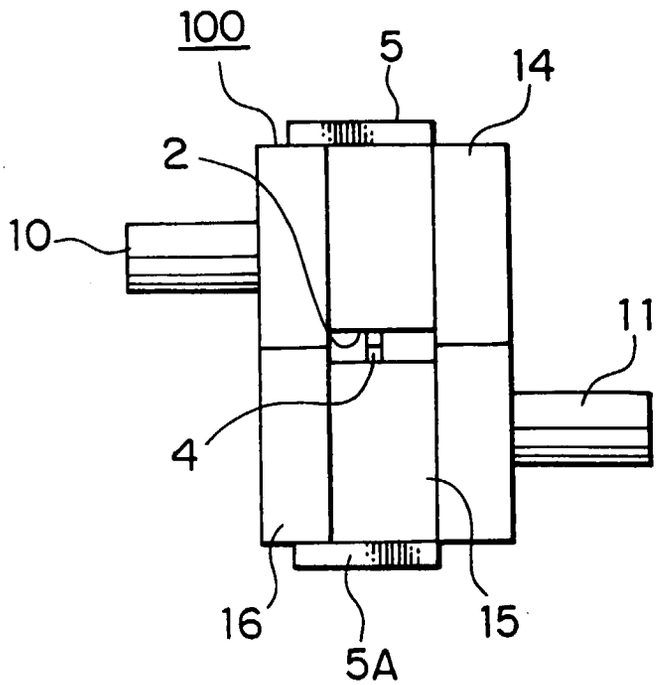


FIG. 4

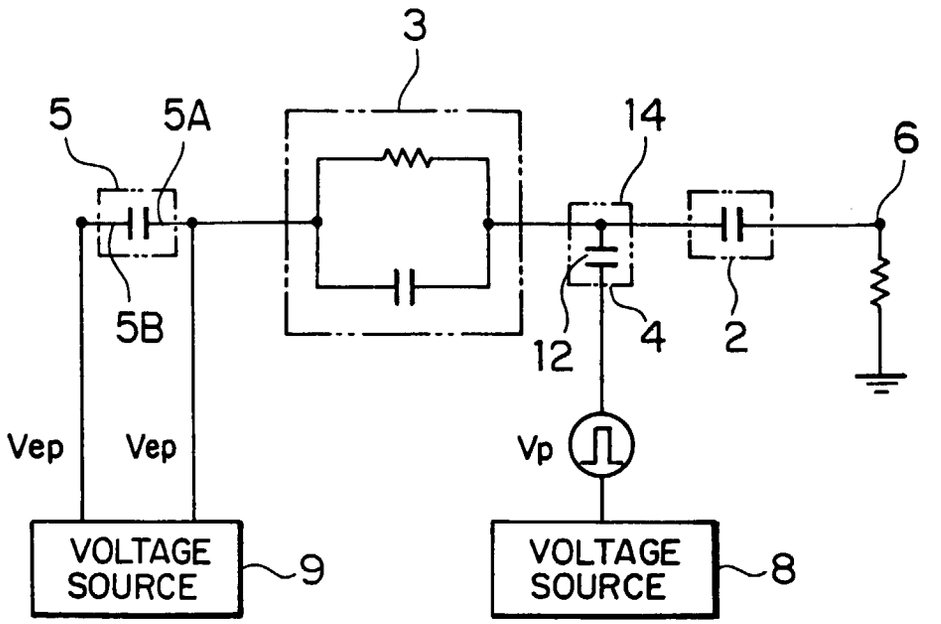

3
5
5A
14
6
5B
12
4
2
Vep
Vep
Vp
VOLTAGE SOURCE
9
VOLTAGE SOURCE
8

FIG. 5

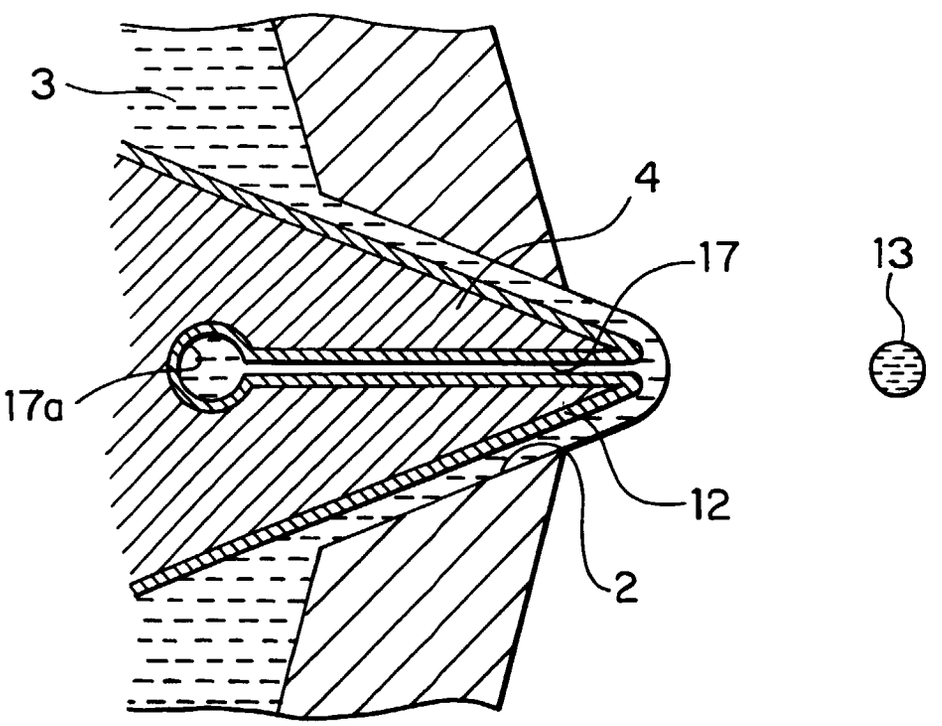
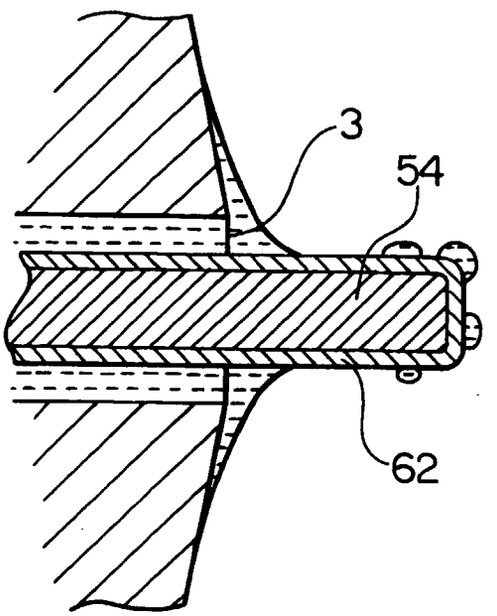

3
4
17
13
17a
12
2

FIG. 6



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EUROPEAN SEARCH REPORT

Application Number
EP 96 12 0204

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	PATENT ABSTRACTS OF JAPAN vol. 010, no. 218 (M-503), 30 July 1986 & JP 61 057343 A (TOSHIBA CORP), 24 March 1986, * abstract; figure 3 *	1	B41J2/06
A	US 4 396 925 A (KOHASHI TADAO) 2 August 1983 * column 4, line 7 - column 12, line 53; figure 3 *	1	
A	WO 93 11866 A (AUSTRALIA RES LAB) 24 June 1993		
A	US 4 768 044 A (SHIMOSATO MASASHI ET AL) 30 August 1988		
A	US 4 806 956 A (NISHIKAWA HISASHI ET AL) 21 February 1989		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 February 1997	Van Oorschot, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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