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

(11) EP 0 753 410 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.01.1997 Bulletin 1997/03

(51) Int Cl.6: B41J 2/05

(21) Application number: 96304746.9

(22) Date of filing: 27.06.1996

(84) Designated Contracting States:
DE FR GB

(30) Priority: 28.06.1995 JP 162206/95

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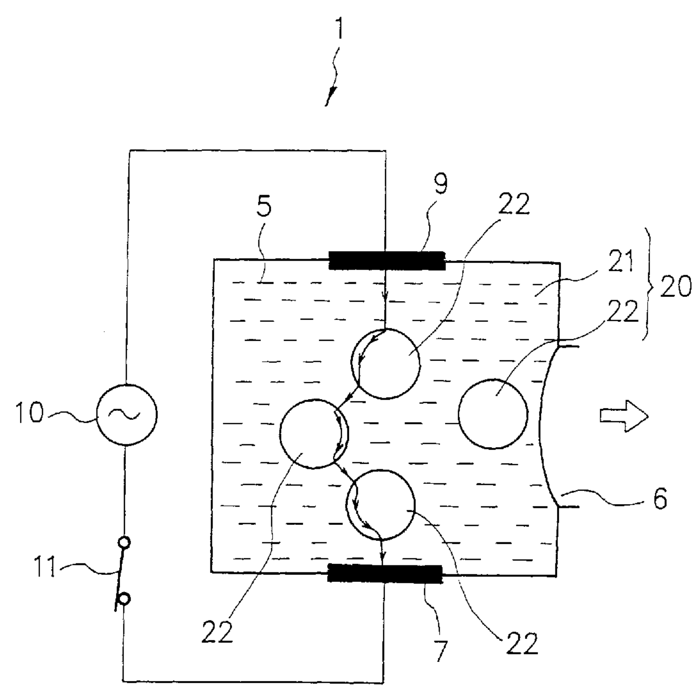
(54) Ink jet device and conductive liquid

(57) An ink jet device including a storing chamber (5) for storing a conductive ink (20) containing a conductive liquid (21) and a conductive material (22); an electrode (7,9) for applying an alternating current to the conductive ink (20) stored in the storing chamber (5) in order to generate bubbles in the conductive liquid (21); and a nozzle (6) for ejecting the conductive ink (20) owing to generation of the bubbles by application of the alternating current.

F I G. 5



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Description

The present invention relates to an ink jet device capable of forming a high-density recorded image, and also to a conductive ink effective in application to this ink jet device.

The principle of a conventional ink jet device, a bubble jet system and a conductive jet system are known, for example. The bubble jet system is such that ink in a container is vaporized by heat generated from a resistance heating element to thereby generate bubbles, and the ink thus pressurized by the bubbles is ejected from a nozzle of the container. The conduction jet system is such that conductive ink in a container is heated to be vaporized by passing a current therethrough to thereby generate bubbles, and the ink thus pressurized by the bubbles is ejected from a nozzle of the container.

In the bubble jet system using the resistance heating element, the ink kept in contact with a heating surface of the resistance heating element is vaporized by the heat generated from the heating surface. That is, the heat is given from the heating surface of the resistance heating element to the ink, so that thermal energy allowed to be injected into the ink is limited by the area of the heating surface of the resistance heating element. Accordingly, energy for ejecting the ink is also limited. If a current applied to the resistance heating element is increased to heat the ink beyond the limit, there is a possibility that the resistance heating element may be broken rather than increasing of the ink ejection energy.

In the conduction jet system, the conductive ink through which a current is passed has a uniform composition and therefore has a constant resistance. Accordingly, there is no means for increasing the thermal energy to be injected into the ink and increasing the ink ejection force.

In recent ink jet devices, it has been desired to increase the density of dots to be printed and thereby improve the definition of a printed image. To meet this desire, the opening size or pitch of nozzles for ejecting the ink must be made smaller than those in the prior art. However, in the conventional bubble jet system, the ink ejection force cannot simply be increased as mentioned above. If the opening size or pitch of the nozzles is reduced without increasing the ink ejection force, ink sediment or dust tends to stay in the nozzles, causing the clog of the nozzles. In this manner, there is a limit of ink ejection force in the conventional ink jet device, causing a difficulty of improvement in definition of a printed image.

It is accordingly an object of the present invention to provide an ink jet device which can increase an ink ejection force from each nozzle and support high-definition printing.

It is another object of the present invention to provide a conductive ink effective in application to this ink jet device.

In accordance with a first aspect of the present invention, provided is an ink jet device comprising a storing chamber for storing a conductive ink containing a conductive liquid and a conductive material; an electrode for applying an alternating current to the conductive ink stored in the storing chamber in order to generate bubbles in the conductive liquid; and a nozzle for ejecting the conductive ink owing to generation of the bubbles by application of the alternating current.

The conductive material may have conductivity higher than that of the conductive liquid.

The conductive material may have at least a conductive surface, the conductive surface having a conductivity allowing heat generation for generation of the bubbles in the conductive liquid by a skin effect caused by application of the alternating current.

The conductive material may comprise conductive particles, each of the conductive particles having a size smaller than an opening size of the nozzle.

The storing chamber may comprise a plurality of storing chambers defined and separated from each other by a pair of substrates opposed to each other and spaced a given distance, and a plurality of partition members located between the pair of substrates and arranged at given intervals; the nozzle comprise a plurality of nozzles arranged at given intervals so as to respectively correspond to the storing chambers, each nozzle opening at one end of each corresponding storing chamber; the electrode comprise a plurality of pairs of electrodes comprising a plurality of first electrodes provided on an inner surface of one of the substrates so as to respectively correspond to the storing chambers, and a second electrode provided on an inner surface of the other substrate so as to commonly pair with each of the first electrodes; and the ink jet device further comprise a power source for applying an alternating current between the first and second electrodes, a plurality of switching means respectively connected to the first electrodes, and ink supply means for supplying the conductive ink to the storing chambers.

The storing chamber may comprise a plurality of storing chambers defined and separated from each other by a pair of substrates opposed to each other and spaced a given distance, and a plurality of partition members located between the pair of substrates and arranged at given intervals; the nozzle comprise a plurality of nozzles arranged at given intervals so as to respectively correspond to the storing chambers, each nozzle opening at one end of each corresponding storing chamber; the electrode comprise a plurality of pairs of electrodes respectively discretely provided in the storing chambers; and the ink jet device further comprises a power source for applying an alternating current between each pair of electrodes in each storing chamber, a plurality of switching means respectively connected to the plurality of pairs of electrodes, and ink supply means for supplying the conductive ink to the storing chambers.

The electrode may comprise a plurality of elongated electrodes arranged in parallel at given intervals; the storing chamber comprises a plurality of storing chambers defined and separated from each other by the electrodes and a pair of insulating members opposed to each other with the electrodes interposed therebetween; the nozzle comprise a plurality of nozzles arranged at given intervals so as to respectively correspond to the storing chambers, each nozzle opening at one end of each corresponding storing chamber; and the ink jet device further comprises a power source for applying an alternating current between adjacent ones of the electrodes, a plurality of switching means each connected to the adjacent ones of the electrodes, and ink supply means for supplying the conductive ink to the storing chambers.

In accordance with a second aspect of the present invention, a conductive ink comprises a conductive liquid and a conductive material dispersed in the conductive liquid, the conductive material having a conductivity higher than that of the conductive liquid.

The conductive material may have at least a conductive surface, the conductive surface having a conductivity allowing heat generation for generation of bubbles in the conductive liquid by a skin effect caused by application of the alternating current.

According to the above configuration of the present invention, at least the following operation can be obtained. The alternating current is applied between the electrode pair to pass through the conductive ink in the storing chamber. The alternating current flows through the conductive material having a conductivity higher than that of the conductive liquid. In particular, the alternating current flowing through the conductive material is concentrated at the surface of the conductive material owing to the skin effect. The conductive ink stored in the storing chamber between the electrode pair contains the conductive material in a large amount, so that the total surface area of the conductive material can be increased. Accordingly, more energy can be injected into the conductive ink than in the prior art. The heat generated from the surface of the conductive material vaporizes the liquid to form the bubbles in the liquid. As a result, the liquid pressurized by the bubbles is ejected from the nozzle.

Embodiments of the invention will now be disclosed, by way of example only, with reference to the accompanying drawings, of which:

FIG. 1 is a partially cutaway, perspective view of an ink jet device according to a first preferred embodiment of the present invention;
FIG. 2 is a circuit diagram of a drive circuit in the first preferred embodiment;
FIG. 3 is a waveform chart showing an example of an alternating current in the first preferred embodiment;
FIG. 4 is a waveform chart showing another example of the alternating current in the first preferred embodiment;
FIG. 5 is a schematic view illustrating the concept of passage of the alternating current through a conductive ink in the first preferred embodiment;
FIGS. 6A to 6E are schematic views illustrating the process of generation of bubbles in the conductive ink in the first preferred embodiment;
FIGS. 7A to 7E are schematic views illustrating the process of ejection of the conductive ink by the generation of the bubbles in the first preferred embodiment;
FIG. 8 is a partially cutaway, perspective view of an ink jet device according to a second preferred embodiment of the present invention;
FIG. 9 is a partially cutaway, perspective view of an ink jet device according to a third preferred embodiment of the present invention; and
FIG. 10 is a circuit diagram of a drive circuit in the second preferred embodiment.

There will now be described an ink jet device 1 according to a first preferred embodiment of the present invention with reference to FIGS. 1 to 7E. As shown in FIG. 1, a plurality of elongated bar-like partition members 3 are provided on the upper surface of an insulating, first substrate 2 so as to be arranged at given intervals. The front end surface of each partition member 3 is wider than the other portion thereof, and is flush with the front end surface of the first substrate 2. A second substrate 4 is provided on these partition members 3. A plurality of substantially rectangular-cylindrical storing chambers 5 for storing conductive ink 20 (see FIG. 5) are provided so that each storing chamber 5 is defined among adjacent ones of the partition members 3, the first substrate 2, and the second substrate 4. Each storing chamber 5 is open at its front end to form a rectangular nozzle 6 for ejecting the conductive ink 20 stored in the corresponding storing chamber 5.

An electrode 7 is provided in each storing chamber 5 on the first substrate 2. The electrode 7 is formed as a part of a band-like electrode provided in each storing chamber 5. That is, a front end portion of the band-like electrode is exposed as the electrode 7 to each storing chamber 5, and the other portion of the band-like electrode is covered with an insulating film 8.

Another electrode 9 is formed on the whole of the lower surface of the second substrate 4. The electrode 9 is associated with the electrode 7 in each storing chamber 5 to form an electrode pair. That is, the electrode 9 is a common electrode to each electrode 7. The common electrode 9 and each electrode 7 are formed from a thin film or a thick film of any conductive material by a simple technique such as printing or plating.

As shown in FIG. 2, an alternating power source 10 is connected between each electrode 7 and the common electrode 9. Each electrode 7 is provided with switching means 11 to allow a voltage to be applied between the pair of electrodes 7 and 9 in a desired one of the storing chambers 5, thereby passing an alternating current through the conductive ink 20 between these electrodes 7 and 9.

Although not shown, the ink jet device 1 has ink supply means for supplying the conductive ink 20 to each storing chamber 5. An ink supply pipe (not shown) may be connected between the ink supply means and an open end of each storing chamber 5 opposite to the corresponding nozzle 6. Accordingly, each storing chamber 5 is always filled with the conductive ink 20 supplied by the ink supply means.

As shown in FIG. 5, the conductive ink 20 is composed mainly of an liquid 21 having a conductivity of $1 \times 10^{-7}/\Omega$cm or more, for example, and further includes a conductive material 22 having a conductivity higher than that of the liquid 21. The conductive material 22 is formed of a material having at least a conductive surface, such as a carbon particles, metal particles, fine particles covered with carbon, and microcapsules each having a conductive surface. More specifically, the conductive material 22 is formed as particles each having a size of 0.01 to 10 â ∧ or μm in diameter, for example, so as to obtain a good result for generation of heat due to a skin effect which will be hereinafter described. Further, the size of each particle is preferably set so as to avoid clogging of each nozzle 6.

The alternating current passing through the conductive material 22 in the conductive ink 20 is localized in a conductive surface layer of the conductive material 22. That is, the alternating current does not flow into an inside portion of the conductive material 22, but flows only in the surface layer of the conductive material 22. This phenomenon is called a skin effect. In this preferred embodiment, the current is concentrated in the surface layer of the conductive material 22 to increase an effective resistance of the conductive material 22. Accordingly, the surface of the conductive material 22 is heated to thereby generate bubbles in the liquid 21 surrounding the conductive material 22. To generate the heat, the surface and a near surface portion of the conductive material 22 preferably has a resistance allowing heat generation by the passage of a current owing to the above-mentioned skin effect, so as to generate the bubbles.

As described above, it is preferable that the conductive material 22 has a conductivity higher than that of the conductive liquid 21 which is a main component of the conductive ink 20, and that at least the surface of the conductive material 22 has a given resistance.

There will be described more specifically the alternating current applied between the electrodes 7 and 9 by the alternating power source 10 in the above preferred embodiment. The alternating current described in this preferred embodiment and the claims means any current with a changing amperage other than a direct current, and is a term widely indicating a current exhibiting the above-mentioned skin effect. Accordingly, the alternating current used herein includes not only a sinusoidal wave with both positive values and negative values, but also a sinusoidal wave with either positive values or negative values. Further, the alternating current used herein also includes a pulse wave with both positive values and negative values as shown in FIG. 3 or 4. Further, the alternating current may include a pulse wave with either positive values or negative values. The shape of the pulse wave is not limited to a regular rectangular shape as shown in FIG. 3 or 4, and the shape of the sinusoidal wave may be distorted.

The higher the frequency of the sinusoidal wave or the pulse wave of the alternating current, the more pronounced the skin effect, resulting in more concentration of the current at the surface of the conductive material 22, thereby more increasing the effective resistance and more facilitating heat generation. Therefore, it is preferable to set a high frequency of the sinusoidal wave or the pulse wave of the alternating current. Further, the heating value of the conductive ink 20 can be arbitrarily controlled by suitably setting the frequency and amperage of the alternating current to be applied between the electrodes 7 and 9, the concentration of the conductive material 22 in the conductive ink 20, the conductivity or resistance of the conductive material 22, etc.

In the conventional ink jet device employing a resistance heating element for heating ink in direct contact therewith to generate bubbles, only the surface area of the resistance heating element is a heat generation area. In contrast, the heat generation area in the ink jet device 1 according to this preferred embodiment is given as a surface area of the conductive material 22 contained in a large amount in the conductive ink 20 stored in each storing chamber 5 between the electrodes 7 and 9. That is, the total surface area of the conductive material 22 in the ink jet device 1 is large, thereby allowing more energy to be injected over the prior art. Accordingly, an ink ejection force can be easily increased, and a print quality can be easily improved by reducing the opening size or pitch of the nozzles 6 over the prior art.

The operation of the above preferred embodiment will now be described. The alternating current having a pulse wave as shown in FIG. 3 or 4 is applied between the electrodes 7 and 9. As shown in FIG. 5, the current does not uniformly flow in the conductive ink 20, but is collected to the conductive material 22 having a conductivity higher than that of the conductive liquid 21. At this time, the current is concentrated at the surface of the conductive material 22 owing to the skin effect. Since the surface of the conductive material 22 has a given resistance, the current concentrated at the surface of the conductive material 22 generates heat. The conductive ink 20 stored in each storing chamber 5 between the electrodes 7 and 9 contains a large number of particles constituting the conductive material 22, so that the total surface area of these particles kept in contact with the liquid 21 is very large. Accordingly, more thermal energy can be injected into the liquid 21 by passing more current than in the prior art.

When the current flows in the surface of the conductive material 22 as shown in FIG. 6A, heat generation is concentrated especially at two positions on the surface of the conductive material 22, which two positions correspond to an inlet and outlet of the current, so that small bubbles 23 are generated in the liquid 21 near these two positions. As the passage of the current proceeds, the small bubbles 23 are enlarged as shown in FIG. 6B, and subsequently combined together to form a single large bubble 23 as shown in FIG. 6C. When the passage of the current is cut off to stop the heat generation, the single large bubble 23 quickly becomes small as shown in FIGS. 6D and 6E.

The generation of the bubbles in the conductive ink 20 between the electrodes 7 and 9 as following the process as shown in FIG. 6A to 6E causes application of pressure of the bubbles to the conductive ink 20, resulting in ejection of the conductive ink 20 in the form of droplet from the corresponding nozzle 6 as shown in FIGS. 7A to 7E, which respectively correspond to FIGS. 6A to 6E.

In the ink jet device 1 shown in FIG. 1, the plural switching means 11 shown in FIG. 2 are suitably turned on or off to thereby eject the ink from a desired one or ones of the nozzles 6 at a desired timing. As a result, the ejected ink is deposited in the form of dots onto a printing sheet of paper located in front of the nozzles 6 and being fed in a given direction, thus desired images are printed on the paper.

FIG. 8 is a partially cutaway, perspective view of an ink jet device 31 according to a second preferred embodiment of the present invention. Parts of the ink jet device 31 corresponding to those in the first preferred embodiment are denoted by the same reference numerals, and the description thereof will be omitted. A pair of electrodes 32 and 33 spaced from each other are provided in each storing chamber 5 on a first substrate 2. That is, a first band-like electrode is formed on the first substrate 2, and a front end portion of the first band-like electrode is exposed to each storing chamber 5 to form the electrode 33. The other portion of the first band-like electrode is covered with an insulating film 34, and a second band-like electrode as the electrode 34 is formed on the insulating film 34 so as to be exposed to each storing chamber 5. The electrodes 32 and 33 are connected at their ends corresponding to the rear end of the first substrate 2 opposite to nozzles 6, to a drive circuit. No electrode is formed on the inner surface of a second substrate 4 in this preferred embodiment. FIG. 10 shows the drive circuit in this preferred embodiment. As apparent from FIG. 10, a plurality of pair of electrodes 32 and 33 in all storing spaces 5 can be individually driven by an alternating current supplied from an alternating power source 10 through a plurality of switching means 11 respectively provided for the plural pairs of electrodes 32 and 33. This preferred embodiment can exhibit effects substantially similar to those of the first preferred embodiment.

FIG. 9 is a partially cutaway, perspective view of an ink jet device 41 according to a third preferred embodiment of the present invention. A plurality of band-like electrodes 43 are provided on a substrate 42 as an insulating member so as to be arranged at given intervals. Adjacent ones of the electrodes 43 form a pair. Each pair of electrodes 43 are connected through switching means 11 to an alternating power source 10. Accordingly, an alternating current is applied selectively to each electrode pair 43 at a desired timing.

All the electrodes 43 on the substrate 42 are covered with a film 44 as an insulating member, thus defining a plurality of storing chambers 45 for storing conductive ink 20 in such a manner that each storing chamber 45 is defined among the adjacent electrode pair 43, the substrate 42, and the film 44. Each storing chamber 45 is open at its front end to form a nozzle 46 for ejecting the conductive ink 20. Ink supply means (not shown) for supplying the conductive ink 20 to each storing chamber 45 is provided in the ink jet device 41. This ink supply means may have the same configuration as that in the first preferred embodiment.

A platen roller 47 is provided in front of the nozzles 46. A printing sheet of paper 48 is fed by rotating the platen roller 47, and the ink jet device 41 is driven in synchronism with the rotation of the platen roller 47. The plural switching means 11 are suitably turned on or off to thereby eject the ink from a desired one or ones of the nozzles 46 at a desired timing. The ejected ink is deposited in the form of dots onto the paper 48 to print a desired image.

The operations of the second and third preferred embodiments including application of the current between each electrode pair, heat generation by the skin effect, generation of bubbles, and ejection of the ink are similar to that of the first preferred embodiment. In particular, the second and third preferred embodiments have an advantage such that since all the electrode pairs 32 and 33 corresponding to the respective nozzles 6 are electrically discrete, and all the electrode pairs 43 corresponding to the respective nozzles 46 are electrically discrete, there is less possibility that the current for driving a certain electrode pair may influence another electrode pair adjacent thereto. Further, the first preferred embodiment has an advantage such that since the electrode 9 is a common electrode to all the electrodes 7, the ink jet device 1 can be easily manufactured. Further, while the spacing between the adjacent electrodes 43 is equal to the opening width of each nozzle 46 in the third preferred embodiment shown in FIG. 9, the spacing between the front ends of the adjacent electrodes 43 may be reduced, or the height of each electrode 43 may be reduced, for example, to thereby reduce the opening size of each nozzle 46.

According to the ink jet device and the conductive ink of the present invention as described above, the alternating current is applied to the conductive ink containing the conductive material, and is collected to the surface of the conductive material by the skin effect, thereby collectively generating heat from the surface of the conductive material. Accordingly, an energy density can be increased to thereby eject the ink under high pressure. As a result, the opening size and pitch of the nozzles can be reduced to allow high-definition printing.

Claims

1. An ink jet device comprising:

   a storing chamber for storing a conductive ink containing a conductive liquid and a conductive material;
   an electrode for applying an alternating current to said conductive ink stored in said storing chamber in order to generate bubbles in said conductive liquid; and
   a nozzle for ejecting said conductive ink owing to generation of said bubbles by application of said alternating current.

2. An ink jet device according to claim 1, wherein said conductive material has a conductivity higher than that of said conductive liquid.

3. An ink jet device according to claim 2, wherein said conductive material has at least a conductive surface, said conductive surface having a conductivity allowing heat generation for generation of said bubbles in said conductive liquid by a skin effect caused by application of said alternating current.

4. An ink jet device according to claim 3, wherein said conductive material comprises conductive particles, each of said conductive particles having a size smaller than an opening size of said nozzle.

5. An ink jet device according to claim 4, wherein:

   said storing chamber comprises a plurality of storing chambers defined and separated from each other by a pair of substrates opposed to each other and spaced a given distance, and a plurality of partition members located between said pair of substrates and arranged at given intervals;
   said nozzle comprises a plurality of nozzles arranged at given intervals so as to respectively correspond to said storing chambers, each nozzle opening at one end of each corresponding storing chamber;
   said electrode comprises a plurality of pairs of electrodes comprising a plurality of first electrodes provided on an inner surface of one of said substrates so as to respectively correspond to said storing chambers, and a second electrode provided on an inner surface of the other substrate so as to commonly pair with each of said first electrodes; and
   said ink jet device further comprises a power source for applying an alternating current between said first and second electrodes, a plurality of switching means respectively connected to said first electrodes, and ink supply means for supplying said conductive ink to said storing chambers.

6. An ink jet device according to claim 4, wherein:

   said storing chamber comprises a plurality of storing chambers defined and separated from each other by a pair of substrates opposed to each other and spaced a given distance, and a plurality of partition members located between said pair of substrates and arranged at given intervals;
   said nozzle comprises a plurality of nozzles arranged at given intervals so as to respectively correspond to said storing chambers, each nozzle opening at one end of each corresponding storing chamber;
   said electrode comprises a plurality of pairs of electrodes respectively discretely provided in said storing chambers; and
   said ink jet device further comprises a power source for applying an alternating current between each pair of electrodes in each storing chamber, a plurality of switching means respectively connected to said plurality of pairs of electrodes, and ink supply means for supplying said conductive ink to said storing chambers.

7. An ink jet device according to claim 4, wherein:

   said electrode comprises a plurality of elongated electrodes arranged in parallel at given intervals;
   said storing chamber comprises a plurality of storing chambers defined and separated from each other by said electrodes and a pair of insulating members opposed to each other with said electrodes interposed therebetween;
   said nozzle comprises a plurality of nozzles arranged at given intervals so as to respectively correspond to said storing chambers, each nozzle opening at one end of each corresponding storing chamber; and
   said ink jet device further comprises a power source for applying an alternating current between adjacent ones of said electrodes, a plurality of switching means each connected to said adjacent ones of said electrodes, and ink supply means for supplying said conductive ink to said storing chambers.

8. A conductive ink comprising a conductive liquid and

a conductive material dispersed in said conductive liquid, said conductive material having a conductivity higher than that of said conductive liquid.

9. A conductive ink according to claim 8, wherein said conductive material has at least a conductive surface, said conductive surface having a conductivity allowing heat generation for generation of said bubbles in said conductive liquid by a skin effect caused by application of said alternating current.

10. A method of operating the ink jet device of any one of claims 1 to 7 comprising applying an alternating current to the electrode so as to generate bubbles in the conductive ink.

F I G. 1

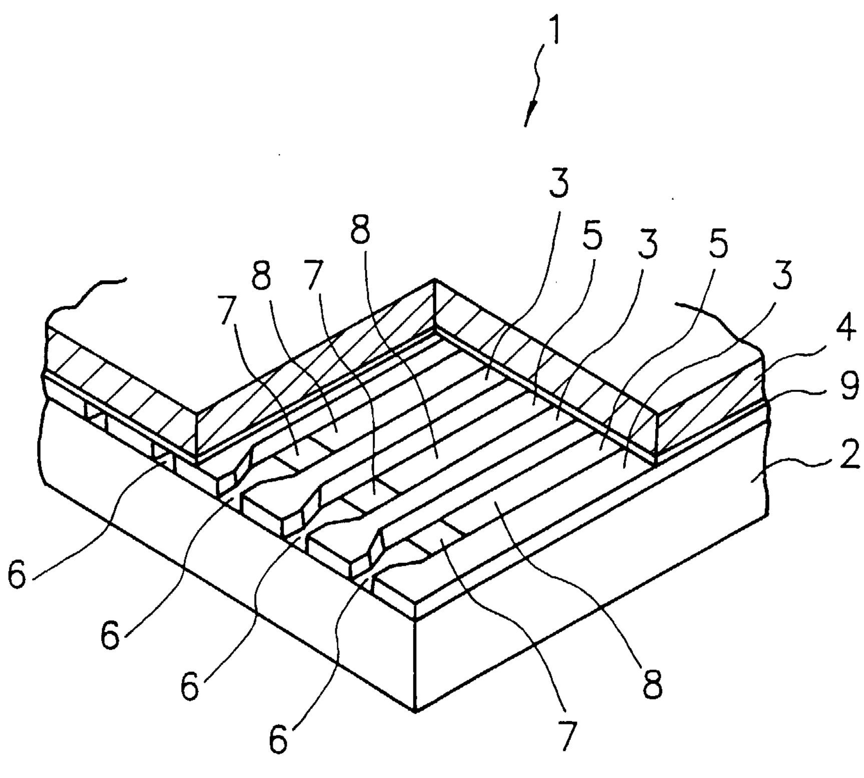

FIG. 2

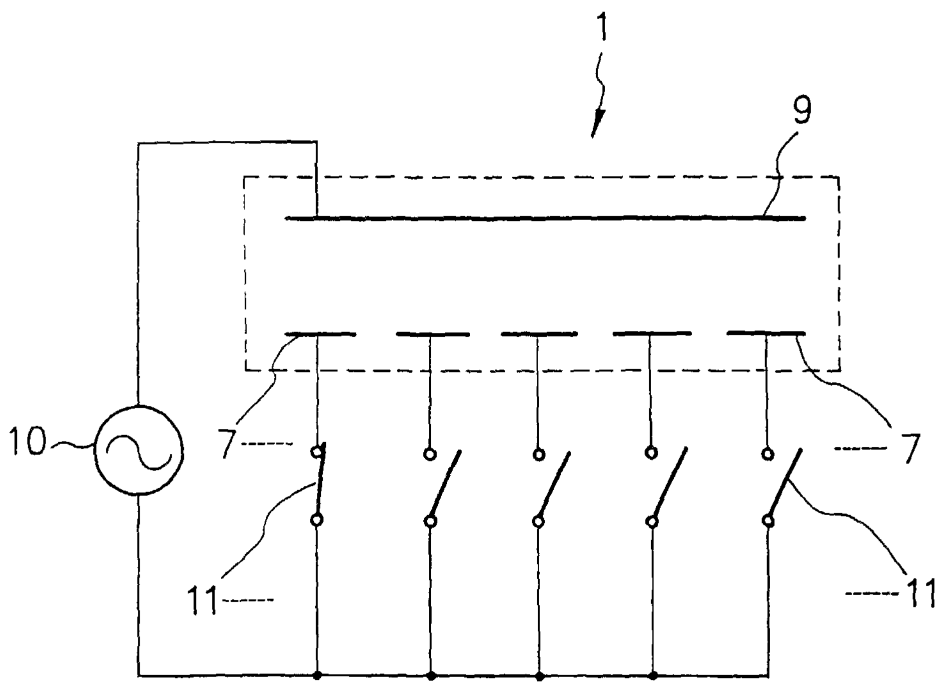

FIG. 3

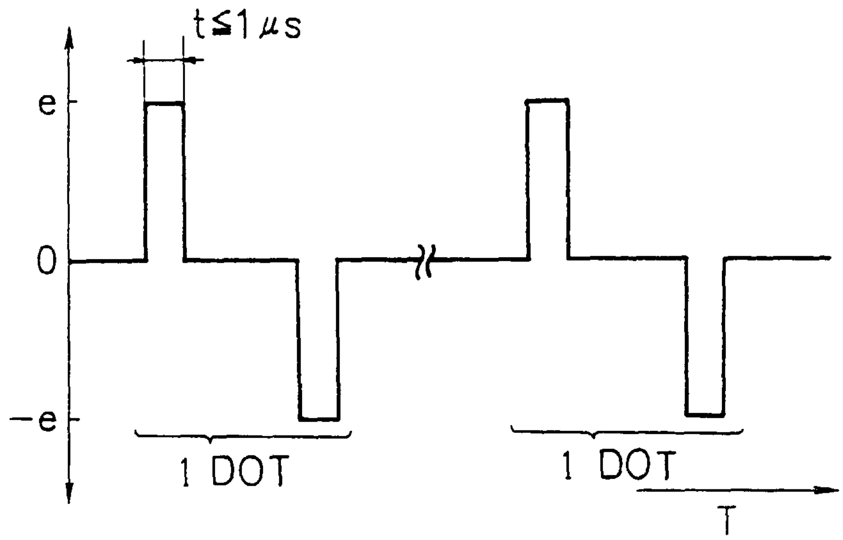

FIG. 4

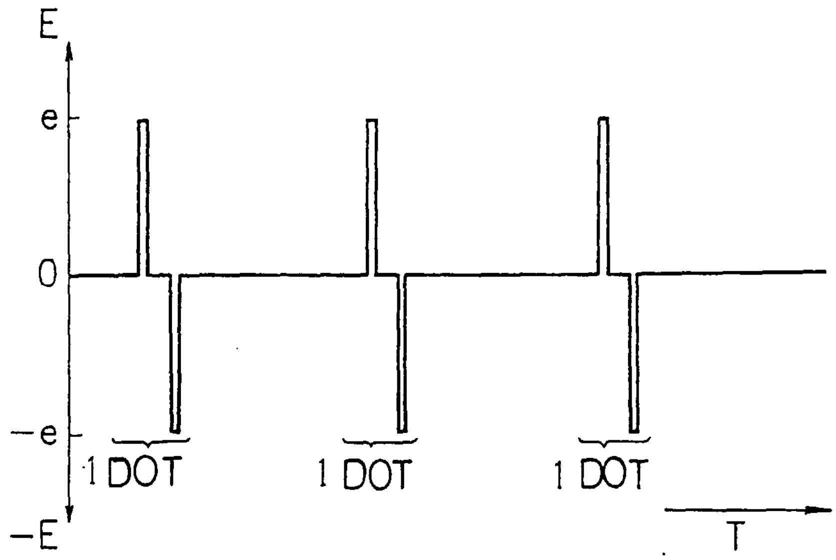

FIG. 5

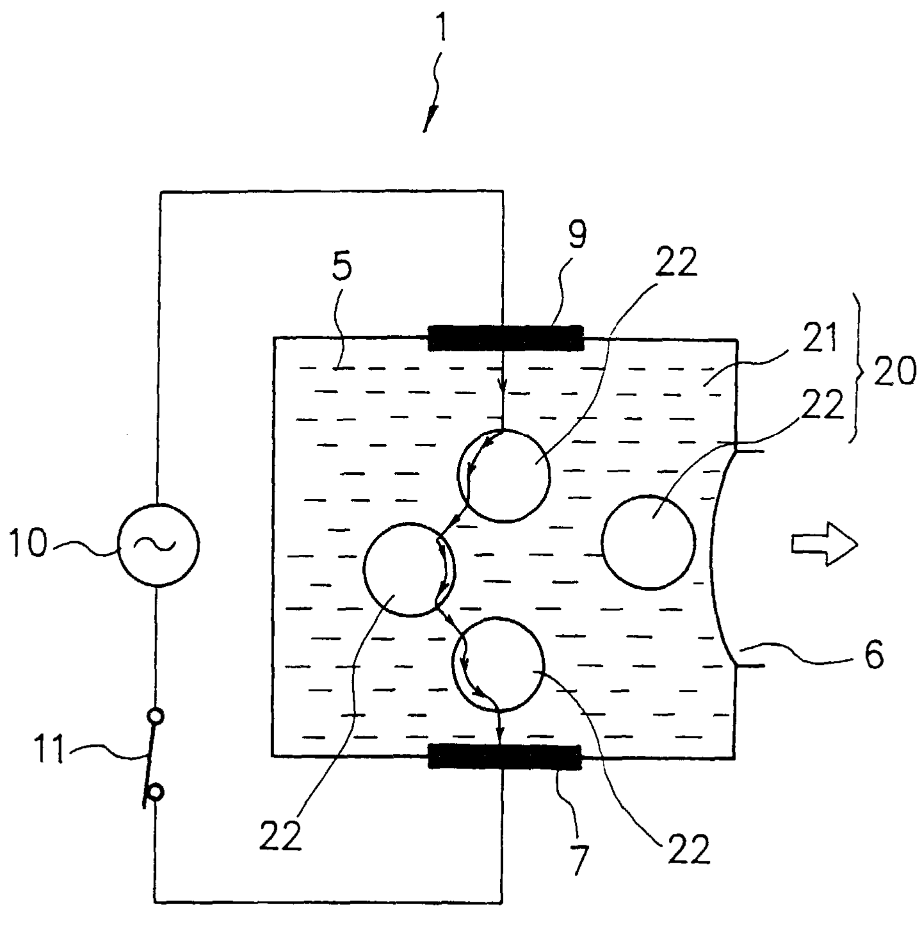

FIG. 6

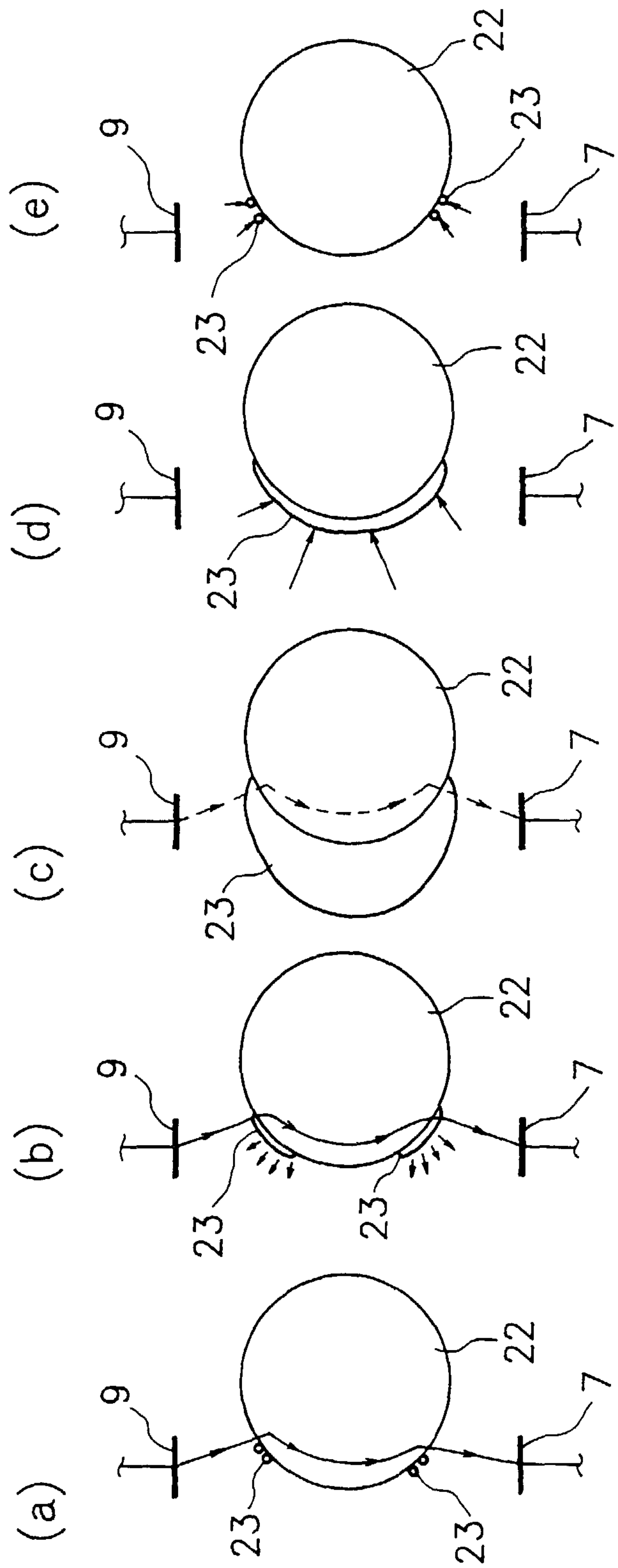

FIG. 7

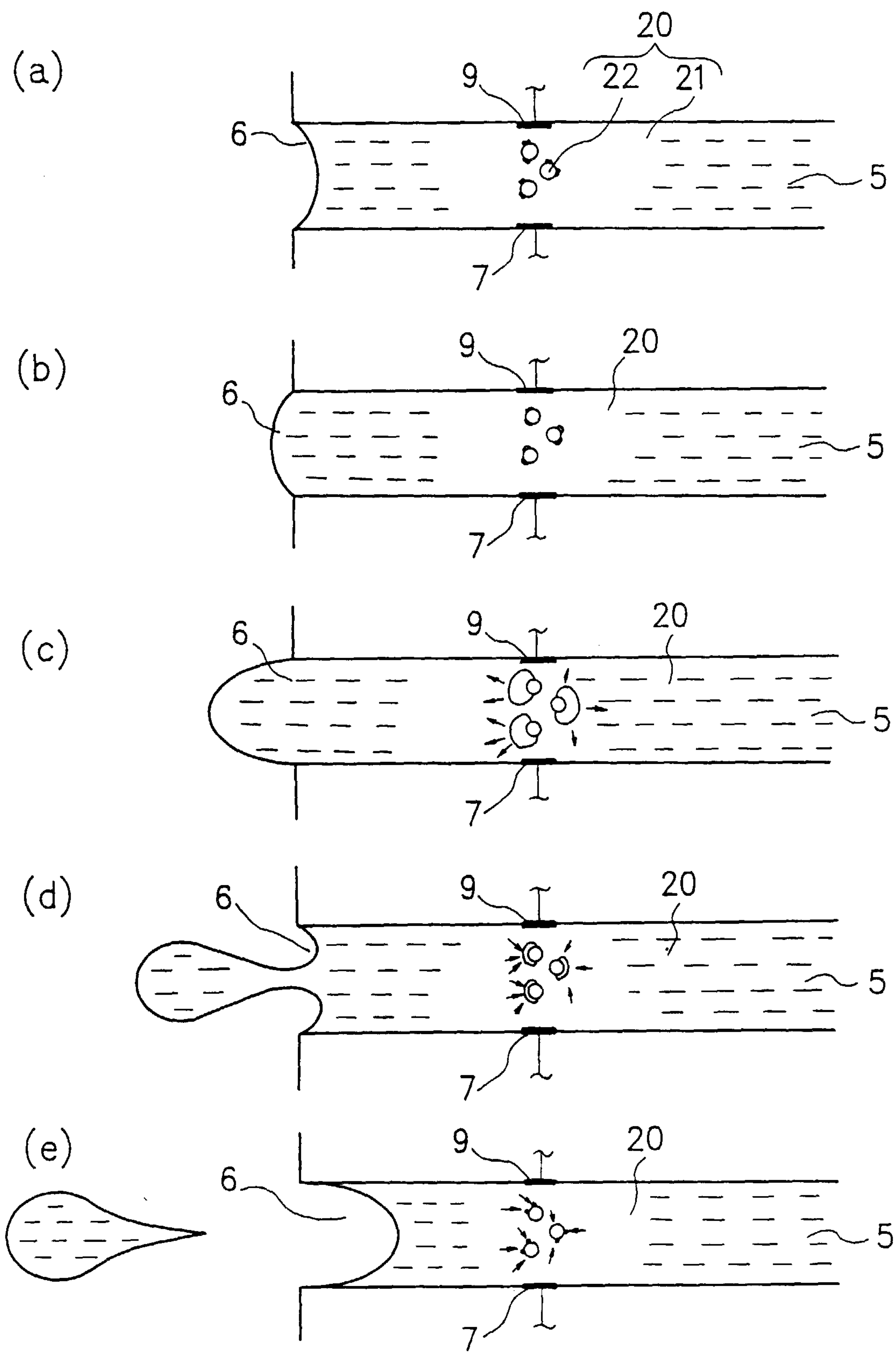

FIG. 8

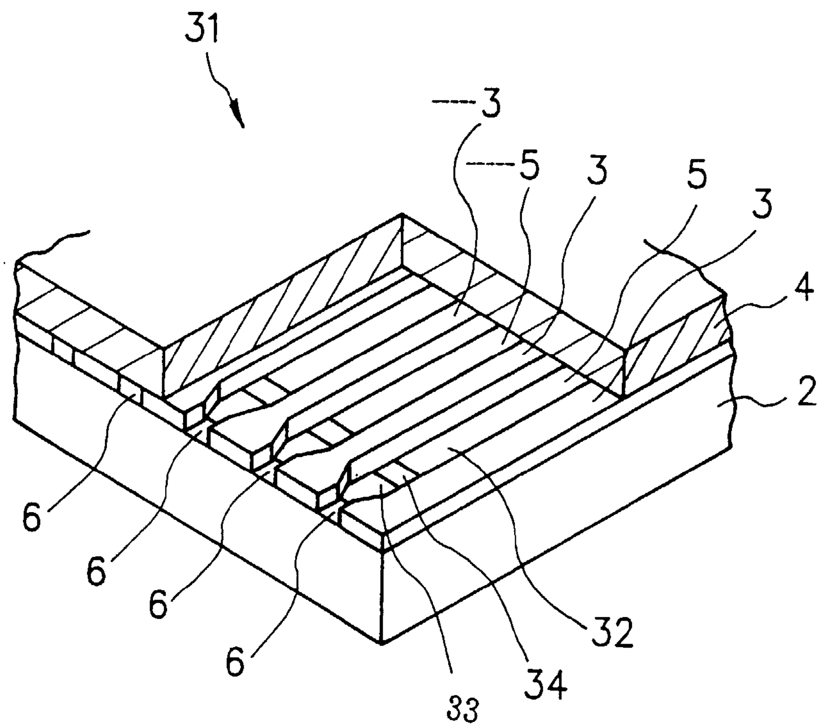

FIG. 9

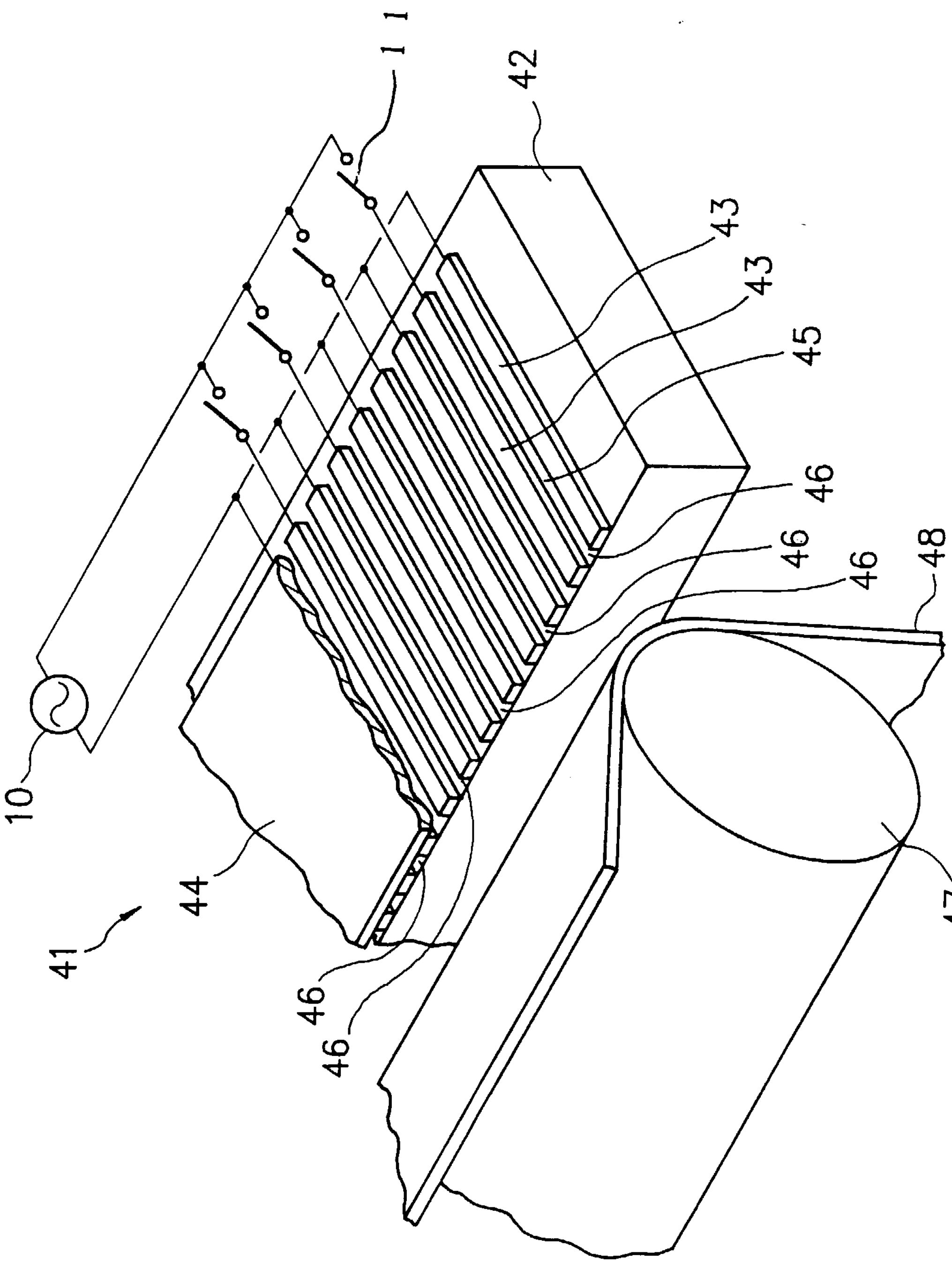

FIG. 10