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(71) Applicant:
SAMSUNG ELECTRONICS CO. LTD.
Suwon-city, Kyounggi-do 441-742 (KR)

(72) Inventors:
- **Dunaev, Boris Nikolaevich**
  Moscow 111558 (RU)
- **Ahn, Byung-sun**
  Paldal-gu, Suwon, Kyonggi-do (KR)
- **Zukov, Andrey Aleksandrovich**
  Moscow 109029 (RU)

(74) Representative:
Sanderson, Nigel Paul et al
Dibb Lupton Alsop,
Fountain Precinct
Balm Green, Sheffield S1 1RZ (GB)

(54) **Method for forming thick film layer of micro injecting device**

(57) A method for forming at thick film layer (30) of micro injecting device is disclosed in which a thin film layer (31') is formed on a substrate (1), a thick film layer (32') is formed on the thin film layer (31') without performing additional heat-treatment, and the thin film layer (31') and thick film layer (32') formed sequentially on the substrate are simultaneously heat-treated, to thereby complete a single thick film layer (30). The single thick film layer (30) is formed by a sequential coating process without being interfered by heat-treatment, thereby eliminating an isolating line. As a result, an overall durability of thick film layer (30) can be significantly enhanced.

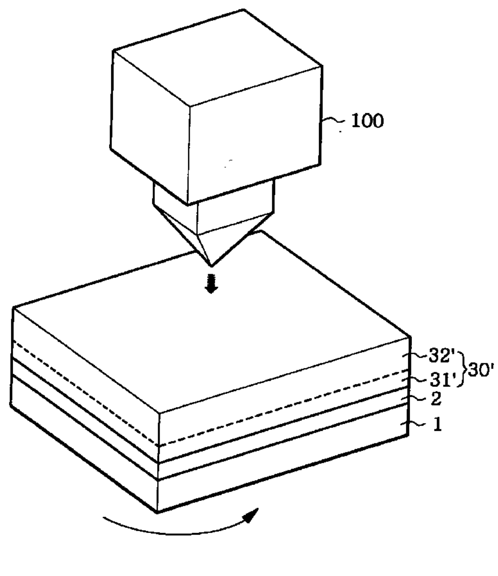

FIG. 1B

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to the field of micro-injecting devices and inkjet printheads, and, more particularly, to a method for forming a thick film layer in the manufacture of a micro-injecting device.

Description of the Related Art

[0002] Generally, a micro-injecting device refers to a device which is designed to provide printing paper, a human body or motor vehicles with a predetermined amount of liquid, for example, ink, injection liquid or petroleum using the method in which a predetermined amount of electric or thermal energy is applied to the above-mentioned liquid, yielding a volumetric transformation of the liquid. This method allows the application of a small quantity of liquid to a specific object.

[0003] Recent developments in electrical and electronic technology have enabled rapid development of such micro-injecting devices. Thus, micro-injecting devices are being widely used in daily life. One example of the use of micro-injecting devices in daily life is the inkjet printer.

[0004] The inkjet printer is a form of micro-injecting device which differs from conventional dot printers in the capability of performing print jobs in various colors by using cartridges. Additional advantages of inkjet printers over dot printers are lower noise and enhanced quality of printing. For these reasons, inkjet printers are gaining immensely in popularity.

[0005] An inkjet printer generally includes a printhead in which ink which is initially in the liquid state is transformed to a bubble state by turning on or off an electric signal applied from an external device. Then, the ink so bubbled expands and is ejected so as to perform a print job on a printing paper.

[0006] Examples of the construction and operation of several ink jet printheads of the conventional art are seen in the following U.S. Patents: U.S. Patent No. 4,490,728, to Vaught et al., entitled *Thermal Ink Jet Printer*, describes a basic printhead; U.S. Patent No. 4,809,428, to Aden et al., entitled *Thin Film Device for An Ink Jet Printhead and Process for Manufacturing Same* and U.S. Patent No. 5,140,345, to Komuro, entitled *Method of Manufacturing a Substrate For A Liquid Jet Recording Head And Substrate Manufactured By The Method*, describe manufacturing methods for inkjet printheads; U.S. Patent No. 5,274,400, to Johnson et al., entitled *Ink Path Geometry For High Temperature Operation Of Ink-Jet Printheads*, describes altering the dimensions of the ink-jet feed channel to provide fluidic drag; U.S. Patent No. 5,420,627, to Keefe et al, entitled *Ink Jet Printhead*, shows a particular printhead design.

[0007] In such a conventional inkjet printhead, chemicals, for example, ink or working liquid, are usually employed in performing a print job. For this reason, a chamber region for storing the chemicals is mounted at or in the printhead.

[0008] A thick film layer which ultimately defines the chamber region is formed on a substrate that constitutes a printhead. Chemicals, for example, ink or working liquid, is stored or retained stably in the chamber region defined by the thick film layer.

[0009] Generally, the thick film layer has a thickness of 10µm or more so that the chamber region has sufficient depth and internal volume, and the thick film layer is made of organic substances to achieve chemical stability of the layer in the presence of ink or working liquid.

[0010] In the prior art, to achieve a thick film layer having a desired thickness, a layer made of an organic substance and which has a predetermined thickness is produced by spin-coating, and subsequently dried and heat-treated. Thus, a basic thin film layer is formed on a protection layer formed on a substrate. Then, numerous further thin film layers are continuously formed on the basic thin film layer by repeatedly performing the above-described process for forming a thin film layer.

[0011] For example, to achieve a thick film layer having a thickness of 10µm, the process for forming a thin film layer having a thickness of 1µm is performed ten times. This of course requires the process of drying and heat-treatment to be performed in each repeated process for forming a thin film layer.

[0012] When such a process for forming a thin film layer is repeatedly performed several times, a plurality of thin film layers are deposited to form multi-layers. Thus, a thick film layer having a desired thickness can be obtained, and the completed thick film layer is then firmly assembled to a relevant position of a printhead.

[0013] However, such a conventional method for forming a thick film layer of inkjet printhead presents several serious problems. As described above, the conventional thick film layer can be formed by depositing a plurality of thin film layers through a repeated process for forming a thin film layer. Here, the thin film layers that constitute a thick film layer each form a definite dividing line at the boundary surface with the next respective layer. In other words, the resulting thick film layer includes discontinuities arising from the boundaries between its constituent thin film layers. The dividing lines are maintained through the assembly of the thick film layer into a certain structure of a printhead, which causes reduction of overall durability of the printhead.

[0014] Moreover, in prior art, to form a thick film layer, the process for drying and heat-treatment must be repeatedly performed. This increases the overall time required for manufacturing the device.

[0015] In addition, in the formation of a thick film layer, because the processes for forming each single thin film layer may not be performed simultaneously, it is extremely difficult to form thin film layers with uniform thicknesses. A particular problem is that impurities, for example, particles can interfere with the process for forming thin film layers. As a result, the overall performance of the printhead is significantly lowered.

SUMMARY OF THE INVENTION

[0016] It is therefore an object of the present invention to provide an improved method for manufacturing a micro-injecting device.

[0017] It is a further object of the present invention to provide a method for manufacturing a micro-injecting device which yields an improved thick film layer of the device.

[0018] It is a yet further object of the invention to provide a method which yields a thick film layer with uniform thickness.

[0019] It is a still further object of the invention to provide a method which eliminates the dividing lines between the multi-layers of the thick film.

[0020] It is a still yet further object of the invention to prevent impurities from being incorporated in the thick film layer.

[0021] It is another object of the invention to provide a method for manufacturing a micro-injecting device which takes less time.

[0022] According to a first aspect of the present invention there is provided a method for forming a thick film layer for use in a micro-injecting device, comprising:

a first step of depositing a first amount of a liquid comprising an organic substance on a substrate and spinning the substrate at a first rotation rate, to form a first organic liquid layer;

a second step of depositing a second amount of a liquid comprising an organic substance on the first organic liquid layer and spinning the substrate at a second rotation rate slower than said first rotation rate, to form a second organic liquid layer; and

drying and heat-treating said first and second organic liquid layers to form a combined thick film layer.

[0023] A particular feature of the method of the invention is that the combined thick film layer can be made substantially free from discontinuities.

[0024] Preferably a protective film is formed on the substrate prior to the first deposition step.

[0025] A second aspect of the present invention provides a thick film layer for a micro-injecting device obtainable by the method of the first aspect of the invention.

[0026] A third aspect of the present invention provides a print head for an ink jet printer including a thick film layer according to the second aspect of the invention

[0027] Another aspect of the present invention provides a print head for an ink jet printer comprising a substrate, a nozzle plate and a thick film layer disposed between the substrate and the nozzle plate and defining chambers for the printing ink, wherein the thick film layer has substantially no discontinuities in a direction from the substrate to the nozzle plate.

[0028] To achieve the above objects and other advantages, in the present invention, an organic substance, for example, a liquid comprising a polyimide, is deposited on a substrate on which a protection film has been formed, while spinning the substrate at high rotation rate, for example, 450 rpm to 550 rpm. Thus, a thin film layer having a thickness of approximately 0.5μm to 5μm is formed on the protection film.

[0029] Subsequently, without performing heat-treatment, an organic substance is deposited again on the thin film layer so formed, while spinning the substrate on which the thin film layer is formed at a low rotation rate, for example, 20 rpm to 40 rpm. Thus, a thick film layer having a thickness of approximately 18μm to 22μm is formed on the protection film.

[0030] Then, the thin film layer and thick film layer on the substrate are simultaneously heat-treated, thus forming a single, combined, thick film layer without the discontinuities of the prior art. Here, the single thick film layer is formed by sequential coating processes without any interference from heat-treatments, thereby eliminating dividing lines. As a result, the overall durability of thick film layer can be significantly enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] A more complete appreciation of the invention, and many of the attendant advantages thereof, will be readily apparent as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings in which like reference symbols indicate the same or similar components, wherein:

Figures 1A to 1D are views showing a process of forming a thick film layer of an inkjet printhead according to the present invention;

Figure 2 is a cutaway perspective view showing an assembly using a thick film of the present invention; and

Figure 3 is a sectional view through I-I of Figure 2 of an inkjet printhead which employs a thick film layer of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0032] The present invention now will be described more fully with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. As the terms mentioned in the specification are determined based upon the function of the present invention, and they can be changed according to the technician's intention or a usual practice, the terms should be determined considering the overall contents of the specification of the present invention.

[0033] As shown in FIG. 1A, a liquid comprising an organic substance, preferably, a solution comprising polyimide, is deposited in a first step, using a deposition means 100, on a silicon-substrate 1 on which a protection film 2 made of SiO_2 has been formed, while spinning, the substrate 1 as shown by arrow 110, by means of driving a spinning stage (not shown). Spinning may be in the direction of arrow 110 or in the opposite direction. Thus, a first organic liquid layer 31' is formed on the protection film 2 of the substrate 1.

[0034] Preferably, the viscosity coefficient of polyimide liquid is approximately 1.03 centipoise. In addition, the substrate 1 spins in the first step at a high rotation rate, preferably in the range of approximately 450 rpm to 550 rpm, for a time period in the range of approximately 35 seconds to 45 seconds. If the substrate 1 spins at a high rotation rate as described above, the polyimide liquid deposited on the substrate 1 by the deposition means 100 spreads all over the substrate 1 by centrifugal force. As a result, the first organic liquid layer 31' has a thickness preferably in the range of approximately 0.5μm to 5μm, and more preferably in the range of 1μm to 2μm.

[0035] In a second step, shown in Fig. 1B, a liquid comprising an organic substance is deposited on the first organic liquid layer 31' by the deposition means 100, while spinning the substrate 1 by driving the spinning stage. Thus, a second organic liquid layer 32' is formed on the first organic liquid layer 31'. Here, the liquid comprising an organic substance is preferably deposited in an amount in the range of approximately $0.6cm^3$ to $0.8cm^3$ for a specific size of substrate, and has a viscosity coefficient of approximately 1.03 centipoise.

[0036] In addition, in the second step, the substrate 1 spins at a low rotation rate, preferably in the range of approximately 20 rpm to 40 rpm, for a time period in the range of approximately 30 to 40 seconds. As described above, if the substrate 1 spins at a low rotation rate, the polyimide liquid deposited on the first organic liquid layer 31' by the deposition means 100 spreads all over the first organic liquid layer 31' by centrifugal force. At this time, a regular wave is generated in the polyimide liquid by a viscosity of the liquid. Thus, the second organic liquid layer 32' having uniform thickness is formed on the first organic liquid layer 31'. The second organic liquid layer 32' has a thickness preferably in the range of 18μm to 22μm.

[0037] Here, the amount of the second deposition of organic liquid and the rotation rate in the second spinning of the substrate can be correctly calculated by the following equation (1).

$$h = h_1 + h_2 = \varepsilon\,[A\sqrt{\frac{\nu}{\omega}} + \frac{V}{S}] \qquad (1)$$

(Wherein, h is the total thickness of first and second organic liquid layers, h_1 is the thickness of the first organic liquid layer, h_2 is the thickness of the second organic liquid layer to be formed, ε is a coefficient which denotes decreases in the first and second organic liquid layers during the heat treatment process, A is a constant, ν is the viscosity coefficient in liquid, ω is the rotation rate in the second spinning of the substrate, S is the surface area of the substrate, and V is the amount of the second deposition of the organic liquid). In this case, various experimental values can be assigned to the above equation (1), being based on the thickness of the second organic liquid layer 32' to be finally formed, and so the amount of second deposition of organic liquid and the speed of second spinning of the substrate can be obtained.

[0038] In the present invention, various experimental values which can be selected as values for the amount of the second deposition of the organic liquid and for the rotation rate of the second spinning of the substrate, can be assigned to the equation (1), being based on the thickness of the second organic liquid layer 32', preferably 18μm to 22μm. That is, values of the rotation rate and the volume of deposition can be determined based on the desired thickness of the second organic liquid layer. Thus, the amount of second deposition of the organic liquid, $0.6cm^3$ and $0.8cm^3$, and the rotation rate of the second spinning of the substrate, 20 rpm to 40 rpm, can be obtained.

[0039] As a result, the first organic liquid layer 31' as a thin film layer and the second organic liquid layer 32' as a thick film layer are deposited in turn on the substrate 1 on which the protection film 2 is formed, thereby forming a single, combined, organic liquid layer 30' (see figure 1B).

[0040] Subsequently, the substrate 1 on which the single organic liquid layer 30's is formed is taken out from the spinning stage, and is taken into a heating tank or oven (not shown). Then, the first and second organic liquid layers 31' and 32' which constitute the single organic liquid layer 30' are dried and heat-treated.

[0041] Here, the drying is performed at a temperature in the range of approximately 80°C to 90°C for a time in the range of approximately 25 minutes to 35 minutes, and the heat-treatment is performed preferably in two stages at temperatures in the range of approximately 200°C to 220°C and 300°C to 330°C, and for times in the range of 25 to 35 minutes and 60 to 70 minutes, respectively.

[0042] As a result, as shown in FIG. 1B, the first and second organic liquid layers 31' and 32' are hardened and transformed respectively into a first organic film layer 31 as a thin film layer and a second organic film layer 32 as a thick film layer, to thereby form a single, combined, thick film layer 30.

[0043] As described above, in the present invention, the first and second organic liquid layers 31' and 32' are sequentially formed without performing additional heat-treatment, and each is hardened by a heat-treatment at the same time. Thus, the single thick film layer 30 in which the first organic film layer 31 as a thin film layer and the second organic film layer 32 as a thick film layer are sequentially deposited can be obtained. Thus, a dividing line between the first and second organic film layers 31 and 32 can be prevented. As a result, the durability of an inkjet printhead is not lowered even when the single thick film layer 30 is assembled into the inkjet printhead.

[0044] In addition, in the present invention, drying and heat-treatment are performed only once so as to form the single thick film layer 30. Thus, the time required for completion of the manufacturing process can be significantly reduced.

[0045] Further, in the present invention, because a thin film layer and a thick film layer are sequentially formed so as to form a single thick film layer, the time period of the process for forming a film can be reduced. Thus, the problem of impurities introduced to the process can be rectified and a single thick film layer which has been completed can have uniform thickness. As a result, the overall performance of an inkjet printhead can be significantly improved.

[0046] In a subsequent manufacturing step, as shown in FIG. 1C, a pattern film (not shown) is formed on the second organic film layer 32 and the first and second organic film layers 31 and 32 are etched using the pattern film as a mask so that the protection film 2 can be exposed. Subsequently, the residual pattern film is removed by chemicals, to thereby complete the single thick film layer 30 which defines a chamber region 33.

[0047] When the chamber region 33 is formed, the single thick film layer 30 is detached from the substrate 1 using chemicals, for example, hydrogen fluoride, as shown in FIG. 1D. Then, the single thick film layer 30 is formally assembled in the relevant position in an inkjet printhead.

[0048] As shown in FIG. 2, on the substrate 1, the single thick film layer 30 of the present invention is assembled with a nozzle plate 8 which defines nozzles 10. An ink feed channel 200 for defining an ink feed path is formed adjacent to the chamber region 33, and the ink fed from an external device flows along the ink feed channel 200 to thereby fill the chamber region 33. Here, a plurality of nozzles 10 for injecting an ink are formed at the nozzle plate 8. Such nozzles 10 perforate through the nozzle plate 8 and thus are exposed towards the external surface.

[0049] An inkjet printhead which employs a single thick film layer of the present invention operates as follows. As shown in FIG. 3, if an electric signal is applied from an external power supply to an electrode layer (not shown), a heater 11 that contacts the electrode layer is energized by the electric energy and rapidly heated to a high temperature, 500°C or higher. During such a process, the electric energy is converted to a thermal energy of approximately 500°C to 550°C. Then, the thermal energy is transmitted to the chamber region 33 that contacts the heater 11, and an ink 300 that fills the chamber region 33 is rapidly heated and caused to bubble by the transmitted thermal energy.

[0050] Here, if the thermal energy continues to be transmitted to the chamber region 33, the bubbled ink 300 is rapidly transformed in volume and expanded. Thus, the ink 300 is expelled from the chamber region 33 via the nozzle 10 of the nozzle plate 8 and is about to be discharged. The ink 300 is then transformed into oval and circular shapes in turn due to its own weight and discharged onto external printing paper.

[0051] As described above, because the single thick film layer 30 of the present invention consists of the first and second organic film layers 31 and 32 which are sequentially formed without additional heat-treatment, a dividing line is eliminated, thereby improving the durability of the inkjet printhead.

[0052] Then, if the electric signal supplied from an external device is cut off at the state where the ink 300 has been discharged, the heater 11 rapidly cools down. Then, the bubbled ink 300 remaining in the ink chamber 33 is rapidly contracted and generates restoring force by which the ink 300 can be restored to the original state. The restoring force so generated serves to rapidly lower the pressure maintained in the chamber region 33 so that the ink 300 flowing through the ink feed channel 200 can rapidly refill the chamber region 33. An inkjet printhead repeats the above-described process via an electric signal, to thereby perform a print job onto printing paper fed by an external device.

[0053] In the present invention, a first organic film layer as a thin film layer and a second organic film layer as a thick film layer are sequentially deposited without an additional heat-treatment so as to thereby form a single thick film layer. Thus, a dividing line can be eliminated and impurities are prevented from being introduced during the process can be obtained. The present invention is applicable not only to an inkjet printhead but also to any micro-injecting device which is used as a micro-pump of medical appliances or fuel-injecting device, etc.

[0054] This invention has been described above with reference to the aforementioned embodiments. It is evident, however, that many alternative modifications and variations will be apparent to those having skill in the art in light of the foregoing description. Accordingly, the present invention embraces all such alternative modifications and variations as fall within the spirit and scope of the appended claims.

Claims

1. A method for forming a thick film layer (30) for use in a micro-injecting device, comprising:

   a first step of depositing a first amount of a liquid comprising an organic substance on a substrate and spinning the substrate at a first rotation rate, to form a first organic liquid layer (31');

   a second step of depositing a second amount of a liquid comprising an organic substance on the first organic liquid layer (31') and spinning the substrate at a second rotation rate slower than said first rotation rate, to form a second organic liquid layer (32'); and

   drying and heat-treating said first and second organic liquid layers to form a combined thick film layer (30);

2. A method as claimed in claim 1 wherein the combined thick film layer (30) is substantially free from discontinuities;

3. A method as claimed in claim 1 or 2 wherein a protective film (2) is formed on the substrate (1) prior to the first deposition step.

4. A method according to any of claims 1 to 3, wherein said liquid comprising organic substance is a solution comprising a polyimide.

5. A method according to any of claims 1 to 4 wherein said first depositing step comprises using a liquid with a viscosity coefficient of approximately 1.03 centipoise.

6. A method according to any of claims 1 to 5 wherein the spinning of the substrate in the first step is performed at a first rotation rate in the range of approximately 450 to 550 rpm.

7. A method according to any of claims 1 to 6 wherein the spinning of the substrate in the first step is performed for approximately 35 to 45 seconds.

8. A method according to any of claims 1 to 7 wherein the first step is performed to achieve a thickness of the first organic liquid layer (31') in the range of approximately 0.5 µm to 5µm.

9. A method according to claim 6 wherein the first step is performed to achieve a thickness of the first organic liquid layer (31')in the range of approximately 1 µm to 2µm.

10. A method as claimed in any preceding claim, wherein said second depositing step comprises using an organic liquid with a viscosity coefficient of approximately 1.03 centipoise.

11. A method as claimed in any preceding claim, wherein the spinning of the substrate in the second step is performed at a second rotation rate in the range of approximately 20 to 40 rpm.

12. A method as claimed in any preceding claim wherein the spinning of the substrate in the second step is performed for approximately 30 to 40 seconds.

13. A method as claimed in any preceding claim, wherein the second step is performed to achieve a thickness of the second organic liquid layer (32') in the range of approximately 18 to 22µm.

14. A method as claimed in any preceding claim, wherein the second amount of liquid is in the range of approximately 0.6 to 0.8cm^3.

15. A method as claimed in any preceding claim, further comprising the step of:

   determining values for said second amount of the organic liquid and said second rotation rate to be used in said second step, by using the formula:

$$h = h_1 + h_2 = \varepsilon\left[A\sqrt{\frac{\nu}{\omega}} + \frac{V}{S}\right] \qquad (1)$$

   where h is the total thickness of first and second organic liquid layers, h_1 is the thickness of the first organic liquid layer, h_2 is the thickness of the second organic liquid layer to be formed, ε is a coefficient which denotes the decreases in the first and second organic liquid layers during heat-treatment process, A is a constant, ν is the viscosity coefficient of the organic liquid, ω is the second rotation rate, S is the surface area of the substrate, and V is the second amount of the organic liquid.

16. A method as claimed in any preceding claim, wherein the said drying is performed at a temperature in the range of approximately 80 to 90°C.

17. A method as claimed in claim 16, wherein in the drying is performed for approximately 25 to 35 minutes.

18. A method as claimed in any preceding claim, wherein the heat treatment step includes a first

heating of the first and second organic liquid layers (31', 32')to a temperature in the range of approximately 200 to 220°C for approximately 25 to 30 min.

19. A method as claimed in claim 18, wherein the heat treatment step further comprises, after the first heating, a second heating to a temperature in the range of approximately 300 to 330°C for approximately 60 to 70 min.

20. A method as claimed in any preceding claim further comprising the steps of

forming a chamber (33) by etching the combined thick film layer (30) to partially expose the substrate (1); and

detaching the combined thick film layer (30) from the substrate (1).

21. A method as claimed in claim 21, wherein the etching step comprises using a pattern film formed on the top of the combined thick film layer (30) as a mask.

22. A method as claimed in claim 20 or 21, wherein the detaching step comprises the use of hydrogen fluoride.

23. A method of forming a nozzle assembly for a micro-injecting device comprising forming a thick film layer (30) by the method as claimed in any of claims 20 to 22 and

attaching the detached combined thick film layer (30)to a nozzle plate (8).

24. A thick film layer (3)) for a micro-injecting device obtainable by the method of any preceding claim.

25. A print head (100) for an ink jet printer including a thick film layer (30) as claimed in claim 24.

26. A print head (100) for an ink jet printer comprising a substrate (1), a nozzle plate (8) and a thick film layer (30) disposed between the substrate (1) and the nozzle plate (8) and defining chambers (33) for the printing ink (300), wherein the thick film layer (30) has substantially no discontinuities in a direction from the substrate (1) to the nozzle plate (8).

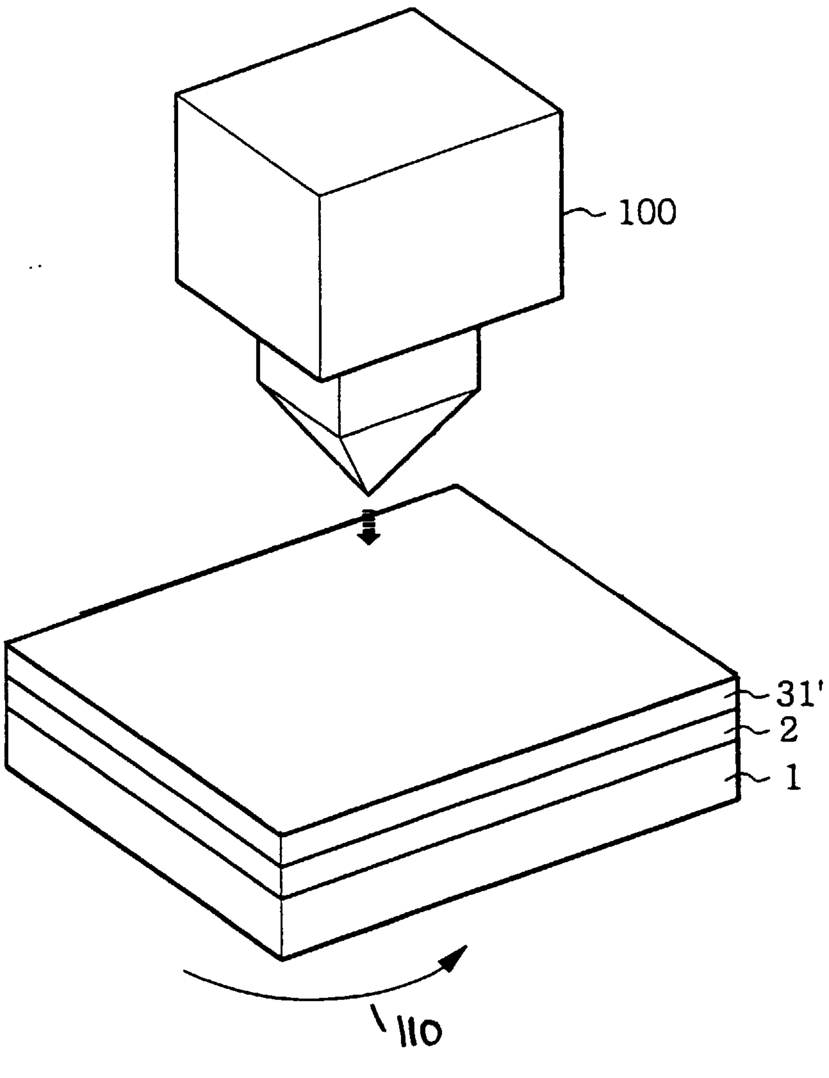

FIG. 1A

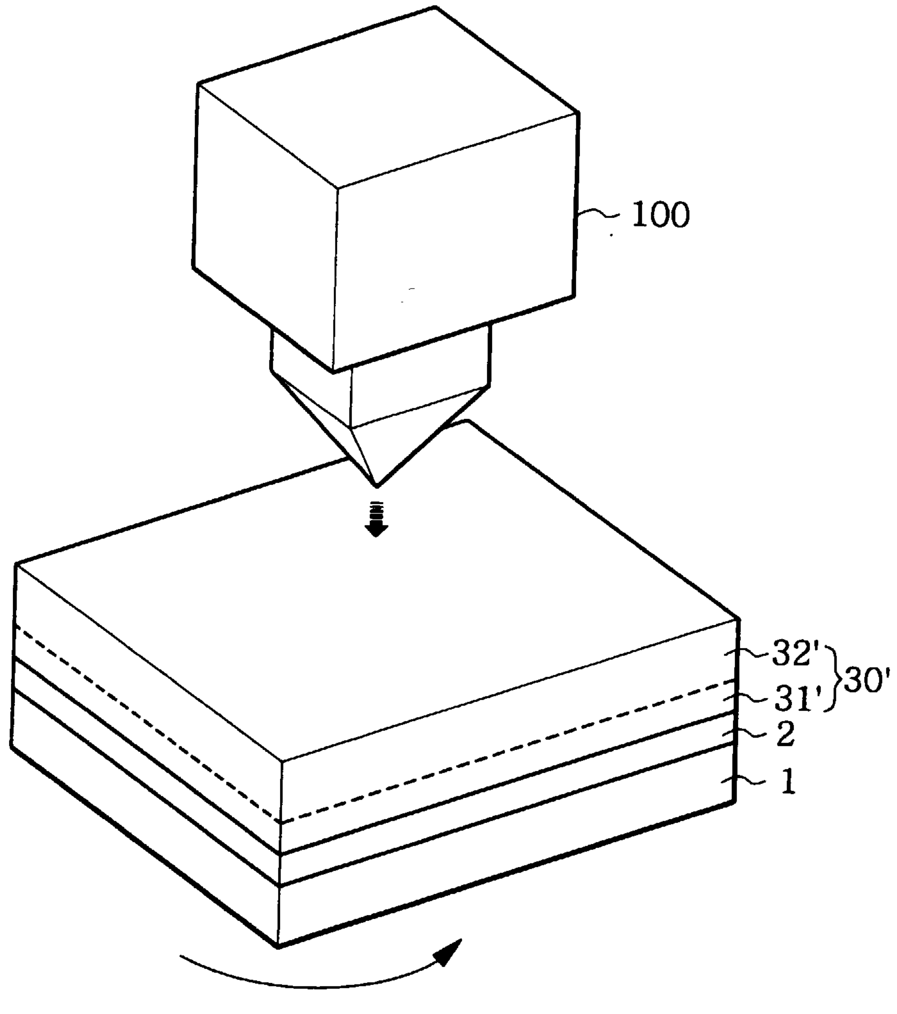

FIG. 1B

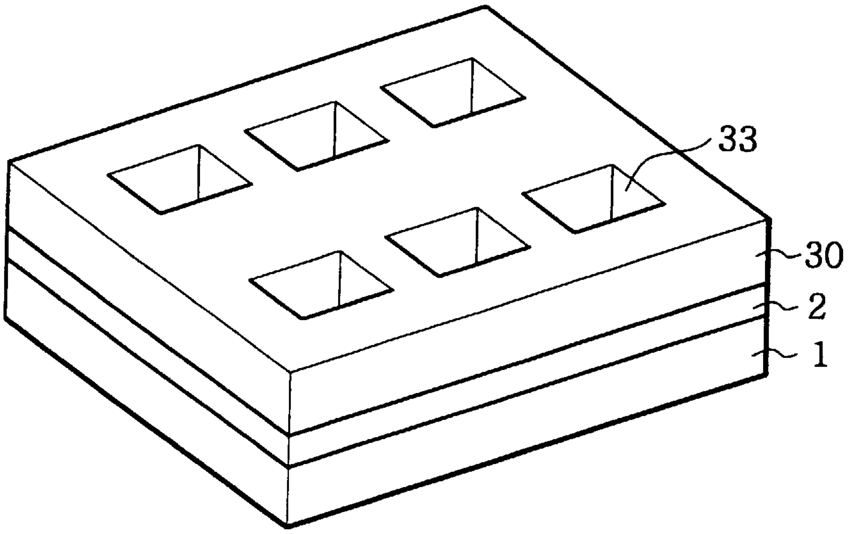

FIG. 1C

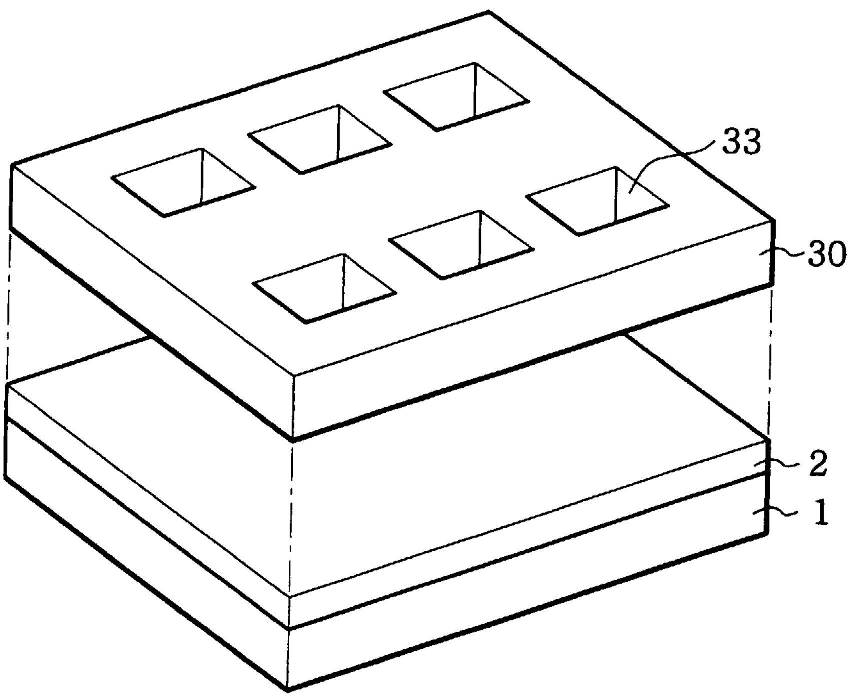

FIG. 1D

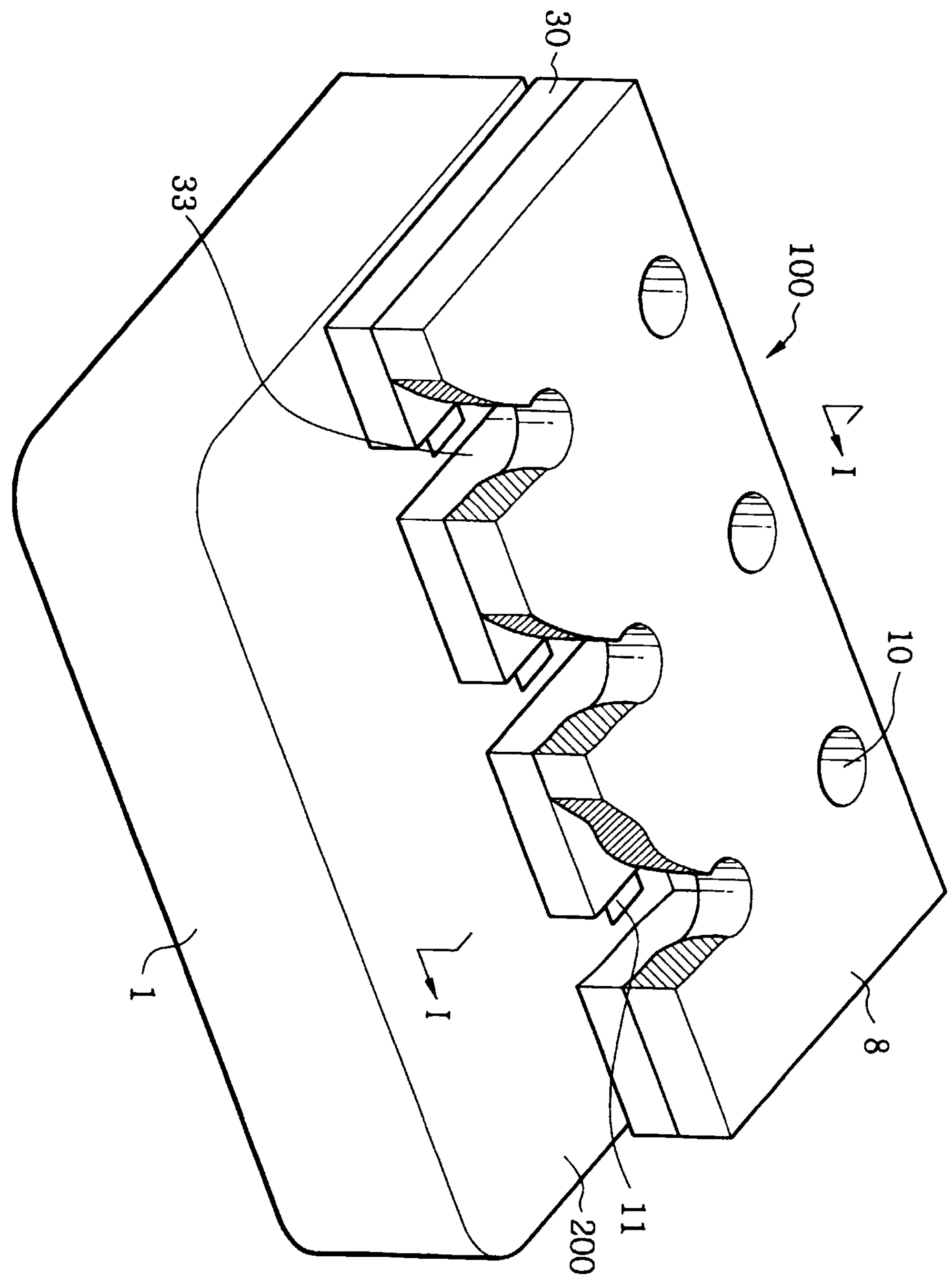

FIG. 2

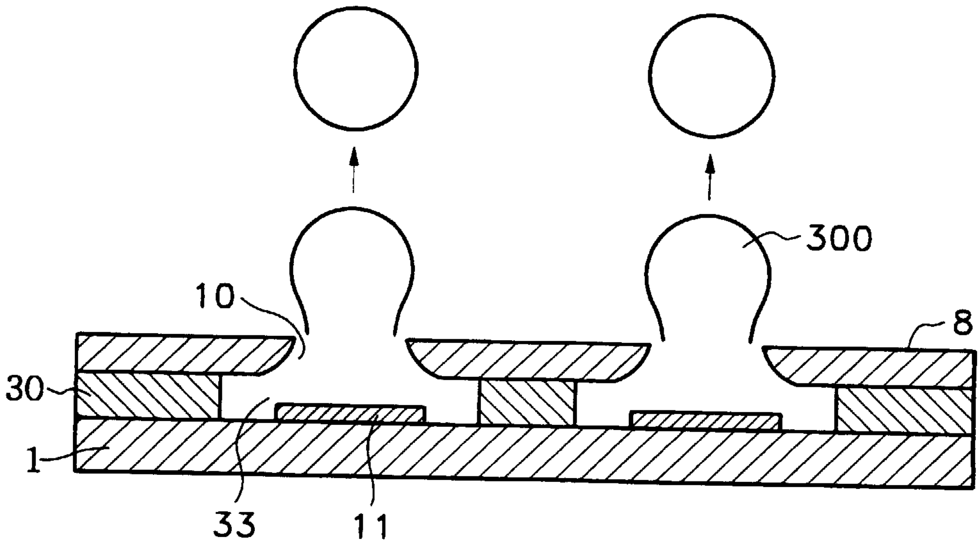

FIG. 3