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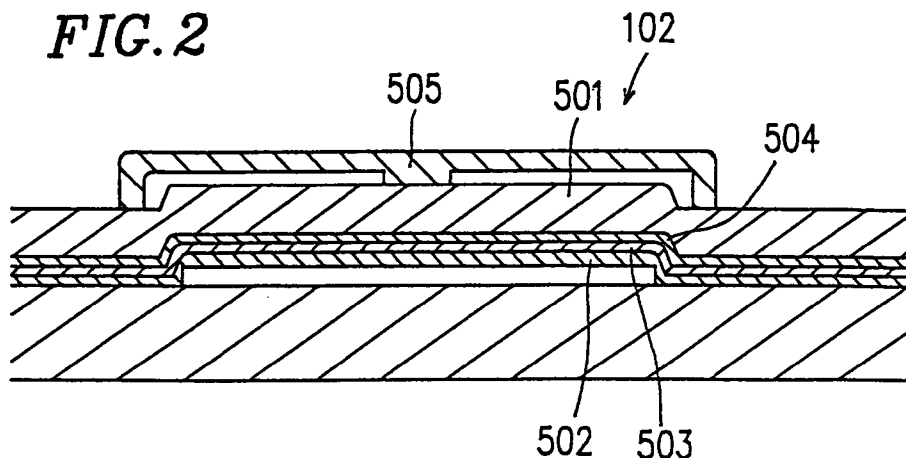
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(54) Ink jet head and method for fabricating the same

(57) An ink jet head according to the present invention includes: a substrate; an orifice plate having an opening, the orifice plate facing the substrate; an element provided on the substrate so as to define an ink cavity provided between the substrate and the orifice plate, the ink cavity being filled with liquid ink, and so as to form a gap between at least a central portion of the element and the substrate, the element ejecting the liquid ink filled in the ink cavity through the opening of the

orifice plate; a main ink supply groove provided on at least one of a surface of the substrate facing the orifice plate and a surface of the orifice plate facing the substrate; an ink supply path for connecting the ink cavity to the main ink supply groove; and a branch ink supply groove for connecting the gap between the element and the substrate to the main ink supplying groove.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to an ink jet head used for an ink jet printer which prints information on a recording medium by way of an ink jet, and to a method for fabricating the same.

2. Description of the Related Art:

Recently, with the development of computers, printers are becoming more and more important as devices for outputting information from the computers. Specifically, as computers become more compact and have higher performance, printers for printing image or code information from the computer onto a sheet of paper or a transparent polymer film for an OHP (over head projector), for example, are required to be more compact and have higher performance and functions.

Among such printers, an ink jet printer for forming character information and images on a paper sheet, a polymer film or the like by producing a jet of liquid ink has been widely and actively developed recently because the ink jet printer is capable of being reduced in size, having enhanced performance, and having reduced power consumption. In an ink jet printer, structurally the most important component is an ink jet head for jetting ink onto a medium (e.g., the paper sheet). Thus, it is important to fabricate an ink jet head, which is small in size and reliable, and can be produced at low cost.

As methods for providing an ink jet in the ink jet printer, the following three methods are conventionally known.

A first method uses a piezoelectric element. In this method, a high voltage is applied to a piezoelectric element 1 so as to cause mechanical deformation in the piezoelectric element 1 (Figures 7A and 7B). Pressure is generated in an ink pressure cavity 2 by the mechanical deformation, thereby jetting ink 4 from a nozzle 3 in a particle form.

A second method is a so-called bubble jet method. According to the bubble jet method, heaters 5 are provided in cavities as shown in Figure 8. By rapidly heating the heaters 5, ink is boiled to form bubbles. The ink is jetted out from nozzles 6 due to a change in pressure which is caused by generation of bubbles.

A third method uses a bimetal element which is provided in an ink cavity. The bimetal element is heated so as to become deformed. Pressure is applied to ink by the deformation, so that the ink is jetted out (see, e.g., Japanese Laid-Open Patent Publication No. 2-30543).

As a method for fabricating an ink jet head, a method using anisotropic etching of single-crystalline silicon is known. As shown in Figure 9, a groove is formed by anisotropically etching a substrate made of Single-crystalline silicon. Then, an upper plate is adhered onto the

substrate, thereby forming an ink cavity (see, K.E. Peterson, "Silicon as a Mechanical Material", Proc. IEEE, vol. 70, no. 5, pp. 420 - 457, May 1982).

However, the ink jet heads utilized in the respective above-mentioned methods have the following problems.

First, in the first method, the ink jet head is fabricated by mechanically processing the piezoelectric element which is obtained by forming a piezoelectric material in a multilayer form. Since it is necessary to perform a mechanical processing for forming the piezoelectric element, the extent which a gap between ink cavities can be reduced is disadvantageously limited. As a result, an interval between nozzles for jetting ink cannot be reduced.

In the case of the second method which utilizes a bubble jet, since ink should be boiled to form bubbles, it is necessary to immediately raise the temperature of the heater to several hundreds of C°. Therefore, it is difficult to prevent the heater from becoming deteriorated, resulting in a short lifetime of the ink jet head.

In the third method, the bimetal serving as a driving source for jetting out the ink should have a layered structure consisting of different laminated materials. Thus, this method is disadvantageous in that the structure is complicated.

Furthermore, regardless of the particular method, in the case where a driving source for jetting out the ink is fabricated, it is necessary to fabricate a number of minute driving sources at the same time. In the third method, in particular, components should be separately fabricated and then assembled. Therefore, it is difficult to integrate the ink jet head.

Thus, none of these methods is satisfactory since a highly integrated head with a long lifetime cannot be obtained.

Moreover, in the case where ink cavities are formed utilizing anisotropic etching of single-crystalline silicon, when a method for jetting out ink utilizing a deformation phenomenon of the driving source caused by heat is adopted, the side of the driving source opposite to the side in contact with ink comes in contact with air. Therefore, since heat is hardly released, a cooling response speed is lowered. As a result, since a response speed is lowered, the ink jet head cannot be operated at a high speed.

SUMMARY OF THE INVENTION

The ink jet head of this invention includes: a substrate; an orifice plate having an opening, the orifice plate facing the substrate; an element provided on the substrate so as to define an ink cavity provided between the substrate and the orifice plate, the ink cavity being filled with liquid ink, and so as to form a gap between at least a central portion of the element and the substrate, the element ejecting the liquid ink filled in the ink cavity through the opening of the orifice plate; a main ink supply groove provided on at least one of a surface of the substrate facing the orifice plate and a surface of the orifice

plate facing the substrate; an ink supply path for connecting the ink cavity to the main ink supply groove; and a branch ink supply groove for connecting the gap between the element and the substrate to the main ink supplying groove.

In one embodiment of the present invention, the element is deformed so as to increase pressure inside the ink cavity, causing the liquid ink filled in the ink cavity to eject through the opening of the orifice plate.

In another embodiment of the present invention, the liquid ink from the main ink supply groove flows into the gap between the element and the substrate via the branch ink supply groove so as to alleviate negative pressure generated in the gap between the element and the substrate, the negative pressure being caused by increasing a volume of the gap between the element and the substrate due to the deformation of the element.

In still another embodiment of the present invention, the element includes a heater circuit for heating the element, and the element is thermally deformed by heating so as to increase pressure inside the ink cavity.

In still another embodiment of the present invention, the element includes a piezoelectric element for causing contraction in response to an application of a voltage, and the element is deformed due to the contraction of the piezoelectric element so as to increase pressure inside the ink cavity.

In still another embodiment of the present invention, the liquid ink filled in the ink cavity has a higher thermal conductivity than that of air so as to quickly cool the element.

In still another embodiment of the present invention, the ink jet head further includes a wiring circuit for supplying a current to the element, wherein the wiring circuit is provided within the main ink supplying groove.

In still another embodiment of the present invention, the substrate is made of single-crystalline silicon, and walls of the main ink supplying groove and the branch ink supplying groove are a (111) surface of the single-crystalline silicon.

A method for fabricating an ink jet head according to the present invention, the ink jet head including: a substrate; an orifice plate having an opening, the orifice plate facing the substrate; an element provided on the substrate so as to define an ink cavity provided between the substrate and the orifice plate, the ink cavity being filled with liquid ink, and so as to form a gap between at least a central portion of the element and the substrate, the element ejecting the liquid ink filled in the ink cavity through the opening of the orifice plate; a main ink supply groove provided on at least one of a surface of the substrate facing the orifice plate and a surface of the orifice plate facing the substrate; an ink supply path for connecting the ink cavity to the main ink supply groove; and a branch ink supply groove for connecting the gap between the element and the substrate to the main ink supplying groove, the method includes the steps of: forming an oxide film on the substrate; removing at least a portion corresponding to the branch ink supplying groove from

the oxide film; forming a sacrifice layer on the oxide film from which at least the portion corresponding to the branch ink supplying groove has been removed; forming a plurality of laminated layers constituting the element on the sacrifice layer so that the end of the sacrifice layer is exposed apart from the laminated layers; removing the sacrifice layer; and utilizing anisotropic etching of the substrate made of single-crystalline silicon by introducing an anisotropic etchant into the gap formed as a result of removing the sacrifice layer.

Thus, the invention described herein makes possible the advantages of: (1) providing a highly integrated ink jet head with a long lifetime and which is capable of being operated at a high speed; and (2) providing a method for fabricating the same.

These and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a plan view showing an ink jet head according to Example 1; and Figure 1B is a cross-sectional view of the ink jet head shown in Figure 1A.

Figure 2 is a cross-sectional view showing an example of an ink ejecting element which can be used for the present invention.

Figure 3A is a plan view showing an ink jet head according to Example 2; and Figure 3B is a cross-sectional view of the ink jet head shown in Figure 3A.

Figure 4A is a plan view showing an ink jet head according to Example 3; and Figure 4B is a cross-sectional view of the ink jet head shown in Figure 4A.

Figure 5 is a cross-sectional view showing an ink jet head according to Example 4.

Figures 6A(i) to 6H(i) are cross-sectional views showing a fabrication process of the ink jet head according to Example 1.

Figures 6A(ii) to 6G(ii) are plan view showing a fabrication process of the ink jet head according to Example 1.

Figures 7A and 7B each is a cross-sectional view showing a conventional ink jet head.

Figure 8 is a cross-sectional view showing another conventional ink jet head.

Figure 9 is a cross-sectional view showing still another conventional ink jet head during its formation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, the present invention will be described by way of illustrative examples.

Example 1

Figure 1A is a plan view showing an ink jet head according to Example 1. In Figure 1A, an orifice plate

104 is omitted to expose the various other elements described herein. Figure 1B is a cross-sectional view of the ink jet head of Figure 1A. The ink jet head includes a main ink supplying groove 101 and branch ink supplying grooves 107. The main ink supplying groove 101 and the branch ink supplying grooves 107 are formed on a surface of a substrate 100 facing the orifice plate 104. The substrate 100 is, for example, made of single-crystalline silicon. The cross-sectional view of the main ink supplying groove 101 and the branch ink supplying grooves 107 each has a concave shape. Ink ejecting elements 102, an adhesive film 103 (in Figures 1A and 1B, shown as adhesive films 103a and 103b) and a wiring circuit 108 (in Figures 1A and 1B, shown as wiring circuits 108a, 108b, 108c and 108d) are provided on the substrate 100. The orifice plate 104 is provided so that these components are interposed between the orifice plate 104 and the substrate 100. The space which is enclosed by the orifice plate 104, the ink ejecting element 102 and the adhesive layer 103 defines an ink cavity 105. The ink cavity 105 is filled with ink.

The periphery of the ink ejecting element 102 is fixed to the substrate 100. However, a gap 110 is provided between at least the central portion of the ink ejecting element 102 and the substrate 100. Since the central portion of the ink ejecting element 102 is kept apart from the substrate 100, the ink ejecting element 102 can be vertically deformed with respect to the orientation shown in Figure 1B. Ink supplying paths 106 for connecting the ink cavities 105 and the main ink supplying groove 101 are formed through the adhesive layer 103b. With the ink supplying paths 106, the ink delivered through the main ink supplying groove 101 can be supplied to the ink cavities 105. The gap 110 between the ink ejecting element 102 and the substrate 100 is connected to the main ink supplying groove 101 through the branch ink supplying groove 107. Since the periphery of the ink ejecting element 102 is fixed to the substrate 100 as described above, the ink cavity 105 and the main ink supplying groove 101 are connected to each other only through the ink supplying path 106, and the gap 110 and the main ink supplying groove 101 are connected to each other only through the branch ink supplying groove 107.

The ink ejecting element 102 is made of a thermally deformable material and contains a heater circuit (not shown). The ink ejecting element 102 is heated by supplying a current to the heater circuit. A current for heating is supplied to the heater circuit via the wiring circuit 108. The ink ejecting element 102 is controlled by selectively supplying a current to the wiring circuit 108. The ink ejecting element 102 is deformed into a dome-like shape in a direction perpendicular to the substrate 100 by heating. As a result, a volume of the ink cavity 105 is reduced to increase pressure inside the ink cavity 105, whereby ink is jetted out from a nozzle opening 109 provided through the orifice plate 104.

Due to the deformation of the ink ejecting element 102, a volume of the gap 110 between the ink ejecting element 102 and the substrate 100 is increased so as to

generate negative pressure in the gap 110. However, this negative pressure is alleviated or eliminated because the liquid ink from the main ink supplying groove 101 flows into the gap 110 via the branch ink supplying groove 107 in response to the deformation of the ink ejecting element 102. The alleviation of the negative pressure provides an advantage of effectively apply pressure onto the ink cavity.

A method for constructing an ink jet head in accordance with Example 1 and the exemplary materials associated therewith, together with the other examples of the invention described herein, will be discussed in detail below with reference to Figures 6A(i) through 6H(i) and 6A(ii) through 6G(ii).

In the ink jet head thus configured, since the ink ejecting element 102 ejects the liquid ink filed in the ink cavity 105 through the opening 109 by utilizing thermal deformation of the ink ejecting element 102, ink ejecting element 102 can be driven at lower temperature than a bubble jet head. As a result, the lifetime of the ink jet head of Example 1 can be prolonged compared with the bubble jet head. Moreover, when the ink ejecting element 102 is thermally deformed, pressure is applied onto the ink cavity 105 to jet out ink. Since the gap 110 is provided between the ink ejecting element 102 and the substrate 100, and is filled with ink having a higher thermal conductivity than that of air, the ink ejecting elements 102 are quickly cooled and can be operated at a high speed. Furthermore, since the ink ejecting elements 102 do not require a mechanical processing such as that required by the piezoelectric element, the ink ejecting elements 102 can be highly integrated.

In addition, since the main ink supplying groove 101 and the branch ink supplying grooves 107 are provided on the surface of the substrate 100 facing the orifice plate 104, it is possible to fabricate the ink jet head from the side of the surface of the substrate 100 facing the orifice plate 104. As a result, the fabrication process can be simplified. Moreover, since no opening is provided through the substrate 100, there is no possibility of lowering the strength of the substrate 100. This function is particularly useful in the case where a number of elements and nozzles are placed on the substrate 100; since it is not necessary to bore a number of openings through the substrate 100, the strength of the substrate 100 is not lowered.

While Figures 1A and 1B show the case where four ink ejecting elements 102 are arranged on the substrate 100, a larger number of elements may be arranged in the actual embodiments. By arranging a large number of elements, a highly integrated head can be configured. Furthermore, when a large number of elements, which are arranged in a column in Figures 1A and 1B, are arranged in a plurality of columns, a larger number of elements can be arranged on a single head having a limited area. As a result, it is possible to enhance the degree of integration of the ink jet head. According to the present invention, even in such a case, since it is not necessary to form openings through the substrate 100, the strength

of the substrate **100** is not lowered. Therefore, it is possible to arrange a large number of elements.

Moreover, when a (110) single-crystalline silicon substrate is used as the substrate **100**, anisotropic etching can be used for fabricating the main ink supplying groove **101** and the branch ink supplying grooves **107**. As a result, walls of the main ink supplying groove **101** and branch ink supplying grooves **107** can be constituted utilizing (111) crystal planes. Thus, it is possible to form precise walls. In addition, the cost can be intended to be lowered.

In Example 1, the main ink supplying groove **101** and the branch ink supplying grooves **107** for alleviating negative pressure are formed only on the front surface of the silicon substrate **100**. On the other hand, it is possible to form these supplying grooves from the back surface in such a manner that the grooves are bored through the substrate. In such a case, however, a three-dimensional processing is required. In particular, it is required to form a location hole for aligning the position of the pattern of the front surface with that of the back surface, or a specific exposure apparatus for exposing the silicon substrate to light while observing both front and back surfaces of the substrate. Thus, the fabrication process becomes complicated, resulting in increased cost.

According to Example 1, it is sufficient to form the grooves only on the surface of the silicon substrate. Therefore, Example 1 is advantageous in that the ink jet head can be fabricated by a simple process. Since no openings leading to the back surface of the substrate are required, the strength of the substrate is not lowered even in the case where a number of elements are integrated on the substrate. Thus, Example 1 is advantageous in that a head including a number of integrally formed elements can be obtained.

It is possible to adopt, for example, the structure as shown in Figure 2 as the structure of an ink ejecting element **102** used in Example 1. The ink ejecting element **102** includes: a buckling element **501**; a first insulating layer **502**; a heater layer **503**; a second insulating layer **504**; and a diaphragm **505**. The first insulating layer **502**, the heater layer **503** and the second insulating layer **504** are formed below the buckling element **501**. The diaphragm **505** and the buckling element **501** are connected to each other only through the central portion of the buckling element **501**. When a current flows through the buckling element **501** so as to heat the buckling element **501**, the buckling element **501** is thermally expanded. When compressive stress due to the thermal expansion exceeds a buckling limitation of the buckling element **501**, buckling is caused to deform the buckling element **501** in a direction perpendicular to the substrate **100**, thereby deforming the diaphragm **505**. In this structure, the heater layer **503** and the buckling element **501** are located apart from the ink cavity. Therefore, since ink, the heater layer **503** and the buckling element **501** are not in direct contact with each other, it is possible to inhibit ink from being deteriorated.

Example 2

Figure **3A** is a plan view showing an ink jet head according to Example 2, and Figure **3B** is a cross-sectional view thereof. Again, in Figure **3A**, an orifice plate **204** is omitted for ease of viewing. In this ink jet head, a main ink supplying groove **201** is provided on the surface of the orifice plate **204** facing the substrate **200**.

On the surface of the substrate **200**, ink ejecting elements **202**, an adhesive layer **203** (in Figures **3A** and **3B**, shown as **203a** and **203b**) and a wiring circuit **208** are provided. The orifice plate **204** is provided above the substrate **200** so as to face the substrate **200**. An ink cavity **205** is defined as a space enclosed by the orifice plate **204**, the ink ejecting element **202**, and the adhesive layers **203**. The ink cavity **205** is filled with ink.

The periphery of the ink ejecting element **202** is fixed to a substrate **200**. However, a gap **210** is provided between at least the central portion of the ink ejecting element **202** and the substrate **200**. Since the central portion of the ink ejecting element **202** is kept apart from the substrate **200**, the ink ejecting element **202** can be vertically deformed. Ink supplying paths **206** for connecting the ink cavities **205** with the main ink supplying groove **201** are formed through the adhesive layer **203b**. The gap **210** between the ink ejecting element **202** and the substrate **200** is connected to the main ink supplying groove **201** through the branch ink supplying groove **207**.

Since the periphery of the ink ejecting element **202** is connected to the substrate **200** as described above, the ink cavities **205** and the main ink supplying groove **201** are connected to each other only through the ink supplying paths **206**, and the gaps **210** and the main ink supplying groove **201** are connected to each other only through the branch ink supplying grooves **207**. Each branch ink supplying groove **207** is formed on the substrate **200**. The sectional view of the branch ink supplying groove **207** has a concave shape. Similarly to Example 1, in the case where single-crystalline silicon is used as the substrate **200**, the branch ink supplying grooves **207** can be formed using anisotropic etching so that walls thereof are constituted by (111) planes.

The ink ejecting element **202** contains a heater circuit (not shown). When a current flows through the heater circuit, the heater circuit is heated. A current for heating is supplied via a wiring circuit **208**. The ink ejecting element **202** is controlled by selectively supplying a current to the wiring circuit **208**. The ink ejecting element **202** is made of a thermally deformable material and is deformed into a dome-like shape in a direction perpendicular to the substrate **200** by heating. As a result, a volume of the ink cavity **205** is reduced so as to increase pressure inside the ink cavity **205**. In response, ink is jetted out from a nozzle opening **209** provided through the orifice plate **204**. The structure of the ink ejecting element **202** can be the same as that shown in Figure 2.

According to Example 2, since a thermally deformable ink ejecting element **202** is used, a lifetime of the ink jet head can be prolonged. When the ink ejecting ele-

ment 202 is thermally deformed, pressure is applied on the ink cavity 205 to jet out ink. Since the gap 210 is provided between the ink ejecting element 202 and the substrate 200, the gap 210 is filled with ink having a higher thermal conductivity than that of air. Thus, the ink ejecting elements 202 are quickly cooled and can be operated at a high speed. Furthermore, since the ink ejecting elements 202 do not require mechanical processing such as that required by the piezoelectric element, the ink ejecting elements 202 can be highly integrated.

In Example 2, the main ink supplying groove 201 for alleviating negative pressure is formed only on the back surface of the orifice plate 204. It is possible to form this supplying groove from the back surface through the substrate 200. In such a case, however, a three-dimensional processing is required. In particular, it is required to form a location hole for aligning the position of the pattern of the front surface with that of the back surface, or to use a specific exposure apparatus for exposing the silicon substrate to light while observing both surfaces. Thus, the fabrication process becomes complicated, resulting in increased manufacturing costs.

Moreover, according to Example 2, it is sufficient to form grooves on the back surface of the orifice plate 204, and the grooves can be formed by a process which differs from the process for fabricating the silicon substrate side. Therefore, Example 2 is advantageous in that the number of steps of fabricating the silicon substrate side can be reduced to lower the fabrication cost.

Furthermore, Example 2 is advantageous in that the size of the main ink supplying groove (a cross-sectional area of a flow path of ink) can be increased, thereby smoothly supplying ink. In particular, ink can be smoothly supplied by reducing resistance of the main ink supplying groove against ink.

Furthermore, since there are no openings leading to the back surface of the substrate 200, the strength of the substrate is not lowered even in the case where a number of elements are integrated on the substrate. Therefore, an ink jet head including a large number of integrated elements can be obtained. Although four ink ejecting elements are arranged in the example shown in Figures 3A and 3B, a highly integrated head can be obtained by placing a large number of elements.

Example 3

Figure 4A is a plan view showing an ink jet head according to Example 3 (in Figure 4A, an orifice plate 304 is omitted). Figure 4B is a cross-sectional view of the ink jet head of Example 3. In this ink jet head, a main ink supplying groove 301 is formed on the surface of the orifice plate 304 facing the substrate 300. An ink ejecting element 302, an adhesive layer 303 (in Figures 4A and 4B, denoted by 303a and 303b) and a wiring circuit 308 are provided on the surface of a substrate 300. The wiring circuit 308 is provided inside the main ink supplying groove 301.

The orifice plate 304 and the substrate 300 are oriented to face each other. The space enclosed by the orifice plate 304, the ink ejecting element 302 and the adhesive layer 303 defines an ink cavity 305. The ink cavity 305 is filled with ink. The periphery of the ink ejecting element 302 is fixed to the substrate 300. A gap 310 is provided between the ink ejecting element 302 and the substrate 300. The gap 310 is kept apart from the substrate 300 so that the ink ejecting element 302 can be vertically deformed.

Ink supplying paths 306 connecting the ink cavities 305 to the main ink supplying groove 301 are formed in the adhesive layer 303b. The gap 310 between the ink ejecting element 302 and the substrate 300 is connected to the main ink supplying groove 301 through the branch ink supplying groove 307. The periphery of the ink ejecting element 302 is fixed to the substrate 300. The ink cavity 305 is connected to the main ink supplying groove 301 only via the ink supplying path 306, and the gap 310 is connected to the main ink supplying groove 301 only via the branch ink supplying groove 307. Example 3 is the same as Example 1 in that the branch ink supplying groove 307 is formed on the surface of the substrate 300 facing the orifice plate 304. The cross-sectional view of the branch ink supplying groove 307 has a concave shape, and such a shape can be formed, for example, using a {111} single-crystalline silicon plane.

The ink ejecting element 302 contains a heater circuit (not shown). The ink ejecting element 302 is heated by flowing a current through the heater circuit. The current for heating is supplied via the wiring circuit 308. The ink ejecting element 302 is controlled by selectively supplying a current to the wiring circuit 308. The ink ejecting element 302 is deformed in a dome-shape in a direction perpendicular to the substrate 300 by heating. As a result, a volume of the ink cavity is reduced to increase pressure inside the ink cavity 305, whereby ink is jetted out from a nozzle opening 309 formed through the orifice plate 304.

In Example 3, since a thermally deformable ink ejecting element 302 is used, the lifetime of the ink jet head can be prolonged. Moreover, when the ink ejecting element 302 is thermally deformed, pressure is applied onto the ink cavity 305 to jet out the ink. In this case, the gap 310 is provided between the ink ejecting element 302 and the substrate 300. Since the gap 310 is filled with ink having a higher thermal conductivity than that of air, the ink ejecting element 302 is quickly cooled. Therefore, the ink ejecting element 302 can be operated at high speed. Since the ink ejecting element 302 does not require a mechanical processing as that required by the piezoelectric element, the ink jet head can be highly integrated.

Furthermore, since the main ink supplying groove 301 is configured so as to be positioned above the wiring circuit 308 connected to the heater circuit, the area required for the wiring circuit 308 and the area required for the main ink supplying groove 301 can be commonly

used. Therefore, the total area of the ink jet head can be reduced.

Although a structure including four elements is shown in Figures 4A and 4B, a highly integrated head can be configured by placing a larger number of elements. The structure of the ink ejecting element 302 can be the same as that shown in Figure 2.

Example 4

In Examples 1 through 3, the ink ejecting element utilizes thermal expansion by heating as a mechanism of ejecting ink. However, the present invention is not limited to the use of such type of the ink ejecting element. For example, a piezoelectric element can be used as the ink ejecting element.

Figure 5 shows a structure of an ink jet head including a piezoelectric element in Example 4 according to the present invention.

The piezoelectric element is obtained by forming a piezoelectric material in multilayer form. For example, the piezoelectric element is obtained by forming a gap 510 on a silicon substrate 500 using a sacrifice layer; forming a lower electrode 512, an insulating layer 514, a piezoelectric layer 516 and a nickel layer 518 on the gap 510 in this order; and forming an ink supplying groove 520 by utilizing anisotropic etching of single-crystal-line silicon.

Thus, an ink jet head having the same structure as Example 1 through 3 except the ink ejecting element can be obtained.

The nickel layer 518 is used as a common electrode which is commonly used by all elements, and the lower electrode 512 is used as a selection electrode. When a voltage is applied to the selection electrode, the piezoelectric layer 516 is contracted. As the result of the contraction of the piezoelectric layer 516, the nickel layer 518 is deformed in a direction perpendicular to the substrate 500, for example, along a dotted line shown in Figure 5.

This deformation of the nickel layer 518 serves the same function as the deformation of the above described thermally deformable ink ejecting elements 102, 202 and 302 caused by heating the ink ejecting elements.

(Fabrication Process)

Next, a method for fabricating the ink jet head according to the present invention will be described.

Figures 6A(i) through 6H(i) and 6A(ii) through 6G(ii) show a fabrication process of the ink jet head according to Example 1. Figure 6A(ii) shows a plan view, and Figure 6A(i) shows a cross-sectional view taken along a line A-A' of Figure 6A(ii). Similarly, Figures 6B(ii) to 6G(ii) are plan views showing the ink jet head, and Figures 6B(i) through 6G(i) are respective cross-sectional views thereof.

First, as shown in Figures 6A(i) and 6A(ii), oxide films 402 are formed on both faces of a substrate 401 made of single-crystalline silicon. The oxide films 402

may be formed by adhering silicon oxide by means of evaporation or sputtering. Normally it is preferable to use thermal oxide films which are formed by heating the substrate 401 in an oxygen atmosphere so as to oxidize the surfaces of the substrate 401.

Next, a pattern is formed on the oxide film 402 by lithography. Then, processing by etching or ion milling is performed, thereby forming an anisotropic etching window 403. The anisotropic etching window 403 can be separated into two parts: a part 403A on which a branch ink supplying groove is formed and a part 403B on which a main ink supplying groove is formed in a later step, respectively.

Next, as shown in Figures 6B(i) and 6B(ii), a first sacrifice layer 404 is formed, and then a pattern is formed on the first sacrifice layer 404. As a material of the first sacrifice layer 404, it is possible to use a photoresist, aluminum (Al), a polyimide resin or the like. Since a diaphragm is formed on the first sacrifice layer 404, the first sacrifice layer 404 is made to have a shape corresponding to the diaphragm.

Next, as shown in Figures 6C(i) and 6C(ii), a lower insulating layer 405A, a heater layer 406 and an upper insulating layer 405B are successively laminated. Then, these layers are subjected to patterning. A window is provided in the region of an upper insulating layer 405B corresponding to pad portions 420A, 420B and 420C for supplying a current so as to be electrically conducted to a wiring layer and a buckling layer which are laminated by plating in a later step. One end of the heater layer 406 is connected to the wiring layer, and the other end is connected to the buckling layer so as to serve as a common line among all elements. Since the buckling layer and the heater layer 406 are insulated by the insulating layer 405, the wiring is not shorted. Materials such as SiO, SiO₂, SiN, AlN or Al₂O₃ can be used as the insulating film 405.

Next, as shown in Figures 6D(i) and 6D(ii), a conductive layer 407 is formed. Subsequently, the conductive layer 407 is patterned so as to remove a conductive layer 407A on the region corresponding to the periphery of the buckling element of the resist frame which is formed in a later step.

Next, a resist frame 408 (in Figures 6D(i) and 6D(ii), indicated with regions hatched with righthand-upwardly inclined lines) for plating the buckling element is formed with a photoresist. Then, plating is performed by using the conductive layer 407 as a cathode, thereby forming a buckling element 409. Materials such as Ni, Al, Ta, Cr, Co or the like can be used for the conductive layer 407. As a material of the buckling element 409, Ni, Cu, Fe, Co or an alloy thereof can be used. If the buckling element 409 is formed in this way, a wiring layer 421 can be simultaneously formed. The wiring layer 421 is formed by plating as is the buckling element 409, and is connected to the heater layer 406 through the pad 420A formed in the previous process. The other end of the heater layer 406 is connected to the buckling element 409 through the pads 420B and 420C so as to serve as a common line.

Next, as shown in Figures 6E(i) and 6E(ii), a second sacrifice layer 410 is formed. After the second sacrifice layer 410 is subjected to patterning, the diaphragm 411 (corresponding to 505 in Figure 2) is formed by plating. As a material of the second sacrifice layer 410, the same material as that of the first sacrifice layer 404 can be used. Moreover, as a material of the diaphragm 411, the same material as that of the buckling element 409 can be used.

The pattern to be formed on the first sacrifice layer 404 is formed so that an end 414 of the first sacrifice layer 404 is exposed apart from the end of the buckling element 409 at its completion. Such a configuration is adopted so as to make an etchant enter from the end 414 in such a manner that the first sacrifice layer 404 can be removed. The patterns are arranged so that the branch ink supplying groove formed in the later step is isolated from an ink cavity by the region 403A where the branch ink supplying groove is formed, and the ink cavity and the main ink supplying groove are connected to each other through the branch ink supplying groove alone.

Next, as shown in Figures 6F(i) and 6F(ii), the resist frame 408 which is externally exposed is removed. Then, since the conductive layer 407, which is placed under the resist frame 408, is exposed, the conductive layer 407 is removed. It is possible to use ion milling for removing the conductive layer 407.

Next, the first sacrifice layer 404 is removed with an etchant. The etchant gradually proceeds in a horizontal direction while removing the exposed end 414 of the first sacrifice layer 404. The etchant enters inside the first sacrifice layer 404, and then completely removes the first sacrifice layer 404 at last.

Next, as shown in Figures 6G(i) and 6G(ii), the substrate 401 is anisotropically etched from the anisotropic etching window 403 using an anisotropic etchant, thereby forming a main ink supplying groove 412 (corresponding to 101 in Figures 1A and 1B) and a branch ink supplying groove 413 (corresponding to 107 in Figures 1A and 1B). At this time, the anisotropic etchant enters a gap, which is formed by removing first sacrifice layer, so as to etch the branch ink supplying groove 413 of the substrate 401. If a (100) plane single-crystalline silicon substrate is used as the substrate 401 and a potassium hydroxide (KHO) solution is used as the anisotropic etchant, walls constituted by (111) planes remain.

If the branch ink supplying groove 413 and the main ink supplying groove 412 are formed by anisotropic etching, dimensionally precise and deep grooves can be easily formed. Therefore, as shown in Figures 1A and 1B, when the main ink supplying groove 101 is deeply and widely formed, a resistance against a flow path of ink is reduced. Thus, this configuration is effective in that ink can be supplied smoothly. Moreover, when the branch ink supplying groove 107 can be deeply and widely formed, ink easily flows to the bottom face of the ink ejecting element 102. Therefore, the function for alleviating negative pressure, which is generated in the gap 110 under the ink ejecting element 102 when the ink ejecting

element 102 is deformed, increase. Thus, resistance upon moving the ink ejecting element 102 can be reduced.

Next, as shown in Figure 6H(i), an etchant is introduced from the gap of the first sacrifice layer 404 so as to remove the resist frame 408 and the second sacrifice layer 410.

Thereafter, an orifice plate is attached onto the thus fabricated substrate, thereby completing the ink jet head. The orifice plate is attached after applying an adhesive layer on the orifice substrate and then patterning the ink supplying paths on the orifice substrate.

Also in Examples 2 and 3, the same fabrication process as that of Example 1 can be applied except that the pattern to be fabricated differs from each other depending on whether or not there is the main ink supplying groove.

A photosensitive glass plate, a polysulfon (PS) resin plate, a polyethersulfon (PES) resin plate or the like can be used as the orifice plate.

According to the present invention, since the thermally deformable ink ejecting element is used, the lifetime can be prolonged. When the ink ejecting element is thermally deformed, pressure is applied onto the ink cavity so that ink is jetted out. Moreover, since a gap is provided between the ink ejecting element and the substrate, and is filled with ink having a higher thermal conductivity than that of air, the ink ejecting element is quickly cooled and can be operated at high speed. Furthermore, since the ink ejecting element does not require a mechanical processing as that required by the piezoelectric element, the ink jet head can be highly integrated.

Since the gap is connected to the main ink supplying groove via the branch ink supplying groove, negative pressure which is generated in the gap between the ink ejecting element and the substrate is alleviated or eliminated when the ink ejecting element applies pressure on the ink cavity. Therefore, it is possible to effectively apply pressure onto the ink cavity. Moreover, since the ink cavity is connected to the main ink supplying groove via the ink supplying groove, ink can be supplemented at a time by supplementing ink to the ink jet head.

With the configuration in which a wiring pattern is provided inside the main ink supplying groove, even in the case where a large number of elements are placed, the required area is reduced. As a result, the total size of the substrate can be reduced.

In the case where the ink supplying paths are constituted by single-crystalline silicon (111) planes, accurate flowing paths can be formed at the same time by photolithography and anisotropic etching. Thus, not only processing precision can be improved, but also the cost can be reduced.

In the case where the piezoelectric element is used as the ink ejecting element, this type of element can be fabricated by fine processing technique because of using piezoelectric material as a thin film, thereby forming an integrated element with high density. As a result, the

number of the elements (nozzles) mounted to a single ink head increases, resulting in improving the printing speed or the printing resolution. Further, piezoelectric material has a high capability of converting electric energy into mechanical energy, thereby reducing power consumption. As a result, it is possible to fabricate an ink jet head having a small size and weight.

Furthermore, according to the method of the present invention, when the main ink supplying groove and the branch ink supplying grooves are formed by anisotropic etching, dimensionally precise deep grooves can be easily formed. At this time, when the main ink supplying groove is deeply and widely formed, ink can be smoothly supplied. Furthermore, when the branch ink supplying grooves can be deeply and widely formed, ink easily flows toward the back surface of the ink ejecting element. Thus, the function for alleviating negative pressure which is generated in the gap between the ink ejecting element and the substrate when the ink ejecting element is deformed, increases.

Various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope and spirit of this invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein, but rather that the claims be broadly construed.

Claims

1. An ink jet head comprising:
 - a substrate;
 - an orifice plate having an opening, the orifice plate facing the substrate;
 - an element provided on the substrate so as to define an ink cavity provided between the substrate and the orifice plate, the ink cavity being filled with liquid ink, and so as to form a gap between at least a central portion of the element and the substrate, the element ejecting the liquid ink filled in the ink cavity through the opening of the orifice plate;
 - a main ink supply groove provided on at least one of a surface of the substrate facing the orifice plate and a surface of the orifice plate facing the substrate;
 - an ink supply path for connecting the ink cavity to the main ink supply groove; and
 - a branch ink supply groove for connecting the gap between the element and the substrate to the main ink supplying groove.
2. An ink jet head according to claim 1, wherein the element is deformed so as to increase pressure inside the ink cavity, causing the liquid ink filled in the ink cavity to eject through the opening of the orifice plate.
3. An ink jet head according to claim 2, wherein the liquid ink from the main ink supply groove flows into the gap between the element and the substrate via

the branch ink supply groove so as to alleviate negative pressure generated in the gap between the element and the substrate, the negative pressure being caused by increasing a volume of the gap between the element and the substrate due to the deformation of the element.

4. An ink jet head according to claim 2, wherein the element includes a heater circuit for heating the element, and the element is thermally deformed by heating so as to increase pressure inside the ink cavity.
5. An ink jet head according to claim 2, wherein the element includes a piezoelectric element for causing contraction in response to an application of a voltage, and the element is deformed due to the contraction of the piezoelectric element so as to increase pressure inside the ink cavity.
6. An ink jet head according to claim 1, wherein the liquid ink filled in the ink cavity has a higher thermal conductivity than that of air so as to quickly cool the element.
7. An ink jet head according to claim 1, further comprising a wiring circuit for supplying a current to the element, wherein the wiring circuit is provided within the main ink supplying groove.
8. An ink jet head according to claim 1, wherein the substrate is made of single-crystalline silicon, and walls of the main ink supplying groove and the branch ink supplying groove are a (111) surface of the single-crystalline silicon.
9. A method for fabricating an ink jet head, the ink jet head comprising: a substrate; an orifice plate having an opening, the orifice plate facing the substrate; an element provided on the substrate so as to define an ink cavity provided between the substrate and the orifice plate, the ink cavity being filled with liquid ink, and so as to form a gap between at least a central portion of the element and the substrate, the element ejecting the liquid ink filled in the ink cavity through the opening of the orifice plate; a main ink supply groove provided on at least one of a surface of the substrate facing the orifice plate and a surface of the orifice plate facing the substrate; an ink supply path for connecting the ink cavity to the main ink supply groove; and a branch ink supply groove for connecting the gap between the element and the substrate to the main ink supplying groove,
 - the method comprising the steps of:
 - forming an oxide film on the substrate;
 - removing at least a portion corresponding to the branch ink supplying groove from the oxide film;
 - forming a sacrifice layer on the oxide film from which at least the portion corresponding to the

branch ink supplying groove has been removed;
forming a plurality of laminated layers constituting the element on the sacrifice layer so that the end of the sacrifice layer is exposed apart from the laminated layers;

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removing the sacrifice layer; and
utilizing anisotropic etching of the substrate made of single-crystalline silicon by introducing an anisotropic etchant into the gap formed as a result of removing the sacrifice layer.

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FIG. 1A

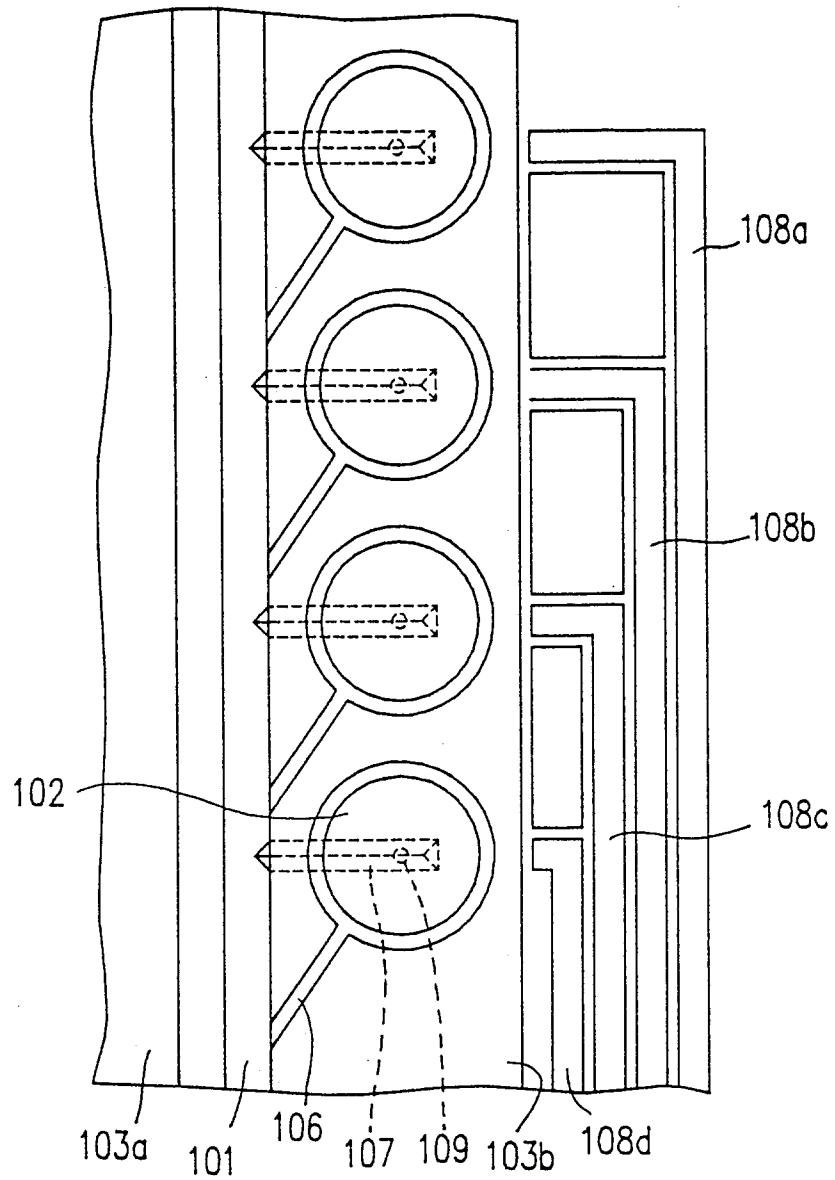


FIG. 1B

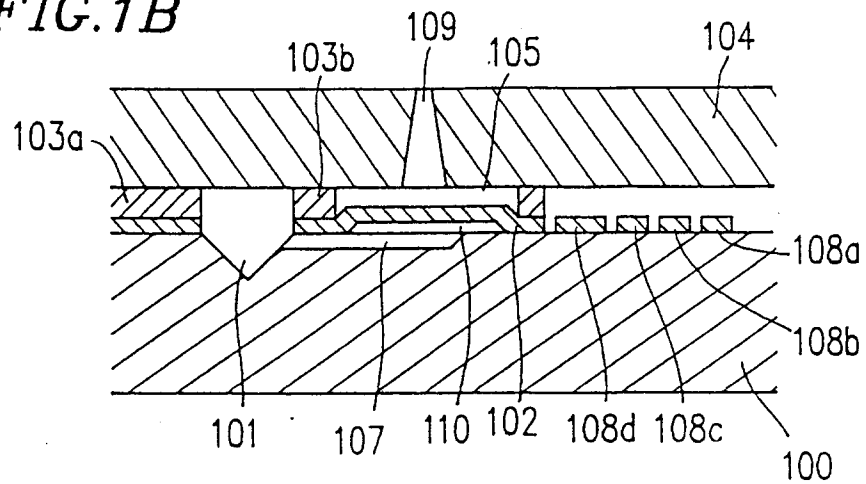


FIG. 2

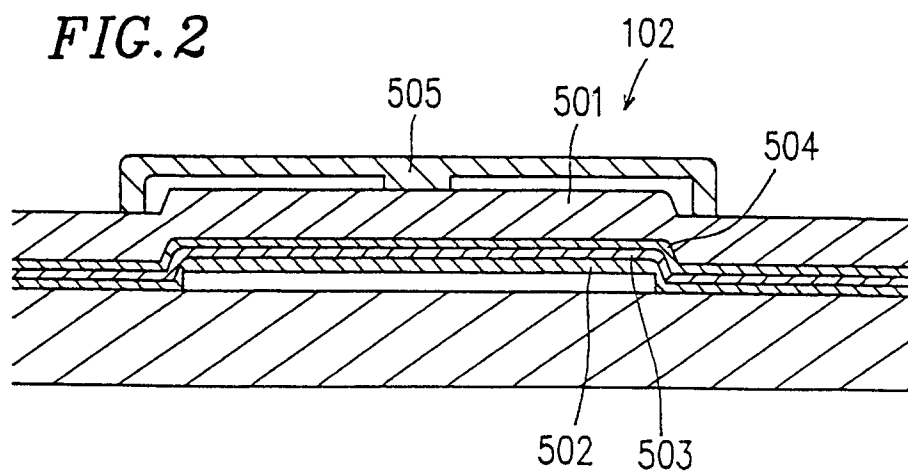


FIG. 3A

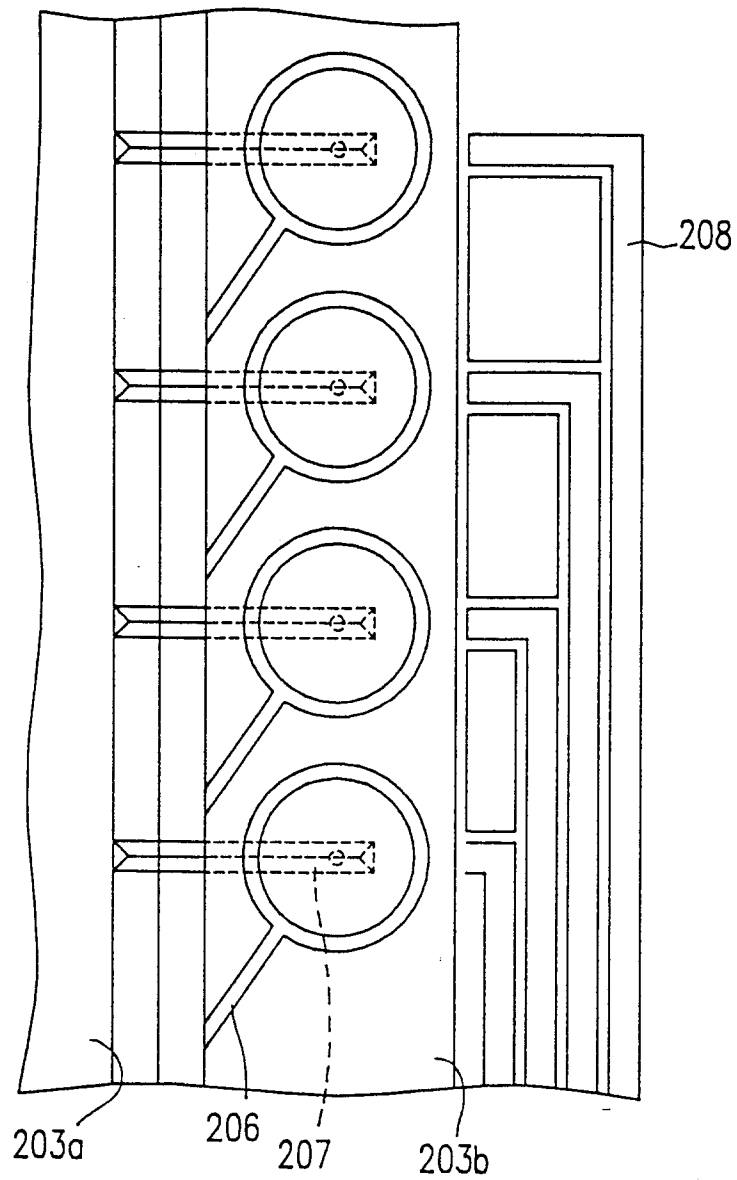


FIG. 3B

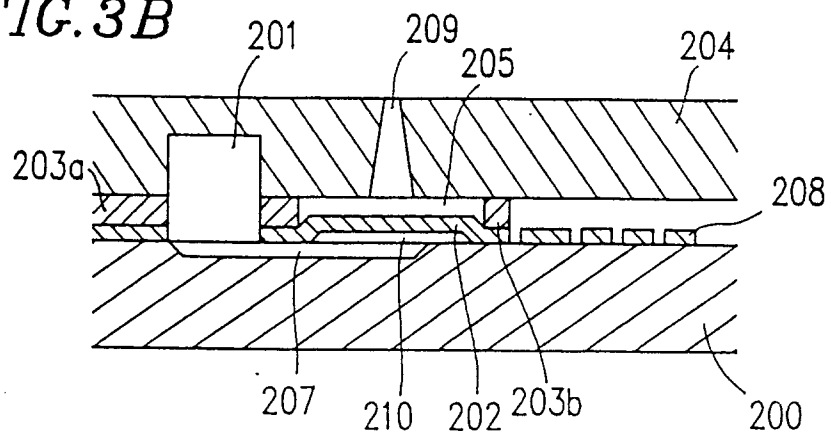


FIG. 4A

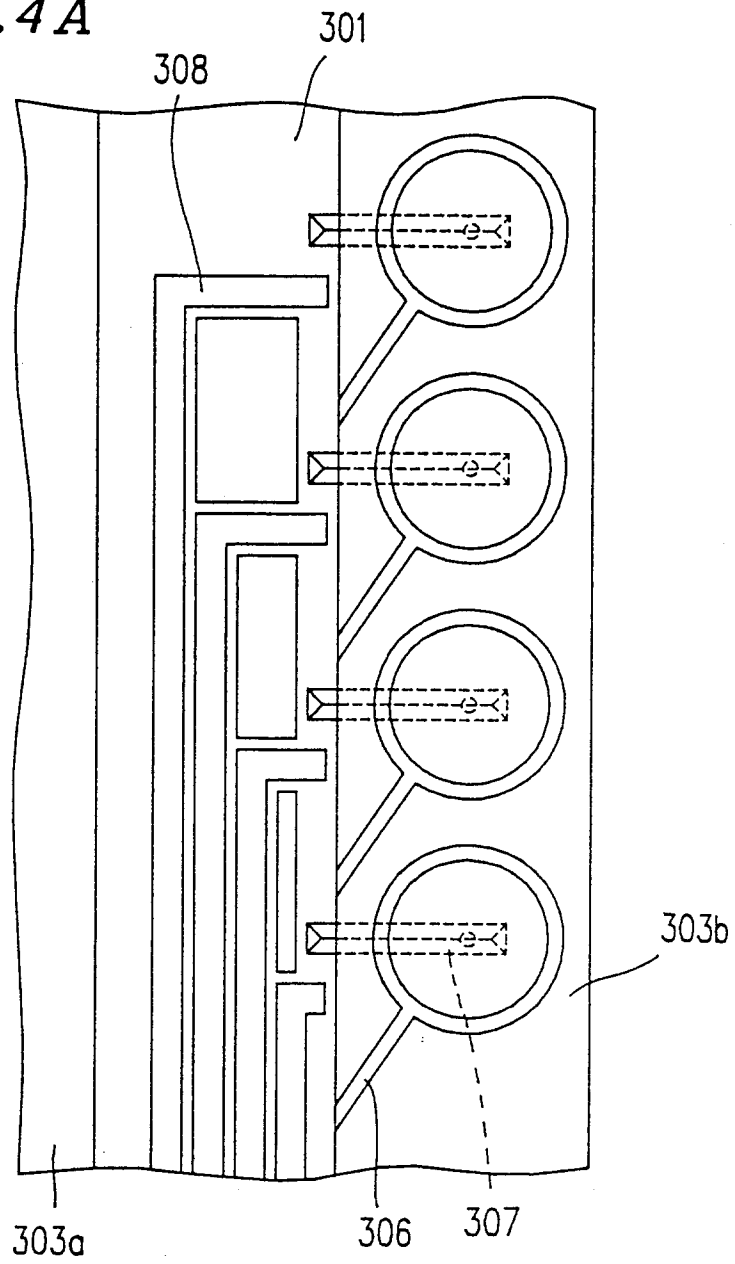


FIG. 4B

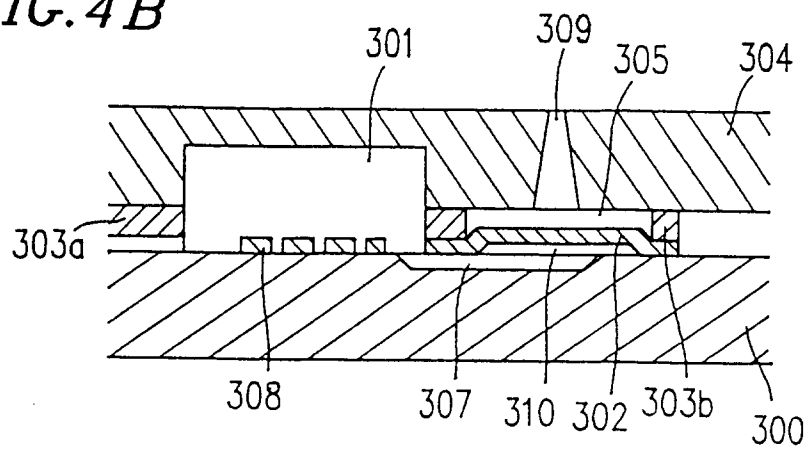


FIG. 5

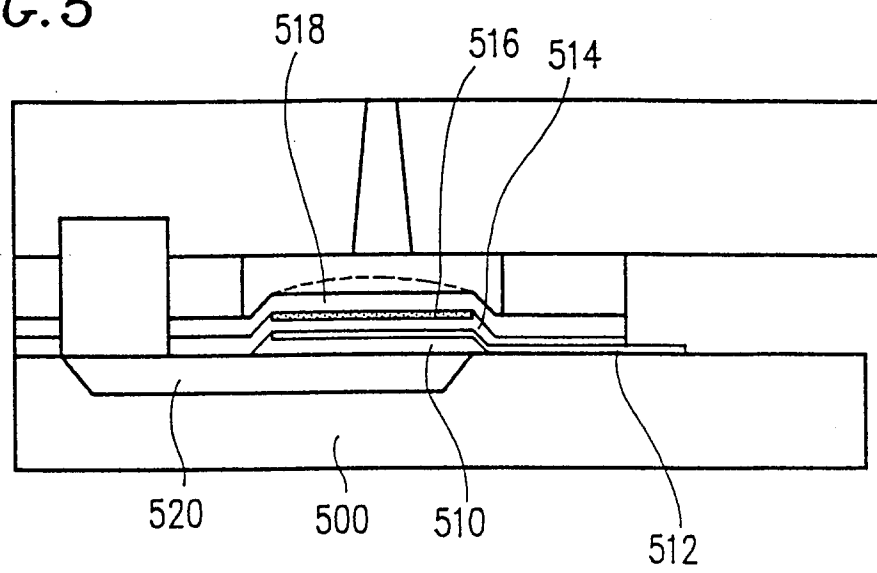


FIG. 6A(i)

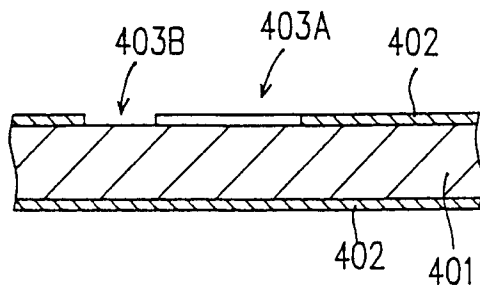


FIG. 6A(ii)

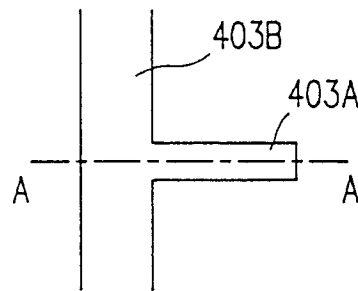


FIG. 6B(i)

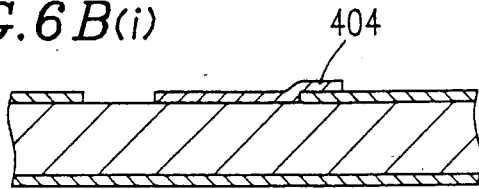


FIG. 6B(ii)

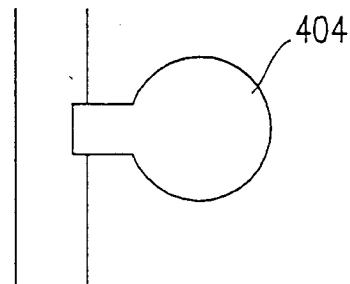


FIG. 6C(i)

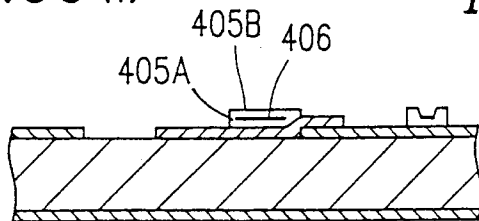


FIG. 6C(ii)

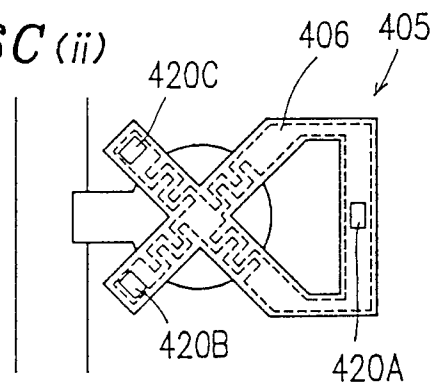


FIG. 6D(i)

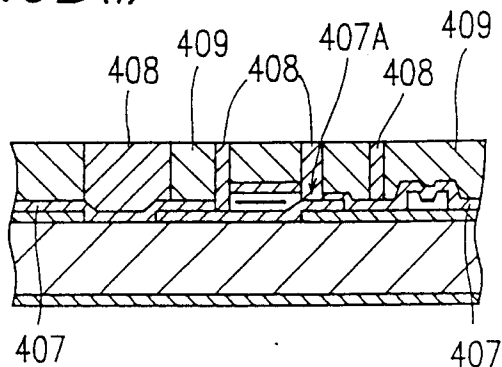


FIG. 6D(ii)

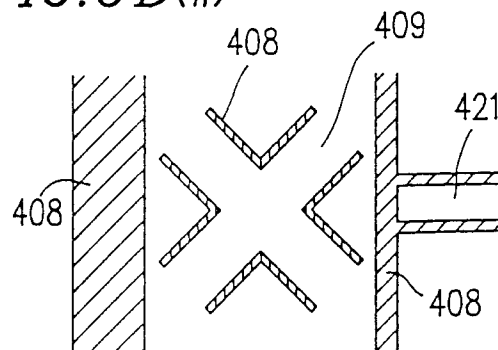


FIG. 6E(i)

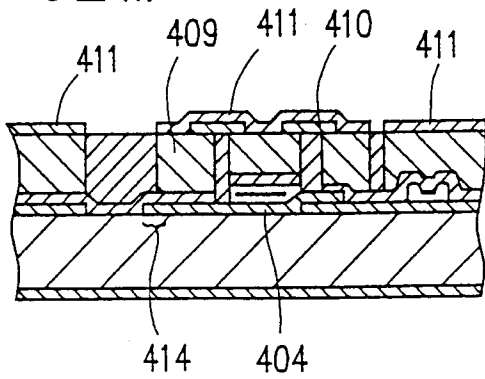


FIG. 6E(ii)

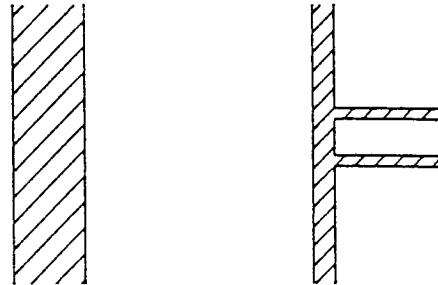


FIG. 6F(i)

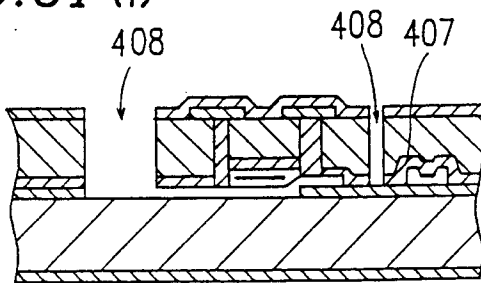


FIG. 6F(ii)

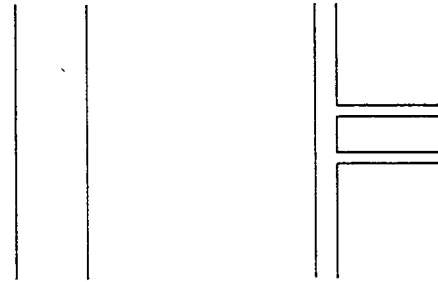


FIG. 6G(i)

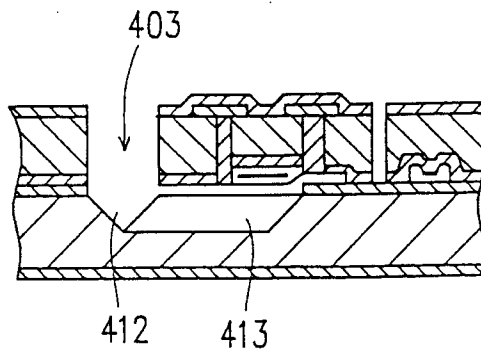


FIG. 6G(ii)

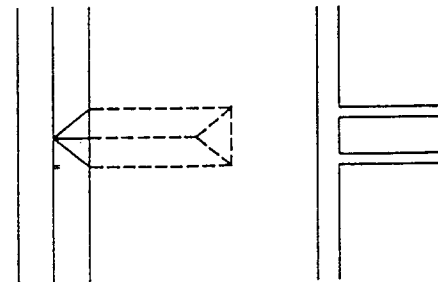


FIG. 6H(i)

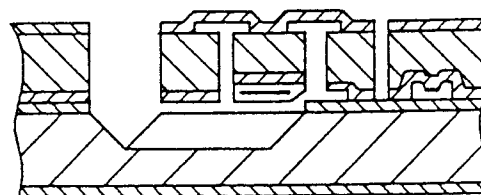


FIG. 7A

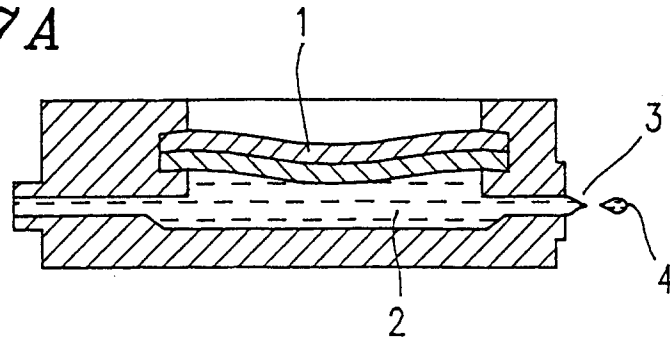


FIG. 7B

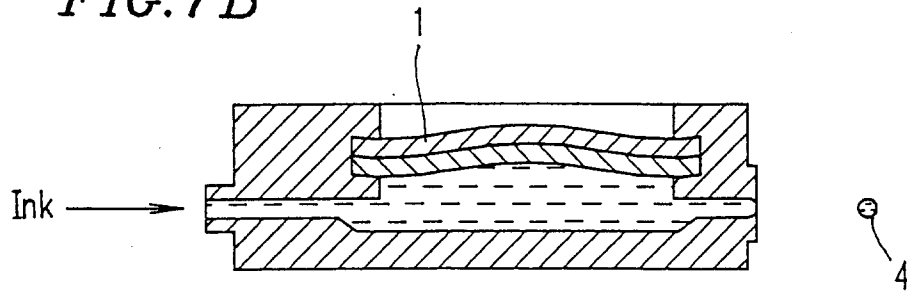


FIG. 8

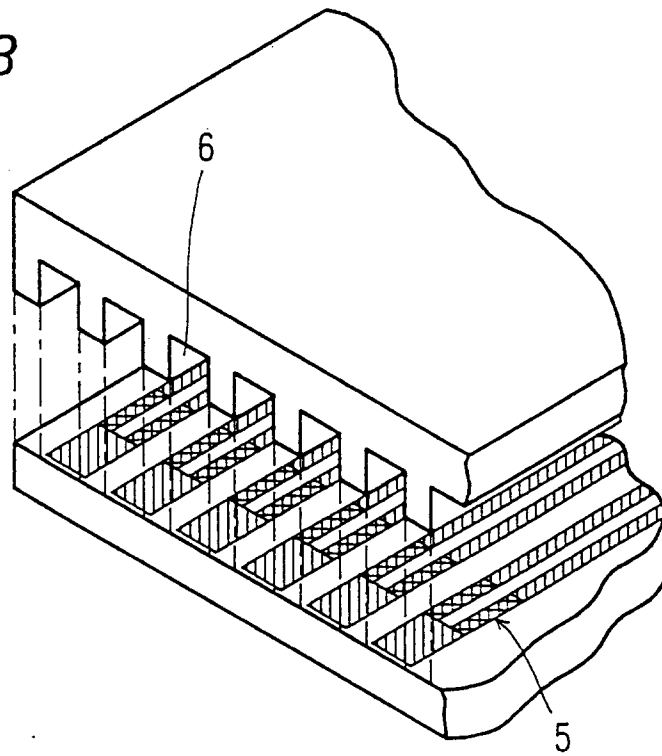
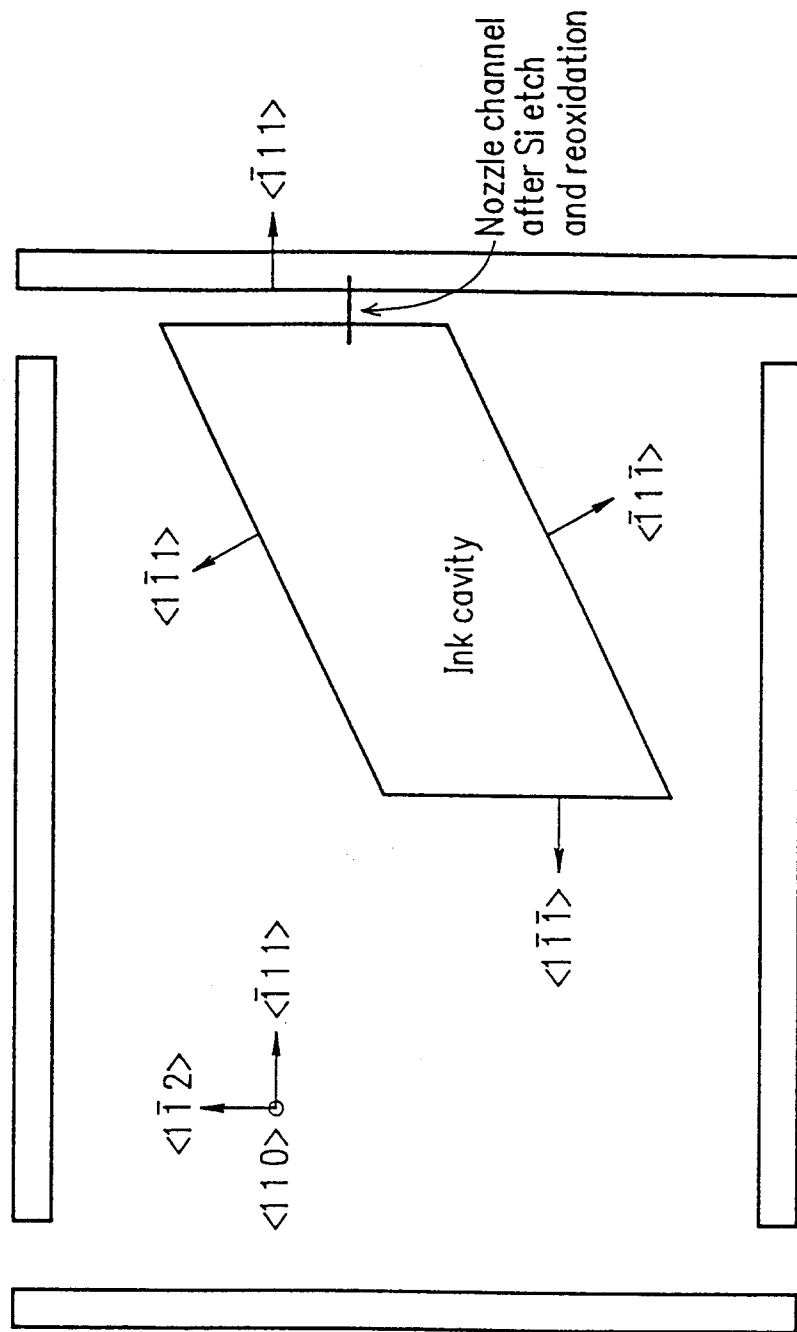


FIG. 9



Orientation of the anisotropically etched ink cavity and deep grooves.
 After EDP etching, all the (111) surfaces will have flat, vertical walls.
 Typical cavity size is about 0.5 cm.