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

(11) EP 1 484 178 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
08.12.2004 Bulletin 2004/50

(51) Int Cl.[7]: **B41J 2/14**, B41J 2/16

(21) Application number: **04253173.1**

(22) Date of filing: **28.05.2004**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL HR LT LV MK

(30) Priority: **05.06.2003 KR 2003036332**

(71) Applicant: **Samsung Electronics Co., Ltd.**
Suwon-si, Gyeonggi-do (KR)

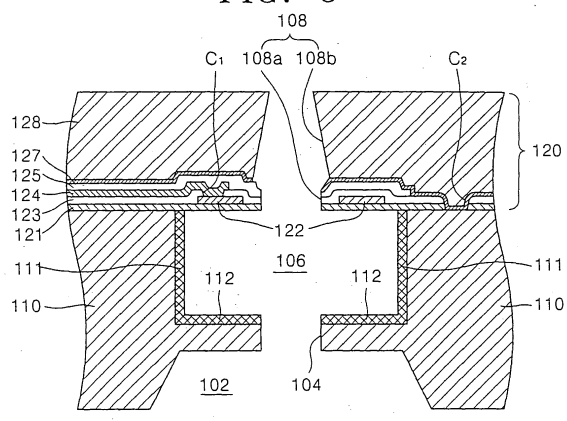
(72) Inventors:
- **Shin, So-ho**
  Suwon-si Gyeonggi-do (KR)
- **Shin, Seung-joo**
  Nowon-gu Seoul (KR)
- **Baek, Seog-soon**
  Suwon-si Gyeonggi-do (KR)
- **Oh, Yong-soo**
  Budang-gu Seongnam-si Gyeonggi-do (KR)
- **Shin, Jong-woo**
  Seocho-gu Seoul (KR)
- **Lee, Chang-seung**
  Bundang-gu Seongnam-si Gyeonggi-do (KR)
- **Bae, Ki-deok**
  Suji-eub Yongin-si Gyeonggi-do (KR)

(74) Representative: **Greene, Simon Kenneth**
Elkington and Fife LLP,
Prospect House,
8 Pembroke Road
Sevenoaks, Kent TN13 1XR (GB)

(54) **Monolithic ink-jet printhead and method of manufacuturing the same**

(57) A monolithic ink-jet printhead and a method of manufacturing the same are provided. The monolithic ink-jet printhead comprises a substrate, an ink chamber to be filled with ink to be ejected being formed on a front surface of the substrate, a manifold which supplies ink to the ink chamber being formed on a rear surface of the substrate, and an ink channel being vertically formed through the substrate between the ink chamber and the manifold; sidewalls, which are formed to a predetermined depth from the front surface of the substrate and define side surfaces of the ink chamber; a bottom wall, which is formed at a position of to a predetermined depth from the front surface of the substrate and define a bottom surface of the ink chamber; a nozzle plate, which includes a plurality of passivation layers stacked on the substrate and formed of an insulating material and a heat dissipating layer stacked on the passivation layers and formed of a metallic material having good thermal conductivity and through which a nozzle connected to the ink chamber is formed; a heater, which is disposed between the passivation layers of the nozzle plate, positioned above the ink chamber, and heats ink in the ink chamber; and a conductor, which is disposed between the passivation layers of the nozzle plate, electrically connected to the heater, and delivers a current to the heater.

FIG. 6



EP 1 484 178 A1

Description

[0001] The present invention relates to an ink-jet printhead, and more particularly, to a thermally-driven monolithic ink-jet printhead in which a plurality of nozzles are densely disposed to implement high resolution printing, and a method of manufacturing the same.

[0002] In general, ink-jet printheads are devices for printing a predetermined color image by ejecting droplets of ink at desired positions on a recording sheet. ink-jet printheads are generally categorized into two types according to an ink ejection mechanism. One is a thermally-driven ink-jet printhead in which a source of heat is employed to form bubbles in ink to eject the ink due to the expansive force of the bubbles. The other is a piezoelectrically-driven ink-jet printhead in which ink is ejected by a pressure applied to the ink and a change in ink volume due to deformation of a piezoelectric element.

[0003] The ink droplet ejection mechanism of the thermally-driven ink-jet printhead will be explained in further detail. When a pulse current is supplied to a heater formed of a resistive heating material, the heater generates heat such that ink near the heater is instantaneously heated in a short time. As the ink boils to generate bubbles, the generated bubbles expand to exert a pressure on the ink filled in an ink chamber. Therefore, the ink in the vicinity of a nozzle is ejected in the form of droplets to the outside of the ink chamber.

[0004] The thermal ink-jet printhead is classified into a top-shooting type, a side-shooting type, and a back-shooting type, according to a bubble growing direction and a droplet ejection direction. In a top-shooting type printhead, bubbles grow in the same direction in which ink droplets are ejected. In a side-shooting type of printhead, bubbles grow in a direction perpendicular to a direction in which ink droplets are ejected. In a back-shooting type of printhead, bubbles grow in a direction opposite to a direction in which ink droplets are ejected.

[0005] The thermal ink-jet printhead generally needs to meet the following conditions. First, a manufacturing process must be simple, a manufacturing cost must be low, and mass production must be feasible. Second, cross-talk between adjacent nozzles must be avoided to produce a high-quality image, and a distance between the adjacent nozzles must be as narrow as possible. That is, a plurality of nozzles should be densely disposed to increase dots per inch (DPI). Third, a refill cycle after ink ejection must be as short as possible to permit high-speed printing. That is, an operating frequency must be high by fast-cooling the heated ink.

[0006] FIGS. 1 through 3 illustrate the structure of a conventional back-shooting type thermal ink-jet printhead.

[0007] FIG. 1 is a perspective view illustrating the structure of an ink-jet printhead disclosed in U.S. Patent No. 5,502,471. Referring to FIG. 1, an ink-jet printhead 20 has a structure in which a substrate 11 having a nozzle 10 through which ink droplets are ejected and an ink chamber 16 filled with ink to be ejected, a cover plate 3 having a through hole 2 connecting the ink chamber 16 and an ink reservoir 12, and the ink reservoir 12 which supplies ink to the ink chamber 16, are sequentially stacked. Here, a heater 22 has a ring shape and is disposed around the nozzle 10 of the substrate 11.

[0008] In the above structure, if a pulse current is supplied to the heater 22 and heat is generated by the heater 22, ink in the ink chamber 16 boils and bubbles are generated. The bubbles expand continuously and apply pressure to ink in the ink chamber 16. As a result, ink is ejected in droplets through the nozzle 10. Next, ink is drawn into the ink chamber 16 from the ink reservoir 12 through the through hole 2 formed in the cover plate 3, and the ink chamber 16 is refilled with ink.

[0009] However, in the ink-jet printhead 20, since the height of the ink chamber 16 is almost the same as the thickness of the substrate 11, unless a very thin substrate is used, the size of the ink chamber 16 increases. Thus, pressure generated by bubbles for ejecting ink is dispersed by the ink, resulting in degradation of an ejection performance. Meanwhile, if a thin substrate is used to reduce the size of the ink chamber 16, it is difficult to process the substrate 11. In other words, the height of the ink chamber 16 in a typical conventional ink-jet printhead is about 10-30 μm. In order to form an ink chamber having this height, a silicon substrate having a thickness of 10-30 μm should be used. However, it is impossible to process a silicon substrate having such a thickness using semiconductor processes.

[0010] In addition, in order to manufacture an ink-jet printhead 20 having the above structure, the substrate 11, the cover plate 3, and the ink reservoir 12 should be bonded to one another. Thus, a process of manufacturing the ink-jet printhead becomes complicated, and an ink passage which has a large effect on the ejection property cannot be made very elaborate due to misalignment during the bonding process.

[0011] FIGS. 2A and 2B illustrate the structure of a monolithic ink-jet printhead disclosed in U.S. Patent No. 6,533,399. Referring to FIGS. 2A and 2B,a hemispherical ink chamber 32 is formed on a front surface of a silicon substrate 30, a manifold 36 which supplies ink to the ink chamber 32 is formed on a rear surface of the substrate 30, and an ink channel 34 which connects the ink chamber 32 and the manifold 36 is formed at a bottom of the ink chamber 32. A nozzle plate 40 in which a plurality of material layers 41, 42, and 43 are stacked is formed integrally with the substrate 30. A nozzle 47 is formed at a position of the nozzle plate 40 corresponding to the center of the ink chamber 32, and a heater 45 connected to a conductor 46 is disposed around the nozzle 47. A nozzle guide 44 that extends in a lengthwise direction of the ink chamber 32 is formed at edges of the nozzle 47. Heat generated by the heater 45 is transferred to ink 48 in the ink chamber 32 through an insulating layer 41. As a result, the ink 48 boils, and bubbles 49 are generated in the ink 48. The bubbles 49 expand, and pressure is applied to the ink 48 in the ink chamber 32. As a result, the ink 48 in the vicinity of the nozzle 47 is ejected as ink droplets 48' through the nozzle 47. Next, due to a surface tension that acts on the surface of the ink 48 contacting air, the ink 48 is drawn into the ink chamber 32 through the ink channel 34 from the manifold 36, and the ink chamber 32 is refilled with the ink 48.

[0012] In the conventional monolithic ink-jet printhead having the above structure, the silicon substrate 30 and the nozzle plate 40 form a single body such that a process of manufacturing the ink-jet printhead is simple and misalignment is prevented.

[0013] However, in the monolithic ink-jet printhead shown in FIGS. 2A and 2B, in order to form the ink chamber 32, the substrate 30 is etched isotropically through the nozzle 47. As a result, the ink chamber 32 has a hemispherical shape. Thus, in order to form the ink chamber 32 having a predetermined volume, the radius of the ink chamber 32 should be maintained at a constant level. As a result, there is a limitation in making a distance between the adjacent nozzles 47 narrower and disposing the nozzles 47 more densely. In other words, in order to make the distance between the adjacent nozzles 47 narrower, the radius of the ink chamber 32 should be reduced. This results in a decrease in the volume of the ink chamber 32, and thus is not preferable.

[0014] Thus, there is a limitation in disposing a plurality of nozzles more densely using the structure of the conventional monolithic ink-jet printhead, so as to meet the requirement for the ink-jet printhead with high DPI to print an image with high resolution.

[0015] FIG. 3 illustrates the structure of an ink-jet printhead disclosed in U.S. Patent No. 6,382,782. Referring to FIG. 3, the ink-jet printhead has a structure in which a nozzle plate 50 having a nozzle 51, an insulating layer 60 having an ink chamber 61 and an ink channel 62, and a silicon substrate 70 having a manifold 55 for supplying ink to the ink chamber 61 are sequentially stacked.

[0016] In this ink-jet printhead, since the ink chamber 61 is formed using the insulating layer 60 stacked on the substrate 70, the ink chamber 61 may have a variety of shapes, and backflow of ink can be suppressed.

[0017] However, when manufacturing this ink-jet printhead, a method of depositing the thick insulating layer 60 on the silicon substrate 70, etching the insulating layer 60, and forming the ink chamber 61 is generally used. This method has the following problems. First, it is difficult to stack the thick insulating layer 60 on the substrate 70 using existing semiconductor processes. Second, it is difficult to etch the thick insulating layer 60. Thus, there is a limitation in the height of the ink chamber 61. As shown in FIG. 3, the ink chamber 61 and the nozzle 51 have a combined height of only about 6 μm. However, with such a shallow ink chamber 61, it is impossible for an ink-jet printhead to have a relatively large drop size.

[0018] According to an aspect of the present invention, there is provided a monolithic ink-jet printhead, the monolithic ink-jet printhead comprising a substrate, an ink chamber to be filled with ink to be ejected being formed on a front surface of the substrate, a manifold which supplies ink to the ink chamber being formed on a rear surface of the substrate, and an ink channel being vertically formed through the substrate between the ink chamber and the manifold; sidewalls, which are formed to a predetermined depth from the front surface of the substrate and define side surfaces of the ink chamber; a bottom wall, which is formed at a position of to a predetermined depth from the front surface of the substrate and define a bottom surface of the ink chamber; a nozzle plate, which includes a plurality of passivation layers stacked on the substrate and formed of an insulating material and a heat dissipating layer stacked on the passivation layers and formed of a metallic material having good thermal conductivity and through which a nozzle connected to the ink chamber is formed; a heater, which is disposed between the passivation layers of the nozzle plate, positioned above the ink chamber, and heats ink in the ink chamber; and a conductor, which is disposed between the passivation layers of the nozzle plate, electrically connected to the heater, and delivers a current to the heater.

[0019] The sidewalls and the bottom wall may be formed of a material other than a material used in forming the substrate.

[0020] The ink chamber may be surrounded by sidewalls to have a rectangular shape. The ink chamber may be formed to a depth of about 10-80 μm by the sidewalls and the bottom wall.

[0021] The substrate may be a silicon-on-insulatior (SOI) substrate in which a lower silicon substrate, an insulating layer, and an upper silicon substrate are sequentially stacked. In this case, the ink chamber and the sidewalls may be formed on the upper silicon substrate of the SOI substrate, and the insulating layer of the SOI substrate may form the bottom wall.

[0022] The heater may be disposed above the ink chamber not to overlap with the nozzle in the plane. For example, the nozzle may be disposed at a position corresponding to a center of the ink chamber, and the heater may be disposed at both sides of the nozzle. The nozzle and the heater may be respectively disposed at both sides of the center of the ink chamber.

[0023] The ink channel may be vertically formed through the substrate and may be disposed at a position in which the ink chamber and the manifold are connected to each other. At least one ink channel or a plurality of ink channels may be disposed.

[0024] The passivation layers may include at least one passivation layer disposed between the substrate and the heater and at least one passivation layer disposed between the heater and the heat dissipating layer.

[0025] The passivation layers may include at least one passivation layer disposed between the substrate and the conductor and at least one passivation layer disposed between the conductor and the heat dissipating layer.

[0026] The passivation layers may be formed on upper portions of the heater and the conductor and at portions adjacent thereto.

[0027] A lower portion of the nozzle may be formed in the plurality of passivation layers, and an upper portion of the nozzle may be formed in the heat dissipating layer. The upper portion of the nozzle formed in the heat dissipating layer may have a tapered shape such that a diameter thereof becomes smaller in the direction of an outlet. The upper portion of the nozzle formed in the heat dissipating layer may have a pillar shape.

[0028] The heat dissipating layer may be formed of one or a plurality of metallic layers, and each of the metallic layer may be formed of at least one material selected from the group consisting of Ni, Cu, Al, and Au. The heat dissipating layer may be formed to a thickness of about 10-100 μm by electroplating. The heat dissipating layer may contact the surface of the substrate via a contact hole formed in the passivation layers.

[0029] A seed layer for electroplating the heat dissipating layer may be formed on the passivation layers and at least part of the substrate. In this case, the seed layer may be formed of one or a plurality of metallic layers, and each of the metallic layer may be formed of at least one material selected from the group consisting of Cu, Cr, Ti, Au, and Ni.

[0030] According to another aspect of the present invention, there is provided a method of manufacturing a monolithic ink-jet printhead, the method comprising forming a sacrificial layer surrounded by sidewalls and a bottom wall on a front surface of a substrate; sequentially stacking a plurality of passivation layers on the substrate and forming a heater and a conductor connected to the heater between the passivation layers; forming a heat dissipating layer of metal on the passivation layers and forming a nozzle through which ink is ejected through the passivation layers and the heat dissipating layer to form a nozzle plate comprising the passivation layers and the heat dissipating layer on the substrate; forming an ink chamber defined by the sidewalls and the bottom wall by etching the sacrificial layer exposed through the nozzle using the sidewalls and the bottom wall as an etch stop ; forming a manifold for supplying ink by etching a rear surface of the substrate; and forming an ink channel by etching the substrate between the manifold and the ink chamber to penetrate the substrate.

[0031] Forming the sacrificial layer may comprise etching the surface of the substrate to form a groove having a predetermined depth; oxidizing the surface of the substrate in which the groove is formed to form the sidewalls and the bottom wall of silicon oxide; filling the groove surrounded by the sidewalls and the bottom wall with a predetermined material to form the sacrificial layer; and planarizing the surfaces of the substrate and the sacrificial layer. Filling groove with the predetermined material may be performed by epitaxially growing polysilicon in the groove.

[0032] Forming the sacrificial layer may comprise etching an upper silicon substrate of an SOI substrate to a predetermined depth to form a trench; and filling the trench with a predetermined material to form the sidewalls. The predetermined material may be silicon oxide.

[0033] Forming the passivation layers may comprise forming a first passivation layer on the surface of the substrate; forming the heater on the first passivation layer; forming a second passivation layer on the first passivation layer and the heater; forming the conductor on the second passivation layer; and forming a third passivation layer on the second passivation layer and the conductor. The third passivation layer may be formed on upper portions of the heater and the conductor and at portions adjacent thereto.

[0034] The heat dissipating layer may be formed of one or a plurality of metallic layers, and each of the metallic layers may be formed by electroplating at least one material selected from the group consisting of Ni, Cu, Al, and Au. The heat dissipating layer may be formed to a thickness of 10-100 μm.

[0035] Forming the heat dissipating layer and the nozzle may comprise forming a lower nozzle by etching the passivation layers formed on the sacrificial layer; forming a plating mold for forming an upper nozzle vertically from the inside of the lower nozzle; forming the heat dissipating layer on the passivation layers by electroplating; and removing the plating mold to form the nozzle comprising the upper nozzle and the lower nozzle.

[0036] The lower nozzle may be formed by dry etching the passivation layers through reactive ion etching (RIE), and the plating mold may be formed of a photoresist or photosensitive polymer.

[0037] The method may further comprise planarizing the upper surface of the heat dissipating layer by a chemical mechanical polishing (CMP) process, after forming the heat dissipating layer.

[0038] Forming the ink channel may comprise dry etching the substrate from a rear surface of the substrate having the manifold.

[0039] According to the present invention, since an ink chamber having optimum planar shape and depth by sidewalls and a bottom wall that serve as an etch stop is formed, a distance between adjacent nozzles is made narrower and a monolithic ink-jet printhead with high DPI to print an image with high resolution is implemented. In addition, since a nozzle plate is formed integrally with a substrate having the ink chamber and an ink channel, the monolithic ink-jet printhead can be implemented by a series of processes on a single wafer without any subsequent processes, the yield of the monolithic ink-jet printhead is improved, and a process of manufacturing the monolithic ink-jet printhead is simplified.

[0040] The present invention thus provides a thermally-driven monolithic ink-jet printhead having an ink chamber in which a distance between adjacent nozzles is made narrower to print an image with high resolution, and a method of manufacturing the same.

[0041] The above and other aspects and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a perspective view illustrating an example of a conventional ink-jet printhead;
FIGS. 2A and 2B are respectively a plane view and a vertical cross-sectional view taken along line A-A' of FIG. 2A, which illustrate another example of a conventional ink-jet printhead;
FIG. 3 is a vertical cross-sectional view illustrating still another example of a conventional ink-jet printhead;
FIG. 4 is a plane view schematically illustrating an ink-jet printhead according to an embodiment of the present invention;
FIG. 5 is an enlarged plane view of a portion B of FIG. 4 illustrating the shape and disposition of an ink passage and a heater;
FIG. 6 is a vertical cross-sectional view of the ink-jet printhead taken along line X-X' of FIG. 5;
FIG. 7 is a plane view illustrating the structure of an ink-jet printhead according to another embodiment of the present invention;
FIG. 8 is a plane view illustrating the structure of an ink-jet printhead according to still another embodiment of the present invention;
FIG. 9 is a vertical cross-sectional view illustrating the structure of an ink-jet printhead according to yet still another embodiment of the present invention;
FIGS. 10A through 10D illustrate the operation of ejecting ink from an ink-jet printhead shown in FIG. 5 according to the embodiment of the present invention;
FIGS. 11 through 22 are cross-sectional views illustrating a method of manufacturing the ink-jet printehead shown in FIG. 5 according to an embodiment of the present invention; and
FIGS. 23 and 24 are cross-sectional views illustrating a method of manufacturing an ink-jet printhead according to another embodiment of the present invention.

[0042] Hereinafter, exemplary embodiments of the present invention will be described in detail with reference to the accompanying drawings. In the drawings, whenever the same element reappears in subsequent drawings, it is denoted by the same reference numeral. Also, the sizes or thicknesses of elements may be exaggerated for clarity. It will be understood that when a layer is referred to as being on another layer or on a substrate, it can be directly on the other layer or on the substrate, or intervening layers may also be present.

[0043] FIG. 4 is a plane view schematically illustrating a monolithic ink-jet printhead according to an embodiment of the present invention. Referring to FIG. 4, a plurality of nozzles 108 are disposed in two rows on the surface of the ink-jet printhead manufactured in a chip state, and bonding pads 101 which can be bonded to wires are disposed at edges of the surface of the ink-jet printhead. In alternative embodiments, the nozzles 108 may be arranged in one row, or in three or more rows to improve printing resolution.

[0044] FIG. 5 is an enlarged plane view of a portion B of FIG. 4 illustrating the shape and disposition of an ink passage and a heater, and FIG. 6 is a cross-sectional view illustrating a vertical structure of the ink-jet printhead taken along line X-X' of FIG. 5.

[0045] Referring to FIGS. 5 and 6, the ink-jet printhead includes an ink passage which includes a manifold 102, an ink channel 104, an ink chamber 106, and a nozzle 108.

[0046] The ink chamber 106 to be filled with ink is formed on a front surface of a substrate 110 to a predetermined depth, preferably, 10-80 μm. Side surfaces and bottom surface of the ink chamber 106 are defined by sidewalls 111 for defining the planar shape and width of the ink chamber 106 and a bottom wall 112 for defining the depth of the ink chamber 106. The sidewalls 111 and the bottom wall 112 serve as an etch stop when forming the ink chamber 106 by etching the substrate 110, as will be described later. Thus, the ink chamber 106 can be accurately formed by the sidewalls 111 and the bottom wall 112 to have desired dimensions. In other words, the ink chamber 106 may have an optimum volume at which the ejection performance of ink droplets is improved, that is, an optimum cross-section and depth.

[0047] The ink chamber 106 defined by the sidewalls 111 may have a variety of planer shapes. In particular, the ink chamber 106 may have a rectangular shape, preferably, a rectangular shape in which the width of a nozzle disposition direction is small and the length of a direction perpendicular to the nozzle disposition direction is large. Since the width of the ink chamber 106 is reduced in this manner, the distance between the adjacent nozzles 108 can be made narrower. Thus, the plurality of nozzles 108 can be densely disposed, resulting in realization of an ink-jet printhead with high DPI at which an image with high resolution is printed.

[0048] The sidewalls 111 and the bottom wall 112 are formed of materials other than a material used in forming the substrate 110. This is because the ink chamber 106 is formed so that the sidewalls 111 and the bottom wall 112 serve as an etch stop. Thus, when the substrate 110 is formed of a silicon wafer, the sidewalls 111 and the bottom wall 112 are formed of silicon oxide.

[0049] The manifold 102 is formed on a rear surface of the substrate 110 and is connected to an ink reservoir (not shown) storing ink. Thus, the manifold 102 supplies ink to the ink chamber 106 from the ink reservoir.

[0050] The ink channel 104 is vertically formed through the substrate 110 between the ink chamber 106 and the manifold 102. In the drawings, the ink channel 104 is formed at a position corresponding to the center of the ink chamber 106, or may be formed at any position in which the ink chamber 106 and the manifold 102 are vertically connected to each other. The ink channel 104 may have a variety of cross-sectional shapes, such as a circular shape and a polygonal shape. In addition, one or a plurality of ink channels 104 may be formed in consideration of ink supply speed.

[0051] A nozzle plate 120 is disposed on the substrate 110 on which the ink chamber 106, the ink channel 104, and the manifold 102 are formed. The nozzle plate 120 forms an upper wall of the ink chamber 106. A nozzle 108 through which ink is ejected from the ink chamber 106 is vertically formed through the nozzle plate 120.

[0052] The nozzle plate 120 is formed of a plurality of material layers stacked on the substrate 110. The plurality of material layers includes first, second, and third passivation layers 121, 123, and 125, and a heat dissipation layer 128. A plurality of heaters 122 are disposed between the first passivation layer 121 and the second passivation layer 123, and a conductor 124 is disposed between the second passivation layer 123 and the third passivation layer 125.

[0053] The first passivation layer 121 is a lowermost material layer of the plurality of material layers which are components of the nozzle plate 120 and is formed on the surface of the substrate 110. The first passivation layer 121 is formed to provide insulation between the heater 122 and the substrate 110 and to protect the heater 122. The first passivation layer 121 may be formed of silicon oxide or silicon nitride.

[0054] The heater 122 which heats ink in the ink chamber 106 is disposed on the first passivation layer 121 formed on the ink chamber 106. The heater 122 is formed of a resistive heating material, such as impurity-doped polysilicon, tantalum-aluminum alloy, tantalum nitride, titanium nitride, or tungsten silicide. The heater 122 is disposed above the ink chamber 106 not to overlap with the nozzle 108 in the plane. Specifically, the heaters 122 may be disposed at both sides of the nozzle 108 and may have a rectangular shape, preferably, a rectangular shape having a large length parallel to a disposition direction of the nozzle 108. Meanwhile, only one heater 122 may be formed, and the disposition or shape thereof may be different from that shown in FIG. 5. For example, the heater 122 may be formed in a ring shape to surround the nozzle 108.

[0055] The second passivation layer 123 is formed on the first passivation layer 121 and the heater 122. The second passivation layer 123 is formed to provide insulation between the heat dissipating layer 128 formed thereon and the heater 122 formed thereunder and to protect the heater 122. The second passivation layer 123 may be formed of silicon nitride or silicon oxide, like the first passivation layer 121.

[0056] The conductor 124 which is electrically connected to the heater 122 and delivers a pulse current to the heater 122 is formed on the second passivation layer 123. One end of the conductor 124 is connected to both ends of the heater 122 via a contact hole C_1 formed in the second passivation layer 123, and the other end thereof is electrically connected to a bonding pad (101 of FIG. 4). The conductor 124 may be formed of metal with good conductivity, for example, aluminum (Al), aluminum alloy, gold (Au), or silver (Ag).

[0057] The third passivation layer 125 is formed on the conductor 124 and the second passivation layer 123. The third passivation layer 125 may be formed of tetraethylorthosilicate (TEOS) oxide or silicon oxide. Preferably, within a range in which an insulation function of the third passivation layer 125 is not damaged, the third passivation layer 125 is formed on upper portions of the heater 122 and the conductor 124 and at portions adjacent thereto and is not formed at the remaining portions as possible, for example, at portions out of an upper portion of the ink chamber 106 in which the conductor 124 is not installed. This is because a distance between the heat dissipating layer 128 and the substrate 110 is made narrower such that thermal resistance is reduced and the heat dissipating capability of the heat dissipating layer 128 is further improved. In addition, the third passivation layer 125 is formed to a predetermined thickness, preferably, 0.5-3 μm so that while a current is applied to the heater 122, a larger amount of heat generated by the heater 122 is transferred to ink filled in the ink chamber 106 and after delivering a current to the heater 122 is completed, heat generated by the heater 122 and remaining around the heater 122 is smoothly dissipated to the substrate 110 through the heat dissipating layer 128.

[0058] The heat dissipating layers 128 are formed on the third passivation layer 125 and the second passivation layer 123 and contact the top surface of the substrate 110 via a contact hole C_2 formed through the second passivation layer 123 and the first passivation layer 121. The heat dissipating layer 128 may be formed of a metallic material with good thermal conductivity, such as Ni, Cu, Al, or Au. In addition, the heat dissipating layer 128 may be formed of one or a plurality of metallic layers. The heat dissipating layer 128 may be formed to a larger thickness of about 10 - 100 μm by electroplating the above-described metallic material on the third passivation layer 125 and the second passivation layer 123. To this end, a seed layer 127 for electroplating of the above-described metallic material may be formed on the third passivation layer 125 and the second passivation layer 123. The seed layer 127 may be formed of a metallic material with good electrical conductivity, such as Cu, Cr, Ti, Au, or Ni. In addition, the seed layer 127 may be formed of one or a plurality of metallic layers.

[0059] As described above, since the heat dissipating layer 128 formed of metal is formed by electroplating, the heat dissipating layer 128 may be formed integrally with the other elements of the ink-jet printhead and may be formed to a larger thickness so that heat can be dissipated effectively.

[0060] The heat dissipating layer 128 dissipates heat generated by the heater 122 and remaining around the heater 122 while contacting the top surface of the substrate 110 via the second contact hole C_2. In other words, heat generated by the heater 122 and remaining around the heater 122 after ink is ejected is dissipated to the substrate 110 and outside via the heat dissipating layer 128. Thus, heat is dissipated after ink is ejected, and the temperature around the nozzle 108 falls rapidly so that printing can be performed stably at a high driving frequency.

[0061] As described above, since the heat dissipating layer 128 may be formed to a larger thickness, the nozzle 108 can be formed to have a sufficient length. Thus, a stable high-speed operation can be performed, and linearity of ink droplets ejected through the nozzle 108 is improved. That is, the ink droplets can be ejected in a direction exactly perpendicular to the substrate 110.

[0062] The nozzle 108 comprising a lower nozzle 108a and an upper nozzle 108b is formed through the nozzle plate 120. The lower nozzle 108a has a cylindrical shape and is formed in the first, second, and third passaivation layers 121, 123, and 125. The upper nozzle 108b is formed through the heat dissipating layer 128. the upper nozzle 108b may have a cylindrical shape. However, as shown in FIG. 6, the upper nozzle 108b may have a tapered shape such that a diameter thereof becomes smaller in the direction of an outlet. Since the upper nozzle 108b has a tapered shape, a meniscus at the surface of ink in the nozzle 108 is more quickly stabilized after ink is ejected.

[0063] FIG. 7 is a plane view illustrating the structure of a monolithic ink-jet printhead according to another embodiment of the present invention. The structure of the monolithic ink-jet printhead shown in FIG. 7 is similar to the structure of the monolithic ink-jet printhead shown in FIGS. 5 and 6, and thus, will be described briefly based on a different therebetween.

[0064] Referring to FIG. 7, an ink chamber 206, which is defined by sidewalls 211 and a bottom wall 212, has a nearly rectangular shape, preferably, a rectangular shape in which the width of a nozzle disposition direction is small and the length of a direction perpendicular to the nozzle disposition direction is large. A nozzle 208 and an ink channel 204 are formed at a position corresponding to the center of the ink chamber 206. A plurality of heaters 222 are formed on the ink chamber 206. The heaters 222 are disposed at both sides of the nozzle 208 and may have a rectangular shape, preferably, a rectangular shape having a large length parallel to a lengthwise direction of the ink chamber 206. A conductor 224 is connected to both ends of the heater 222 via a first contact hole C_1. Second contact holes C_2 through which a heat dissipating layer contacts a substrate are formed at both sides of the ink chamber 206.

[0065] FIG. 8 is a plane view illustrating the structure of a monolithic ink-jet printhead according to still another embodiment of the present invention. The structure of the monolithic ink-jet printhead shown in FIG. 8 is similar to the structure of the monolithic ink-jet printhead shown in FIGS.-5 and 6, and thus, will be described briefly based on a different therebetween.

[0066] Referring to FIG. 8, an ink chamber 306 defined by sidewalls 311 and a bottom wall 312 has a nearly rectangular shape, preferably, a rectangular shape in which the width of a nozzle disposition direction is small and the length of a direction perpendicular to the nozzle disposition direction is large. In the present embodiment, an ink channel 304 is formed at a position corresponding to the center of the ink chamber 306 whereas a nozzle 308 is formed out of the lengthwise center of the ink chamber 306. A plurality of heaters 322 are formed on the ink chamber 306. The heaters 322 are disposed at one side of the nozzle 308 and may have a rectangular shape, preferably, a rectangular shape having a large length parallel to a widthwise direction of the ink chamber 306. A conductor 324 is connected to both ends of the heater 322 via a first contact hole C_1. Second contact holes C_2 through which a heat dissipating layer contacts a substrate are formed at both sides of the ink chamber 306.

[0067] FIG. 9 is a plane view illustrating the structure of a monolithic ink-jet printhead according to yet still another embodiment of the present invention. The structure of the monolithic ink-jet printhead shown in FIG. 9 is similar to the structure of the monolithic ink-jet printhead shown in FIGS. 5 and 6, and thus, will be described briefly based on a different therebetween.

[0068] Referring to FIG. 9, two or more ink channels 404 connect a manifold 102 formed on a rear surface of a substrate 110 and an ink chamber 106 formed on a front surface of the substrate 110. In this way, if the ink channels 404 are formed, since the cross-section of each ink channel 404 can be reduced without a reduction in ink supply speed, backflow of ink while ink droplets are ejected can more easily be suppressed, and foreign substances are prevented from mixing into the ink chamber 106 from the manifold 102.

[0069] An operation of ejecting ink from the monolithic ink-jet printhead shown in FIG. 5 according to the embodiment of the present invention will now be described with reference to FIGS. 10A through 10D.

[0070] Referring to FIG. 10A, if the pulse current is applied to a heater 122 via a conductor 124 in a state in which an ink chamber 106 and a nozzle 108 are filled with ink, heat is generated by the heater 122 and transferred to the ink 131 in the ink chamber 106 through a first passivation layer 121 formed under the heater 122. As a result, as shown in FIG. 10B, the ink 131 boils, and a bubble 132 is generated. The bubble 132 expands due to a continuous supply of heat, causing ink to be ejected through the nozzle 108.

[0071] Referring to FIG. 10C, when the applied current is cut off at a time when the bubble 132 expands to the maximum, the bubble 132 contracts and collapses, causing the ink 131 in the nozzle 108 to be returned to the ink chamber 106. Simultaneously, portions pushed out to the outside of the nozzle 108 are separated from the ink 131 in the nozzle 108 and ejected in droplets 131' due to an inertia force.

[0072] A meniscus at the surface of the ink 131 in the nozzle 108 after the droplets 131' are separated retreats toward the ink chamber 106. In this case, since the nozzle 108 is formed to have a sufficient length by the nozzle plate 120, the meniscus retreats only in the nozzle 108 and does not retreat into the ink chamber 106. Thus, air is prevented from flowing into the ink chamber 106, the meniscus is quickly returned to its initial state, and high-speed ejection of the droplets 131' can be performed stably. In addition, since heat generated by the heater 122 and remaining around the heater 122 after the droplets 131' are ejected is dissipated to the substrate 110 and outside via the heat dissipating layer 128, the temperature of the heater 122, the nozzle 108, and the temperature around the heater 122 and the nozzle 108 fall rapidly.

[0073] Referring to FIG. 10D, if the negative pressure in the ink chamber 106 vanishes, due to a surface tension acting on the meniscus at the surface of ink in the nozzle 108, the ink 131 rises toward an outlet end of the nozzle 108. In this case, if the upper nozzle 108b has a tapered shape, the rising speed of the ink 131 is faster. As a result, the ink 131 supplied through the ink channel 104 is refilled in the ink chamber 106. If a refill operation of the ink 131 is completely performed and the ink 131 is returned to its initial state, the above-described steps are repeatedly performed. In this procedure, heat is dissipated through the heat dissipating layer 128, and the ink 131 is thermally and quickly returned to its initial state.

[0074] A method of manufacturing a monolithic ink-jet printhead having the above structure according to the present invention will now be described.

[0075] FIGS. 11 through 22 are cross-sectional views illustrating a method of manufacturing a monolithic ink-jet printhead shown in FIG. 5 according to the present invention. Meanwhile, a method of manufacturing a monolithic ink-jet printhead shown in FIGS. 7 through 9 is substantially the same as the method of manufacturing the monolithic ink-jet printhead that will be described as below, and thus, will be described briefly in the following descriptions.

[0076] FIG. 11 illustrates a state in which a groove having a predetermined depth is formed on the surface of a substrate 110. Referring to FIG. 11, in the present embodiment, a silicon wafer is processed to a thickness of about 300-700 μm and is used as the substrate 110. Silicon wafers are widely used to manufacture semiconductor devices, and thus, are good for mass production of a printhead.

[0077] While FIG. 11 illustrates only part of a silicon wafer, several tens to hundreds of chips corresponding to ink-jet printheads may be contained in one wafer.

[0078] An etch mask 114 for defining a portion to be etched is formed on an upper surface of the silicon substrate 110. A photoresist is coated on the upper surface of the substrate 110 to a predetermined thickness and is patterned, thereby forming the etch mask 114.

[0079] Subsequently, the substrate 110 exposed by the etch mask 114 is etched, thereby forming a groove 116 having the predetermined depth. The substrate 110 may be etched by dry etching such as reactive ion etching (RIE). The groove 116 is a portion in which an ink chamber is to be formed. Preferably, the depth of the groove 116 is about 10-80 μm. The groove 116 may have a variety of shapes depending on the shape in which the surface of the substrate 110 is etched by designing the planar shape of the ink chamber. Thus, the ink chamber can be formed to have desired size and shape, for example, having a planar rectangular shape. After the groove 116 is formed, the etch mask 114 is removed from the substrate 110.

[0080] Subsequently, as shown in FIG. 12, the silicon substrate 110 on which the groove 116 is formed is oxidized to form the silicon oxide layers 117 and 118 on the front and rear surfaces of the substrate 110. Portions of the silicon oxide layer 117 formed on the front surface of the substrate 110, which is formed at the sides of the groove 116, are sidewalls for defining side surfaces of the ink chamber, and a portion of the silicon oxide layer 117, which is formed at a bottom surface of the groove 116, is a bottom wall for defining the bottom surface of the ink chamber. Since the sidewalls and the bottom wall are formed of a material other than a material used in forming the substrate 110, the sidewalls and the bottom wall serve as an etch stop when forming the ink chamber that will be described later.

[0081] FIG. 13 illustrates a state in which a sacrificial layer is formed in the groove formed on the substrate 110 and the surface of the substrate 110 is planarized.

[0082] Specifically, a polysilicon layer is formed in the groove 116, and the polysilicon layer is epitaxially grown, thereby forming a sacrificial layer 119 for completely filling the groove 116. Next, the upper surface of the sacrificial layer 119 and the substrate 110 are planarized by a chemical mechanical polishing (CMP) process. Here, the silicon oxide layer 117 exposed to the surface of the substrate 110 is removed together, but sidewalls 111 and bottom wall 112 which serve as an etch stop as described above remain in the sides and bottom surface of the groove 116.

[0083] FIG. 14 illustrates a state in which a first passivation layer and a heater are formed on the surface of the substrate and the sacrificial layer.

[0084] Specifically, a first passivation layer 121 may be formed by depositing silicon oxide or silicon nitride on the front surface of the substrate 110 and the sacrificial layer 119.

[0085] Subsequently, a heater 122 is formed on the first passivation layer 121 formed on the upper surface of the substrate 110 and the sacrificial layer 119. The heater 122 is formed by depositing a resistive heating material, such as impurity-doped polysilicon, tantalum-aluminum alloy, tantalum nitride, or tungsten silicide, on the entire surface of the first passivation layer 121 to a predetermined thickness and patterning the deposited material in a predetermined shape, for example, in a rectangular shape. Specifically, impurity-doped polysilicon may be formed to a thickness of about 0.7-1 μm by depositing polycrystalline silicon together with impurities, for example, a source gas of phosphorous (P), by low pressure chemical vapor deposition (LP CVD). When the heater 122 is formed of tantalum-aluminum alloy, tantalum nitride, or tungsten silicide, the heater 122 may be formed to a thickness of about 0.1-0.3 μm by depositing tantalum-aluminum alloy, tantalum nitride, or tungsten silicide by sputtering or chemical vapor deposition (CVD). The deposition thickness of the resistive heating material may be varied so as to have proper resistance in consideration of the width and length of the heater 122. Subsequently, the resistive heating material deposited on the entire surface of the first passivation layer 121 is patterned by a photolithographic process using a photomask and a photoresist and an etch process using a photoresist pattern as an etch mask.

[0086] Next, as shown in FIG. 15, a second passivation layer 123 is formed on the upper surface of the first passivation layer 121 and the heater 122. Specifically, the second passivation layer 123 may be formed by depositing silicon oxide or silicon nitride to a thickness of about 0.05-1 μm. Subsequently, part of the second passivation layer 123 is etched to form a first contact hole C_1 through which part of the heater 122, that is, portions to be connected to a conductor 124 in the step shown in FIG. 16 is exposed, and the second passivation layer 123 and the first passivation layer 121 are etched sequentially to form a second contact hole C_2 through which part of the substrate 110, that is, portions to be connected to a heat dissipating layer that will be formed later is exposed. The first and second contact holes C_1 and C_2 may be formed at the same time.

[0087] FIG. 16 illustrates a state in which a conductor and a third passivation layer are formed on the upper surface of the second passivation layer 123. Specifically, a conductor 124 may be formed by depositing metal having good conductivity, such as aluminum (Al), aluminum alloy, gold (Au), or silver (Ag), on the upper surface of the second passivation layer 123 to a thickness of about 0.5-2 μm by sputtering and patterning the deposited metal. Then, the conductor 124 is connected to the heater 122 via a first contact hole C_1.

[0088] Next, a third passivation layer 125 is formed on upper surfaces of the second passivation layer 123 and the conductor 124. The third passivation layer 125 is a material layer that provides insulation between the conductor 124 and a heat dissipating layer that will be formed later. The third passivation layer 125 may be formed to a thickness of about 0.5-3 μm by depositing TEOS oxide using plasma enhanced chemical vapor deposition (PE CVD). Subsequently, part of the third passivation layer 125 is etched to expose portion of the second passivation layer 123 other than upper portions of the heater 122 and the conductor 124 and portions adjacent to the heater 122 and the conductor 124 within a range in which an insulation function of the third passivation layer 125 is not damaged. In this case, at least portions of the second passivation layer 123 out of the upper portion of the ink chamber 106 in which the conductor 124 is not disposed are exposed, and simultaneously, the substrate 110 is also exposed via a second contact hole C_2. As a result, a distance between the heat dissipating layer 128 and the substrate 110 is made narrower, thermal resistance is reduced, and a heat dissipating capability of the heat dissipating layer 128 is improved.

[0089] FIG. 17 illustrates a state in which a lower nozzle is formed. Referring to FIG. 17, a lower nozzle 108a may be formed by sequentially etching the third passivation layer 125, the second passivation layer 123, and the first passivation layer 121 through RIE. In this case, part of the sacrificial layer 119 formed on the surface of the substrate 110 is exposed through the lower nozzle 108a.

[0090] Next, as shown in FIG. 18, a seed layer 127 for electroplating is formed on the entire surface of the structure shown in FIG. 17. For electroplating, the seed layer 127 may be formed to a thickness of about 500-3000 Å by depositing metal having good conductivity, such as Cu, Cr, Ti, Au, or Ni, by sputtering. Alternatively, the seed layer 127 may be formed of a plurality of metallic layers.

[0091] Subsequently, a plating mold 109 for forming an upper nozzle is formed. The plating mold 109 may be formed by coating a photoresist on the entire surface of the seed layer 127 to a predetermined thickness and patterning a coated photoresist in the shape of the upper nozzle. Meanwhile, the plating mold 109 may be formed of a photoresist or photosensitive polymer. Specifically, a photoresist is coated on the entire surface of the seed layer 127 to a thickness higher than the height of the upper nozzle. In this case, the photoresist is also filled in the lower nozzle 108a. Subsequently, the photoresist is patterned, and only portions in which the upper nozzle is to be formed and portions filled in the lower nozzle 108a are left. In this case, the photoresist is patterned to have a tapered shape such that a diameter thereof becomes smaller in an upward direction. The patterning step may be performed by proximity exposure in which the photoresist is exposed through a photomask, which is isolated a predetermined distance from an upper surface of the photoresist. In this case, light that has passed the photomask is diffracted. As a result, an interface between exposed portion and unexposed portion of the photoresist is formed to be inclined. The inclination degree of the interface and an exposure depth may be adjusted by the distance between the photomask and the photoresist and an exposure energy. Alternatively, the upper nozzle may have a pillar shape. In this case, the photoresist is patterned in the pillar shape.

[0092] Meanwhile, the step of forming the plating mold 109 may be divided into two steps, that is, a first step of filling an inside of the lower nozzle 108a with a photoresist to form a lower plating mold and a second step of forming an upper plating mold to form an upper nozzle. In this case, the step of forming the seed layer 127 may be performed between the first step and the second step.

[0093] Next, as shown in FIG. 19, the heat dissipating layer 128 formed of a metallic material having a predetermined thickness is formed on an upper surface of the seed layer 127. The heat dissipating layer 128 may be formed to a thickness of about 10-100 μm by electroplating metal having good thermal conductivity, such as Ni, Cu, Al, or Au, on the surface of the seed layer 127. In this case, the heat dissipating layer 128 may be formed of a plurality of metallic layers. An electroplating process is terminated at a time when the heat dissipating layer 128 is formed up to a height which is lower than the height of the plating mold 109 and in which a cross-section of an outlet of the upper nozzle is formed. The thickness of the heat dissipating layer 128 may be determined in consideration of a cross-sectional area and shape of the upper nozzle and a heat dissipating capability to the substrate 110 and the outside.

[0094] The surface of the heat dissipating layer 128 after electroplating is completed, is uneven due to material layers formed under the heat dissipating layer 128. Thus, the surface of the heat dissipating layer 128 can be planarized by CMP.

[0095] Subsequently, the plating mold 109 is removed, and then, a portion of the seed layer 127 exposed by removing the plating mold 109 is removed. The plating mold 109 may be formed by a general method of removing a photoresist, for example, using acetone. The seed layer 127 may be etched by wet etching using an etchant capable of selectively etching the seed layer 127 in consideration of etch selectivity of the metallic material used in forming the heat dissipating layer 128 to the metallic material used in forming the seed layer 127. For example, when the seed layer 127 is formed of copper (Cu), an acetic acid based etchant may be used, and when the seed layer 127 is formed of titanium (Ti), a HF based etchant may be used. Then, as shown in FIG. 20, the lower nozzle 108a and the upper nozzle 108b are connected to each other, thereby forming a complete nozzle 108 and completing the nozzle plate 120 formed of a stack of a plurality of material layers. In this case, a partial surface of the sacrificial layer 119 that occupies a space in which the ink chamber is to be formed, is exposed through the nozzle 108.

[0096] FIG. 21 illustrates a state in which an ink chamber 106 is formed on the surface of the substrate 110. The ink chamber 106 may be formed by isotropically etching the sacrificial layer 119 exposed through the nozzle 108. Specifically, the sacrificial layer 119 is dry etched using an etchant, such as an XeF_2 gas or a BrF_3 gas for a predetermined amount of time. In this case, since the sacrificial layer 119 is etched isotropically, it is etched at a uniform speed in all directions from a portion exposed through the nozzle 108. However, further etching of sidewalls 111 and bottom wall 112 which serve as an etch stop is suppressed. As shown in FIG. 17, the ink chamber 106 defined by the sidewalls 111 and the bottom wall 112 is formed. In this case, the depth of the ink chamber 106 is almost the same as the depth of the above-described groove 116, and the planar shape of the ink chamber 106 is defined by the shape of the sidewalls 111.

[0097] FIG. 22 illustrates a state in which the manifold 102 and the ink channel 104 are formed by etching a rear surface of the substrate 110. Specifically, a partial area of the silicon oxide layer 117 formed on the rear surface of the substrate 110 is removed to expose the rear surface of the substrate 110. Subsequently, by wet etching the exposed rear surface of the substrate 110 using tetramethyl ammonium hydroxide (TMAH) or potassium hydroxide (KOH) as an etchant, as shown in FIG. 22, the manifold 102 having an inclined side is formed. Meanwhile, the manifold 102 may be formed by anisotropically dry etching the rear surface of the substrate 110. Subsequently, after an etch mask for defining the ink channel 104 is formed on the rear surface of the substrate 110 on which the manifold 102 is formed, the substrate 110 and the bottom wall 112 between the manifold 102 and the ink chamber 106 are dry etched through RIE, thereby forming the ink channel 104. In this case, the ink channel 104 may have a circular shape or a polygonal shape, and as shown in FIG. 9, a plurality of ink channels 104 may be formed.

[0098] By performing the above-described steps, the monolithic ink-jet printhead having the structure shown in FIG. 22 according to the present invention is manufactured.

[0099] FIGS. 23 and 24 illustrate a method of manufacturing a monolithic ink-jet printhead according to another embodiment of the present invention. This method is the same as the method of the previous embodiment, except for the step of forming the sacrificial layer, and thus, only the step of forming the sacrificial layer will be described below.

[0100] As shown in FIG. 23, a silicon-on-insulator (SOI) substrate 500, in which an insulating layer 520 formed of silicon oxide is interposed between two silicon substrates 510 and 530, is used as a substrate. Here, the thickness of the upper silicon substrate 530 is about 10-80 μm, and the thickness of the lower silicon substrate 510 is about 300-700 μm.

[0101] Subsequently, the surface of the upper silicon substrate 530 is etched, thereby forming a trench 540 having a predetermined shape so that the insulating layer 520 is exposed. The upper silicon substrate 530 may be etched by dry etching such as RIE. The trench 540 is formed to surround portions in which an ink chamber is to be formed. The trench 540 is formed to a width of several µm so that it can easily be filled with a predetermined material.

[0102] Next, as shown in FIG. 24, the trench 540 is filled with a material different from a material used in forming the silicon substrate 530, for example, silicon oxide, and then, the surface of the upper silicon substrate 530 is planarized. By doing so, sidewalls 551 formed of silicon oxide are formed in the trench 540, and portions that are surrounded by the sidewalls 551 and the insulating layer 520 become a sacrificial layer 550 for forming the ink chamber. In this way, the sacrificial layer 550 is formed of silicon, unlike in the previous embodiment in which it was formed of polysilicon, and the sidewalls 551 and the insulating layer 520, which are formed of silicon oxide, serve as an etch stop when forming the ink chamber.

[0103] Subsequent steps are the same as the above-described steps shown in FIGS. 14 through 22.

[0104] As described above, the monolithic ink-jet printhead and the method of manufacturing the same according to the present invention have the following effects. First, an ink chamber having optimum planar shape and depth by sidewalls and a bottom wall that serve as an etch stop is formed such that a distance between adjacent nozzles is made narrower and a monolithic ink-jet printhead with high DPI to print an image with high resolution is implemented. Second, since a heat dissipating capability is improved by a heat dissipating layer formed of metal having a large thickness, ejection performance is improved and a driving frequency is increased. In addition, a nozzle can be formed to have a sufficient length. Thus, a meniscus at the surface of ink in the nozzle can be maintained in the nozzle, an ink refill operation can be stably performed, and linearity of ink droplets ejected through the nozzle is improved. Third, the shape and dimensions of a heater, a nozzle, an ink chamber, and an ink channel are not closely connected with one another, and the degree of freedom in designing and manufacturing the monolithic ink-jet printhead is high. Thus, ejection performance can be improved, and a driving frequency can easily be increased. Fourth, since a nozzle plate is formed integrally with a substrate having the ink chamber and the ink channel, the monolithic ink-jet printhead can be implemented by a series of processes on a single wafer without any subsequent processes such that the yield of the monolithic ink-jet printhead is improved and a process of manufacturing the monolithic ink-jet printhead is simplified.

[0105] While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the scope of the present invention as defined by the following claims. For example, materials used in forming each element of an ink-jet printhead according to the present invention may be varied. In other words, a substrate may be formed of a material having a good processing property other than silicon, and the case of the substrate may also be applied to sidewalls, a bottom wall, a heater, a conductor, passivation layers, and a heat dissipating layer. In addition, methods for depositing and forming each element may be modified. Furthermore, specific dimensions exemplified in each step may be adjusted within the range in which the manufactured printhead operates normally. In addition, the order in which steps of a method of manufacturing the ink-jet printhead are performed may be changed, all within the scope of the present invention as defined by the appended claims.

Claims

1. A monolithic ink-jet printhead comprising:

a substrate, an ink chamber to be filled with ink to be ejected being formed on a front surface of the substrate, a manifold which supplies ink to the ink chamber being formed on a rear surface of the substrate, and an ink channel being vertically formed through the substrate between the ink chamber and the manifold;
sidewalls, which are formed to a predetermined depth from the front surface of the substrate and define side surfaces of the ink chamber;
a bottom wall, which is formed of to a predetermined depth from the front surface of the substrate and defines a bottom surface of the ink chamber;
a nozzle plate, which includes a plurality of passivation layers stacked on the substrate formed of an insulating material and a heat dissipating layer stacked on the passivation layers formed of a metallic material and through which a nozzle connected to the ink chamber is formed;
a heater, which is disposed between the passivation layers of the nozzle plate, positioned above the ink chamber, for heating ink in the ink chamber; and
a conductor, which is disposed between the passivation layers of the nozzle plate, electrically connected to the heater, for delivering a current to the heater.

2. The monolithic ink-jet printhead of claim 1, wherein the sidewalls and the bottom wall are formed of a material other than a material used in forming the substrate.

3. The monolithic ink-jet printhead of claim 2, wherein the material used in forming the sidewalls and the bottom wall is silicon oxide.

4. The monolithic ink-jet printhead of any one of the preceding claims, wherein the ink chamber is surrounded by sidewalls to have a rectangular shape.

5. The monolithic ink-jet printhead of any one of the preceding claims, wherein the ink chamber is formed to a depth of about 10-80 μm by the sidewalls and the bottom wall.

6. The monolithic ink-jet printhead of any one of the preceding claims, wherein the substrate is a silicon-on-insulatior substrate in which a lower silicon substrate, an insulating layer, and an upper silicon substrate are sequentially stacked.

7. The monolithic ink-jet printhead of claim 6, wherein the ink chamber and the sidewalls are formed on the upper silicon substrate of the silicon-on-insulator substrate, and the insulating layer of the silicon-on-insulator substrate forms the bottom wall.

8. The monolithic ink-jet printhead of any one of the preceding claims, wherein the heater is disposed above the ink chamber not to overlap with the nozzle in the plane.

9. The monolithic ink-jet printhead of claim 8, wherein the nozzle is disposed at a position corresponding to a center of the ink chamber, and the heater is disposed at both sides of the nozzle.

10. The monolithic ink-jet printhead of claim 8, wherein the nozzle and the heater are respectively disposed at both sides of the center of the ink chamber.

11. The monolithic ink-jet printhead of any one of the preceding claims, wherein the ink channel is vertically formed through the substrate and is disposed at a position in which the ink chamber and the manifold are connected to each other.

12. The monolithic ink-jet printhead of any one of the preceding claims, wherein at least one ink channel is disposed, and ink is supplied to the ink chamber from the manifold through the ink channel.

13. The monolithic ink-jet printhead of any one of the preceding claims, wherein the passivation layers include at least one passivation layer disposed between the substrate and the heater and at least one passivation layer disposed between the heater and the heat dissipating layer.

14. The monolithic ink-jet printhead of any one of the preceding claims, wherein the passivation layers include at least one passivation layer disposed between the substrate and the conductor and at least one passivation layer disposed between the conductor and the heat dissipating layer.

15. The monolithic ink-jet printhead of any one of the preceding claims, wherein a lower portion of the nozzle is formed in the plurality of passivation layers, and an upper portion of the nozzle is formed in the heat dissipating layer.

16. The monolithic ink-jet printhead of claim 15, wherein the upper portion of the nozzle formed in the heat dissipating layer has a tapered shape such that a diameter thereof becomes smaller in the direction of an outlet.

17. The monolithic ink-jet printhead of claim 15, wherein the upper portion of the nozzle formed in the heat dissipating layer has a pillar shape.

18. The monolithic ink-jet printhead of any one of the preceding claims, wherein the heat dissipating layer is formed of one or a plurality of metallic layers, and each of the metallic layer is formed of at least one material selected from the group consisting of Ni, Cu, Al, and Au.

19. The monolithic ink-jet printhead of any one of the preceding claims, wherein the heat dissipating layer is formed to a thickness of about 10-100 μm by electroplating.

20. The monolithic ink-jet printhead of any one of the preceding claims, wherein the heat dissipating layer contacts the surface of the substrate via a contact hole formed in the passivation layers.

21. The monolithic ink-jet printhead of any one of the preceding claims, wherein a seed layer for electroplating the heat dissipating layer is formed on the passivation layers and at least part of the substrate.

22. The monolithic ink-jet printhead of claim 21, wherein the seed layer is formed of one or a plurality of metallic layers, and each of the metallic layer is formed of at least one material selected from the group consisting of Cu, Cr, Ti, Au, and Ni.

23. A method of manufacturing a monolithic ink-jet printhead, the method comprising:forming a sacrificial layer surrounded by sidewalls and a bottom wall on a front surface of a substrate;

sequentially stacking a plurality of passivation layers on the substrate and
forming a heater and a conductor connected to the heater between the passivation layers;
forming a heat dissipating layer of metal on the

passivation layers and forming a nozzle through which ink is ejected through the passivation layers and the heat dissipating layer to form a nozzle plate comprising the passivation layers and the heat dissipating layer on the substrate;
forming an ink chamber defined by the sidewalls and the bottom wall by etching the sacrificial layer exposed through the nozzle using the sidewalls and the bottom wall as an etch stop ;
forming a manifold for supplying ink by etching a rear surface of the substrate; and
forming an ink channel by etching the substrate between the manifold and the ink chamber to penetrate the substrate.

24. The method of claim 23, wherein forming the sacrificial layer comprises:

etching the surface of the substrate to form a groove having a predetermined depth;
oxidizing the surface of the substrate in which the groove is formed to form 5 the sidewalls and the bottom wall of silicon oxide;
filling the groove surrounded by the sidewalls and the bottom wall with a predetermined material to form the sacrificial layer; and
planarizing the surfaces of the substrate and the sacrificial layer.

25. The method of claim 24, wherein filling groove with the predetermined material is performed by epitaxially growing polysilicon in the groove.

26. The method of claim 23, wherein forming the sacrificial layer comprises:

etching an upper silicon substrate of a silicon-on-insulator substrate to a predetermined depth to form a trench; and
filling the trench with a predetermined material to form the sidewalls.

27. The method of claim 26, wherein the predetermined material is silicon oxide.

28. The method of any one of claims 23 to 27, wherein forming the passivation layers comprises:

forming a first passivation layer on the surface of the substrate;
forming the heater on the first passivation layer;
forming a second passivation layer on the first passivation layer and the heater;
forming the conductor on the second passivation layer; and
forming a third passivation layer on the second passivation layer and the conductor.

29. The method of claim 28, wherein the third passivation layer is formed on upper portions of the heater and the conductor and at portions adjacent thereto.

30. The method of any one of claims 23 to 29, wherein the heat dissipating layer is formed of one or a plurality of metallic layers, and each of the metallic layers is formed by electroplating at least one material selected from the group consisting of Ni, Cu, Al, and Au.

31. The method of any one of claims 23 to 30, wherein the heat dissipating layer is formed to a thickness of 10-100 μm.

32. The method of any one of claims 23 to 31, wherein forming the heat dissipating layer and the nozzle comprises:

forming a lower nozzle by etching the passivation layers formed on the sacrificial layer;
forming a plating mold for forming an upper nozzle vertically from the inside of the lower nozzle;
forming the heat dissipating layer on the passivation layers by electroplating; and
removing the plating mold to form the nozzle comprising the upper nozzle and the lower nozzle.

33. The method of claim 32, wherein the lower nozzle is formed by dry etching the passivation layers through reactive ion etching.

34. The method of claim 32 or 33, wherein the plating mold is formed of a photoresist or photosensitive polymer.

35. The method of any one of claims 32 to 34, wherein forming the heat dissipating layer and the nozzle further comprises forming a seed layer for electroplating the heat dissipating layer on the passivation layers.

36. The method of claim 35, wherein the seed layer is formed of one or a plurality of metallic layers, and each of the metallic layers is formed by depositing at least one metallic material selected from the group consisting of Cu, Cr, Ti, Au, and Ni.

37. The method of any one of claims 32 to 36, further comprising planarizing the upper surface of the heat dissipating layer by a chemical mechanical polishing process, after forming the heat dissipating layer.

38. The method of any one of claims 23 to 37, wherein forming the ink channel comprises dry etching the substrate from a rear surface of the substrate having the manifold.

FIG. 1 (PRIOR ART)

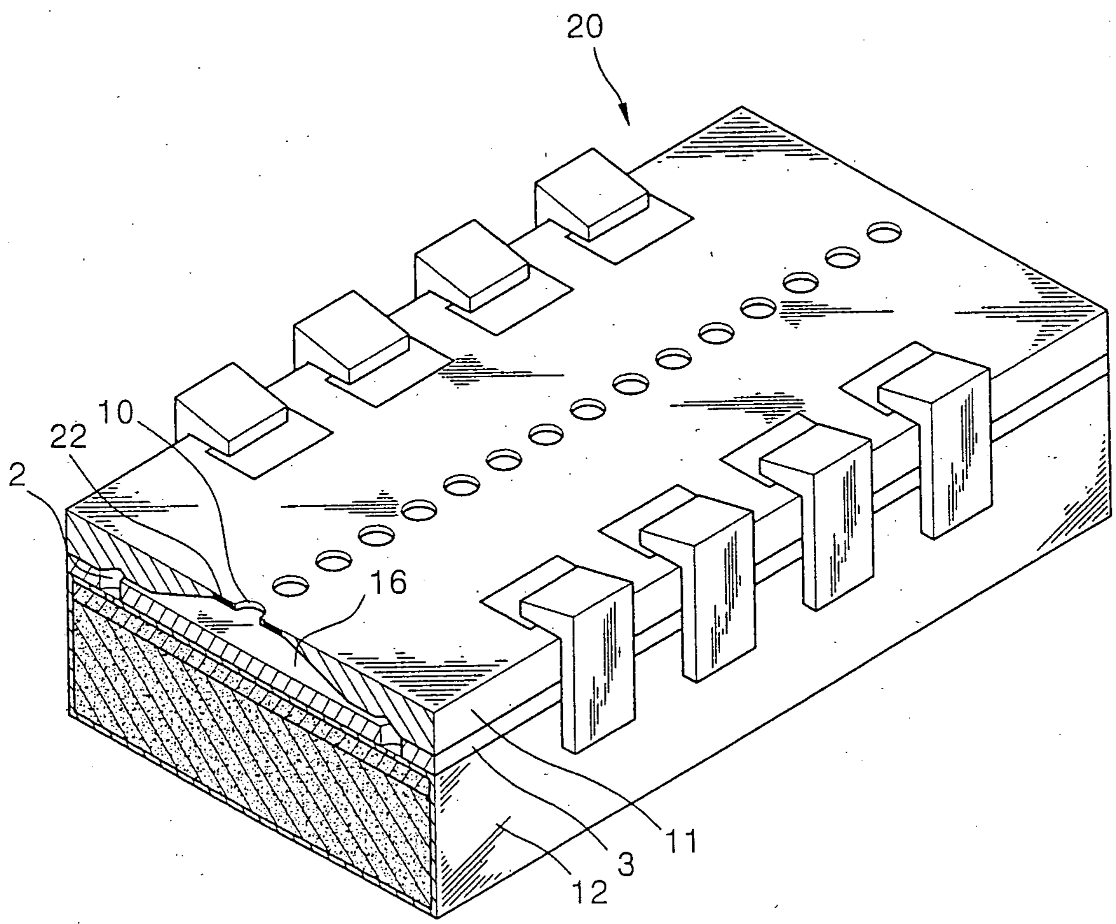


FIG. 2A (PRIOR ART)

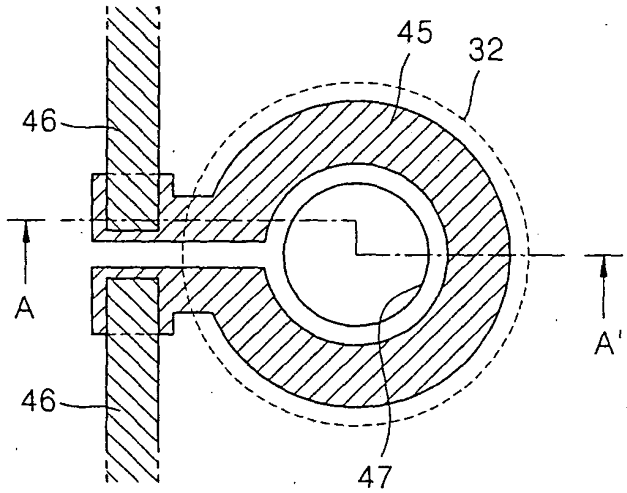


FIG. 2B (PRIOR ART)

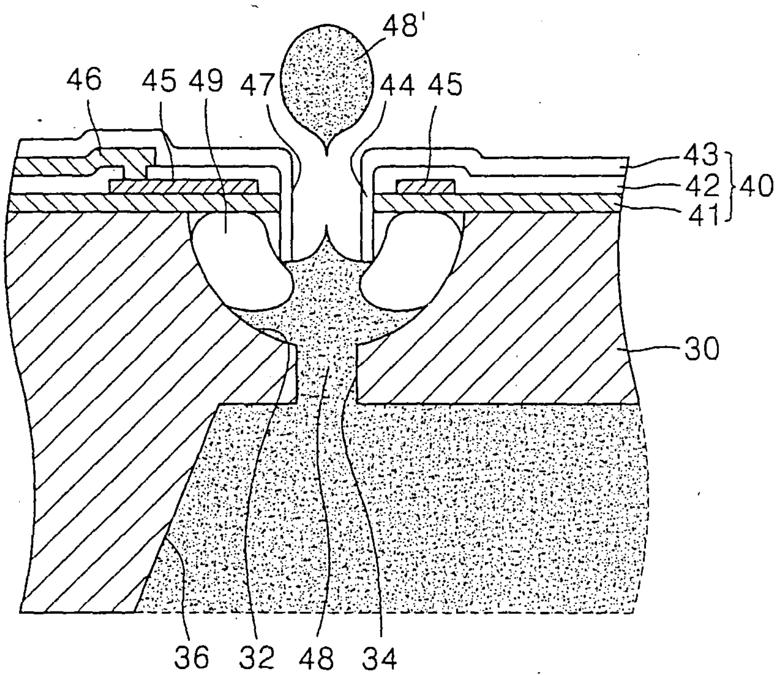


FIG. 3 (PRIOR ART)

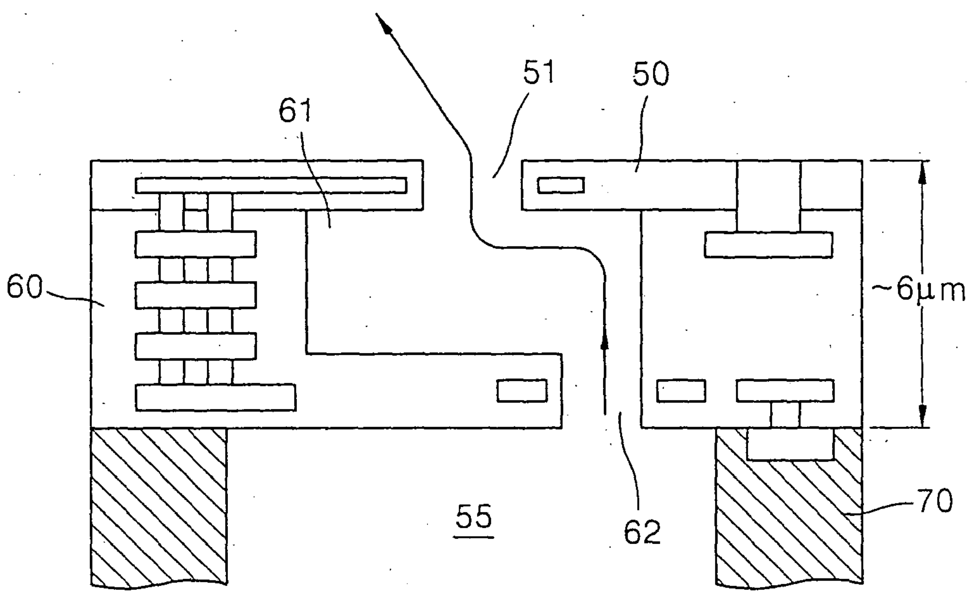


FIG. 4

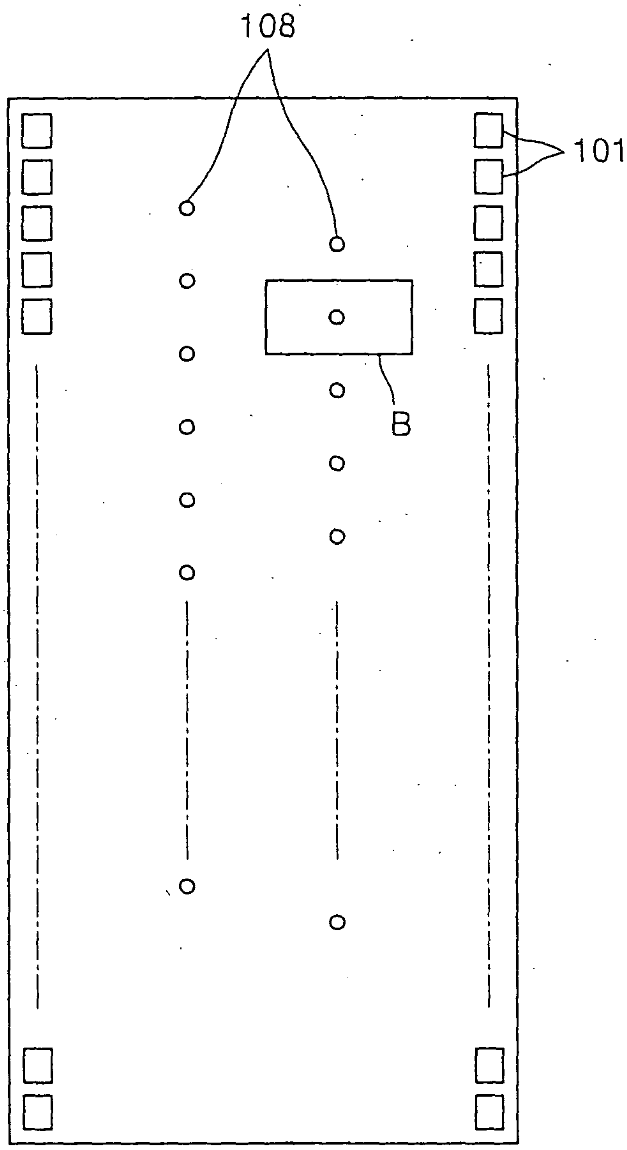


FIG. 5

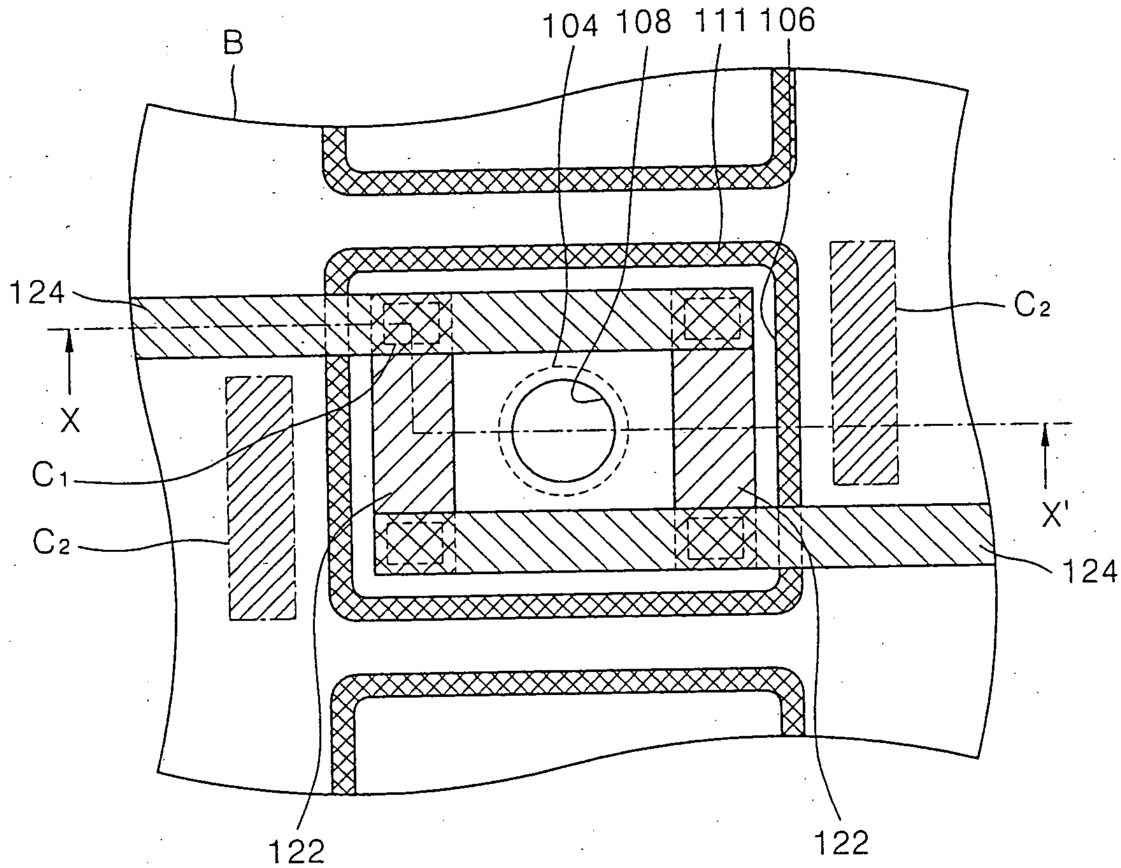


FIG. 6

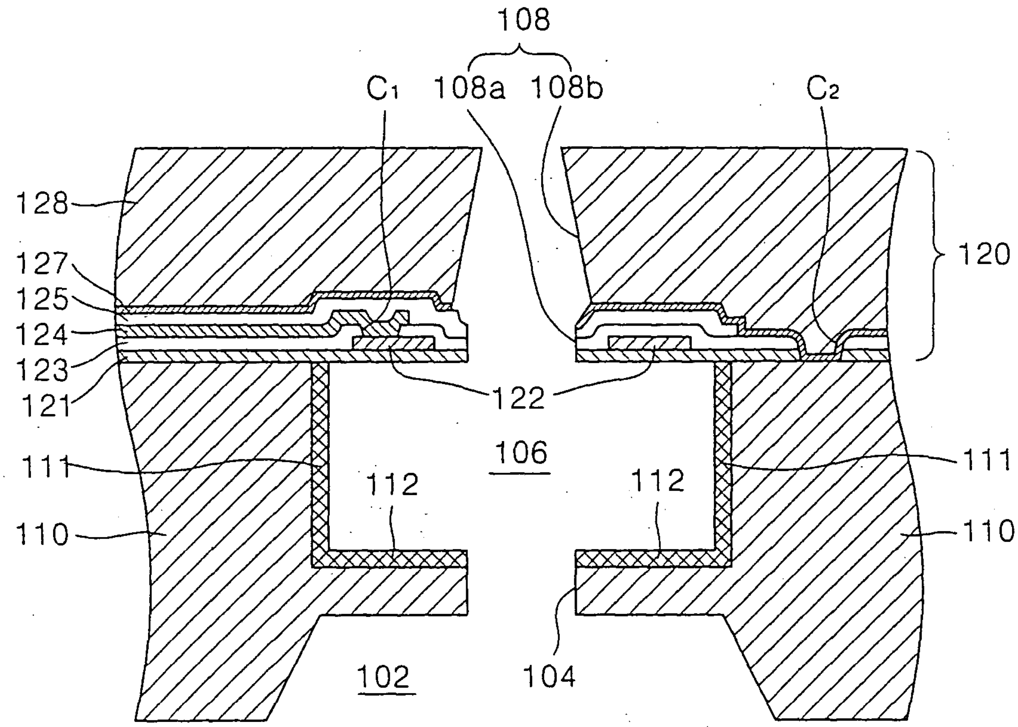

108
C1
108a
108b
C2
128
127
125
124
123
121
120
122
106
111
112
110
102
104

FIG. 7

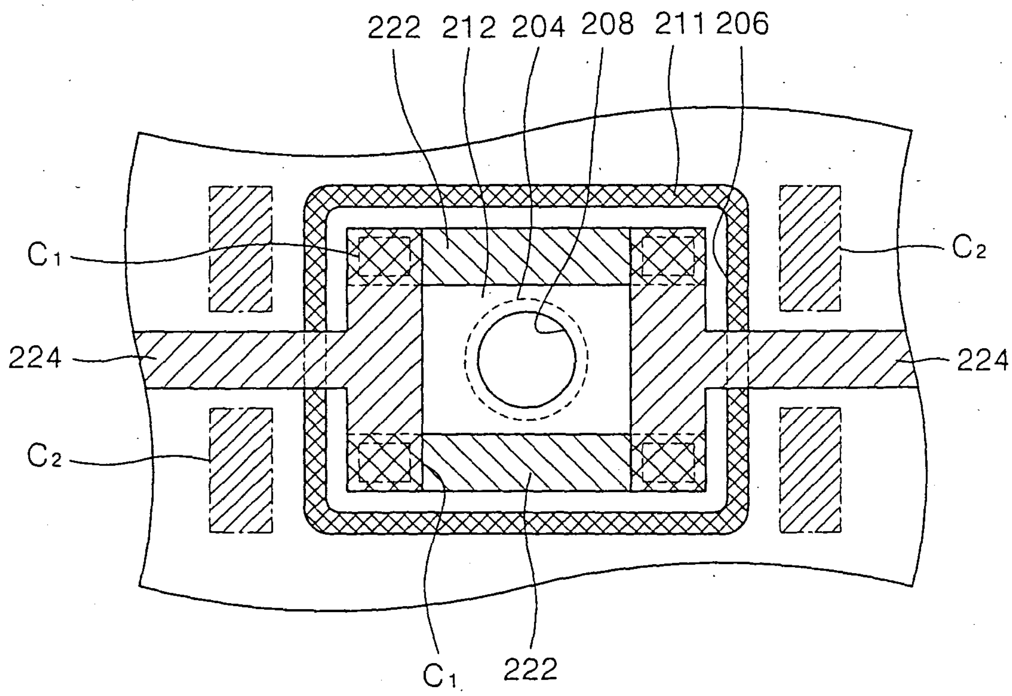

222
212
204
208
211
206
C1
C2
224

FIG. 8

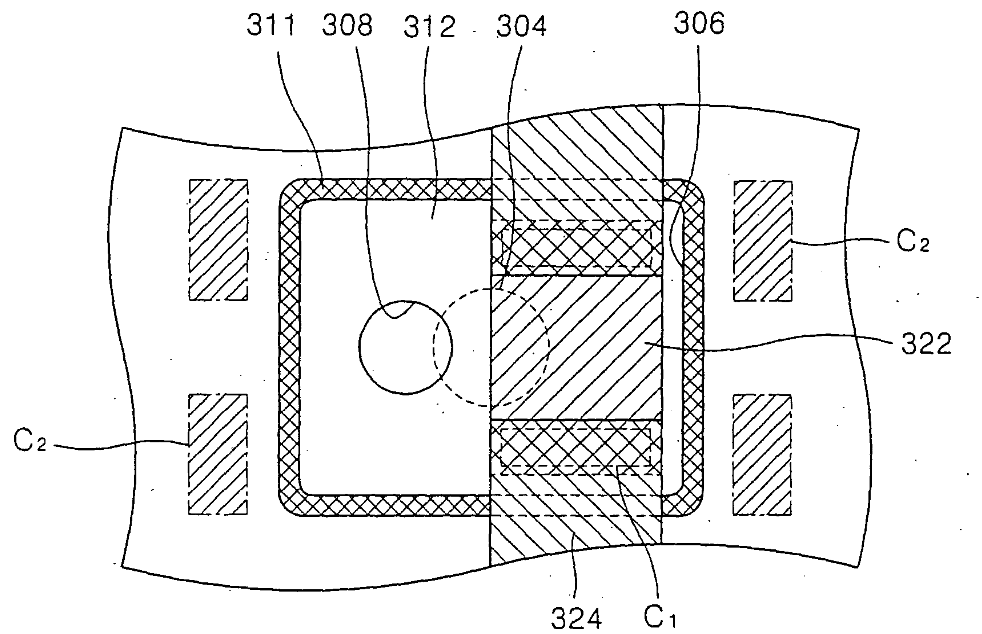

311
308
312
304
306
C2
322
C2
324
C1

FIG. 9

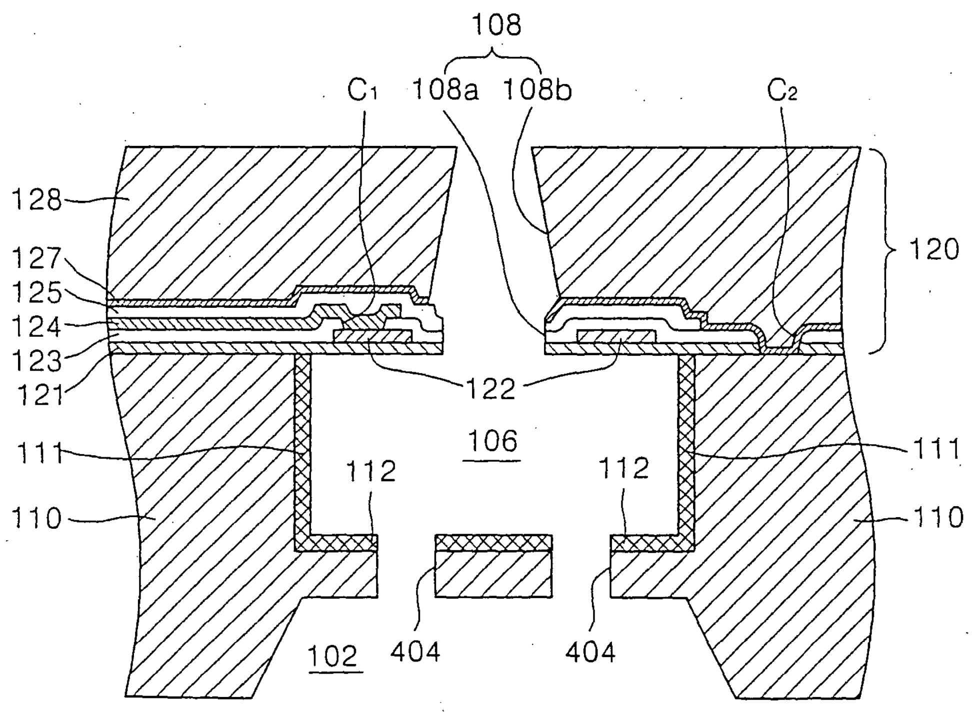

108
108a
108b
C1
C2
128
127
125
124
123
121
120
122
106
111
112
110
102
404

FIG. 10A

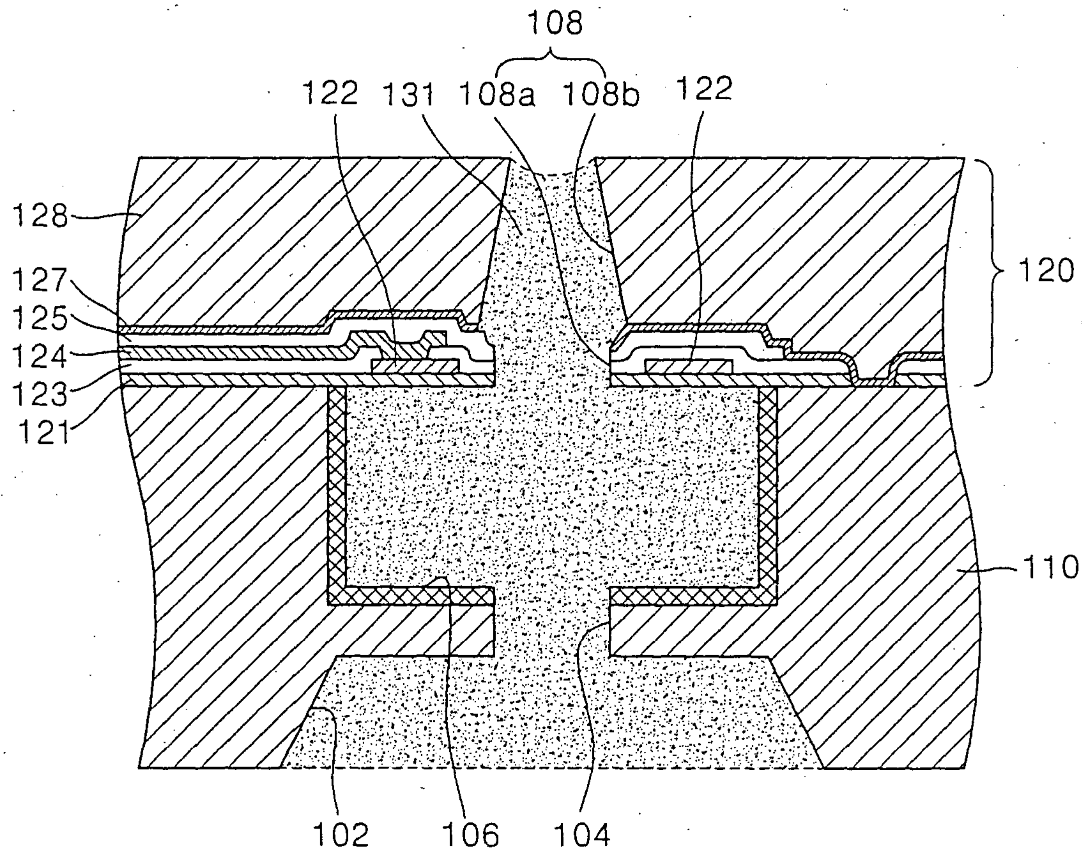

108
122
131
108a
108b
122
128
127
125
124
123
121
120
110
102
106
104

FIG. 10B

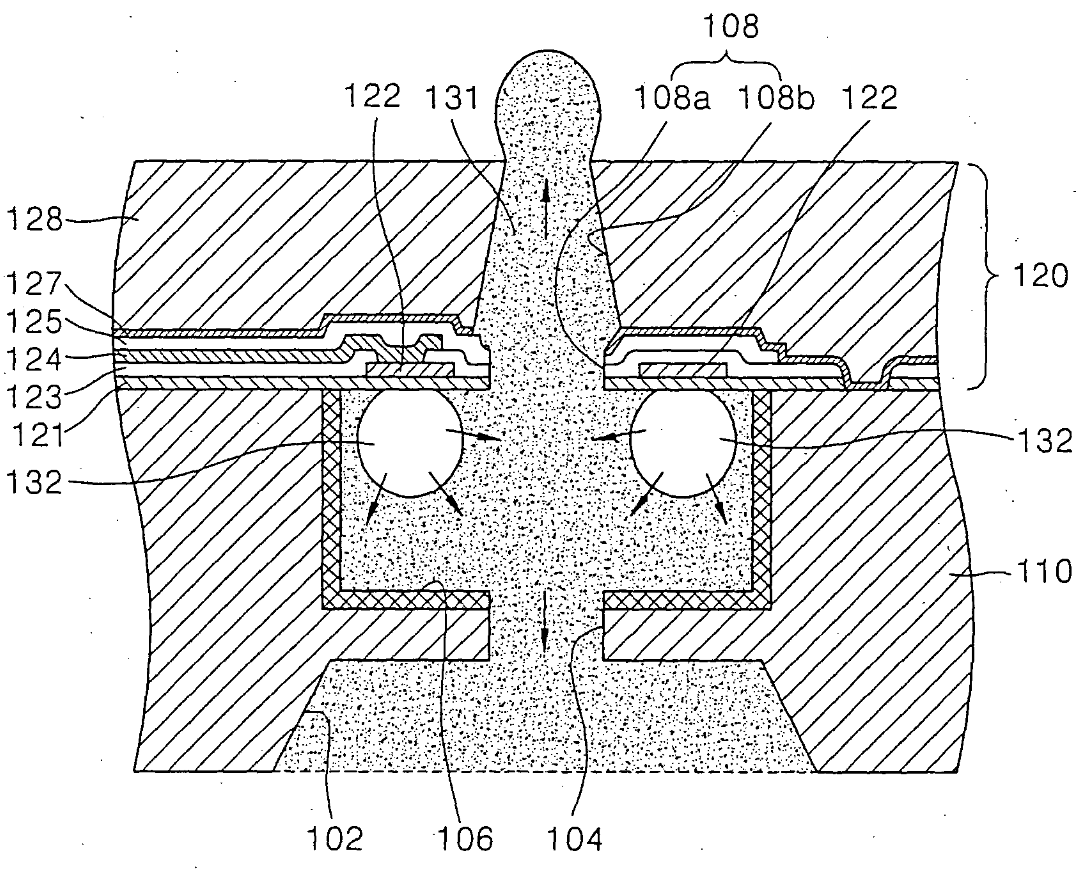

108
122
131
108a
108b
122
128
127
125
124
123
121
132
120
132
110
102
106
104

FIG. 10C

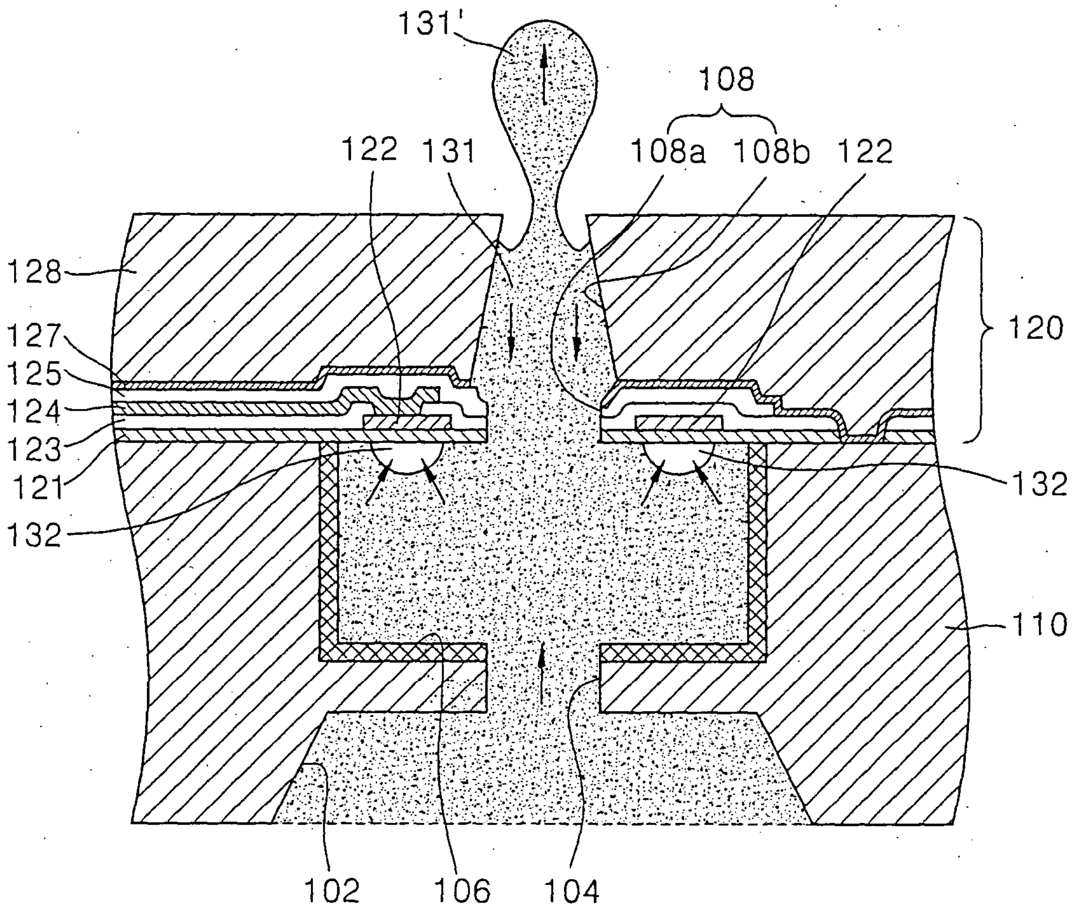

131'
108
122
131
108a
108b
122
128
127
125
124
123
121
132
120
132
110
102
106
104

FIG. 10D

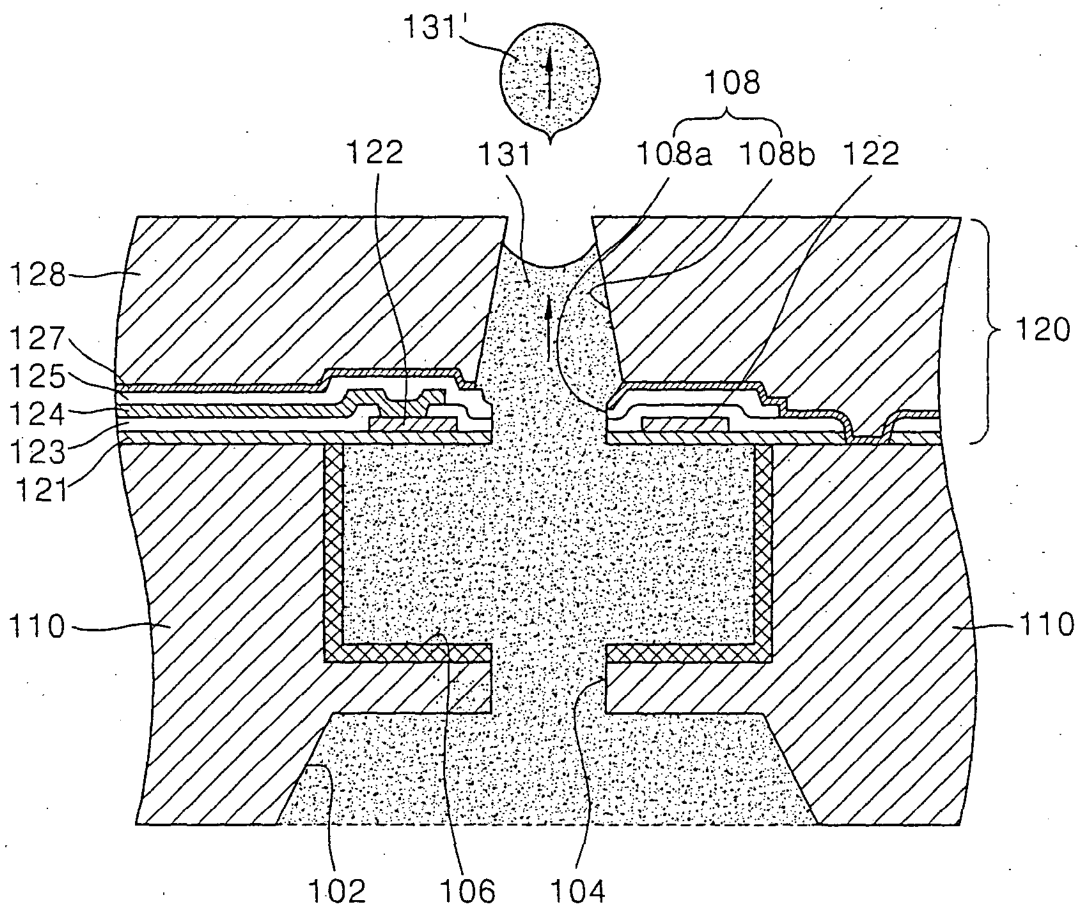

131'
108
122
131
108a
108b
122
128
127
125
124
123
121
120
110
110
102
106
104

FIG. 11

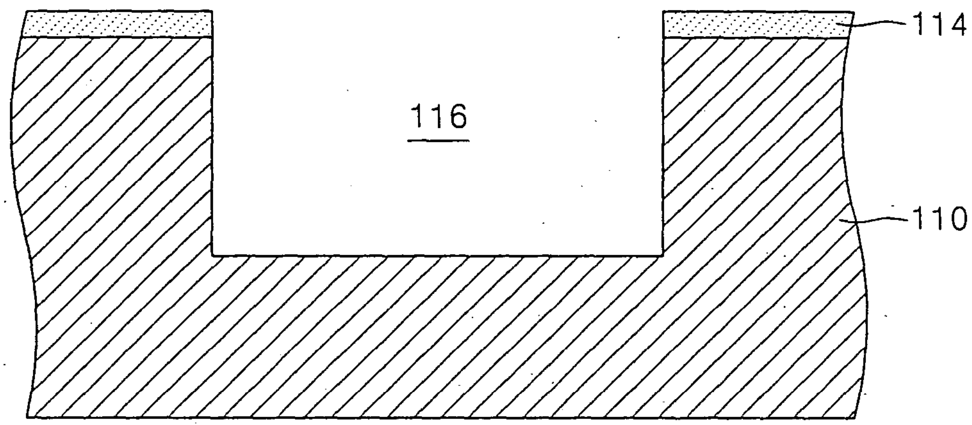


FIG. 12

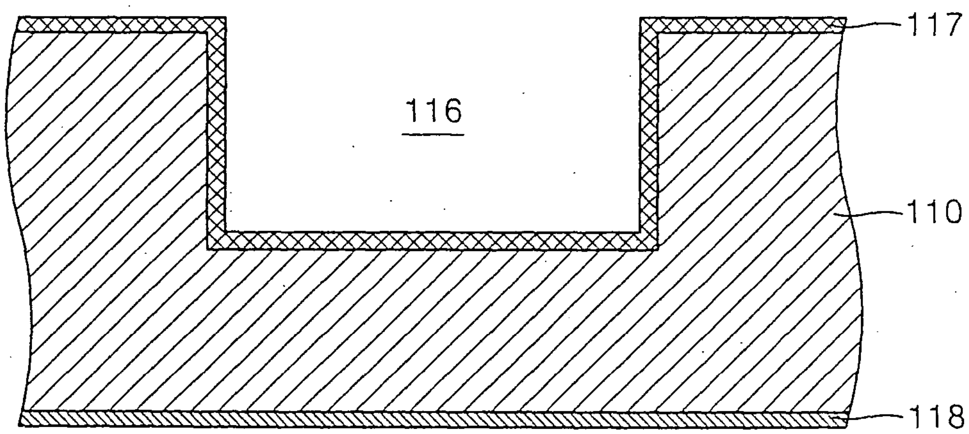


FIG. 13

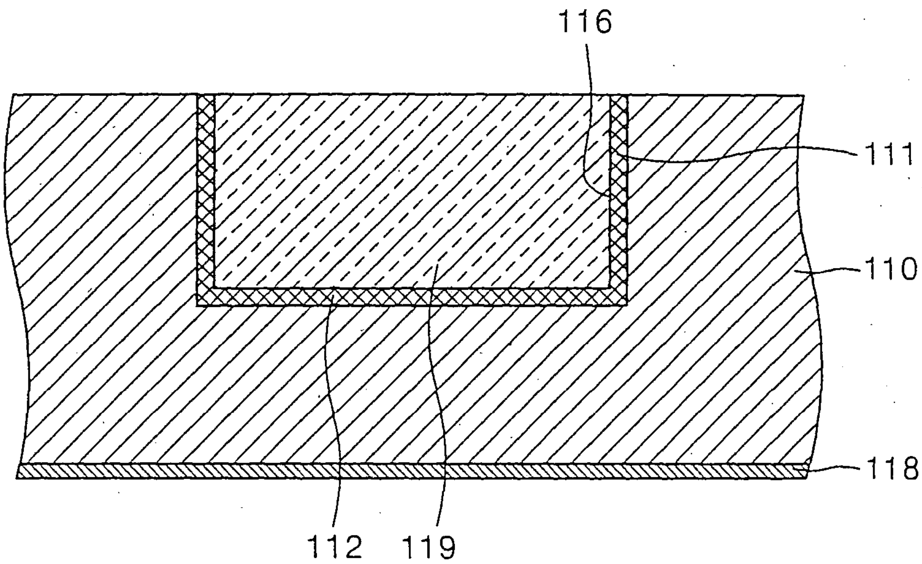


FIG. 14

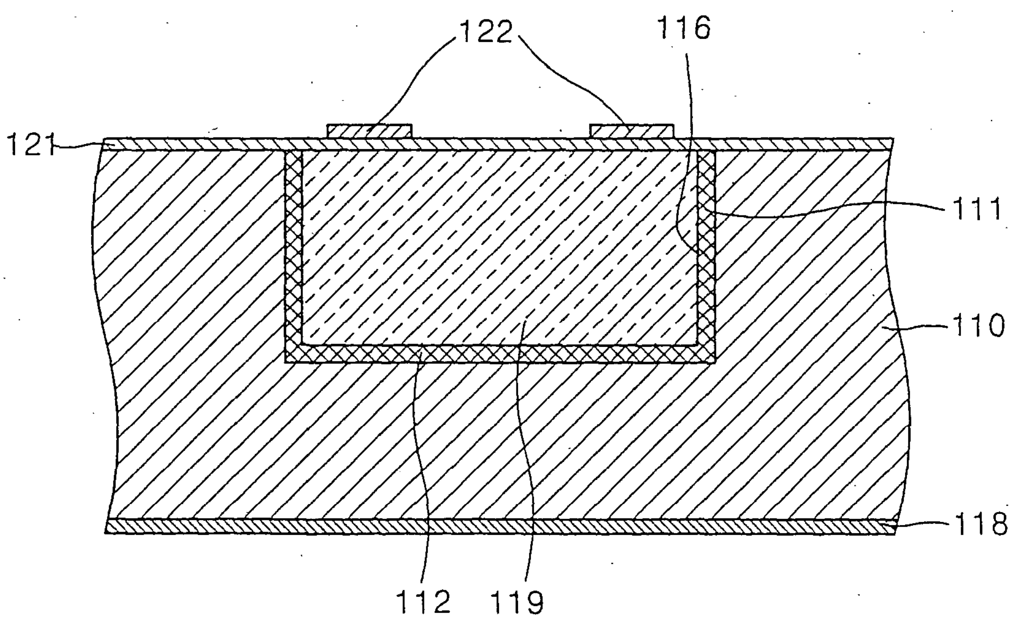


FIG. 15

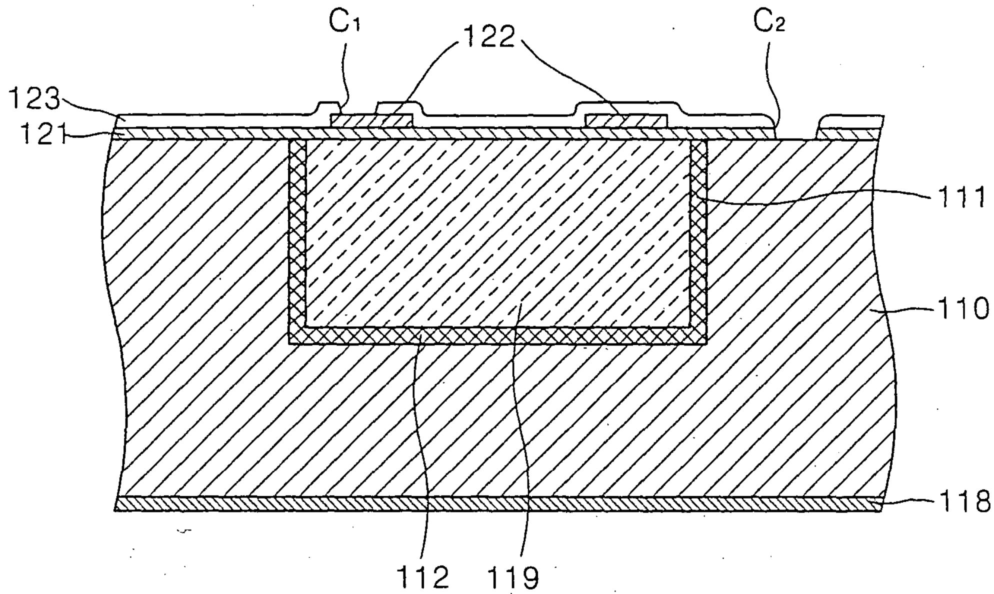

C1
122
C2
123
121
111
110
118
112
119

FIG. 16

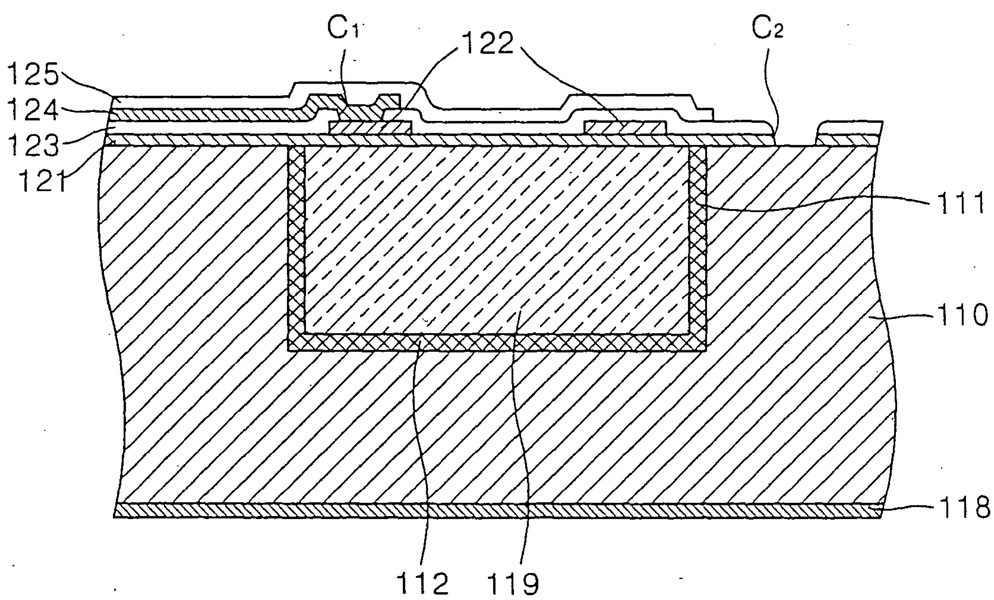

C1
122
C2
125
124
123
121
111
110
118
112
119

FIG. 17

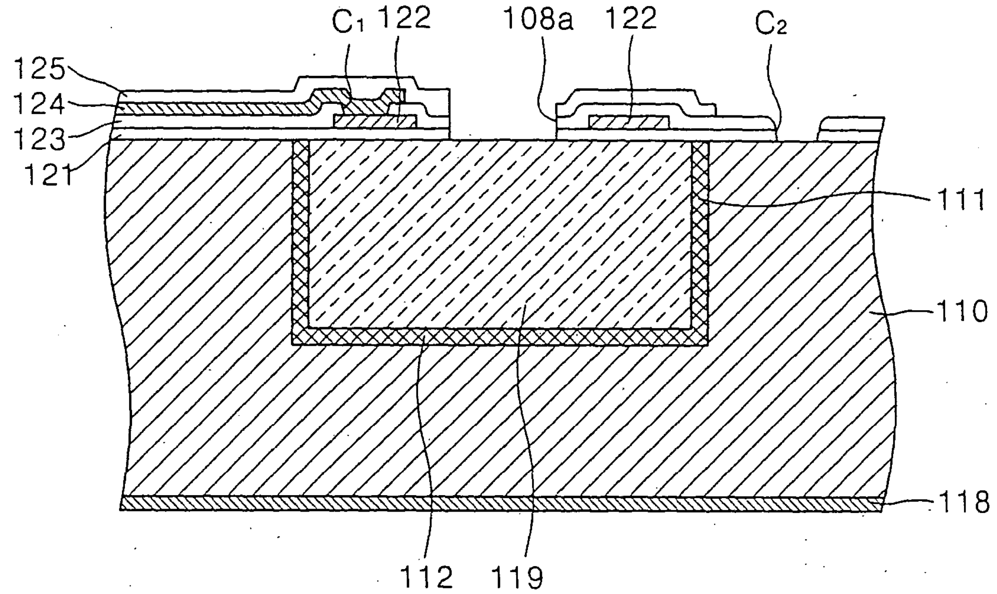

C1
122
108a
122
C2
125
124
123
121
111
110
118
112
119

FIG. 18

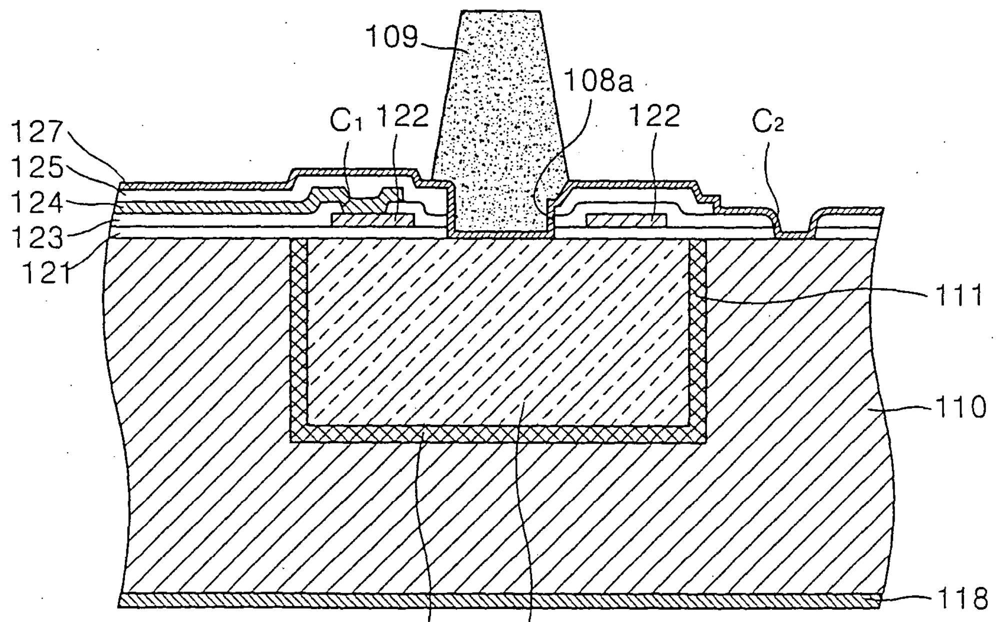

109
108a
C1
122
122
C2
127
125
124
123
121
111
110
118
112
119

FIG. 19

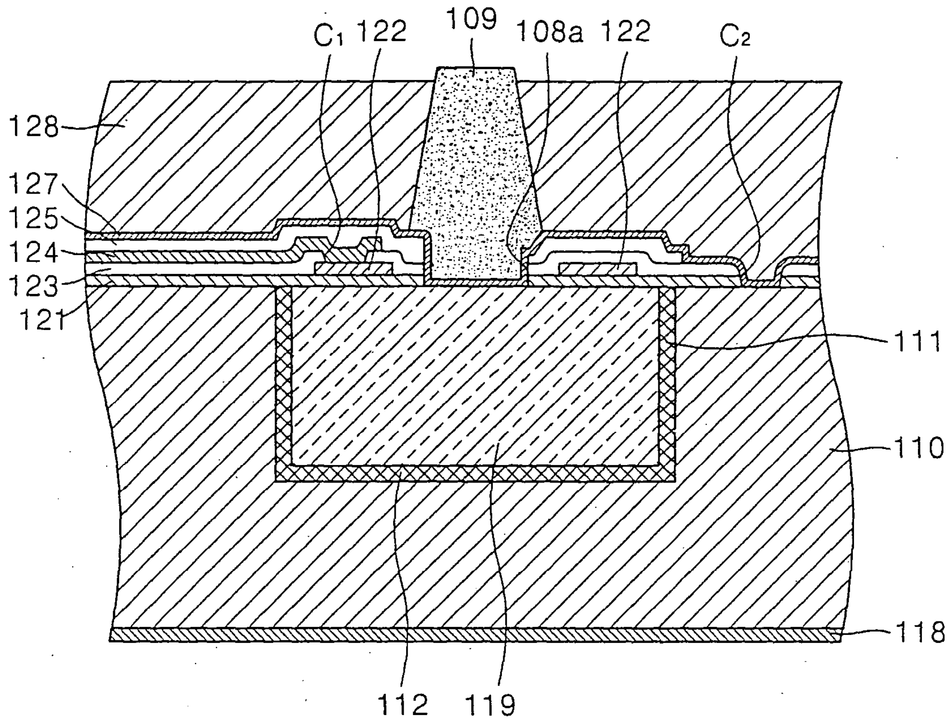

C1
122
109
108a
122
C2
128
127
125
124
123
121
111
110
118
112
119

FIG. 20

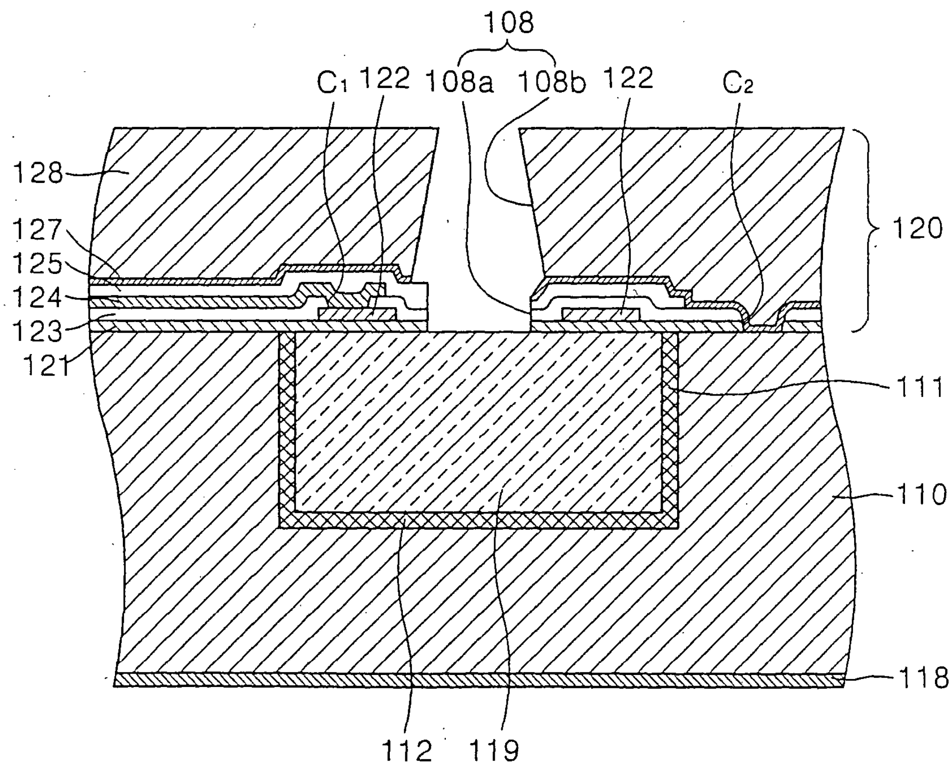

108
C1
122
108a
108b
122
C2
128
127
125
124
123
121
120
111
110
118
112
119

FIG. 21

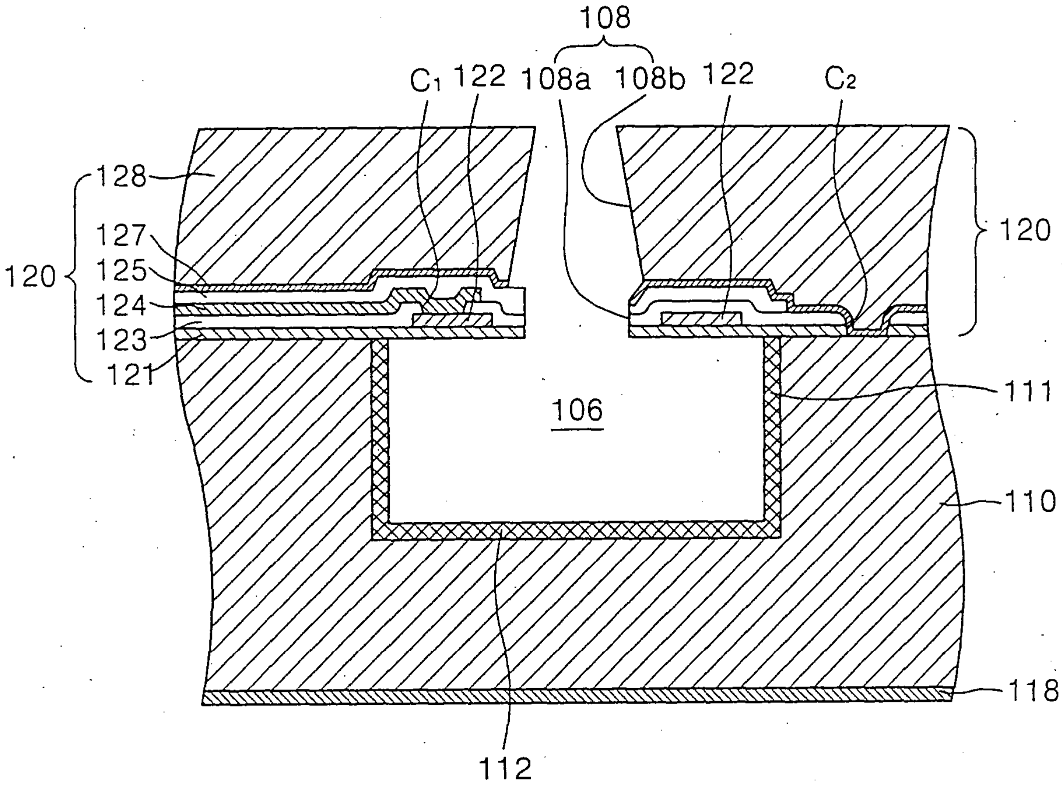

108
C1
122
108a
108b
122
C2
128
127
125
120
124
123
121
120
106
111
110
118
112

FIG. 22

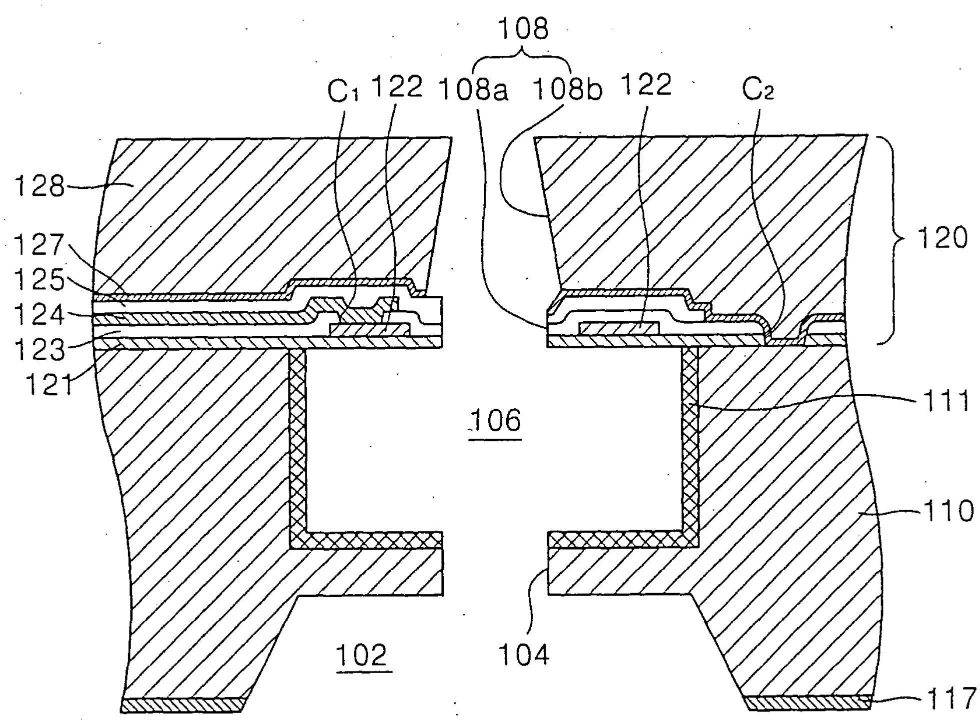

108
C1
122
108a
108b
122
C2
128
127
125
124
123
121
120
106
111
110
102
104
117

FIG. 23

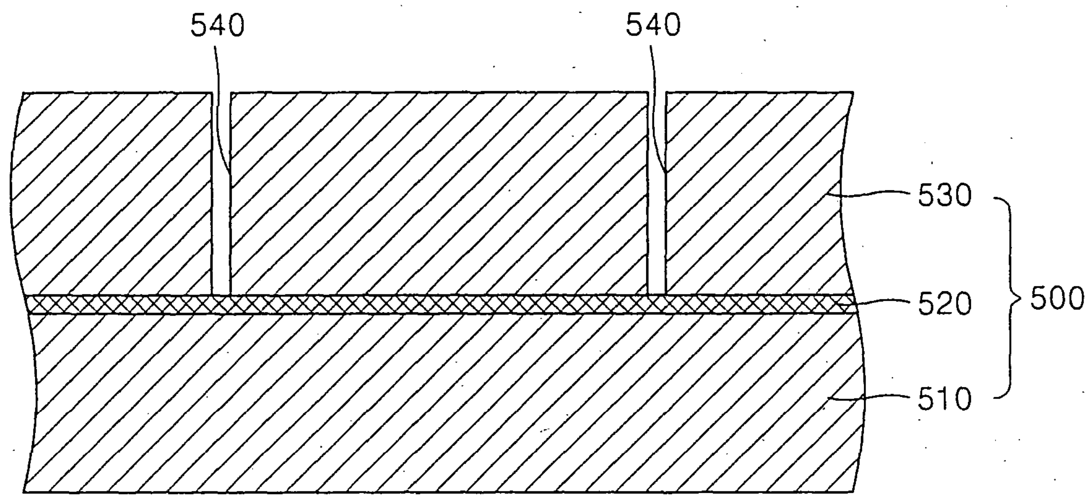
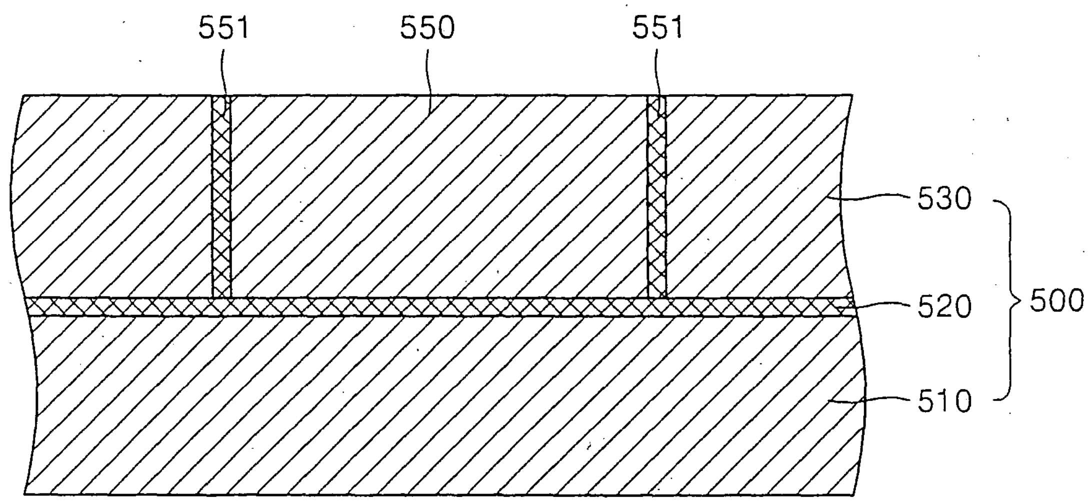


FIG. 24



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 25 3173

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
Y	US 2003/090548 A1 (MIN JAE-SIK ET AL) 15 May 2003 (2003-05-15) * the whole document * -----	1,4,5, 8-15,17	B41J2/14 B41J2/16
Y	EP 1 215 048 A (SAMSUNG ELECTRONICS CO LTD) 19 June 2002 (2002-06-19) * paragraph [0059] * * figure 19 * -----	1,4,5, 8-15,17	
A	EP 0 841 167 A (CANON KK) 13 May 1998 (1998-05-13) * page 9, line 9 - page 10, line 7 * * figure 1 * -----	23	
A	US 2003/081072 A1 (TRUEBA KENNETH E) 1 May 2003 (2003-05-01) * the whole document * -----	23	
A	PATENT ABSTRACTS OF JAPAN vol. 0112, no. 34 (M-611), 30 July 1987 (1987-07-30) & JP 62 044467 A (NIPPON TELEGR & TELEPH CORP <NTT>), 26 February 1987 (1987-02-26) * abstract * -----	1	TECHNICAL FIELDS SEARCHED (Int.Cl.7) B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	6 September 2004	Didenot, B

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 04 25 3173

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-09-2004

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 2003090548	A1	15-05-2003	KR	2003040689	A	23-05-2003
			US	2003160842	A1	28-08-2003
EP 1215048	A	19-06-2002	KR	2002046824	A	21-06-2002
			KR	2002061982	A	25-07-2002
			EP	1215048	A2	19-06-2002
			JP	2002200757	A	16-07-2002
			US	2002075360	A1	20-06-2002
			US	2003142169	A1	31-07-2003
EP 0841167	A	13-05-1998	EP	0841167	A2	13-05-1998
			JP	10181032	A	07-07-1998
			US	6143190	A	07-11-2000
US 2003081072	A1	01-05-2003	US	2003186474	A1	02-10-2003
JP 62044467	A	26-02-1987	NONE			

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82