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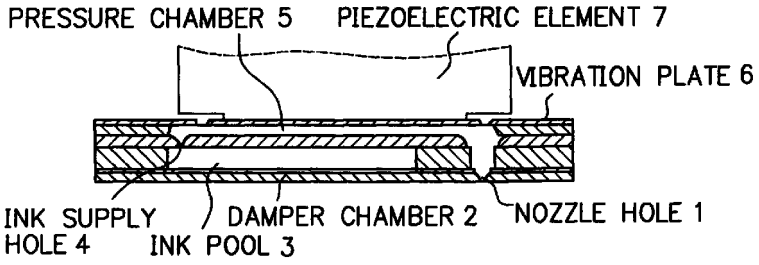
(54) Ink jet printing head, nozzle plate and manufacturing method thereof

(57) A nozzle plate (21) of an ink jet printing head is formed so that its surface facing toward the ink drop discharge direction will have protruding parts (40) around each of its nozzle holes (1). Each protruding part (40) is formed in the shape of a circle that is concentric with a corresponding nozzle hole (1), and the outer edge (41) of the protruding part (40) is formed so as to have an appropriate slope. Due to the configuration of the nozzle plate (21), a wiper blade (30) can make good contact with the surface (protruding parts (40)) of the nozzle plate (21) around the nozzle holes (1) and ink around the nozzle holes (1) can be cleaned successfully in wiping operation, thereby the ink drop discharge properties of the ink jet printing head can be stabilized and improved. Such a configuration of the nozzle plate (21) is realized by electrodeposition without using a photoresist. Therefore, the shape of the nozzle hole (1) is not affected by the coating status of the photoresist, the precision of a patterning image which is used for the exposure and development, the precision and life of a mask, etc. Therefore, the dimensional accuracy (diameter, roundness, etc.) of the nozzle holes (1) can be improved, manufacturing yield of the ink jet printing heads can be increased, manufacturing costs can be reduced, and high quality printing can be realized.

F I G. 3



EP 1 093 919 A2

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to an ink jet printing head, a nozzle plate of the ink jet printing head and a manufacturing method of the nozzle plate, and in particular, to an ink jet printing head, a nozzle plate of the ink jet printing head and a manufacturing method of the nozzle plate by which factors deteriorating image quality can be reduced and thereby quality of printed outputs can be improved. Description of the Related Art

[0002] Today, printers are used a lot for printing various information on objects such as paper, and among them, ink jet printers which conduct printing by discharging ink drops from nozzles onto the objects are regarded as advantageous from the viewpoints of high speed printing, low noise, etc.

[0003] An ink jet printer includes an ink jet printing head for discharging ink drops to an object such as paper. A color ink jet printing head of an ordinary type includes four common ink channels (which are provided corresponding to each of the CMYK (cyan, magenta, yellow and black) colors) for supplying ink from corresponding ink tanks to the ink jet printing head, four ink pools (which are provided corresponding to each of the four colors) each of which is filled with the ink supplied from the common ink channel of the corresponding color, nozzle holes which are provided to a nozzle plate as holes from which the ink (of a corresponding color) is discharged to the object such as paper, and pressure chambers (which are provided corresponding to each of the nozzle holes) to each of which pressure is applied by a piezoelectric element etc. in order to cause the discharge of the ink stored in the ink pool.

[0004] The nozzle plates of conventional ink jet printing heads used to be formed by means of electrolytic plating casting, as disclosed in Japanese Patent Application Laid-Open No.HEI4-182134. In the formation of the nozzle plate, a base plate made of a metal plate is generally used, and a nozzle section is patterned on the base plate by use of a photoresist. On the metal base plate which has been patterned by use of the photoresist, electrodeposition of Ni is conducted and thereby a Ni layer for becoming the nozzle plate is formed. Thereafter, the nozzle plate made of the Ni layer is removed from the metal base plate and thereby the nozzle plate is completed.

[0005] As materials for the nozzle plate, metal (SUS (stainless steel), Ni, etc.), plastic (polyimide, PES (PolyEther Sulfone), etc.), etc. are used. The formation of the nozzle holes in the nozzle plate is usually conducted by means of electroforming, etching, press working, excimer laser machining, etc.

[0006] Fig.1 is a cross sectional view showing an example of a conventional manufacturing method of a nozzle plate by means of electroforming. A photoresist 10 is coated on a base plate 9 which is formed of metal such as SUS, and thereafter exposure by use of a mask and development are conducted, thereby a photoresist pattern is formed on the base plate 9. Thereafter, electrodeposition of a metal is conducted onto exposed surfaces of the base plate 9. When the thickness of the electrodeposited metal layer reached a predetermined thickness, the electrodeposited metal layer (that is, a nozzle plate 21) is removed from the base plate 9 and thereby the nozzle plate 21 is completed.

[0007] However, the shape of each nozzle hole 1 which is formed by means of the electroforming is affected by the coating status of the photoresist 10, the precision of patterning by means of exposure and development, the precision and life of the mask, etc. Therefore, the diameter, roundness, etc. of the nozzle holes 1 are necessitated to vary depending on the above conditions.

[0008] Due to the variation of the diameter, roundness, etc. of the nozzle holes 1, the diameter and speed of ink drops which are discharged from the nozzle holes 1 are necessitated to vary, thereby quality of printed images is deteriorated. Uniformity of the direction of ink drop discharge is also deteriorated due to the poor roundness of the nozzle holes 1 and thereby the image quality is deteriorated further.

[0009] Further, since the photoresist 10 which is used for the patterning of the nozzle plate 21 has a certain thickness, concave parts are necessarily formed on the surface of the nozzle plate 21. As shown in (C) of Fig.1, the concave parts are formed around the nozzle holes 1. Due to the concave parts around the nozzle holes 1, cleaning of ink around the nozzle holes 1 by use of a wiper blade in the refresh (cleaning) operation of the ink jet printer becomes difficult.

[0010] Figs.2A and 2B are cross sectional views showing the wiping operation of the wiper blade in the case of a conventional ink jet printing head (or a conventional nozzle plate) manufactured by the aforementioned conventional manufactured method. Referring to Figs.2A and 2B, when the wiper blade 30 moves from the left to the right (as shown by the arrow) for wiping the nozzle plate, the wiper blade 30 can not touch the recessed surface around the nozzle hole 1 correctly and thus can not clean the ink around the nozzle hole 1 perfectly, thereby the ink remaining around the nozzle hole 1 might cause troubles in the ink drop discharge.

SUMMARY OF THE INVENTION

[0011] It is therefore the primary object of the present invention to provide an ink jet printing head, a nozzle plate of the ink jet printing head and a manufacturing method of the nozzle plate, by which dimensional accuracy of the nozzle holes which are formed by means of electroforming can be increased and thereby image quality of printed outputs can be improved.

[0012] Another object of the present invention is to provide an ink jet printing head, a nozzle plate of the ink

jet printing head and a manufacturing method of the nozzle plate, by which the cleaning of ink around the nozzle holes by the wiping operation can be ensured, the variations in the ink drop diameter, the ink drop velocity and the ink drop discharge direction can be reduced, and thereby high quality printing can be realized at a low cost.

[0013] In accordance with a first aspect of the present invention, there is provided a nozzle plate having nozzle holes which is used for an ink jet printing head for discharging ink drops from the nozzle holes by means of electrostriction of piezoelectric elements and pressure waves generated in pressure chambers due to the electrostriction of the piezoelectric elements. In the nozzle plate, a surface of the nozzle plate facing toward the ink drop discharge direction is formed so that parts of the surface around each of the nozzle holes will be protruding from other parts into the ink drop discharge direction.

[0014] In accordance with a second aspect of the present invention, in the first aspect, each of the protruding parts of the surface is formed in the shape of a circle that is concentric with a corresponding nozzle hole.

[0015] In accordance with a third aspect of the present invention, in the first aspect, the height of the protruding part is set between 5 μm and 100 μm.

[0016] In accordance with a fourth aspect of the present invention, in the second aspect, each of the protruding parts is formed so that its outer edge will have an appropriate slope.

[0017] In accordance with a fifth aspect of the present invention, in the fourth aspect, the slope of the outer edge of the protruding part is set between 10° and 50° with respect to the ink drop discharge direction.

[0018] In accordance with a sixth aspect of the present invention, in the first aspect, the protruding parts and the nozzle holes are formed by means of electroforming.

[0019] In accordance with a seventh aspect of the present invention, in the sixth aspect, the nozzle plate is formed of Ni.

[0020] In accordance with an eighth aspect of the present invention, in the sixth aspect, the nozzle plate is formed of an ally of Ni and Co.

[0021] In accordance with a ninth aspect of the present invention, there is provided a manufacturing method of a nozzle plate having nozzle holes which is used for an ink jet printing head for discharging ink drops from the nozzle holes by means of electrostriction of piezoelectric elements and pressure waves generated in pressure chambers due to the electrostriction of the piezoelectric elements. The manufacturing method comprises a base plate formation step, an electrodeposition step and a removal step. In the base plate formation step, a base plate is formed on the upper surface of a base which is made of an electrical insulating material, avoiding parts of the upper surface of the base where the nozzle holes are planned to be formed. In the electrodeposition step, a metal layer is electrodeposited to a predetermined thickness using the base plate which has been formed in the base plate formation step as a seed layer. In the removal step, the metal layer which has been electrodeposited in the electrodeposition step as the nozzle plate is removed from the base after the thickness of the electrodeposited metal layer reached a predetermined thickness.

[0022] In accordance with a tenth aspect of the present invention, in the ninth aspect, a surface of the nozzle plate facing toward the ink drop discharge direction is formed so that parts of the surface around each of the nozzle holes will be protruding from other parts into the ink drop discharge direction.

[0023] In accordance with an eleventh aspect of the present invention, in the tenth aspect, each of the protruding parts of the surface is formed in the shape of a circle that is concentric with a corresponding nozzle hole.

[0024] In accordance with a twelfth aspect of the present invention, in the tenth aspect, the height of the protruding part is set between 5 μm and 100 μm.

[0025] In accordance with a thirteenth aspect of the present invention, in the eleventh aspect, each of the protruding parts is formed so that its outer edge will have an appropriate slope.

[0026] In accordance with a fourteenth aspect of the present invention, in the thirteenth aspect, the slope of the outer edge of the protruding part is set between 10° and 50° with respect to the ink drop discharge direction.

[0027] In accordance with a fifteenth aspect of the present invention, in the ninth aspect, the metal layer which is electrodeposited in the electrodeposition step is formed of Ni.

[0028] In accordance with a sixteenth aspect of the present invention, in the ninth aspect, the metal layer which is electrodeposited in the electrodeposition step is formed of an ally of Ni and Co.

[0029] In accordance with a seventeenth aspect of the present invention, there is provided an ink jet printing head for discharging ink drops from nozzle holes by means of electrostriction of piezoelectric elements and pressure waves generated in pressure chambers due to the electrostriction of the piezoelectric elements. The ink jet printing head includes a nozzle plate having the nozzle holes which is manufactured by forming a base plate on the upper surface of a base which is made of an electrical insulating material avoiding parts of the upper surface of the base where the nozzle holes are planned to be formed, electrodepositing a metal layer to a predetermined thickness using the base plate as a seed layer, and removing the electrodeposited metal layer from the base after the thickness of the electrodeposited metal layer reached a predetermined thickness.

[0030] In accordance with an eighteenth aspect of the present invention, in the seventeenth aspect, a sur-

face of the nozzle plate facing toward the ink drop discharge direction is formed so that parts of the surface around each of the nozzle holes will be protruding from other parts into the ink drop discharge direction.

[0031] In accordance with a nineteenth aspect of the present invention, in the eighteenth aspect, each of the protruding parts of the surface is formed in the shape of a circle that is concentric with a corresponding nozzle hole.

[0032] In accordance with a twentieth aspect of the present invention, in the eighteenth aspect, the height of the protruding part is set between 5 μm and 100 μm.

[0033] In accordance with a twenty-first aspect of the present invention, in the nineteenth aspect, each of the protruding parts is formed so that its outer edge will have an appropriate slope.

[0034] In accordance with a twenty-second aspect of the present invention, in the twenty-first aspect, the slope of the outer edge of the protruding part is set between 10° and 50° with respect to the ink drop discharge direction.

[0035] In accordance with a twenty-third aspect of the present invention, in the seventeenth aspect, the metal layer which is electrodeposited is formed of Ni.

[0036] In accordance with a twenty-fourth aspect of the present invention, in the seventeenth aspect, the metal layer which is electrodeposited is formed of an ally of Ni and Co.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] The objects and features of the present invention will become more apparent from the consideration of the following detailed description taken in conjunction with the accompanying drawings, in which:

Fig.1 is a cross sectional view showing an example of a conventional manufacturing method of a nozzle plate by means of electroforming;

Figs.2A and 2B are cross sectional views showing the operation of a wiper blade which is wiping a conventional ink jet printing head (or a conventional nozzle plate) manufactured by the conventional manufactured method;

Fig.3 is a cross sectional view for explaining the composition of an ink jet printing head in accordance with an embodiment of the present invention;

Fig.4 is a cross sectional view showing a status of the ink jet printing head of Fig.3 when a vibration plate of the ink jet printing head is deformed;

Fig.5 is a schematic diagram showing the composition of a head unit of the ink jet printing head in accordance with the embodiment of the present invention;

Fig.6 is a schematic diagram showing the composition of a multilayer plate assembly which is shown in Fig.5;

Fig.7 is a cross sectional view showing a manufacturing method of a nozzle plate in accordance with an embodiment of the present invention;

Fig.8 is a schematic diagram showing the detailed configuration of the nozzle plate of Fig.7 around a nozzle hole; and

Figs.9A and 9B are cross sectional views showing the operation of a wiper blade which is wiping the nozzle plate manufactured by the manufactured method in accordance with the embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0038] Referring now to the drawings, a description will be given in detail of preferred embodiments in accordance with the present invention.

[0039] Fig.3 is a cross sectional view for explaining the composition of an ink jet printing head in accordance with an embodiment of the present invention. The ink jet printing head shown in Fig.3 includes nozzle holes 1, damper chambers 2, ink pools 3, ink supply holes 4, pressure chambers 5, a vibration plate 6, and piezoelectric elements 7. The damper chambers 2 and the ink pools 3 are provided corresponding to each color. Therefore, in the case of a color ink jet printing head using four colors (CMYK (cyan, magenta, yellow and black) for example), four damper chambers 2 and four ink pools 3 are provided. The ink supply holes 4, the pressure chambers 5 and the piezoelectric elements 7 are provided corresponding to each nozzle hole 1.

[0040] The ink pool 3 is a room which is filled with ink of a color (cyan, magenta, yellow or black, for example) which is supplied from an unshown ink tank (ink cartridge) corresponding to the color. The nozzle hole 1 is a hole from which the ink is discharged to an object such as paper. The damper chambers 2 (corresponding to each color) are provided in order to eliminate acoustic crosstalk between nozzles. The damper chamber 2, in which the ink is not packed, is formed almost in the same shape as the ink pool 3.

[0041] The ink supply holes 4 (corresponding to the nozzle holes 1) are formed above the ink pool 3 so as to connect the ink pool 3 and the pressure chambers 5 corresponding to the nozzle holes 1.

[0042] The vibration plate 6 is a plate whose part is deformed according to the deformation (electrostriction) of the piezoelectric elements 7. When an electrical signal is applied to a piezoelectric element 7 and thereby the piezoelectric element 7 is deformed, corresponding part of the vibration plate 6 is deformed and thereby the volume (capacity) of a corresponding pressure chamber 5 is changed. Due to the volume change of the pressure chamber 5, a pressure wave is transferred to the nozzle hole 1 and thereby the ink in the pressure chamber 5 is discharged as an ink drop to the object such as paper.

[0043] Fig.4 is a cross sectional view showing a sta-

tus of the ink jet printing head of Fig.3 when the vibration plate 6 is deformed. Referring to Fig.4, the vibration plate 6 is deformed inward due to the electrostriction of a piezoelectric element 7 and thereby the volume of the pressure chamber 5 is rapidly decreased. Due to the rapid decrease of the volume of the pressure chamber 5, a pressure wave is transferred to the nozzle hole 1 and thereby the ink drop discharge from the nozzle hole 1 is caused.

[0044] Fig.5 is a schematic diagram showing the composition of a head unit of the ink jet printing head in accordance with the embodiment of the present invention. The head unit shown in Fig.5 includes the piezoelectric elements 7 (a piezoelectric element unit), a multilayer plate assembly 11, a nozzle cover 12, a head drive circuit board 13, a cable 14, a head case 15, a joint 16, a connection board 17 and a head cover 18.

[0045] Fig.6 is a schematic diagram showing the composition of the multilayer plate assembly 11 which is shown in Fig.5. The multilayer plate assembly 11 shown in Fig.6 includes a nozzle plate 21 on which the nozzle holes 1 have been formed, a damper plate 22 on which the damper chambers 2 (corresponding to the colors) have been formed, a pool plate 23 on which the ink pools 3 (corresponding to the colors) have been formed, an ink supply plate 24 on which the ink supply holes 4 (corresponding to the nozzle holes 1) have been formed, a pressure chamber plate 25 on which the pressure chambers 5 (corresponding to the nozzle holes 1) have been formed, the vibration plate 6, and the piezoelectric element unit (piezoelectric elements 7).

[0046] In the head unit of the ink jet printing head of this embodiment, ink of a color is supplied from an unshown ink tank (ink cartridge) to one of the ink pools 3 corresponding to the color via a common ink channel which is provided through the joint 16 and the head case 15, and thereby packed in the ink pool 3. Above the ink pool 3, the ink supply holes 4 corresponding to the nozzle holes 1 are formed on the ink supply plate 24. Corresponding to each ink supply hole 4, a pressure chamber 5 and a nozzle hole 1 for discharging ink drops are provided. The nozzle holes 1 are formed through the nozzle plate 21 in the ink drop discharge direction. Between the ink pools 3 and the nozzle plate 21, the damper chambers 2 (in which the ink is not packed) having almost the same shapes as the ink pools 3 are formed on the damper plate 22 in order to eliminate the acoustic crosstalk between nozzles. The pressure chambers 5 which are formed on the pressure chamber plate 25 are covered by the vibration plate 6, and the piezoelectric element unit (piezoelectric elements 7) is attached to the vibration plate 6.

[0047] As the plates (the nozzle plate 21, the damper plate 22, the pool plate 23, the ink supply plate 24, the pressure chamber plate 25 and the vibration plate 6), metal plates made of SUS (stainless steel), Ni (nickel), etc. are used, and the concavities and holes (such as the nozzle holes 1) on the plates are formed by means of etching, electroforming, etc.

[0048] The plates can also be implemented by the so-called dry films. In such cases, the formation of the concavities and holes on the plates can be done by patterning by means of photolithography (exposure and development).

[0049] The plates are stacked up and bonded together and thereby the multilayer plate assembly 11 is formed. The bonding of the plates can be done by adhesion by use of epoxy adhesives, dry films, etc., thermal diffusion bonding, etc.

[0050] It is also possible to form the pool plate 23, the ink supply plate 24 and the pressure chamber plate 25 in one piece by means of plastics molding of PPE (PolyPhenylene Ether), PES (PolyEther Sulfone), etc.

[0051] When the ink jet printing head of this embodiment is installed on an ink jet printer, the head drive circuit board 13 to which the cable 14 is connected is attached to the piezoelectric element unit (piezoelectric elements 7) of the multilayer plate assembly 11 by means of reflow soldering, as shown in Fig.5. The multilayer plate assembly 11 and the joint 16 are attached to the head case 15. The connection board 17 to which the cable 14 is connected is stored in the head cover 18, and the head cover 18 is attached to the head case 15.

[0052] As mentioned before, the common ink channels (corresponding to the colors) for the supply of the ink from the unshown ink tanks (ink cartridges for the colors) are formed through the joint 16 and the head case 15. The joint 16 and the head case 15 are formed by plastics molding of PPE, PES, etc.

[0053] On the lower surface of the nozzle plate 21 of the multilayer plate assembly 11, the nozzle cover 12 is attached so as to protect the nozzle plate 21 in cases of paper jams etc. The nozzle cover 12 is made of SUS (stainless steel) for example and formed by press working. The ink jet printing head including the head unit which is composed as above is installed in an ink jet printer.

[0054] Fig.7 is a cross sectional view showing a manufacturing method of the nozzle plate in accordance with an embodiment of the present invention. Fig.7 also shows the distinctive features of the nozzle plate in accordance with the present invention.

[0055] Referring to (A) of Fig.7, an electrical insulating material 8 is used as a base, and a thin base plate 9 is patterned on the upper surface of the electrical insulating material 8 by means of etching etc. Subsequently, as shown in (B) of Fig.7, electrodeposition is conducted on the base plate 9 till the thickness of the electrodeposited metal layer reaches a predetermined thickness. Thereafter, as shown in (C) of Fig.7, the electrodeposited metal layer (i.e. the nozzle plate 21) is removed from the base (electrical insulating material 8). The electrodeposited metal layer (nozzle plate 21) is preferably formed of Ni, an alloy of Ni and Co, etc., however, the materials for the nozzle plate 21 can be changed if possible.

[0056] Fig.8 is a schematic diagram showing the detailed configuration of the nozzle plate 21 of Fig.7 around a nozzle hole 1. As shown in Fig.8, on the lower surface of the nozzle plate 21 which is manufactured by the manufacturing method of Fig.7, a protruding (convex) part 40 is formed around the nozzle hole 1. The height of the protruding part 40 becomes almost the same as the thickness of the base plate 9 which is used for the formation of the nozzle plate 21. In the case of the manufacturing method of Fig.7, the protruding part 40 is formed in the shape of a circle that is concentric with the nozzle hole 1, and the outer edge 41 of the circular protruding part 40 is formed so as to have an appropriate slope. The slope of the outer edge 41 of the circular protruding part 40 is preferably set between 100° and 140° with respect to a surface of the nozzle plate (21) facing the ink drop discharge direction (i.e. between 10° and 50° with respect to the ink drop discharge direction) from the viewpoint of the formation of the protruding parts 40 by means of electroforming. The height of the protruding part 40 can be set properly between 5 ~ 100 μm from the viewpoints of the thickness and dimensional (thickness) accuracy of the base plate 9 which is used for the formation of the nozzle plate 21.

[0057] Figs.9A and 9B are cross sectional views showing the operation of a wiper blade which is wiping the nozzle plate 21 manufactured by the manufactured method in accordance with the embodiment of the present invention. Referring to Fig.9A, when the wiper blade 30 moves from the left to the right (as shown by the arrow) for wiping the nozzle plate 21, the edge of the wiper blade 30 makes good contact with the protruded surface (protruding part 40) of the nozzle plate 21 around the nozzle holes 1, thereby the ink around the nozzle holes 1 can be cleaned perfectly. The contact between the wiper blade 30 and the protruding parts 40 of the nozzle plate 21 is also shown in Fig.9B. By the improved cleaning ability of the wiper blade 30 due to the configuration of the nozzle plate 21 of the embodiment of the present invention, the deterioration of the ink drop discharge properties of the ink jet printing head caused by the ink remaining around the nozzle holes 1 can be eliminated and thereby high quality printing can be realized. The appropriate slope of the outer edge 41 of the protruding part 40 helps the contact between the wiper blade 30 and the protruding part 40 as can be seen in Fig.9A, and thereby the cleaning ability of the wiper blade 30 is improved further. In addition, wear of the wiper blade 30 is reduced by the appropriate slope of the outer edge 41 and thereby the operating life of the wiper blade 30 is prolonged.

[0058] As set forth hereinabove, in the ink jet printing head, the nozzle plate of the ink jet printing head and the manufacturing method of the nozzle plate in accordance with the embodiment of the present invention, a surface of the nozzle plate 21 facing toward the ink drop discharge direction is formed so that parts 40 of the surface around each of the nozzle holes 1 will be protruding from other parts into the ink drop discharge direction. Therefore, the wiper blade 30 can make good contact with the surface (protruding parts 40) of the nozzle plate 21 around the nozzle holes 1 and the ink around the nozzle holes 1 can be cleaned successfully in the wiping operation, thereby the ink drop discharge properties of the ink jet printing head can be stabilized and improved.

[0059] In the preferred embodiment, each protruding part 40 is formed in the shape of a circle that is concentric with a corresponding nozzle hole 1, and the outer edge 41 of the protruding part 40 is formed so as to have an appropriate slope. Such a configuration of the nozzle plate 21 is realized by the electrodeposition process in accordance with the embodiment of the present invention, thereby good contact between the wiper blade 30 and the protruding parts 40 is ensured and thereby the above effects of the present invention is guaranteed. The appropriate slope of the outer edge 41 of the protruding part 40 also prolongs the operating life of the wiper blade 30.

[0060] The protruding parts 40 and the nozzle holes 1 of the nozzle plate 21 of the embodiment are formed by means of electroforming, without using a photoresist. Therefore, the shape of the nozzle hole 1 is not affected by the coating status of the photoresist, the precision of a patterning image which is used for the exposure and development, the precision and life of a mask, etc. Therefore, the dimensional accuracy (diameter, roundness, etc.) of the nozzle holes 1 can be improved, manufacturing yield of the ink jet printing heads can be increased, manufacturing costs can be reduced, and high quality printing can be realized.

[0061] While the present invention has been described with reference to the particular illustrative embodiments, it is not to be restricted by those embodiments but only by the appended claims. It is to be appreciated that those skilled in the art can change or modify the embodiments without departing from the scope and spirit of the present invention.

Claims

1. A nozzle plate (21) having nozzle holes (1) which is used for an ink jet printing head for discharging ink drops from the nozzle holes (1) by means of electrostriction of piezoelectric elements (7) and pressure waves generated in pressure chambers (5) due to the electrostriction of the piezoelectric elements (7), wherein:

   a surface of the nozzle plate (21) facing toward the ink drop discharge direction is formed so that parts (40) of the surface around each of the nozzle holes (1) will be protruding from other parts into the ink drop discharge direction.

2. A nozzle plate (21) as claimed in claim 1, wherein each of the protruding parts (40) of the surface is formed in the shape of a circle that is concentric with a corresponding nozzle hole (1).

3. A nozzle plate (21) as claimed in claim 1, wherein the height of the protruding part (40) is set between 5 μm and 100 μm.

4. A nozzle plate (21) as claimed in claim 2, wherein each of the protruding parts (40) is formed so that its outer edge (41) will have an appropriate slope.

5. A nozzle plate (21) as claimed in claim 4, wherein the slope of the outer edge (41) of the protruding part (40) is set between 10° and 50° with respect to the ink drop discharge direction.

6. A nozzle plate (21) as claimed in claim 1, wherein the protruding parts (40) and the nozzle holes (1) are formed by means of electroforming.

7. A nozzle plate (21) as claimed in claim 6, wherein the nozzle plate (21) is formed of Ni.

8. A nozzle plate (21) as claimed in claim 6, wherein the nozzle plate (21) is formed of an ally of Ni and Co.

9. A manufacturing method of a nozzle plate (21) having nozzle holes (1) which is used for an ink jet printing head for discharging ink drops from the nozzle holes (1) by means of electrostriction of piezoelectric elements (7) and pressure waves generated in pressure chambers (5) due to the electrostriction of the piezoelectric elements (7), comprising the steps of:

   a base plate formation step in which a base plate (9) is formed on the upper surface of a base (8) which is made of an electrical insulating material (8), avoiding parts of the upper surface of the base (8) where the nozzle holes (1) are planned to be formed;
   an electrodeposition step in which a metal layer is electrodeposited to a predetermined thickness using the base plate (9) which has been formed in the base plate formation step as a seed layer; and
   a removal step in which the metal layer which has been electrodeposited in the electrodeposition step as the nozzle plate (21) is removed from the base (8) after the thickness of the electrodeposited metal layer reached a predetermined thickness.

10. A manufacturing method of a nozzle plate (21) as claimed in claim 9, wherein a surface of the nozzle plate (21) facing toward the ink drop discharge direction is formed so that parts (40) of the surface around each of the nozzle holes (1) will be protruding from other parts into the ink drop discharge direction.

11. A manufacturing method of a nozzle plate (21) as claimed in claim 10, wherein each of the protruding parts (40) of the surface is formed in the shape of a circle that is concentric with a corresponding nozzle hole (1).

12. A manufacturing method of a nozzle plate (21) as claimed in claim 10, wherein the height of the protruding part (40) is set between 5 μm and 100 μm.

13. A manufacturing method of a nozzle plate (21) as claimed in claim 11, wherein each of the protruding parts (40) is formed so that its outer edge (41) will have an appropriate slope.

14. A manufacturing method of a nozzle plate (21) as claimed in claim 13, wherein the slope of the outer edge (41) of the protruding part (40) is set between 10° and 50° with respect to the ink drop discharge direction.

15. A manufacturing method of a nozzle plate (21) as claimed in claim 9, wherein the metal layer which is electrodeposited in the electrodeposition step is formed of Ni.

16. A manufacturing method of a nozzle plate (21) as claimed in claim 9, wherein the metal layer which is electrodeposited in the electrodeposition step is formed of an ally of Ni and Co.

17. An ink jet printing head for discharging ink drops from nozzle holes (1) by means of electrostriction of piezoelectric elements (7) and pressure waves generated in pressure chambers (5) due to the electrostriction of the piezoelectric elements (7), wherein:

   the ink jet printing head includes a nozzle plate having the nozzle holes (1) which is manufactured by forming a base plate (9) on the upper surface of a base (8) which is made of an electrical insulating material (8) avoiding parts of the upper surface of the base (8) where the nozzle holes (1) are planned to be formed, electrodepositing a metal layer to a predetermined thickness using the base plate (9) as a seed layer, and removing the electrodeposited metal layer from the base (8) after the thickness of the electrodeposited metal layer reached a predetermined thickness.

18. An ink jet printing head as claimed in claim 17, wherein a surface of the nozzle plate (21) facing toward the ink drop discharge direction is formed so that parts (40) of the surface around each of the nozzle holes (1) will be protruding from other parts into the ink drop discharge direction.

19. An ink jet printing head as claimed in claim 18, wherein each of the protruding parts (40) of the surface is formed in the shape of a circle that is concentric with a corresponding nozzle hole (1).

20. An ink jet printing head as claimed in claim 18, wherein the height of the protruding part (40) is set between 5 μm and 100 μm.

21. An ink jet printing head as claimed in claim 19, wherein each of the protruding parts (40) is formed so that its outer edge (41) will have an appropriate slope.

22. An ink jet printing head as claimed in claim 21, wherein the slope of the outer edge (41) of the protruding part (40) is set between 10° and 50° with respect to the ink drop discharge direction.

23. An ink jet printing head as claimed in claim 17, wherein the metal layer which is electrodeposited is formed of Ni.

24. An ink jet printing head as claimed in claim 17, wherein the metal layer which is electrodeposited is formed of an ally of Ni and Co.

FIG. 1 PRIOR ART

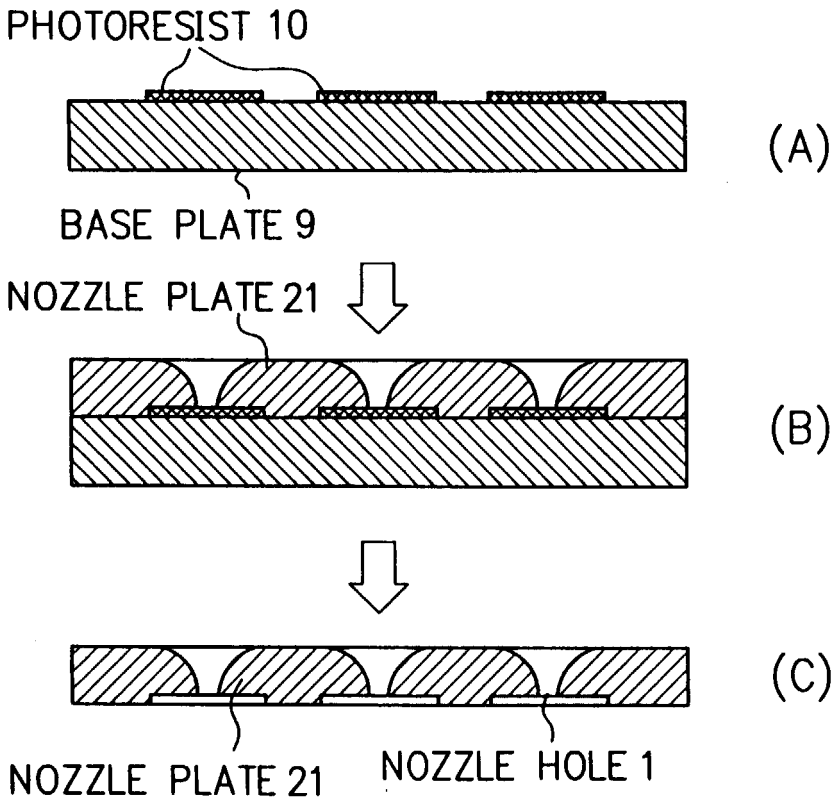


FIG. 2A PRIOR ART

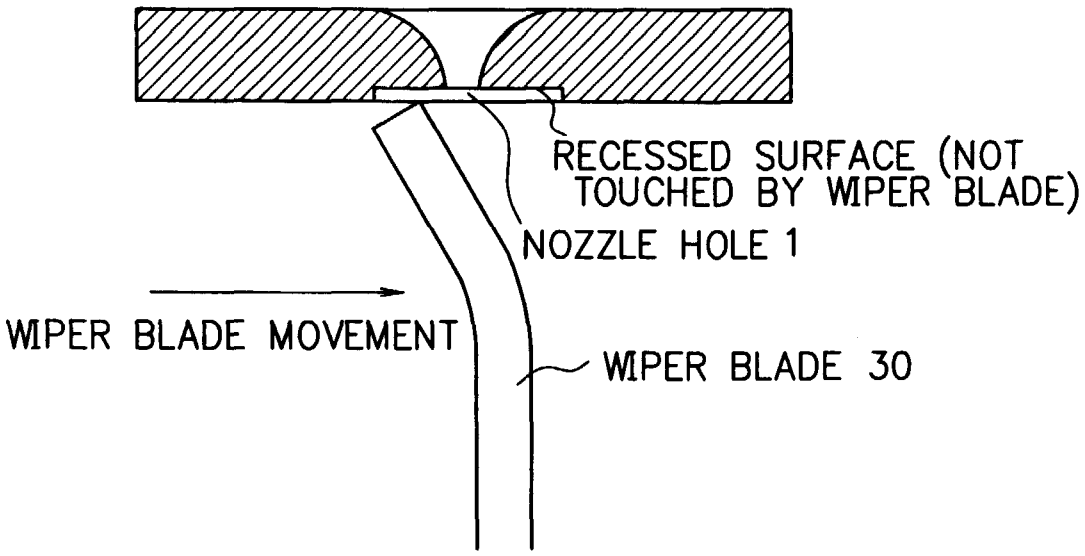


FIG. 2B PRIOR ART

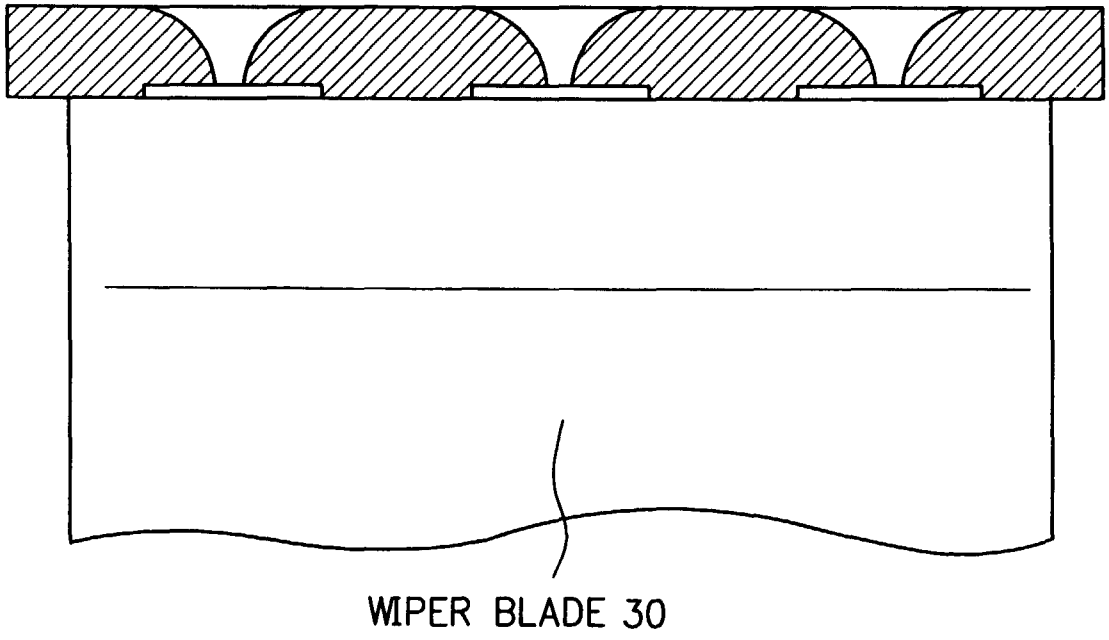


FIG. 3

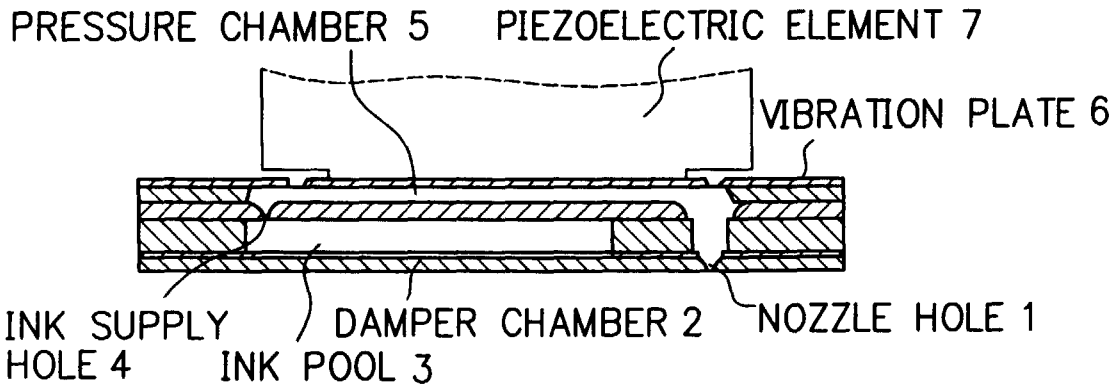

PRESSURE CHAMBER 5
PIEZOELECTRIC ELEMENT 7
VIBRATION PLATE 6
INK SUPPLY HOLE 4
INK POOL 3
DAMPER CHAMBER 2
NOZZLE HOLE 1

FIG. 4

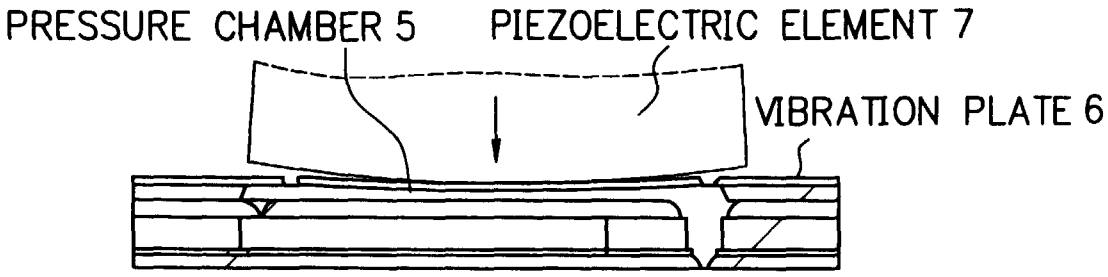

PRESSURE CHAMBER 5
PIEZOELECTRIC ELEMENT 7
VIBRATION PLATE 6

FIG. 5

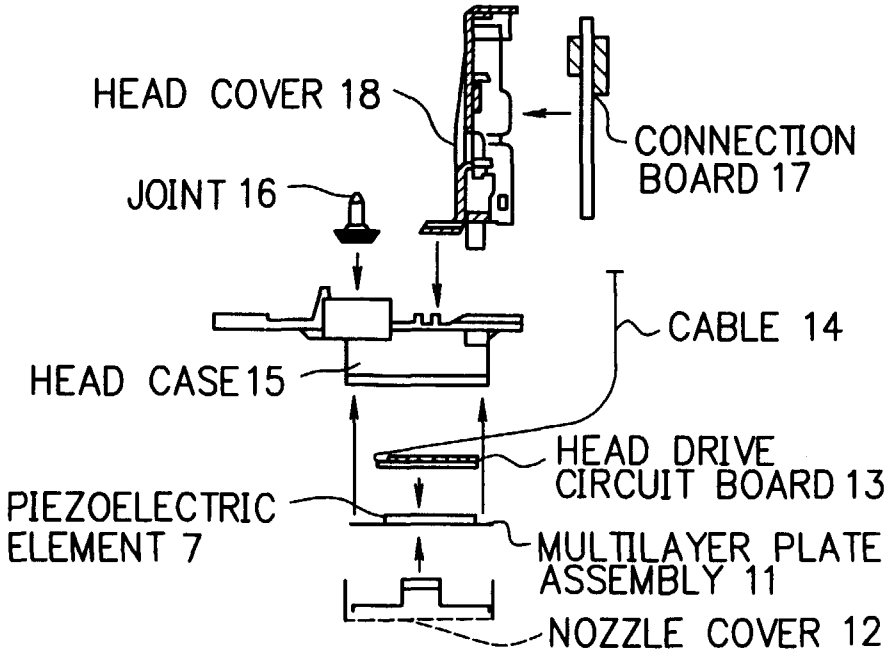

HEAD COVER 18
CONNECTION BOARD 17
JOINT 16
CABLE 14
HEAD CASE 15
HEAD DRIVE CIRCUIT BOARD 13
PIEZOELECTRIC ELEMENT 7
MULTILAYER PLATE ASSEMBLY 11
NOZZLE COVER 12

FIG. 6

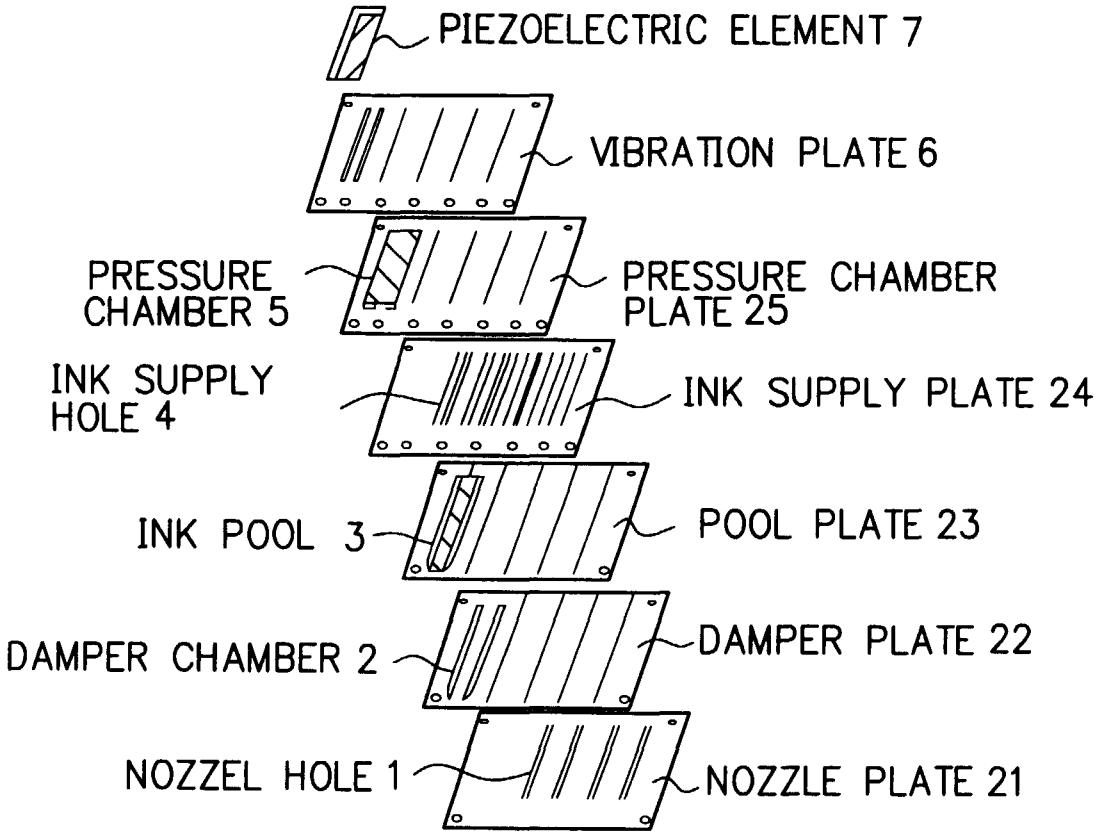

PIEZOELECTRIC ELEMENT 7
VIBRATION PLATE 6
PRESSURE CHAMBER 5
PRESSURE CHAMBER PLATE 25
INK SUPPLY HOLE 4
INK SUPPLY PLATE 24
INK POOL 3
POOL PLATE 23
DAMPER CHAMBER 2
DAMPER PLATE 22
NOZZEL HOLE 1
NOZZLE PLATE 21

FIG. 7

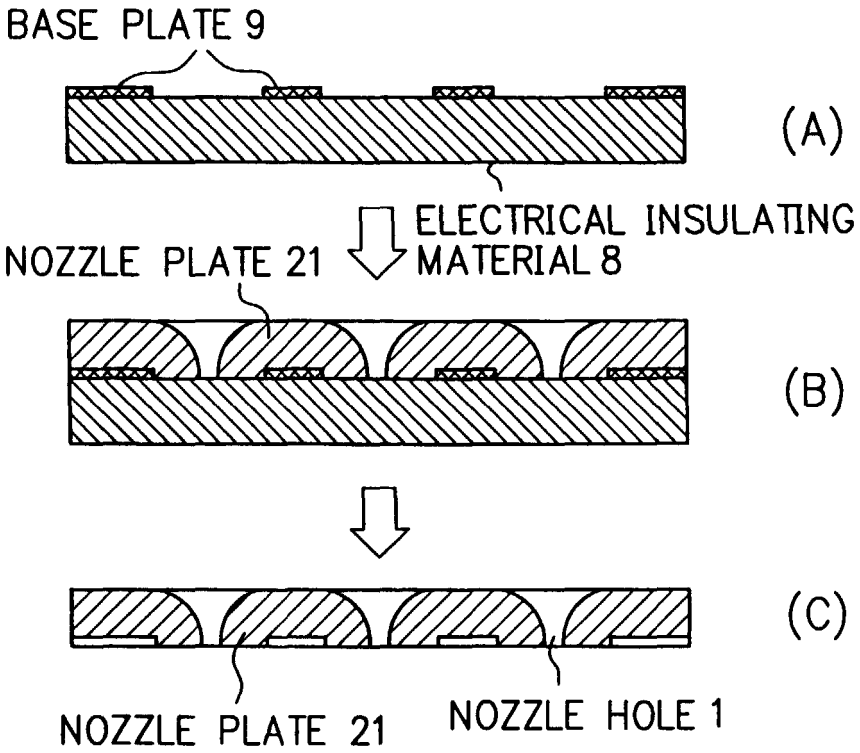

BASE PLATE 9
(A)
ELECTRICAL INSULATING MATERIAL 8
NOZZLE PLATE 21
(B)
(C)
NOZZLE PLATE 21
NOZZLE HOLE 1

FIG. 8

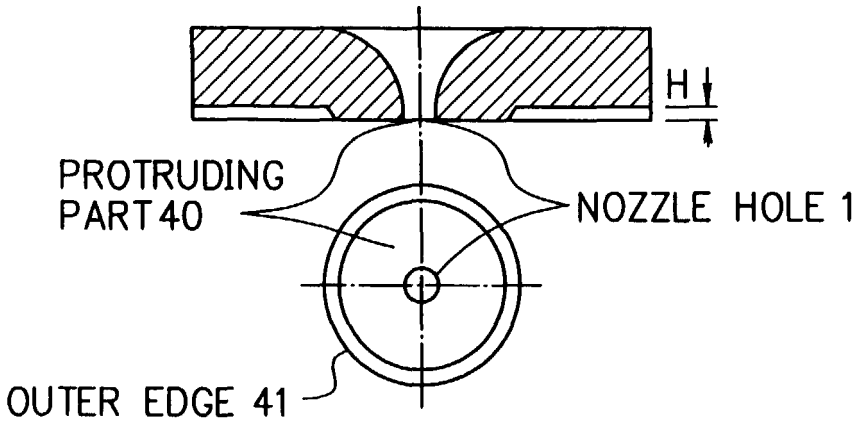

H
PROTRUDING PART 40
NOZZLE HOLE 1
OUTER EDGE 41

FIG. 9A

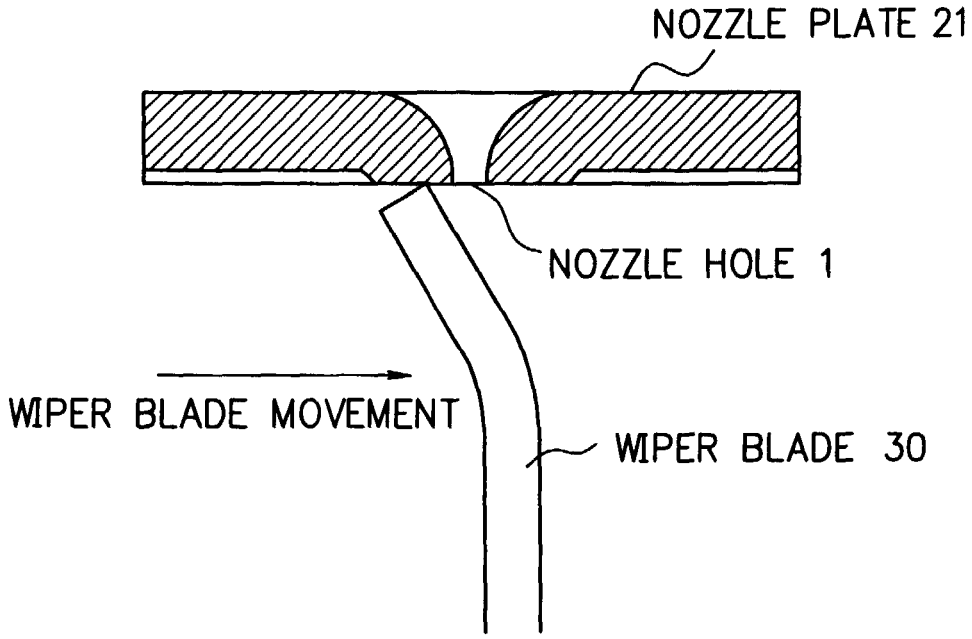
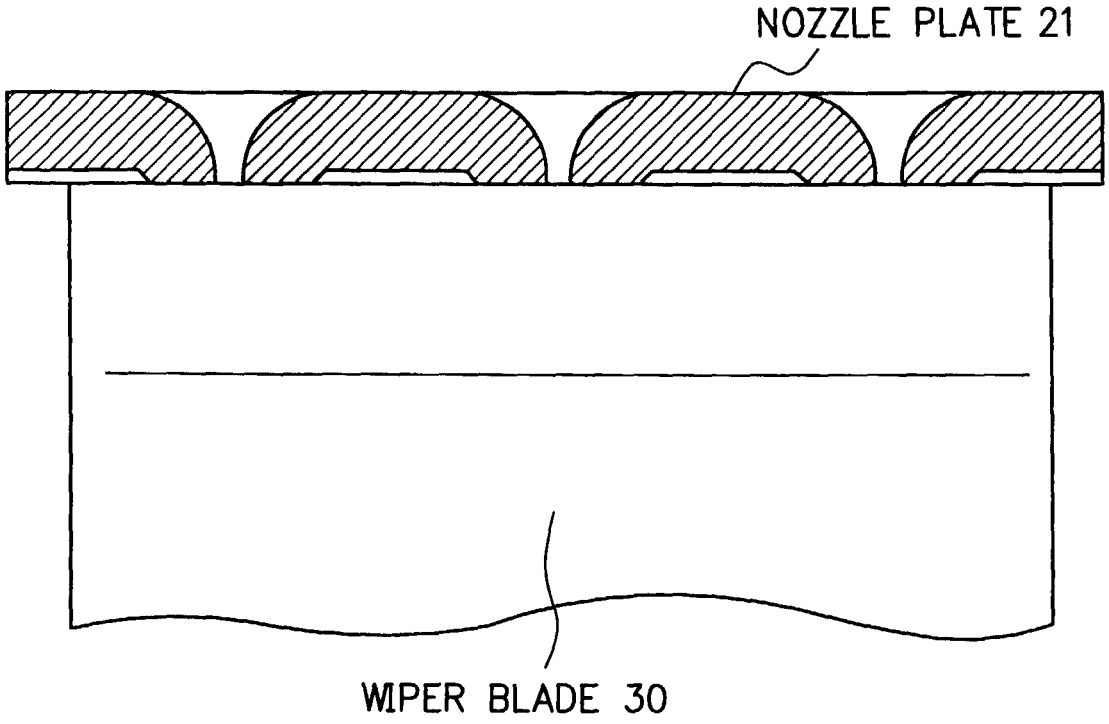

NOZZLE PLATE 21
NOZZLE HOLE 1
WIPER BLADE MOVEMENT
WIPER BLADE 30

FIG. 9B


NOZZLE PLATE 21
WIPER BLADE 30