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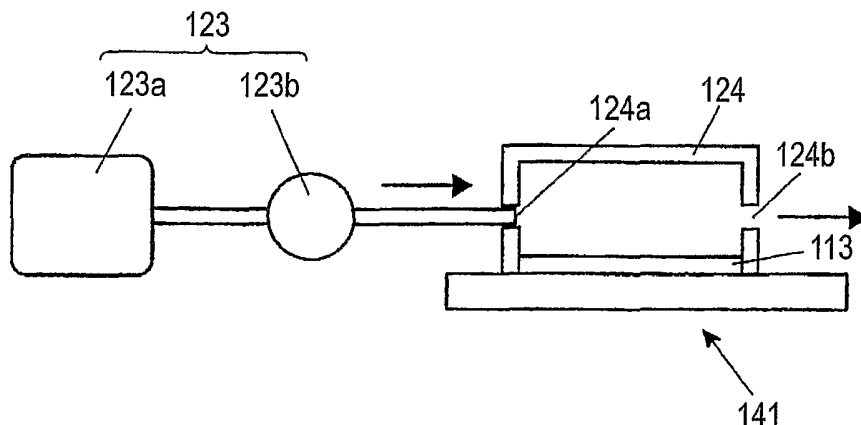
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(54) Title: **INK JET RECORDING APPARATUS**



(57) Abstract: An ink jet recording apparatus, which performs printing by ink injection, comprises a pressure chamber in which ink liquid is filled; a nozzle hole (116) which is formed communicating with the pressure chamber; a piezoelectric element (113) which is formed on the pressure chamber, and deforms the pressure chamber by mechanical expansion and contraction, whereby pressure is generated in the pressure chamber and ink is ejected from the nozzle hole (116); and a dew point control unit (123) which keeps a dew point in an atmosphere of the piezoelectric element (113) and the vicinity of the piezoelectric element (113) at a lower value than a dew point in an environment where the ink jet recording apparatus is set. The dew point control unit comprises a compressor, and an air drier (123b) which dries compression gas from this compressor (123a) and feeds it to the piezoelectric element.

DESCRIPTION

INK JET RECORDING APPARATUS

5 Technical Field

The present invention relates to an ink jet recording apparatus which can control a dew point of air in the apparatus.

Background Art

10 An ink jet recording apparatus, by ejecting ink of tens pico liter through many nozzle holes each having tens μm diameter onto a recording medium such as paper, performs printing. An ink ejecting part comprises a nozzle plate in which many nozzle holes are provided, a pressure chamber
15 communicating with each nozzle hole, a common liquid chamber for supplying the ink to the pressure chambers, and a unit which generates pressure in the pressure chamber.

As a type which generates the pressure in the pressure chamber, there are two types. One of them is a type in which
20 air bubbles are generated in the pressure chamber by Joule heat, and the other is a piezoelectric type in which the pressure chamber is deformed by a piezoelectric element. In the piezoelectric type, since the amount of ink to be ejected and ink ejection speed are more easily controlled than in the type
25 of air bubbles, it is expected that exacter printing is

possible.

In the piezoelectric type, in order to realize fine printing, it is necessary to increase of in-plane density of the nozzle hole, the pressure chamber, and the piezoelectric element set on the pressure chamber. Therefore, it is necessary to reduce the area of the piezoelectric element. In order to form the piezoelectric element having the predetermined area, a method is used, which comprises steps of: firstly, forming a piezoelectric film on the whole of a base material; and thereafter, forming a resist pattern by photolithography to remove the piezoelectric film of no-resist portion by etching. By this method, it is impossible to make the area of the piezoelectric element smaller than the thickness of the piezoelectric film. Therefore, in order to form a piezoelectric element having smaller area, it is necessary to use a thinner piezoelectric film.

For the piezoelectric element used in the ink jet recording apparatus, it is necessary to have a high piezoelectric constant. As its material, lead titanate oxide (PT); lead titanate zirconium oxide (PZT); and magnesium additive, manganese additive, cobalt additive, iron additive, nickel additive, niobium additive, scandium additive, tantalum additive, and bismuth additive to PZT have been generally known. In order to generate the pressure in the pressure chamber, it is generally necessary to apply an electric field of several

KV/cm or more to the piezoelectric element thereby to give strain to the element.

Here, it has been known that many defects such as minute cracks and pores exist in the piezoelectric element. Under
5 existence of moisture, generally, in case that a high electric field is applied to the piezoelectric element including lead, large electric current flows to the lead compound at the defect part and its surroundings, and their portions are broken by the Joule heat, so that a large hole can be formed.

10 In order to prevent formation of the hole due to the Joule heat, for example, two methods are thought. A first method is to thicken the piezoelectric element. In case that the piezoelectric element is thin, a large defect passing through the element is produced by a break of the defect, so that such
15 disadvantage is produced that an upper electrode and a lower electrode short electrically, or displacement property changes. On the contrary, in case that the element has the thickness of some degree, even if the defect breaks, such a hole to pass through the element cannot be made, so that a large influence
20 is given on the piezoelectric property. A second method is to seal the piezoelectric element and a desiccant in a container in order to remove the moisture. For example, it is proposed in JP-A-4-349675.

However, according to the first method, in case that the
25 thickness of the piezoelectric element is made large, the break

is not caused even under a high humidity. However, the high voltage must be applied in order to make the displacement large, which increases consumption power. Further, in case that the film thickness is large, it becomes difficult to increase the in-plane density of the element.

According to the second method, in case that the piezoelectric element is sealed, the sealing work must be performed in a low humidity environment where moisture is little, which requires much labor in case of mass production in a factory and increases a manufacturing cost. Further, since the piezoelectric element is covered with a box in order to seal the element, entry of moisture from a contact surface between the box and element must be strictly prevented, which requires much labor and similarly increases the manufacturing cost.

15

Disclosure of Invention

Therefore, an object of the invention is to provide an ink jet recording apparatus which can achieve reduction of the film thickness of the piezoelectric element, and can readily prevent the element break due to the voltage application to this piezoelectric element.

In order to solve these problems, an ink jet recording apparatus of the invention, which performs printing by ink ejection, comprises a pressure chamber in which ink liquid is filled; a nozzle hole which is formed, communicating with the

25

pressure chamber; a piezoelectric element which is formed on the pressure chamber, and deforms the pressure chamber by mechanical expansion and contraction, whereby pressure is generated in the pressure chamber, and ink is ejected from the nozzle hole; and a dew point control unit which keeps a dew point in an atmosphere of the piezoelectric element and the vicinity of the piezoelectric element at a lower value than a dew point in an environment where the ink jet recording apparatus is set.

Hereby, since the dew point in the vicinity of the piezoelectric element is lowered by the dry gas, the deterioration of the piezoelectric element by the voltage application can be prevented, so that reduction of the film thickness of the piezoelectric element can be achieved, and the element break due to the voltage application to this piezoelectric element can be readily prevented.

Brief Description of Drawings

Fig. 1 is a perspective view schematically showing an ink jet recording apparatus according to one embodiment of the invention;

Fig. 2 is a sectional view showing an ink jet head used in the ink jet recording apparatus of Fig. 1;

Fig. 3 is a conceptual diagram showing a main portion of the ink jet recording apparatus according to one embodiment of the invention;

Fig. 4 is a conceptual diagram showing a main portion of an ink jet recording apparatus according to another embodiment of the invention;

Fig. 5 is a perspective view showing an introduction form of dry gas to an ink jet head attached to a head base;

Fig. 6 is a perspective view showing an introduction form of dry gas to an ink jet head attached to a frame through the bed base;

Figs. 7A and 7B are diagrams showing characteristic evaluation of PZT after the direct voltage of 35V has been applied for the predetermined time under an atmosphere where the temperature is 60°C and the humidity is 80%;

Fig. 8 is a graph showing a relationship between the voltage applied time to PZT and the number of black spots under an atmosphere where the temperature is 25°C and the humidity is 50%;

Fig. 9 is graph showing a relationship between the voltage applied time to a piezoelectric element functioning as an actuator and the number of the black spots under an atmosphere where the temperature is 25°C and the humidity is 50%;

Figs. 10A to 10C are explanatory views of the ink jet head;

Fig. 11 is a schematic diagram showing an ink jet recording apparatus according to one embodiment of the invention;

Fig. 12 is a perspective view showing a line head mounted

on the ink jet recording apparatus of Fig. 11;

Fig. 13 is an explanatory view showing a line head in which a nozzle head according to one embodiment of the invention is used;

5 Fig. 14 is an explanatory view showing a main portion of Fig. 13;

Fig. 15 is a perspective view of the ink-jet head according to Embodiment 1;

Fig. 16 is a front view of Fig. 15;

10 Fig. 17 is a side view of Fig. 15;

Fig. 18 is an explanatory view showing a line head in which a nozzle head according to another embodiment of the invention is used;

Fig. 19 is an explanatory view showing a line head in which
15 a nozzle head according to another embodiment of the invention is used;

Fig. 20 is an explanatory view showing a line head in which a nozzle head according to another embodiment of the invention is used;

20 Fig. 21 is an explanatory view showing a line head in which a nozzle head according to another embodiment of the invention is used;

Fig. 22 is an explanatory view showing a line head in which a nozzle head according to another embodiment of the invention
25 is used;

Fig. 23 is an explanatory view showing a line head in which a nozzle head according to another embodiment of the invention is used;

Fig. 24 is a schematic diagram showing an ink jet recording apparatus according to one embodiment of the invention.

Fig. 25 is a perspective view showing a part of an alignment process in a line head mounted on the ink jet recording apparatus of Fig. 24.

10 Fig. 26 is a sectional view of Fig. 25.

Fig. 27 is an explanatory view in alignment of the line head of Fig. 25, showing one example of a nozzle mark formed on a nozzle head and an alignment mark formed on a plate;

15 Fig. 28 is an explanatory view showing one example of an alignment method of nozzle heads;

Fig. 29 is an explanatory view showing another example of the alignment method of nozzle heads;

Fig. 30 is an explanatory view showing another example of the alignment method of nozzle heads;

20 Fig. 31 is an explanatory view showing another example of the alignment method of nozzle heads;

Fig. 32 is an explanatory view showing another example of the alignment method of nozzle heads;

25 Fig. 33 is an explanatory view showing another example of the alignment method of nozzle heads;

Fig. 34 is an explanatory view showing another example of the alignment method of nozzle heads;

Figs. 35A and 35B are explanatory views showing another example of the alignment method of nozzle heads;

5 Fig. 36 is an explanatory view showing another example of the alignment method of nozzle heads;

Fig. 37 is a perspective view showing an ink jet head unit according to one embodiment of the invention;

10 Fig. 38 is a side view of the ink jet head unit of Fig. 37;

Fig. 39 is a perspective view of the ink jet head unit of Fig. 37, in which a head and a flat cable which are taken out are shown;

Fig. 40 is a side view showing a main portion of Fig. 39;

15 Fig. 41 is a perspective view showing a conventional ink jet head unit; and

Fig. 42 is a front view showing a head and a flat cable in the ink jet head unit of Fig. 41.

20 Best Mode for Carrying Out the Invention

(First Embodiment)

Embodiments of the invention will be described below with reference to Figs. 1 to 10. In these drawings, the same members are denoted by the same reference numerals, and the overlapping
25 description is omitted.

An ink jet recording apparatus 140 shown in Fig. 1 is provided with an ink jet head 141 of the invention which performs recording by use of a piezoelectric effect of a piezoelectric element that is an actuator, and impacts ink droplets ejected
5 from this ink jet head 141 onto a recording medium 142 such as paper thereby to perform recording on the recording medium 142. The ink jet head 141 is mounted on a carriage 144 provided for a carriage shaft 143 arranged in a main scanning direction X, and reciprocates in the main scanning direction X
10 correspondingly to reciprocation of the carriage 144 along the carriage shaft 143. Further, the ink jet recording apparatus 140 has plural rollers (moving unit) 145 which move the recording medium 142 in a sub-scanning direction Y that is nearly vertical to the width direction (i.e., main scanning
15 direction X) of the ink jet head 141.

In Fig. 1, though the number of the ink jet heads 141 is one, it may be two or more. In case that the number of the heads increases, the distance at which the ink jet head 141 is moved in the X-axis direction can be reduced when an image is formed
20 on the recording medium. Therefore, an image forming speed improves.

Next, the structure of the ink jet head 141 will be described with reference to Fig. 2.

Fig. 2 is a sectional view of the ink jet head. The ink
25 jet head 141 has a pressure chamber plate 112 in which a pressure

chamber 111 into which ink liquid is filled is formed, and a piezoelectric element 113 such as a PZT film functioning as an actuator is formed on the pressure chamber 111.

To the pressure chamber plate 112, a common liquid chamber plate 118 is bonded, in which a common liquid chamber 114 that supplies the ink liquid into the pressure chambers 111 arranged in the ink liquid supply direction, an ink flow inlet 115 that communicates the common liquid chamber 114 and the pressure chamber 111, a communication hole 117 that communicates a nozzle hole 116 described later and the pressure chamber 111. To the common liquid chamber plate 118, a nozzle plate 119 is bonded, in which the nozzle hole 119 that communicates with the pressure chamber 111 and ejects an ink droplet is formed.

On the pressure chamber 111, the piezoelectric element 113, and an upper individual electrode 120 corresponding to the pressure chamber 111 and a lower common electrode 121 which apply a voltage to this piezoelectric element 113 thereby to give mechanical displacement (contraction and expansion) to this piezoelectric element 113, are formed; and a vibration plate 122 is formed between the common electrode 121 and the pressure chamber plate 112.

The piezoelectric element 113 is subjected to displacement by the piezoelectric effect due to the voltage applied to the common electrode 121 and the individual electrode 120 corresponding to the pressure chamber 111, and the vibration

plate 122 that vibrates following this displacement changes the volume of the pressure chamber 111, so that the ink liquid in the pressure chamber 111 is ejected from the nozzle hole 116.

In this embodiment, the common electrode 121 and the vibration plate 122 are formed separately. However, they may be formed integrally.

In the ink jet head, with the above structure as one unit, the units of the same structure are periodically arranged in the vertical direction to a paper surface of Fig. 2. In result, ink can be ejected from the many nozzle holes 116. The common liquid chamber is common to each unit, and the ink of the same color is ejected from the many nozzles. Since it is necessary to eject ink of four colors in order to perform color printing, at least four common liquid chambers are necessary. Usually, in the ink jet head, the nozzle holes 116 for ejecting ink of one color are linearly arranged on the nozzle plate 119 at equal intervals. In order to eject the ink of four colors from the ink jet head, at least four nozzle arrays for ejecting ink of each color are arranged. As forming methods of the individual electrode 120, the piezoelectric element 113, the common electrode 121, and the vibration plate 122, the known various film forming methods are appropriately adopted, for example, a thick film forming method such as screen printing, a coating method such as dipping, sputtering, a CVD method, a vacuum evaporation method, a sol-gel processing, and a thin film

forming method such as plating. However, the forming methods are not limited to their methods.

As shown in Fig. 3, in the ink jet recording apparatus 140, there is provided a dew point control unit 123 which keeps
5 a dew point in an atmosphere of the piezoelectric element 113 and the vicinity of the piezoelectric element 113 at a lower value than a dew point in an environment where the ink jet recording apparatus 140 is set.

The dew point control unit 123, by introducing gas of a
10 low humidity (for example, dew point -60°C), for example, dry air, nitrogen gas, or argon gas to the piezoelectric element 113 and in the vicinity of the piezoelectric element 113, lowers the dew point. Namely, the dew point control unit 123 passes the gas from a compressor 123a to an air drier 123b thereby to
15 remove moisture, and supplies this gas from an inlet 124a of a case 124 to the piezoelectric element 113 and the vicinity of the piezoelectric element 113. The dry gas introduced into the case 124 is discharged from an outlet 124b formed in the case 124 to the outside. However, without providing the case
20 124, the dry gas may be blown to the piezoelectric element 113.

Further, as the air drier 123b, a freeze type air drier which lowers the temperature thereby to remove the moisture in the gas; a filter type air drier which lets the gas pass through a filter thereby to remove the moisture in the gas; and
25 absorption type air drier which lets the gas pass through

absorbent such as silica gel thereby to remove the moisture in the gas can be used.

Further, as the dew point control unit, as shown in Fig. 4, a gas cylinder 123 into which dry gas is sealed may be used to supply the dry gas in the cylinder.

Further, as the dew point control unit for supplying the dry gas, using piping of dry gas installed in a building as a plant, the dry gas can be also supplied.

More, specifically, as shown in Fig. 5, the case 124 can be attached to a head base 131 to which the ink jet head 141 has been attached thereby to supply the dry gas. Inlet 124a and outlet 124b are formed on the same plane.

Further, in case that there are the many ink jet heads, as shown in Fig. 6, plural head bases 131 for fixing the respective ink jet heads may be arranged and fixed to a frame 132, and the case 124 may be attached to this frame 132, thereby to supply the dry air.

The inventor, in order to seize characteristics of the piezoelectric element 113 in a dry atmosphere, has manufactured a sample element having the following structure and evaluated it.

Namely, on a silicon substrate having a diameter of 3 inch and a thickness of 0.5 mm, platinum of 100 nm has been evaporated as the lower electrode by sputtering, sequentially $\text{PbZr}_{0.5}\text{Ti}_{0.5}\text{O}_3$ (hereinafter referred to as "PZT") of 3 μm has been evaporated

as the piezoelectric element, and sequentially platinum of 100 nm has been evaporated as the upper electrode. Thereafter, the silicon substrate has been cut into 20 mm by 20 mm, and platinum of the area of 5 mm by 7.5 mm has been evaporated on the PZT by use of a metal mask.

Further, as the air drier, a super drier unit SU3015B7 by CKD Company has been used. This air drier comprises an air filter for removing dust in air, an oil mist filter for removing an oil component in air, a drier body for removing moisture in air, and a regulator for regulating pressure. The drier body is composed of many hollow fibers made of special resin, and the compressed air passes through this hollow fiber. The resin constituting the hollow fiber has such a property that only moisture is caused to selectively pass through the outside of the hollow fiber, and air including the moisture passes through the hollow fiber, whereby the moisture in air is removed. In the embodiment, in order to generate dry air, compression air of about 0.5 Mpa is introduced from the air filter side by the compressor 23a. The introduced compression air passes through the air filter and the oil mist filter, whereby the dust and the oil component are removed. Further, the compression air passes through the drier body, whereby the moisture is removed, and the dry air comes out from the outlet.

As an evaluation system, the aforementioned sample has been set in an acrylic-made case having a size of 40 mm by 40 mm

by 50 mm so that a voltage can be applied between the upper electrode and the lower electrode. Further, this system is constituted so that the dry air generated by the air drier 123b can be introduced into the case. To the air drier 123b, the
· 5 compression air of 0.5Mpa has been introduced by use of the compressor 123a, and a flow regulating valve has been regulated so as to introduce the dry air into the case at flow rate of 2L/min. A dew point in the case when the dry air has been introduced has been -50°C. The case has been set in a constant
10 humidity and temperature bath.

The reason why an introduction speed of the dry air is set to 2L/min is as follows. Namely, in the embodiment, the generation of the dry air uses the dry air system, and the air including the moisture passes through the hollow fiber in the
15 dry air system thereby to remove the moisture and generate the dry air. Since the amount of moisture that can be removed by the hollow fiber per time is limited, in case that the introduction flow rate is over the predetermined level, dry degree of the dry air lowers and the dew point increases. In
20 the dry air system of this embodiment, in case that the introduction flow rate is in a range of 2 to 10L/min, the dew point becomes -50°C; and in case that the flow rate is over this value, the dew point increases. Therefore, the dry air is caused to flow at the flow rate of 2L/min. Since the maximum
25 flow rate by which the dry air can flow is determined by

specification of the system, the introduction speed is not limited to 2L/min but the dry air may be introduced at the flow rate by which the dew point of the generated dry air becomes -50°C. Further, from the experiments by the inventor, it has
5 been proved that when the flow rate of the dry air introduced into the case is 10 mL/min or more per volume of one cubic cm, the dew point in the case 124 is kept at -50°C or less.

Further, the pressure inside the case 124 when the dry air has been introduced is generally higher than the outside
10 air pressure, which is one air pressure or more. However, according to an altitude of a place where the apparatus is used and weather, the pressure inside the case can become lower than the outside air pressure.

Further, in case that the inside of the case 124 is sealed,
15 the internal pressure increases by the introduced dry air, and the moisture attached onto the actuator cannot be exhausted to the outside of the case 124. Therefore, it is necessary to provide an outlet 124b for the case 124 like this embodiment.

Next, evaluation items of the sample will be described.

20 A first evaluation item is a characteristic evaluation of PZT under an atmosphere where the temperature is 60°C and the humidity is 80%. The temperature and the humidity in the constant temperature and humidity bath have been set at 60°C and 80%. In a state where the dry air is introduced into the
25 case, direct current of 35V has been applied for sixteen hours

between the upper electrode of the sample and the lower electrode so that polarity of the lower electrode becomes positive, and thereafter, a surface of the sample has been observed with a microscope. Next, using the same sample, in
5 a state where the dry air is not introduced, the direct current of 35V has been applied for three hours, and thereafter, the surface of the sample has been observed with the microscope.

A second evaluation item is a characteristic evaluation of PZT under an atmosphere where the temperature is 25°C and
10 the humidity is 50%. The temperature and the humidity in the constant temperature and humidity bath have been set at 25°C and 50%. In a state where the dry air is introduced into the case, the direct current of 35V has been applied for 150 hours between the upper electrode of the sample and the lower
15 electrode so that polarity of the lower electrode becomes positive, and thereafter, the surface of the sample has been observed with a microscope. Next, using the same sample, in a state where the dry air is not introduced, the direct current of 35V has been applied for one hour, and thereafter, the surface
20 of the sample has been observed with the microscope.

Results on the above evaluation items will be described.

Regarding the first evaluation item, a microscopic photograph after the test is shown in Fig. 7. After the voltage has been applied in the state where the dry air is introduced,
25 a remarkable change has been observed in the sample (Fig. 7A).

On the other hand, in case that the dry air is not introduced, a large number of black spots have been observed in the sample surface (Fig. 7B). This black spot is a portion in which the upper electrode and the lower electrode have melted. The reason why the electrode melts is thought as follows. Namely, it is surmised that when the voltage is applied to the PZT under the environment of a high humidity, leak current flows in defects existing in the PZT and Joule heat generates, and the electrode melts by this heat.

Regarding the second evaluation item, as shown in Fig. 8, in case that the dry air has been introduced, even after the voltage has been applied for 150 hours, the black spots have not been produced. On the other hand, in case that the dry air is not introduced, six black spots has been produced by the voltage application for one hour.

As described above, by introduction of the dry air, even in case that the voltage has been applied to the PZT, any break has not occurred. Further, it is surmised that: a reason why the number of the black spots in the first evaluation item is larger than that in the second evaluation item is that since the temperature of air in the constant temperature bath in the first evaluation item is higher, the absolute amount of the included moisture is larger than that in the second evaluation item, so that the break of the PZT has advanced more.

Next, similarly to the case of the second evaluation item,

PZT incorporated into an ink jet head has been evaluated (refer to Fig. 2). In this ink jet head, two hundreds pressure chambers and the corresponding actuators made of PZT are formed.

5 Figs. 10A to 10C are explanatory diagrams of the ink jet head used in the evaluation, in which the sectional view of Fig. 2 is shown more detailedly. Fig. 10A is an explanatory view of the nozzle hole 116 and its vicinity. The nozzle hole 116 communicates with the pressure chamber 111, and the vibration plate 122 and the PZT that is the piezoelectric element 113 are
10 formed above the pressure chamber 111. In this figure, the common electrode and the individual electrode between which the piezoelectric element is put are omitted. The pressure chamber is filled with ink, and the ink is supplied from the common liquid chamber 114 through the ink flow inlet 115. When the voltage
15 is applied to the piezoelectric element 113, the piezoelectric element 113 and the vibration plate 122 bend, and the pressure in the pressure chamber 11 increases, so that the ink is ejected from the nozzle 116. Further, a surface of the nozzle plate 119 is subjected to water repellent treatment so that the ink
20 can be ejected from the nozzle hole 116 in the fixed direction.

The piezoelectric element 113 is basically the same as the PZT used in the first and second evaluations, and it is 3 μm in thickness and 100 μm by 1200 μm in area. The vibration plate 122 is 3 μm in thickness.

25 Fig. 10B is an explanatory view which shows a section

taken along a dotted line of Fig. 10A. Herein, though only the structure in the vicinity of about two nozzle holes 116 is shown, actually, many portions having the same structure as the structure shown in Fig. 10B are arranged in a row. The figure shows a state in which the left piezoelectric element 113 and vibration plate 122 bend and the ink is ejected from the nozzle hole 116. As known from the figure, one pressure chamber 111 and one piezoelectric element 113 are assigned to each nozzle hole 116. However, the common liquid chamber 114 which supplies the ink is common to the many nozzle holes 116, and the ink is supplied from the common liquid chamber 114 through the ink flow inlet 115 provided for each pressure chamber 111 (in the figure, the ink flow inlet 115 on the left pressure chamber 111 is covered with a wall partitioning the two pressure chambers 111 and cannot be seen.

Fig. 10C is an explanatory diagram, viewed from the upper portion of the nozzle plate 119. In this example, there are two nozzle arrays up and down, each of which comprises forty nozzle holes 116 arranged right and left at an interval of 340 μm . In the figure, a broken line surrounding each nozzle hole 116 represents the piezoelectric element 113 on the opposite side of the nozzle plate 119, and a nearly rectangular broken line represents the common liquid chamber 114. Since the ink is supplied from one common liquid chamber 114 to the forty nozzle holes 116 arranged right and left, the ink of the same

color is ejected from the forty nozzle holes 116 arranged right and left. In the embodiment, an ink jet head having two hundreds nozzle holes 116 is used. Therefore, there are five arrays of the nozzle holes 116 in total.

5 The ink jet head has been set in an acryl-made case so that the dry air generated by the air drier can be introduced into this case, and the case has been set in a constant temperature and humidity bath in which the temperature is 25°C and the humidity is 50 %. In the state where the dry air is
10 introduced, the voltage has been applied so that the polarity of the common electrode becomes positive and that of the individual electrode becomes negative. Further, also in the state where the dry air is not introduced, the voltage has been similarly applied. An evaluation result is shown in Fig. 9.
15 In case that the dry air has been introduced, even after the voltage has been applied for 200 hours or more, the black spots have not been produced at all. On the other hand, in case that the dry air is not introduced, sixty or more black spots have been produced in fifty hours in the PZT that is the actuator.

20 As described above, also in the PZT used for the actuator, by introducing the dry gas such as dry air, any break does not occur in the PZT at all even in case that the voltage is applied.

 In the embodiment, since the piezoelectric element is manufactured by sputtering, a thin piezoelectric element that
25 is good in crystal orientation can be obtained with good

reproducibility. Therefore, also in case that the voltage applied to the piezoelectric element is small, the great displacement yields. Therefore, the ink can be ejected at a low voltage, so that consumed power of the printer can be reduced.

5 Further, though the area of the used piezoelectric element is 100 μm by 1200 μm , the area can be reduced up to about 3 μm that is the film thickness of the piezoelectric element. As the area of the piezoelectric element is reduced, the in-plane density of the nozzle can be more improved, so that exacter printing
10 can be performed.

As described above, according to this embodiment, since the dew point in the vicinity of the piezoelectric element is lowered by the dry gas, it is prevented that the piezoelectric element deteriorates due to the voltage application. Hereby,
15 achieving reduction of the film thickness of the piezoelectric element, it is possible to readily prevent the element break due to the voltage application to this piezoelectric element.

In the above description, the direct voltage of 35V has been applied to the piezoelectric element to examine its
20 characteristics. However, generally, it is not necessary to apply such the high voltage in order to eject the ink, and the voltage of a rectangular waveform is applied. Also in this voltage applied state, by introducing the dry gas, the deterioration of the piezoelectric element can be prevented,
25 needless to say.

Further, in this embodiment, the PZT is used as the piezoelectric element. However, the invention is not limited to this, but another piezoelectric element including lead may be used because the similar effect can be obtained. Further, though the piezoelectric element is formed by sputtering in this embodiment, the invention is not limited to this, but a piezoelectric element manufactured by sintering or sol-gel processing may be used because the similar effect can be obtained.

As described above, according to the invention, since the dew point in the vicinity of the piezoelectric element is lowered by the dry gas, it is prevented that the piezoelectric element deteriorates due to the voltage application. Hereby, such an effective advantage can be obtained that it is possible to readily prevent the element break due to the voltage application to this piezoelectric element, achieving reduction of the film thickness of the piezoelectric element.

(Second Embodiment)

Embodiments of the invention will be described below with reference to Figs. 11 to 23. In these drawings, the same members are denoted by the same reference numerals, and the overlapping description is omitted.

An ink jet recording apparatus 240 shown in Fig. 11 has an ink jet head 241 which performs recording by use of a

piezoelectric effect of a dielectric thin film element and expansion power of air bubble, and impacts ink droplets ejected from this ink jet head 241 onto a recording medium 242 such as paper thereby to perform recording on the recording medium 242.

5 In case that the line head is constituted by combination of the plural nozzle heads, by characteristic unevenness between the nozzle heads and accuracy of alignment onto the nozzle head holding frame, a streak appears in printing at a joint between the nozzle heads, so that printing quality lowers.

10 Further, in case that the line head is constituted by combination of the plural nozzle heads, it is necessary to align the nozzle heads with a high accuracy. However, depending on accuracy of components, it is difficult to yield alignment accuracy.

15 In the ink jet recording apparatus 240 of this embodiment, which can perform color printing, on the ink jet head 241, a line head 243 having an ink head from which yellow ink is ejected, an ink head from which magenta ink is ejected, an ink head from which cyan ink is ejected, and an ink head from which black ink

20 is ejected is mounted; and plural nozzle holes are arranged in each ink head throughout the entire width of the recording medium 42.

 The ink jet recording apparatus 240 has plural rollers (moving means) 245 which move the recording medium 242 in a

25 transporting direction that is almost perpendicular to a width

direction of the ink jet head 241.

Though the color ink jet recording apparatus 240 is shown in this embodiment, the invention can be also applied to a monochromatic ink jet recording apparatus in which printing of
5 only one color can be performed.

As shown in Fig. 12, the line head 243 includes a holding frame 246 and plural nozzle heads 247 arranged and fixed on this holding frame 246. In each nozzle head 247, plural nozzle holes (refer to Fig. 13 and below) 247a from which ink is ejected are
10 formed. The plural nozzle heads 247 are arranged on the holding frame 246, whereby the nozzle holes 247a are arranged through the entire width of the recording medium 242.

In the ink jet head 241, plural pressure chambers in which ink liquid is filled are formed. By deforming the pressure
15 chamber by an energy generating source such as a piezoelectric element or air bubbles, the ink is ejected from the nozzle hole 247a communicating with the pressure chamber.

Here, in order to achieve simultaneously size-reduction of the nozzle head 247 and improvement of printing resolution,
20 it is important to arrange the nozzle holes 247a on the nozzle surface efficiently. In this embodiment, the nozzle holes 247a of the nozzle head are arranged at a high density as follows.

Namely, as shown in Fig. 13, in the nozzle head, plural nozzle arrays (two arrays in the embodiment) each of which
25 comprises the plural nozzle holes 247a are arranged slantingly

in the main scanning direction. The nozzle holes are arranged so that the distance between the nozzles between the adjacent nozzle arrays is not the same. Namely, the nozzle holes are arranged not with complete cross-stitch arrangement in which
5 the distance between the adjacent nozzle arrays is equal but with cross-stitch arrangement in which the distance is different.

More specifically, in Fig. 14, a distance L1 between a first arbitrary nozzle hole 247a-1 and a second nozzle hole
10 247a-2, in a nozzle array A adjacent to the array to which this first nozzle hole 247a-1 belongs, that is, the nozzle array B, which is adjacent to the first nozzle hole 247a-1, and a distance L2 between the first nozzle hole 247a-1 and a third nozzle hole 247a-3 in the nozzle array A to which the second nozzle hole
15 247a-2 belongs, which is further adjacent to the first nozzle hole 247a-1, are different from each other.

According to such the arrangement, as shown in Fig. 13, the nozzle head is scanned in the main scanning direction with a nozzle width W1 narrower than a nozzle width W2 in the
20 sub-scanning direction, and the nozzles can be arranged in plural array arrangement with good space efficiency. Therefore, the improvement of printing resolution can be achieved, miniaturizing the nozzle head 247. Further, compared with a case where only one nozzle array is formed in
25 the nozzle head, the distance to the nozzle end, which becomes

a retreat region of a purge cap (not shown) and a mounting part can be used in common by the plural nozzle arrays.

Fig. 15 is a perspective view of the ink-jet head 241 to which the line head 243 shown in Fig. 12 is assembled. Figs. 16 and 17 are a front view and a side view of Fig. 15. As shown in Fig. 12 and Figs. 15 to 17, the nozzle head 247 is projected about 4mm from a surface of the holding frame 246. Excessive ink attached to a bottom face of the nozzle head 247 is removed by a cleaning blade 250 made of rubber, which is moved in a sub-scanning direction at a predetermined timing. Reason of why the nozzle head 247 is projected about 4mm is as follow. When projection is too less, in case of that ink is collected at both end of the cleaning blade 250, the excessive ink may be touch with a surface of the holding frame 246. Contrary, when projection is too much, the cleaning blade 250 may be damaged by a corner of the nozzle head 247. It is not necessary to limit to the 4mm projection if these two problems can be solved.

The excessive ink removed by the cleaning blade 250 is collected to a blade holding portion 252 by its gravity. The blade holding portion 252 is slidably held by the shafts 254 and 256, and is driven by not-illustrated motor in the sub-scanning direction.

According to the embodiment, because the nozzle head 247 is projected from a surface of the holding frame 246, even if

the ink is collected at both ends of the cleaning blade 250 when the cleaning blade 250 squeegee the excessive ink attached with bottom face of the nozzle head 247, the excessive ink will not touch the surface of the holding frame 246. Thus, the printing
5 degrade due to the ink adhered to the surface of the holding frame 246 is adhered to the printing media 242 can be prevented.

(Example 2)

Here, in order to arrange the nozzle holes 247a with better space efficiency and prevent occurrence of the aforesaid
10 warp of the nozzle plate, as shown in Fig. 18, the nozzle arrays of even numbers which are four and more are formed so that a distance between a set of nozzle arrays adjacent to each other becomes close, that is, so that the nozzle arrays come close
15 to each other two by two. For example, as shown in Fig. 18, in case that there are the four nozzle arrays of A to D, they are arranged so that the distance between the A array and the B array or the distance between the C array and the D array is closer than the distance between the B array and the C array.

(Example 3)

20 Further, there is another arrangement as shown in Fig. 19. Namely, a distance L1a between a first arbitrary nozzle hole 247a-1 formed in the nozzle array C and a second nozzle hole 247a-2 in the nozzle array B that is one of arrays adjacent to the nozzle array to which this first nozzle hole 247a-1
25 belongs, that is, the nozzle array C, which is adjacent to the

first nozzle hole 247a-1, and a distance L2a between the first
nozzle hole 247a-1 and a third nozzle hole 247a-3 in the nozzle
array B to which the second nozzle hole 247a-2 belongs, which
is further adjacent to the first nozzle hole 247a-1 are
5 different from each other. Further, a distance L1b between a
fourth arbitrary nozzle hole 247a-4 formed in the nozzle array
C and a fifth nozzle hole 247a-5, in the nozzle array D that
is the other of arrays adjacent to the nozzle array to which
this fourth nozzle hole 247a-4 belongs, that is, the nozzle
10 array C, which is adjacent to the fourth nozzle hole 247a-4,
and a distance L2b between the fourth nozzle hole 247a-4 and
a sixth nozzle hole 247a-6, in the nozzle array D to which the
fifth nozzle hole 247a-5 belongs, which is further adjacent to
the fourth nozzle hole 247a-4 are different from each other.

15 Hereby, the nozzle holes 247a are formed densely in the
narrow region on the nozzle surface, so that the space
efficiency can be more improved. Further, since the area of
a region where the nozzle holes are not formed becomes large,
rigidity of the nozzle plate improves and the occurrence of warp
20 is prevented.

(Example 4)

Supporting that the number of nozzle arrays is plural,
for example, four, in case that the nozzle arrays are arranged
in order of A+B, and C+D in the sub-scanning direction, there
25 can be a problem of a joint between the arrays A+B and the arrays

C+D. Namely, due to working accuracy of the nozzle plate and attachment shift (rotation shift) of the head, a gap can be produced in the main scanning direction between a printing region by the nozzles in the arrays A+B and a printing region by the nozzles in the arrays C+D. Further, generally, in one nozzle array, abnormality (bad ejection of ink) is easy to be produced in the nozzle hole 247a located at the end because dust and an air bubble drift and attach to its nozzle hole 247a.

Therefore, as shown in Fig. 20, the nozzle holes are arranged so that the nozzle holes 247a located at one end of the nozzle arrays (here, A array and B array) overlap with the nozzle holes 247a located at the other end of the other arrays (here, C array and D array) in the sub-scanning direction.

By such the arrangement, since the same line can be printed with ink ejected from the plural nozzle holes 247a, pseudo-scanning of plural times is performed, so that a portion where the joint readily appears can be made inconspicuous, and the nozzle hole 247a from which the ink has not been already ejected can be recovered.

Herein, though the nozzle holes are arranged so that the nozzle hole 247a located at one end of the nozzle array overlaps with the nozzle hole 247a located at the other end of the other array in a sub-scanning direction, the nozzle holes 247a located at the both ends may be arranged thus. Further, the nozzle holes may be arranged so that not only the nozzle hole 247a located

at the end but also a part or all of the nozzle holes 247a other than its nozzle hole overlaps with the nozzle hole 247a in another array in the sub-scanning direction.

In case that the nozzle holes 247a are thus arranged, the
5 ink ejection in the sub-scanning direction may be performed alternately or irregularly from the nozzle holes 247a overlapping to each other in the sub-scanning direction. Hereby, since the same line or lines in the vicinity of its line can be printed with the ink ejected from the plural nozzle holes,
10 the portion where the joint readily appears can be made inconspicuous, and the nozzle hole 247a from which the ink has not been already ejected can be recovered.

Here, as described before, in the edge shoot type in which only one nozzle array is formed per a nozzle head, usually, the
15 nozzle holes 247a cannot be arranged at a high density, so that the space efficiency is not good. Therefore, in a case that the above-described plural nozzle heads are arranged and fixed on the holding frame so that the nozzle arrays tilt in the main scanning direction thereby to manufacture a line head, the
20 resolution in the sub-scanning direction that is particularly important for the line head can be readily increased.

(Example 5)

In case that the line head comprises the plural nozzle heads, supporting that the number of nozzle arrays is, for
25 example, four, in case that C+D nozzle arrays in one nozzle head

and next A+B nozzle arrays in a nozzle head adjacent to its nozzle head are arranged, there can be a problem of a joint between the arrays C+D and the arrays A+B. Namely, due to working accuracy of the nozzle plate and attachment shift (rotation shift) of the head, a gap can be produced in the main scanning direction between a printing region by the nozzles in the arrays C+D and a printing region by the nozzles in the arrays A+B. Further, as described before, generally, in one nozzle array, the abnormality (bad ejection of ink) is easy to be produced in the nozzle hole 247a located at the end because dust and an air bubble drift and attach to the nozzle hole 247a.

Therefore, as shown in Fig. 21, the nozzle holes are arranged so that the nozzle holes 247a located at one end of the nozzle arrays (here, C array and D array) of one nozzle head 247 overlap with the nozzle holes 247a located at the other end of the nozzle arrays (here, A array and B array) of a nozzle head adjacent to this nozzle head 247 in the sub-scanning direction.

By such the arrangement, since the same line can be printed with ink ejected from the plural nozzle holes 247a, pseudo-scanning of plural times is performed, so that the portion where the joint between the nozzle heads readily appears can be made inconspicuous, and the nozzle hole 247a from which the ink has not been already ejected can be recovered.

Herein, though the nozzle holes are arranged so that the

nozzle hole 247a located at one end of the nozzle array of one nozzle head 247 overlaps with the nozzle hole 247a located at the end of the nozzle array of another nozzle head in the sub-scanning direction, the nozzle holes 247a located at the both ends may be arranged thus. Further, the nozzle holes may be arranged so that not only the nozzle hole 247a located at the end but also a part or all of the nozzle holes 247a other than its nozzle hole overlaps with the nozzle hole 247a of another array in the sub-scanning direction.

Here, in case that accuracy of the nozzle head 247 is not good when the nozzle heads 247 adjacent to each other are attached closely, the position of the nozzle hole 247a is different, so that alignment accuracy does not appear. Therefore, as shown in Fig. 22, in case that a gap is provided between the adjacent nozzle heads 247, fine adjustment of the head position of the nozzle head 247 is possible, so that a line head in which the nozzle heads 247 are aligned with a high accuracy can be obtained.

Due to scattering of ink in printing, or purge or blade operation, the ink enters in the gap between the nozzle heads 247, so that the gap between the heads can be covered with a film, that is, the gap can be bridged by the film. In case that the amount of this ink increases, a large ink droplet drops on the recording medium and the recording medium can be stained with this ink droplet.

Therefore, as shown in Fig. 23, by forming the gap by the nozzle heads 247 so that its width becomes narrower from one side to the other side, the ink in the gap gathers and ink removal becomes easy, so that it is prevented that the ink that has entered in the gap between the nozzle heads 247 drops on the recording medium.

(Third Embodiment)

Embodiments of the invention will be described below with reference to Figs. 24 to 36. In these drawings, the same members are denoted by the same reference numerals, and the overlapping description is omitted.

An ink jet recording apparatus 340 shown in Fig. 24 has an ink jet head 341 which performs recording by use of a piezoelectric effect of a dielectric thin film element and expansion power of air bubble, and impacts ink droplets ejected from this ink jet head 341 onto a recording medium 342 such as paper thereby to perform recording on the recording medium 342.

In the ink jet recording apparatus 340 of this embodiment, which can perform color printing, on the ink jet head 341, a line head 343 having an ink head from which yellow ink is ejected, an ink head from which magenta ink is ejected, an ink head from which cyan ink is ejected, and an ink head from which black ink is ejected is mounted; and plural nozzle holes are arranged in each ink head throughout the entire width of the recording

medium 342.

The ink jet recording apparatus 340 has plural rollers (moving means) 345 which move the recording medium 342 in a transporting direction that is almost perpendicular to a width direction of the ink jet head 341.

Though the color ink jet recording apparatus 340 is shown in this embodiment, the invention can be also applied to a monochromatic ink jet recording apparatus in which printing of only one color can be performed.

As shown in Fig. 25, the line head 343 includes a holding frame 346 and plural nozzle heads 347 arranged and fixed on this holding frame 346. In each nozzle head 347, plural nozzle holes (not shown) from which ink is ejected are formed. Such the plural nozzle heads are arranged on the holding frame 346, whereby the nozzle holes are arranged through the entire width of the recording medium 342.

In this embodiment, the plural nozzle heads 347 are aligned with a high accuracy by the following method and fixed onto the holding frame 346, whereby the ink ejecting direction is made uniform among the nozzle heads 347 and high quality printing is made possible.

Namely, in Figs. 25 and 26, the holding frame 346 is held at its both sides by a frame holding unit 348, and a positional relation between them is fixed. By this frame holding unit 348, a transparent plate 350 on which an alignment mark 350a is formed

is held along the holding frame 360.

The nozzle head 347 in which many nozzle holes 347a are provided is held by a head holding unit 349 which can move this nozzle head 347 in a horizontal direction and in a vertical
5 direction. The plate 350 and the nozzle head 347 are opposed to each other to observe the nozzle head 347 through the transparent plate 350 by a camera means 351, and registration is performed between the alignment mark 350a of the plate 350 and the predetermined position (for example, nozzle hole 347a
10 or nozzle mark 347b formed for alignment) of the nozzle head 347 on the basis of the alignment mark 350a, whereby alignment of the nozzle heads 347 is performed. After the alignment, the nozzle head 347s are fixed onto the holding frame 346.

In Fig. 25, though the nozzle head 347 is fixed onto the
15 holding frame 346 slantingly, it may be fixed in parallel.

Here, as an example of the marks, shapes of a nozzle mark of the nozzle head 347 and shapes of the alignment mark 350a of the plate 350 are shown in Fig. 27. As shown in Fig. 27, the nozzle mark and the alignment mark 350a overlap each other.
20 The shown shapes are one example, and the invention is not limited to these shapes. In Fig. 27, though the mark of the plate 350 is larger than the mark of the nozzle head 347, they may have the same size or the mark of the nozzle head 347 may be larger.

25 By performing such the alignment in order, the plural

nozzle heads 347 can be aligned easily and with a high accuracy.

It is preferable that the plate 350 is made of not resin such as plastics but glass. Namely, a material used as the plate 350 must be able to be used as gauge, that is, it must be small
5 in expansion coefficient in relation to the temperature. The glass meets this condition. Further, since the glass itself having high smoothness is not a special material but cheap, the cost does not increase.

There is a case in which the many alignment marks 350a
10 are required on the transparent plate 350. Though the alignment mark 350a may be formed by any work on the plate 350, this formation is difficult in accuracy and man-hour in order to form the many marks freely. In such the case, the alignment mark 50a is formed by sputtering of chromium (Cr), whereby the many
15 alignment marks 350a can be readily formed because they can be formed by a usual method using a photo mask. Further, since accuracy of the photo mask is so accurate that position accuracy of the mark on the glass having the large area of 500 mm by 500 mm is $\pm 2 \mu\text{m}$, the alignment mark 50a can be formed at a low cost
20 and with a good accuracy.

Further, as shown in Fig. 26, it is desirable that the alignment mark 350a is formed on an opposed surface of the plate 350 to the nozzle head 347. This reason is that: since index of refraction of the plate 350 is not 1, in case that the
25 alignment mark 350a exists on the opposite side to the surface

opposed to the nozzle head 347, the alignment mark 350a is directly seen and the nozzle head 347 is seen through the plate 350, so that deviation is produced. On the other hand, in case that the alignment mark 350a exists on the surface opposed to
5 the nozzle head 347, both the alignment mark 350a and the nozzle head 347 are seen through the plate 350. Therefore, an influence by index of refraction of the plate 350 is small, and the distance between the alignment mark 350a and the nozzle head 347 becomes short, so that the alignment accuracy can be
10 improved.

Here, it is good that at least two, that is, plural alignment marks 350a are formed on one nozzle head 347. This reason is that: in case that the registration is performed by only one alignment mark 350a, there is fear of generation of
15 rotational deviation, but in case that the alignment is performed by the plural alignment marks 350a, as shown in Fig. 28, the registration can be readily performed with the high accuracy.

Further, it is good that the registration is performed
20 by the nozzle hole 347a of the nozzle head 347 and the alignment mark 350a. As a mark to be formed on the nozzle head 347 itself, a mark obtained by any previous work on the nozzle head 347 may be used. However, accuracy in the positional relation between its worked part and the nozzle hole 347a is not always insured.
25 Further, though it is thought that the registration is performed

at an edge portion of the nozzle head 347, accuracy in the positional relation between the edge part and the nozzle hole 347a is not also always insured. On the other hand, in case that the alignment is performed by the nozzle hole 347a and the alignment mark 350a, even if the nozzle hole 347a formed in the nozzle head 347 shifts from its natural position as shown in Fig. 29, the alignment can be performed in a correct nozzle position, so that an ink droplet can be impacted onto a correct position.

10 Here, it is good that the registration between the plate 350 and the nozzle head 347 is performed in the center of the plural alignment marks 350a. Since the nozzle hole 347a requires a complicated taper shape, the positional accuracy when the nozzle hole 347a is worked is inevitably inferior to
15 that of the alignment mark 350a having a high accuracy. Hereby, a work of performing registration between members that do not completely coincide with each other in their position is required. Further, in case that the position of only one alignment mark 350a is coincided with that of the nozzle hole
20 347a, the registration error between the other alignment mark 350a and the nozzle hole 347a of the next nozzle head 347 is readily produced. On the other hand, in case that the registration between the plate 350 and the nozzle head 347 is performed in the center of the plural alignment marks 350a, as
25 shown in Fig. 30, the deviation between the alignment mark 350a

and the nozzle hole 347a is dispersed in two directions, so that deviation of impact in printing becomes inconspicuous.

It is desirable that the registration is performed between the nozzle holes 347a located at both ends of the nozzle head 347 and the alignment marks 350a. In case that the alignment is performed at the adjacent plural nozzle holes 347a, even if the deviation amount in relation the alignment mark 350a is the same, the whole deviation amount becomes large. However, in case that the registration is performed at the nozzle holes 347a located at the both ends as shown in Fig. 31, since the alignment marks 350a are distant from each other, the alignment accuracy becomes good. Further, since the alignment accuracy becomes good at end-pin parts, streaks between the adjacent nozzle heads become inconspicuous.

Further, the registration may be performed by an alignment mark 350a and a nozzle mark 347b formed on the nozzle head 347 in the same process as the nozzle hole 347a. Namely, before the alignment process, in case that a filling examination and an ejection examination of ink liquid are performed in the nozzle head 347 single, a leading end of the nozzle hole 347a may get wet with the ink in the alignment, and a nozzle edge may become dim. In this case, using not the nozzle hole 347a used for ink ejection but a dummy nozzle hole worked in the same process as the nozzle hole 347a, that is, the nozzle mark 347b, as shown in Fig. 32, the alignment is performed. Hereby, since

the nozzle mark 347b is formed in the same process as the nozzle hole 347a, the shape accuracy and the position accuracy are the same as those in the nozzle hole 347a. Therefore, the alignment of the high accuracy can be performed. In addition, since the
5 nozzle mark 347b is not wetting with the ink, the nozzle edge is clear, so that the alignment is easy to be performed. Even if the nozzle mark 347b gets wet, since it is not used for the ink ejection, the ink can be wiped to solve the wet.

Further, the registration may be performed by an
10 alignment mark 350a and a nozzle mark 347b formed on a line connecting two nozzle holes 347a located at both ends of the nozzle head 347. Hereby, the alignment can be performed with the same accuracy as the accuracy in a case that the registration is performed at the nozzle holes 347a located at the endmost,
15 or with higher accuracy in case that the distance between the nozzle marks 347b is farther than the distance between the nozzle holes 347a located at the endmost. Such the registration is particularly effective when the nozzle head 347 is arranged on the holding frame 46 slantingly. Here, the two nozzle holes
20 347a located at the both ends of the nozzle head 347 may be, as shown in Fig. 33, two nozzle holes 347a located at the both ends in one nozzle array; or, as shown in Fig. 34, two nozzle holes 347a located at ends different from each other in two adjacent or most distant nozzle arrays.

25 Even if the alignment is thus performed, in case that work

accuracy of the nozzle head 347 is bad or the thickness of an adhesive when the nozzle plate is bonded is not uniform, the nozzle surfaces of the plural nozzle heads 347 are different in plane from each other. Namely, in case that deviation is
5 produced in a Z-direction, the distance between the nozzle surface and the recording medium 342 is different in each nozzle head 347, or its distance has an inclination in the Z-direction, so that an impact position of the ink droplet is different in each nozzle head 347, and high quality printing is impossible.

10 In such the case, as shown in Fig. 35, a spacer 352 may be arranged between the holding frame 346 and the nozzle head 347 to hold the nozzle surfaces of the plural nozzle heads 347 on the same plane. Hereby, surface accuracy of the nozzle surfaces of the plural nozzle heads 347 can be readily secured.

15 In order to adjust the nozzle heads 347 so that the nozzle surfaces of the plural nozzle heads 347 are located on the same plane, as shown in Fig. 36, the nozzle heads 347 are closely attached onto the plate 350, whereby, this adjustment can be readily performed.

20

(Fourth Embodiment)

An ink jet head unit used in a conventional ink jet recording apparatus will be described.

Fig. 41 is a perspective view showing a conventional ink
25 jet head unit, and Fig. 42 is a front view showing a head and

a flat cable in the ink jet head unit of Fig. 41.

As shown in Figs. 41 and 42, the conventional ink jet head unit includes a head 20 from which ink is ejected, a head base 21 on which this head 20 is mounted, and two flat cables 22a, 22b which are attached to the head 20 and pulled out from the head 20 in two different directions. In midway positions of the flat cables 22a, 22b, drives 23a, 23b that generate ink ejection signals for driving the head 20 are respectively provided. To the drivers 23a, 23b, heat radiating plates 24a, 24b for efficiently radiating heat generated during operation are attached. In the head 20, two nozzle arrays 20a, 20b of which each comprises many nozzle holes are formed, and ink is ejected from these nozzle holes.

In such the ink jet head unit, conventionally, mounted parts 25a, 25b are formed between the nozzle arrays 20a, 20b and side portions of the head, and the flat cables 22a, 22b are fixed at the mounted parts 25a, 25b onto the head 20.

Here, the head 20 is composed of a laminator of thin films constituting the nozzle hole, a pressure chamber, an ink flow path, and an actuator. These thin films are weak in close attachment power in the vicinity of the side portions. Therefore, the mounted parts 25a, 25b must be formed not in the vicinity of the side portions of the head but at portions which are distant from the side portions, that is, on the insides of the side portions.

According to the conventional constitution, the mounted part must be formed on the inside of the head. Therefore, a dead space is formed between the mounted part and the side portion of the head, so that the size of the head becomes large.

5 Here, in case that the flat cable pulled out from the head is bent with a small curvature, since there is fear of breaking of wire, it must be bent with curvature of some degree. In this case, in the conventional ink jet head unit in which the mounted part is formed between the nozzle array and the side portion
10 of the head, the flat cable sticks out of a width W of the head orthogonal to a surface of the flat cable.

In the conventional constitution, not only the head itself is made large but also the pull-around space of the flat cable connected to the head is required in the width direction.
15 Therefore, the ink jet head unit itself becomes large, which is contrary to a market request of miniaturization.

Therefore, an object of the invention is to provide an ink jet head unit in which a head having a mounted part connected to a flat cable can be miniaturized. Further, another object
20 of the invention is to provide an ink jet head unit in which the flat cable connected to the head can be compactly pulled around.

An embodiment of the invention will be described below with reference to Figs. 37 to 40. In these drawings, the same
25 members are denoted with the same reference numerals, and the

overlapping description is omitted.

Fig. 37 is a perspective view showing an ink jet head unit according to one embodiment of the invention, Fig. 38 is a side view of the ink jet head unit of Fig. 37, Fig. 39 is a perspective view of the ink jet head unit of Fig. 37, in which a head and a flat cable which are taken out are shown, and Fig. 40 is a side view showing a main portion of Fig. 39.

An ink jet head unit 1 shown in Figs. 37 and 38 is mounted on an ink jet recording apparatus (not shown) which ejects an ink droplet from a head 2 by use of a piezoelectric effect of an dielectric thin film element, and impacts this ink droplet onto a recording medium such as paper thereby to perform recording. The head 2 is composed of a laminator of thin films constituting a nozzle hole, a pressure chamber, an ink flow path, and an actuator.

The ink jet head unit 1 comprises the head 2 from which the ink is ejected, a head base 3 on which the head 2 is mounted, and two flexible flat cables 4a, 4b that are attached to the head 2. The flat cables 4a and 4b are formed by covering many transmission wires with an insulation film, and drivers 5a and 5b that generate an ink ejection signal for driving the head 2 are provided respectively in midway positions of the plural flat cables. To the drivers 5a and 5b, heat radiation plates 6a and 6b for radiating heat generated during operation efficiently are attached.

As shown in Fig. 39, four nozzle arrays 2a, 2b, 2c, and 2d are formed, of which each comprises many nozzle holes, and ink is ejected from these nozzle holes. The nozzle arrays are adjacent to each other two by two, that is, the nozzle arrays 2a and 2b make a pair and the nozzle arrays 2c and 2d make a pair. Two mounted parts 7a and 7b are formed between the nozzle arrays 2a, 2b and the nozzle arrays 2c, 2d.

One end side where the transmission wire of the flat cable 4a is exposed is fixed, in the mounted part 7a, onto the head 2, and one end side where the transmission wire of the flat cable 4b is exposed is fixed, in the mounted part 7b, onto the head 2. Further, as shown in Fig. 40, the flat cables 4a and 4b extend respectively in the same direction from the mounted parts 7a and 7b that are in the fixed positions of the head. Further, the flat cables 4a and 4b may be fixed onto the head 2 so as to extend in the different direction.

The ink ejecting signals generated by the drivers 5a and 5b are transmitted to the flat cables 4a and 4b, and supplied to the head 2 from the flat cables 4a and 4b. Hereby, the dielectric thin film element is subjected to displacement, and the ink droplet is ejected.

In the embodiment, though the four nozzle arrays are formed, two or more, that is, plural nozzle arrays are enough, and the invention is not limited to the four arrays. Further, though the two flat cables are used, one, or three or more flat

cables may be used.

Since the mounted parts 7a and 7b are thus formed in the position between the nozzle arrays 2a, 2b and the nozzle arrays 2c, 2d, the nozzle holes which are comparatively difficult to receive an influence caused by weak close attachment power of thin films constituting the head 2 can be formed at side portions of the head. Hereby, since the mounted parts 7a, 7b and the nozzle arrays 2a, 2b, 2c, 2d can be arranged on the head 2 efficiently, a dead space is eliminated, and the head 2 can be miniaturized.

Further, since the mounted parts 7a and 7b are formed in the position between the nozzle arrays 2a, 2b and the nozzle arrays 2c, 2d, even in case that the flat cables 4a and 4b are arranged within a width W of the head 2 in a direction orthogonal to a surface of the flat cable, along the head base 3 (Fig. 40), the flat cables can be bent with such a comparatively large curvature that breaking of wire can be prevented, so that the flat cables 4a and 4b can be pulled around compactly.

On a side surface of the head base 3, a notch part 3a into which the flat cables 4a and 4b that are thus pulled around are fitted is formed. Hereby, the flat cables 4a and 4b can be compactly housed within the width of the head 2 in the direction orthogonal to the surface of the flat cable.

Between the flat cables 4a and 4b, a metallic interference preventing member 8 or a nonmetallic interference preventing

member 8 in which a metal layer is formed is arranged. Hereby, electromagnetic mutual interference between the flat cables 4a and 4b is relaxed. The interference preventing member may not be arranged. Further, though the interference preventing member 8 is arranged at a part between the flat cables 4a and 4b in the figure, it may be arranged throughout the whole between the flat cables 4a and 4b.

Further, as another means for relaxing such the electromagnetic mutual interference, the flat cables 4a and 4b may be arranged so that the transmission wires formed in these flat cables 4a and 4b are nonparallel to each other.

As shown in Fig. 38, the drivers 5a and 5b to which the heat radiation plates 6a and 6b are attached are arranged so as to shift from each other in the length direction of the flat cable 4a, 4b. Hereby, since the drivers 5a and 5b having heat during the operation are distant from each other, it is prevented that heat radiation efficiency of the respective heat radiation plates is lessened due to adjacency between the heat radiation plates 6a and 6b. Further, as described before, since the flat cable 4a is fixed onto the mounted part 7a and the flat cable 4b is fixed onto the mounted part 7b that is in the different position from the position of the mounted part 7a, even in case that the attachment positions of the driver 5a and the driver 5b to the flat cable 4a and the flat cable 4b are not made different, the shift arrangement can be readily

performed.

The flat cables 4a and 4b have respectively at least two bending parts 9 that bend in the length direction of each of the flat cables 4a, 4b, at their parts extending from the head base 3. Hereby, an extra length can be provided for the flat cables 4a, 4b, so that work performance in assembly of the apparatus can be improved by adjusting the forming position of the bending part 9.

As described above, according to the ink jet head unit of the embodiment, since the mounted parts 7a, 7b are formed in the position between the nozzle arrays 2a, 2b and the nozzle arrays 2c, 2d, the nozzle holes which are comparatively difficult to receive the influence caused by weak close attachment power of the thin films constituting the head 2 can be formed at the side portions of the head, so that the mounted parts 7a, 7b and the nozzle arrays 2a, 2b, 2c, 2d can be arranged on the head 2 efficiently. Therefore, the dead space is eliminated, and the head 2 can be miniaturized.

Further, since the mounted parts 7a, 7b are formed in the position between the nozzle arrays 2a, 2b and the nozzle arrays 2c, 2d, even in case that the flat cables 4a, 4b are arranged within the width W of the head 2 in the direction orthogonal to the surface of the flat cable, along the head base 3, the flat cables can be bent with such the comparatively large curvature that breaking of wire can be prevented, so that the

flat cables 4a, 4b can be pulled around compactly.

As understandable from the description, the above described various embodiments may be combined each others to attain its function.

5

Industrial Applicability

As described above, according to the invention, since the dew point in the vicinity of the ink ejecting unit is lowered by the dry gas, it is prevented that the ink ejecting unit deteriorates due to the voltage application. Hereby, such an effective advantage can be obtained that it is possible to readily prevent break and deterioration due to the voltage application to this ink ejecting unit, achieving reduction of the film thickness of the ink ejecting unit.

15 According to the first aspect of the invention, an ink jet recording apparatus, which performs printing by ink ejection, comprises a pressure chamber in which ink liquid is filled; a nozzle hole which is formed, communicating with the pressure chamber; a piezoelectric element which is formed on
20 the pressure chamber, and deforms the pressure chamber by mechanical expansion and contraction, whereby pressure is generated in the pressure chamber, and ink is ejected from the nozzle hole; and a dew point control unit which keeps a dew point in an atmosphere of the piezoelectric element and the vicinity
25 of the piezoelectric element at a lower value than a dew point

in an environment where the ink jet recording apparatus is set. Hereby, reduction of the film thickness of the piezoelectric element can be achieved, and the element break due to the voltage application to this piezoelectric element can be readily
5 prevented.

According to the second aspect of the invention, in the ink jet recording apparatus according to the first aspect of the invention, the dew point control unit introduces dry gas to the piezoelectric element and in the vicinity of the
10 piezoelectric element. Hereby, reduction of the film thickness of the piezoelectric element can be achieved, and the element break due to the voltage application to this piezoelectric element can be readily prevented.

According to the third aspect of the invention, in the
15 ink jet recording apparatus according to the second aspect of the invention, the dew point control unit supplies the dry gas by use of an air drier. Hereby, reduction of the film thickness of the piezoelectric element can be achieved, and the element break due to the voltage application to this piezoelectric
20 element can be readily prevented.

According to the fourth aspect of the invention, in the ink jet recording apparatus according to the second aspect of the invention, the dew point control unit supplies the dry gas from a cylinder. Hereby, reduction of the film thickness of
25 the piezoelectric element can be achieved, and the element break

due to the voltage application to this piezoelectric element can be readily prevented.

According to the fifth aspect of the invention, in the ink jet recording apparatus according to any one of the second to fourth aspects of the invention, a dew point of the dry gas is -50°C or less. Hereby, reduction of the film thickness of the piezoelectric element can be achieved, and the element break due to the voltage application to this piezoelectric element can be readily prevented.

According to the sixth aspect of the invention, in the ink jet recording apparatus according to any one of the first to sixth aspects of the invention, there is provided a case which includes an inlet from which the dry gas is introduced, and an outlet from which the dry gas is exhausted, and surrounds the piezoelectric element; and the dry gas is introduced from the inlet into the case at 10 mL/sec. or more per volume of one cubic cm, and the internal pressure of the case is kept higher than its external pressure. Hereby, reduction of the film thickness of the piezoelectric element can be achieved, and the element break due to the voltage application to this piezoelectric element can be readily prevented.

According to the seventh aspect of the invention, in the ink jet recording apparatus according to any one of the first to sixth aspects of the invention, the piezoelectric element includes a lead compound. Hereby, reduction of the film

thickness of the piezoelectric element can be achieved, and the element break due to the voltage application to this piezoelectric element can be readily prevented.

According to the eighth aspect of the invention, in the
5 ink jet recording apparatus according to any one of the first to seventh aspects of the invention, film thickness of the piezoelectric element is 100 μ m or less. Hereby, reduction of the film thickness of the piezoelectric element can be achieved, and the element break due to the voltage application to this
10 piezoelectric element can be readily prevented.

According to the ninth aspect of the invention, an ink jet recording apparatus which performs printing by ink ejection, comprises a pressure chamber in which ink liquid is filled; a nozzle hole which is formed communicating with the pressure
15 chamber; an ink ejecting unit which ejects the ink liquid filled in the pressure chamber from the nozzle hole; and a dew point control unit which keeps a dew point in peripheral atmosphere of the ink ejecting unit is kept at a lower value than a dew point in an environment where the ink jet recording apparatus
20 is set. Hereby, the break and deterioration of the ink ejecting unit can be suppressed.

CLAIMS

1. An ink jet recording apparatus which performs printing by ink ejection, comprising:

5 a pressure chamber in which ink liquid is filled;

a nozzle hole which is formed communicating with said pressure chamber;

a piezoelectric element which is formed on said pressure chamber, and deforms said pressure chamber by mechanical expansion and contraction, whereby pressure is generated in the pressure chamber, and ink is ejected from said nozzle hole; and

10 a dew point control unit which keeps a dew point in an atmosphere of said piezoelectric element and the vicinity of the piezoelectric element at a lower value than a dew point in an environment where said ink jet recording apparatus is set.

2. The ink jet recording apparatus according to Claim 1, wherein said dew point control unit introduces dry gas to said piezoelectric element and in the vicinity of the piezoelectric element.

3. The ink jet recording apparatus according to Claim 2, wherein said dew point control unit supplies said dry gas by use of an air drier.

25

4. The ink jet recording apparatus according to Claim 2, wherein said dew point control unit supplies said dry gas from a cylinder.

5 5. The ink jet recording apparatus according to Claim 2, wherein a dew point of said dry gas is -50°C or less.

6. The ink jet recording apparatus according to Claim 2, wherein there is provided a case which includes an inlet from
10 which said dry gas is introduced, and an outlet from which said dry gas is exhausted, and surrounds said piezoelectric element;
and

said dry gas is introduced from said inlet into said case at 10 mL/min or more per volume of one cubic cm, and the internal
15 pressure of said case is kept higher than its external pressure.

7. The ink jet recording apparatus according to Claim 1, wherein said piezoelectric element includes a lead (Pb) compound.

20

8. The ink jet recording apparatus according to Claim 1, wherein film thickness of said piezoelectric element is $100\mu\text{m}$ or less.

25 9. An ink jet recording apparatus which performs

printing by ink ejection, comprising:

a pressure chamber in which ink liquid is filled;

a nozzle hole which is formed communicating with said pressure chamber;

5 an ink ejecting unit which ejects said ink liquid filled in said pressure chamber from the nozzle hole; and

a dew point control unit which keeps a dew point in peripheral atmosphere of said ink ejecting unit is kept at a lower value than a dew point in an environment where said ink
10 jet recording apparatus is set.

FIG. 1

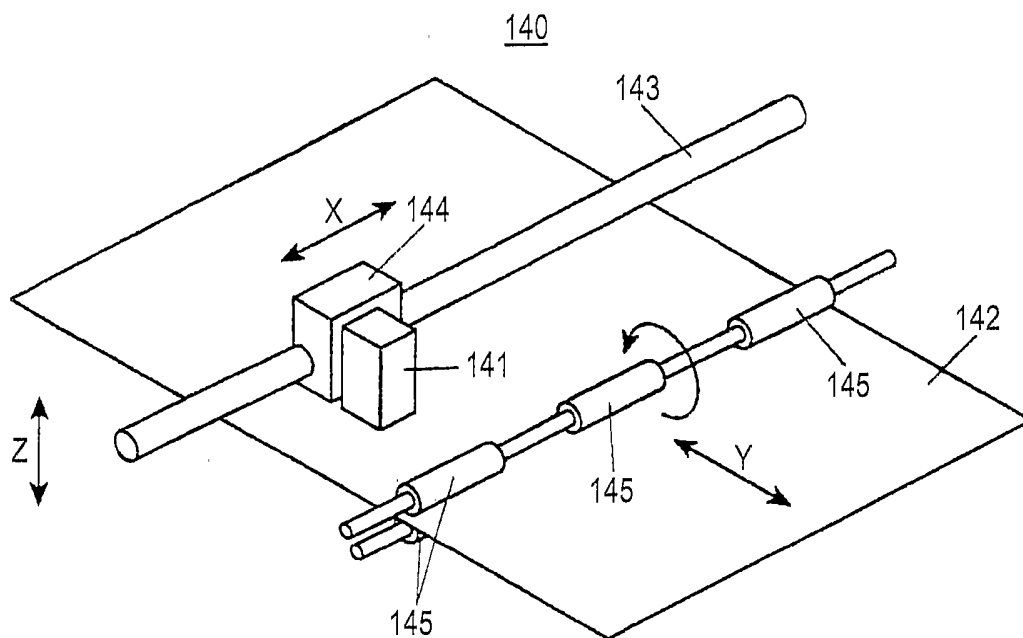


FIG. 2

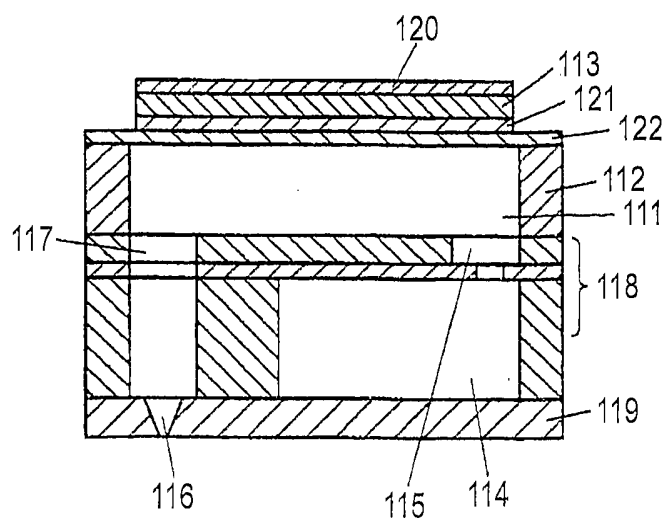


FIG. 3

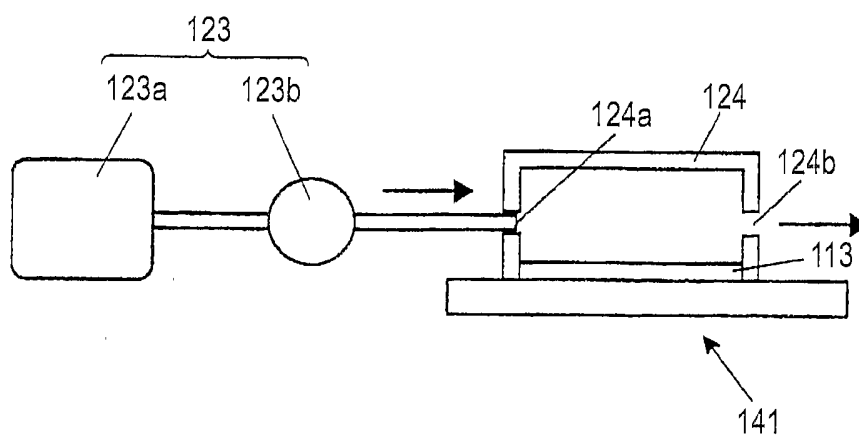


FIG. 4

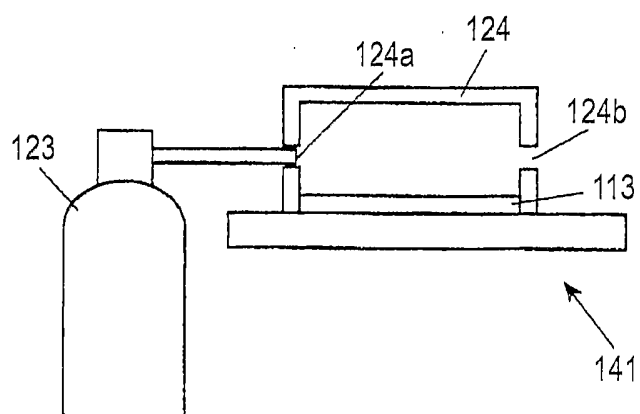


FIG. 5

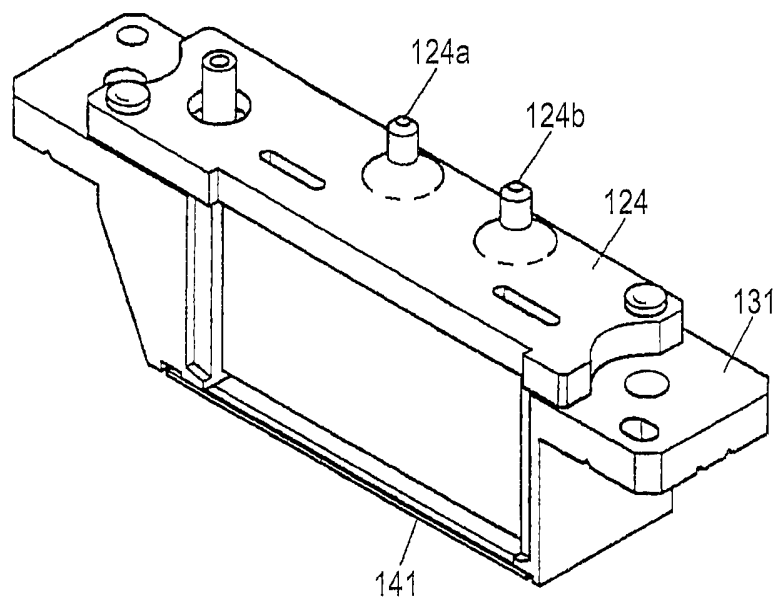


FIG. 6

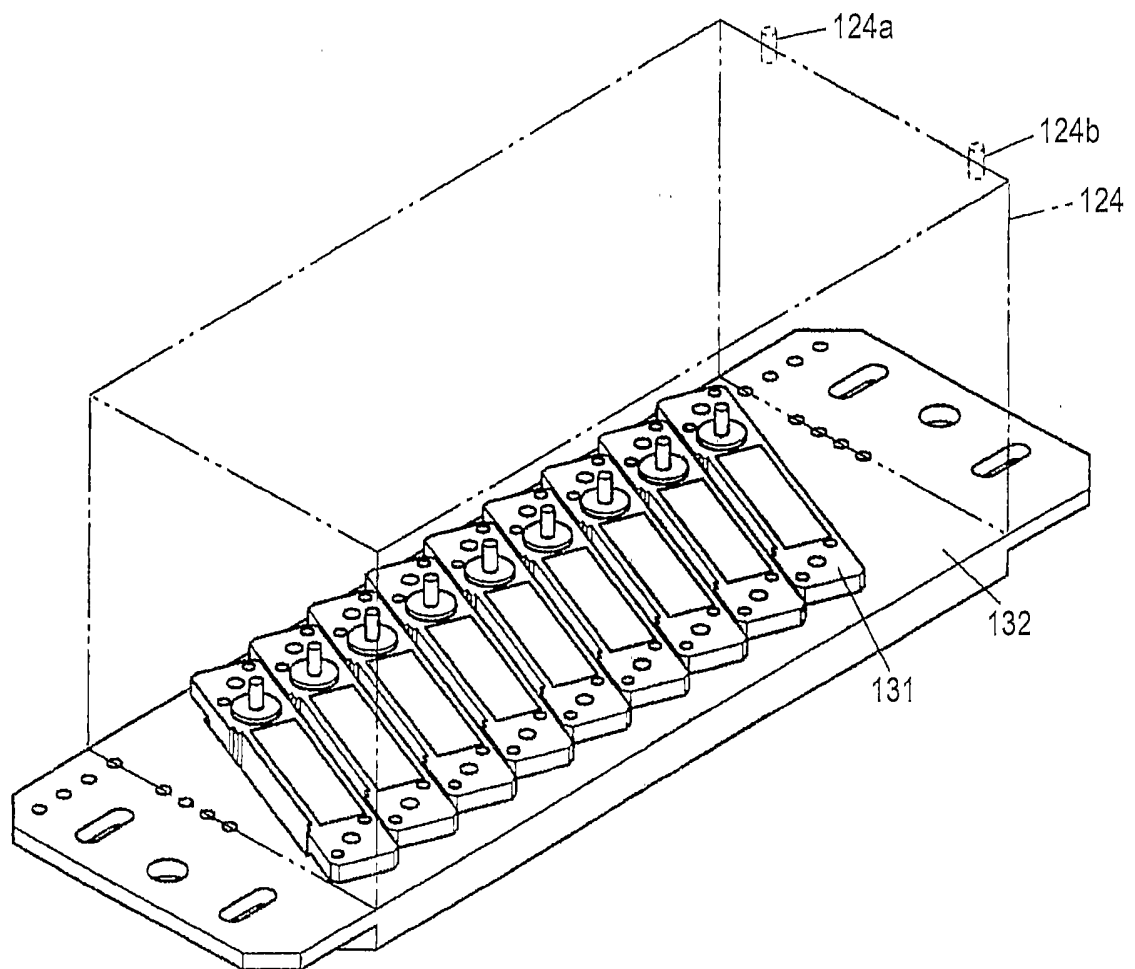
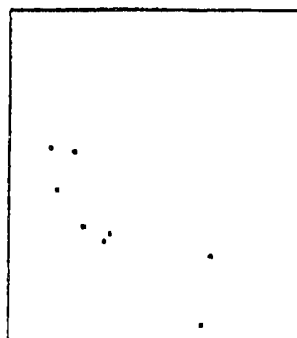


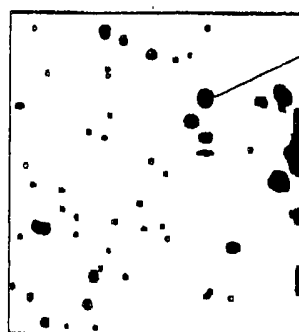
FIG. 7A



(BLACK SPOT IS DUST ONLY)



FIG. 7B



BLACK SPOT IS MELT PORTION

FIG. 8

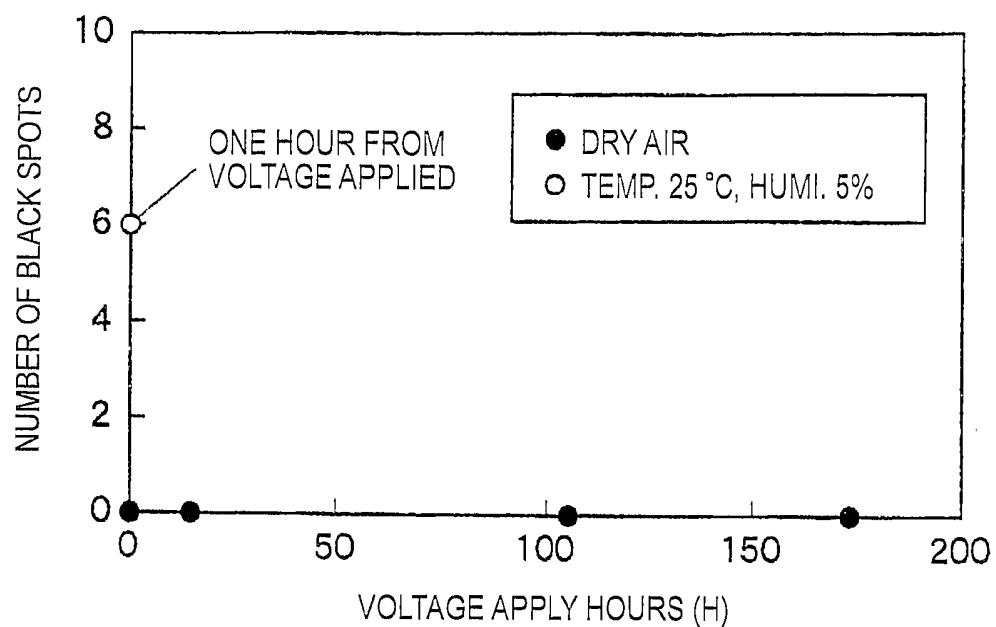


FIG. 9

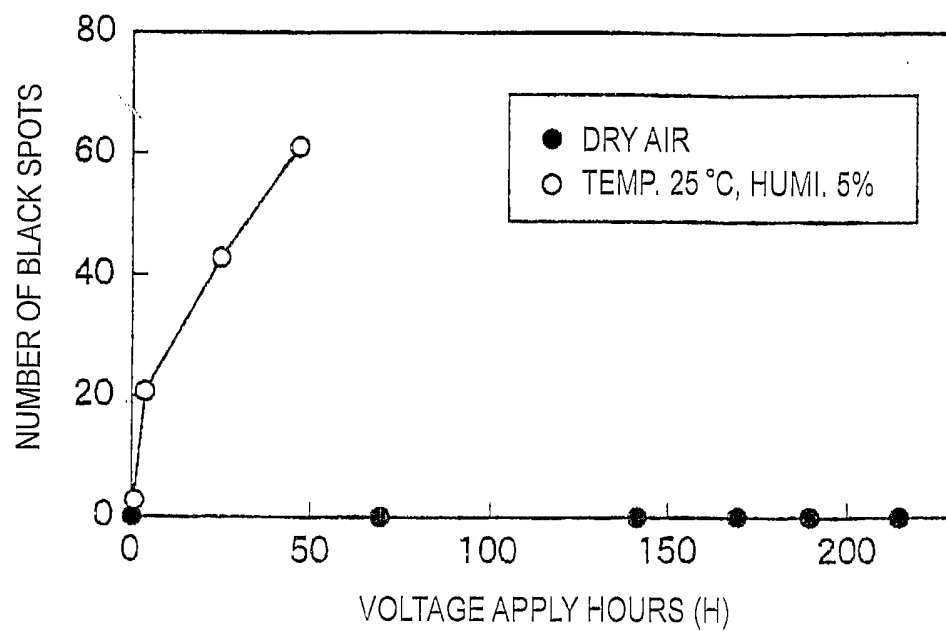


FIG. 10A

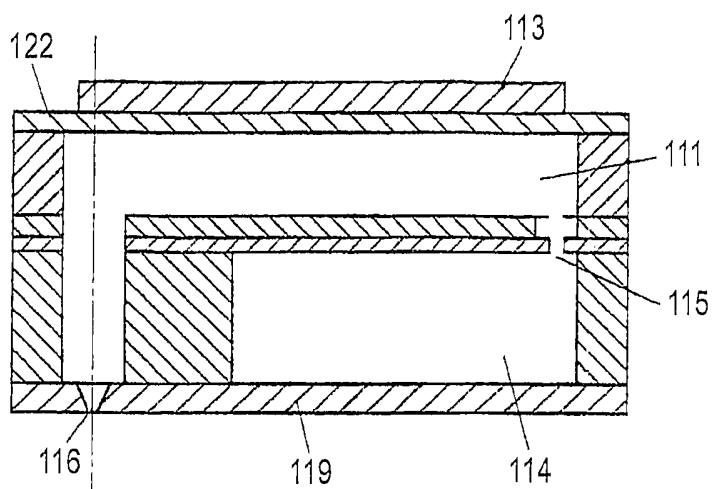


FIG. 10B

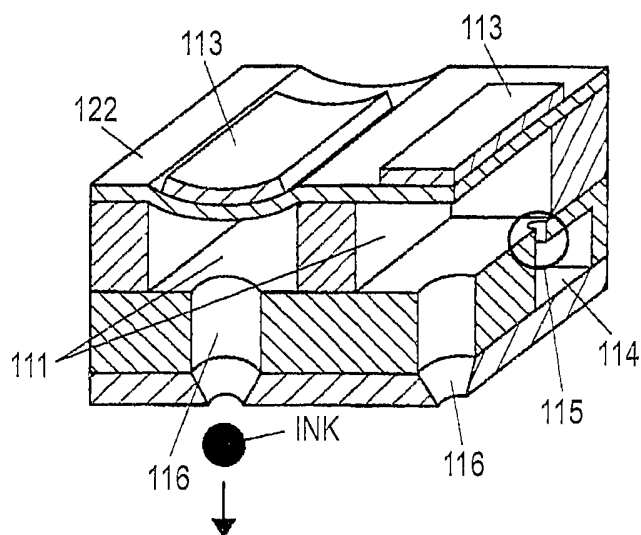


FIG. 10C

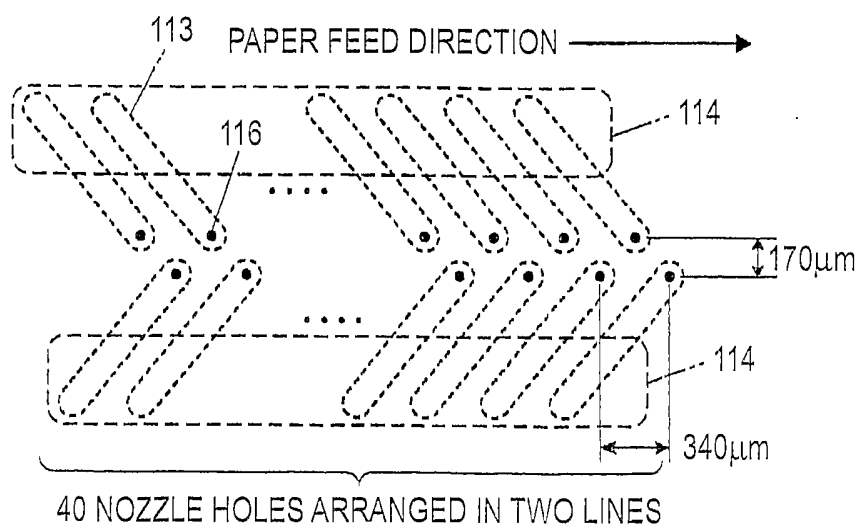


FIG. 11

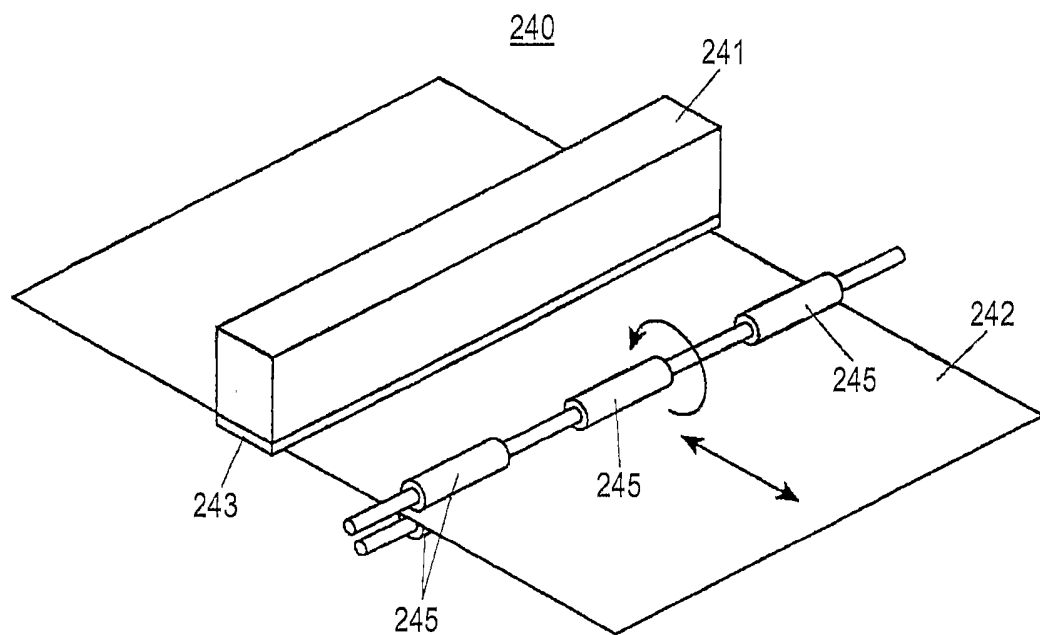


FIG. 12

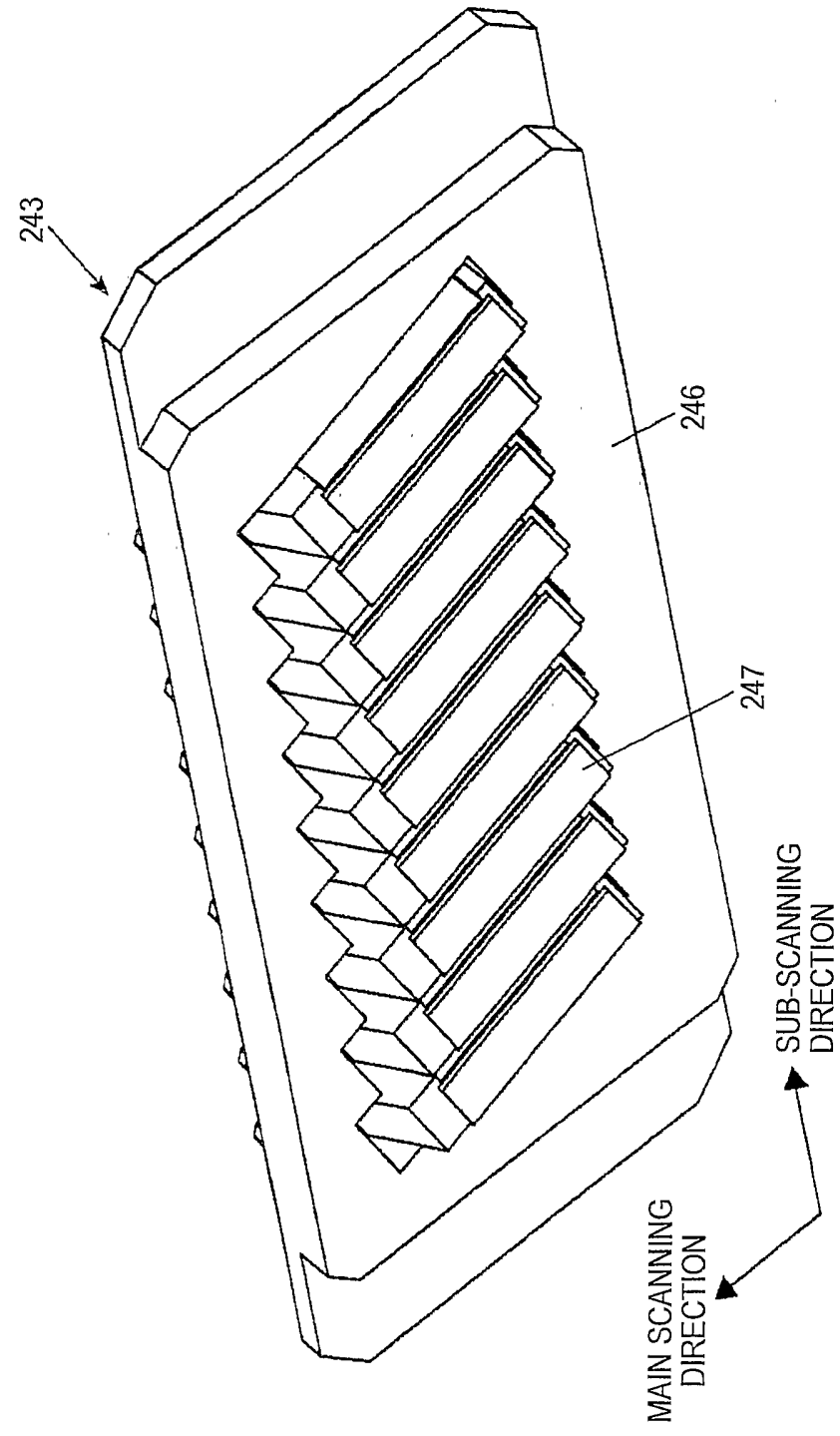


FIG. 13

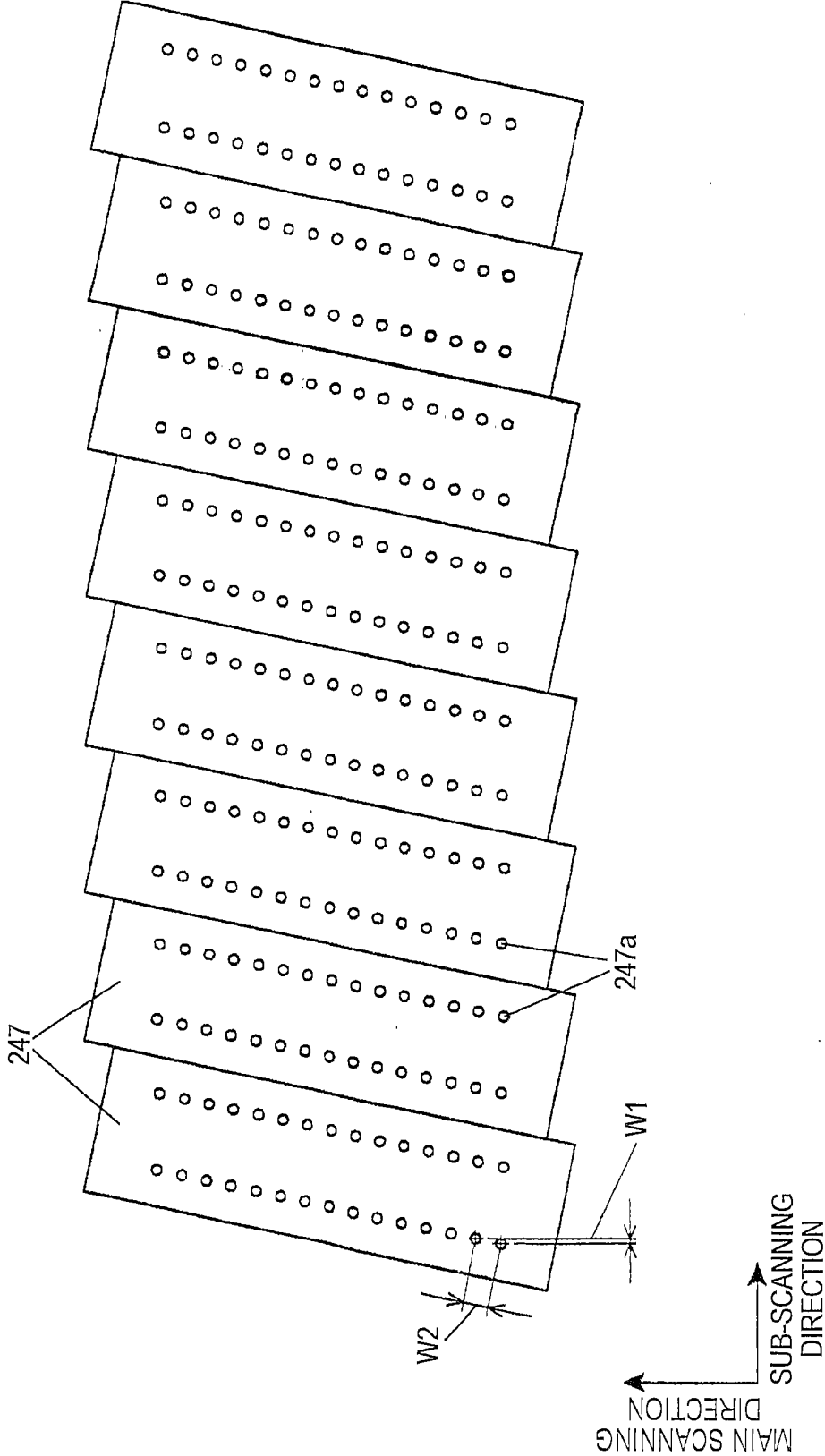


FIG. 14

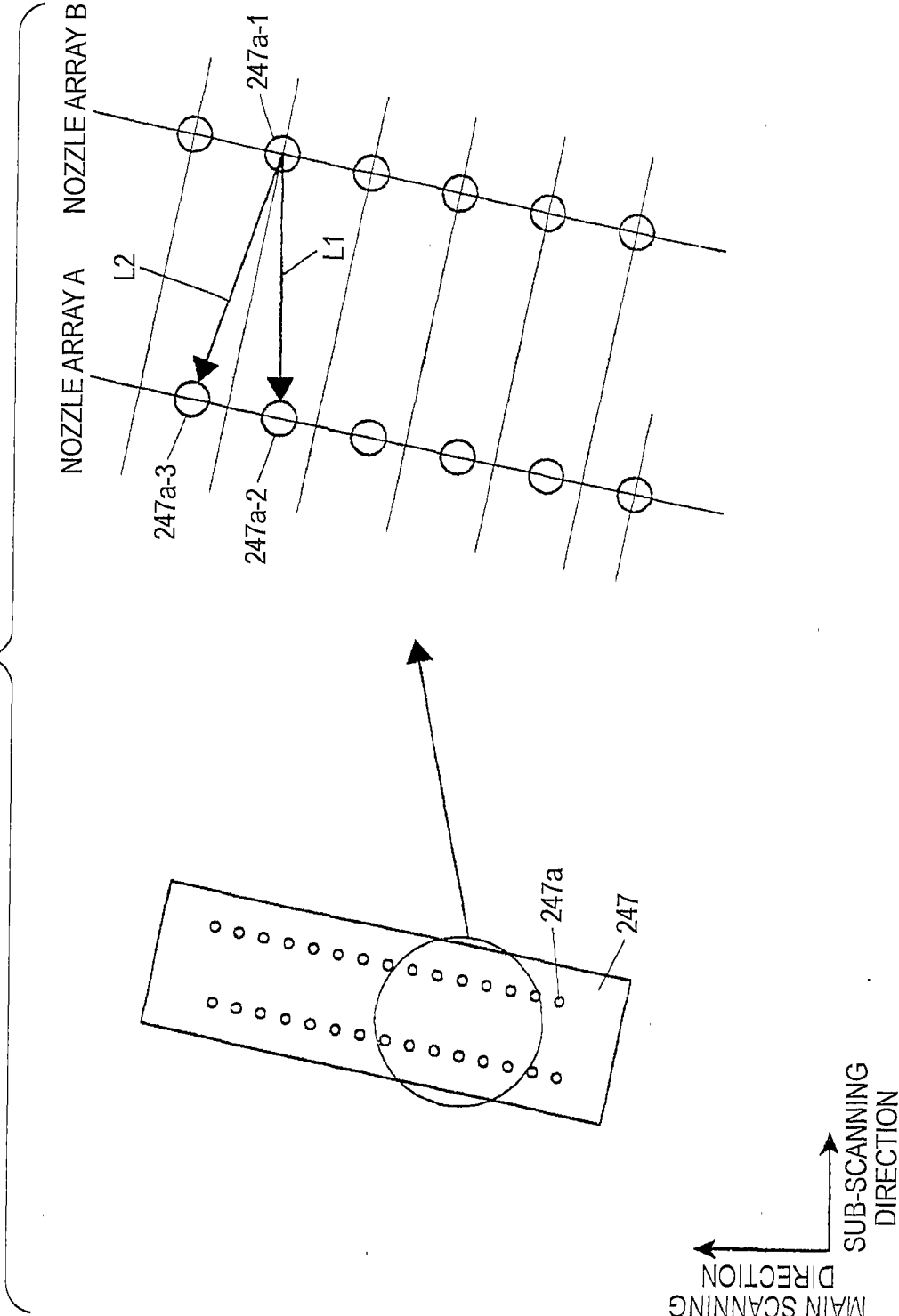


FIG. 15

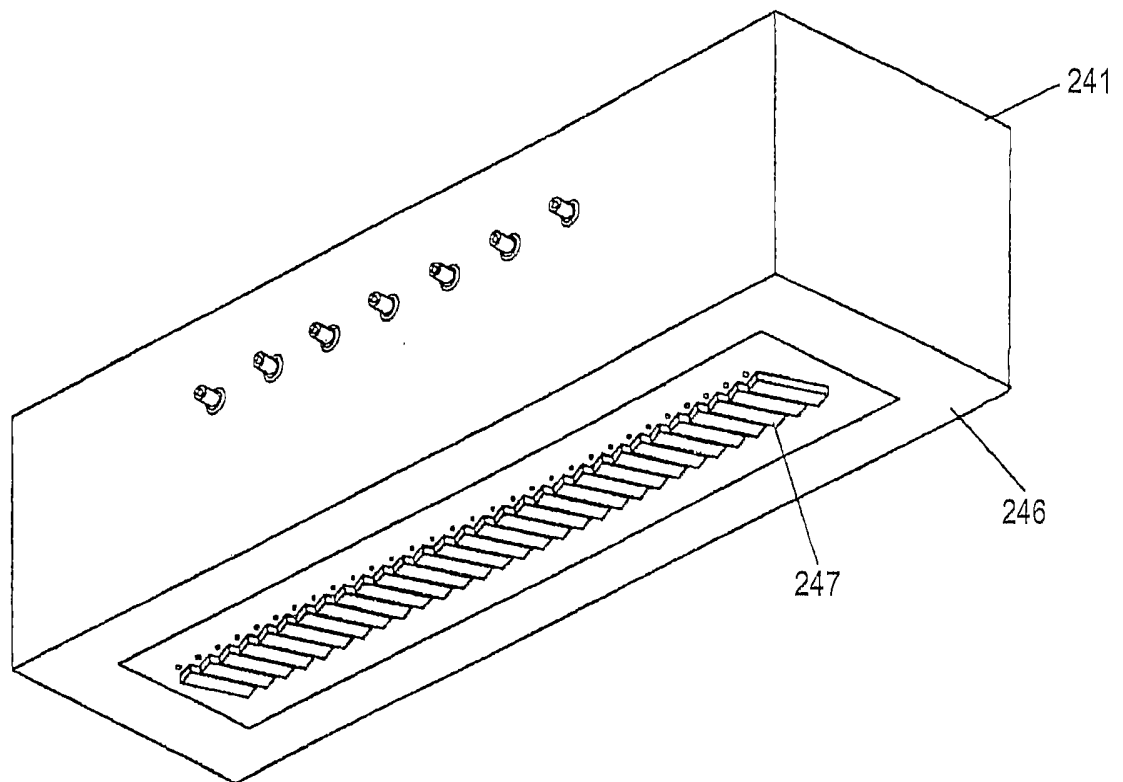


FIG. 16

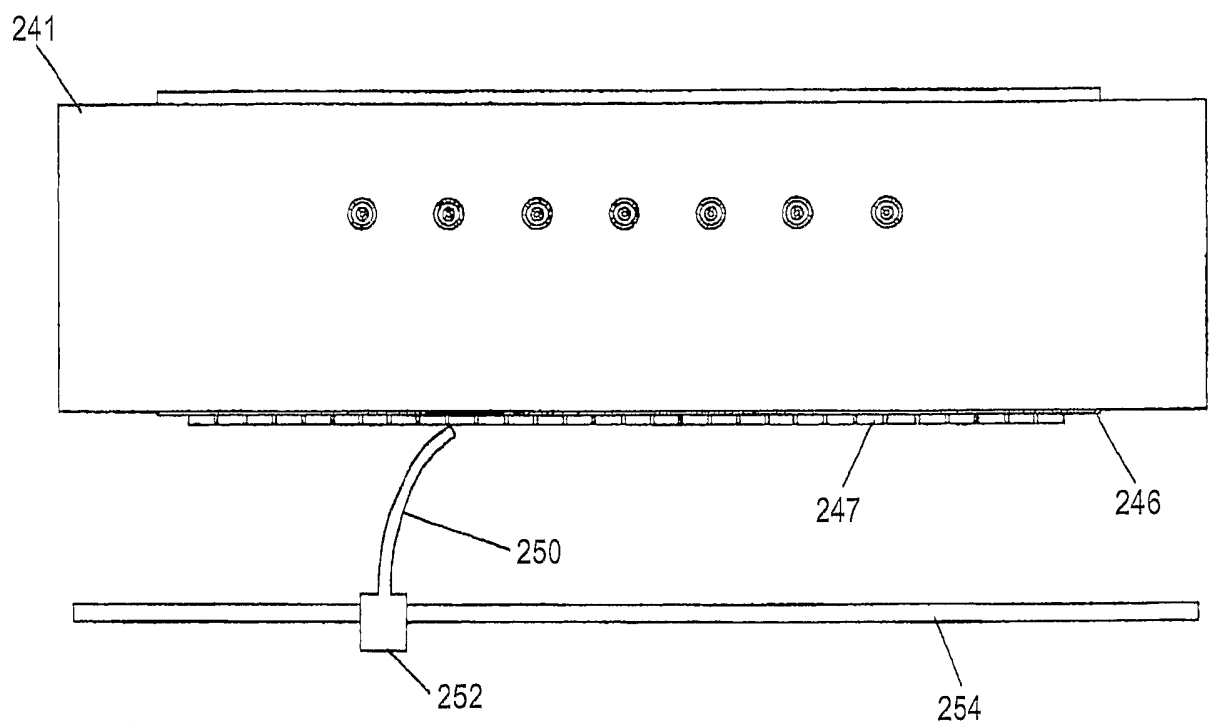


FIG. 17

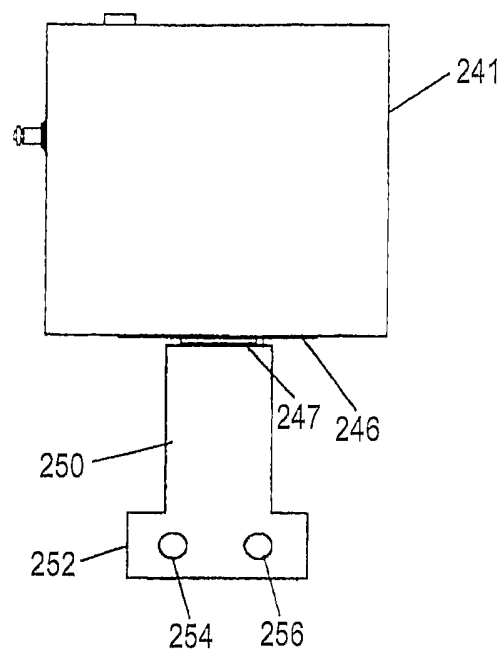


FIG. 18

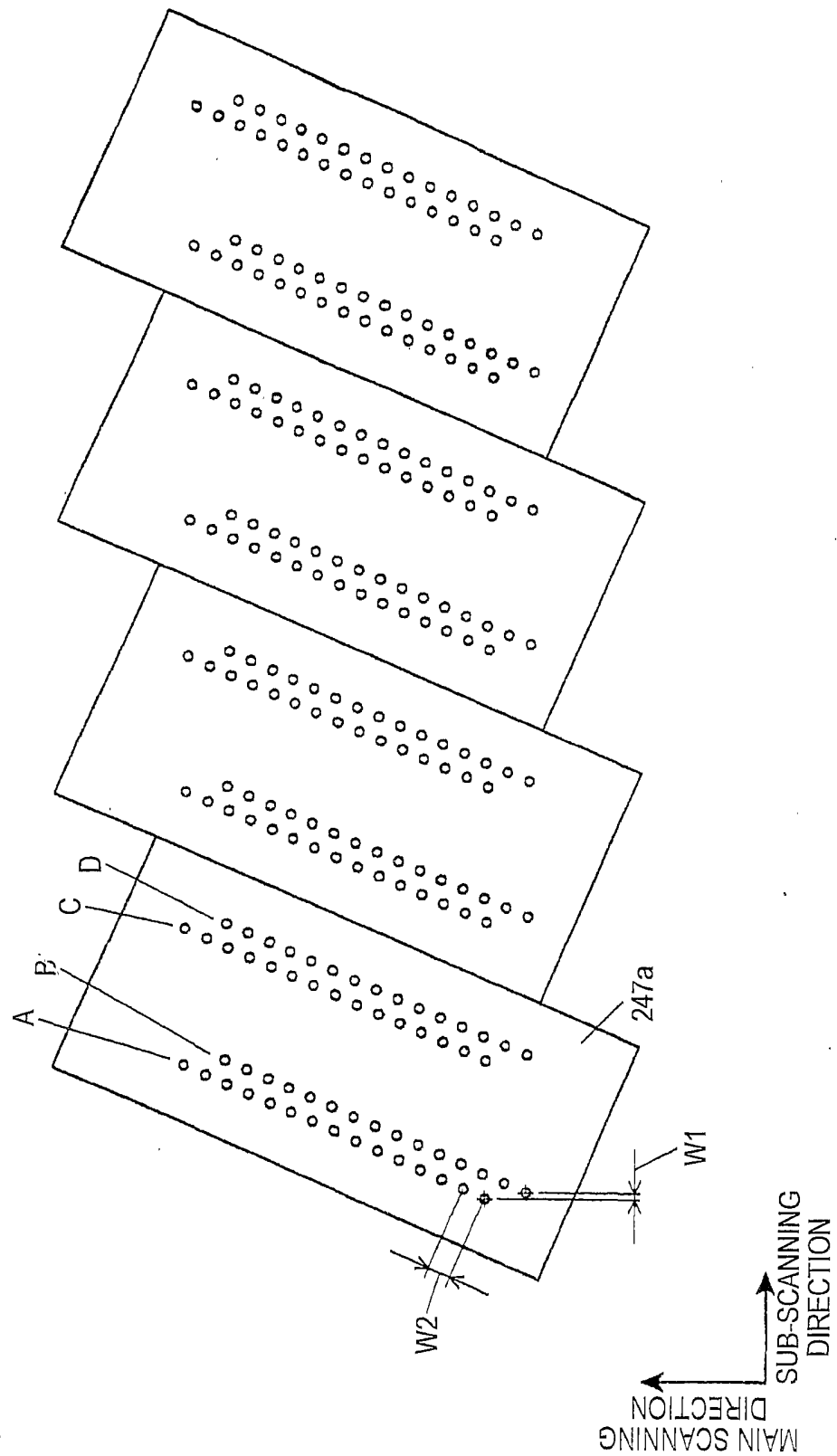


FIG. 19

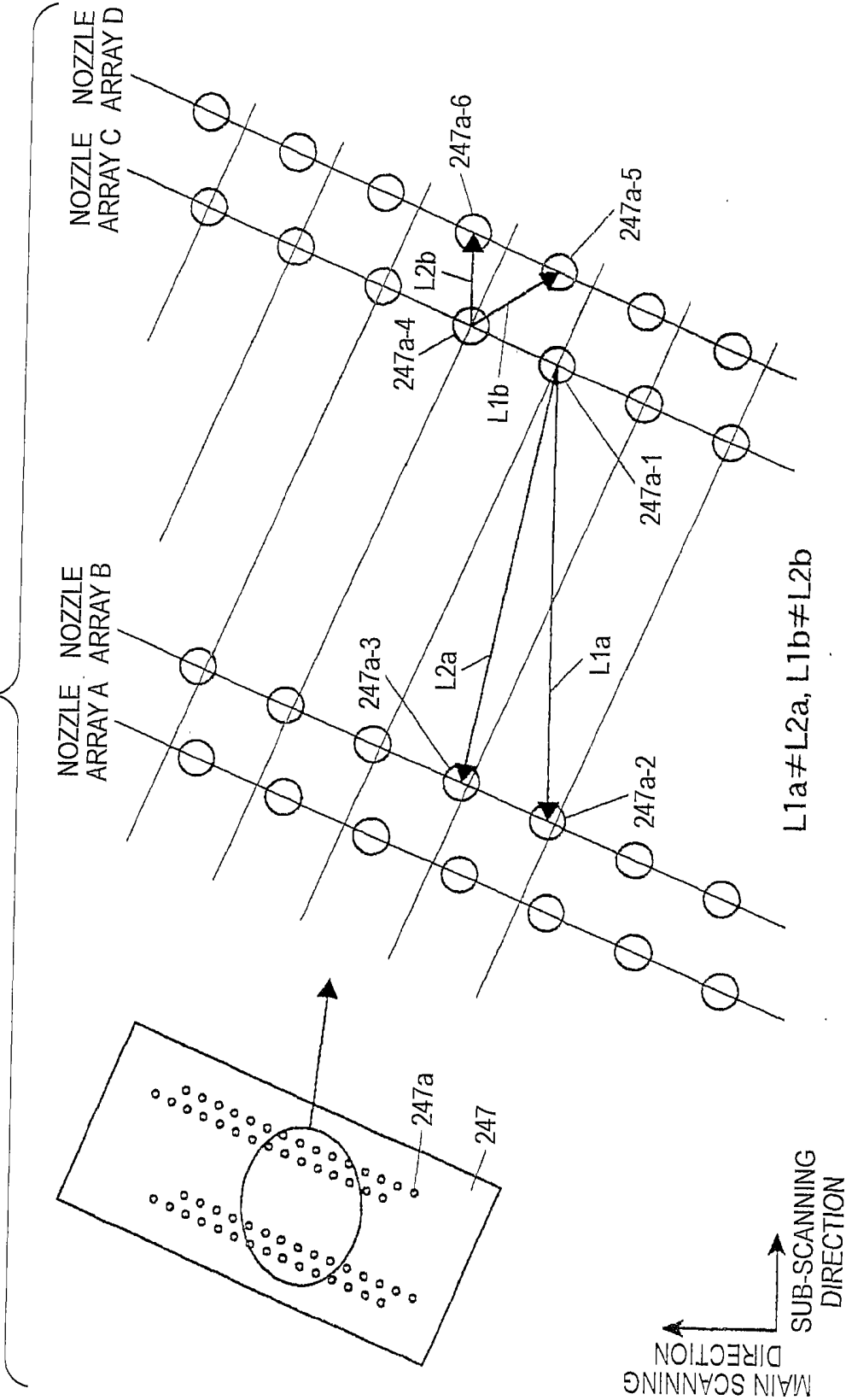


FIG. 20

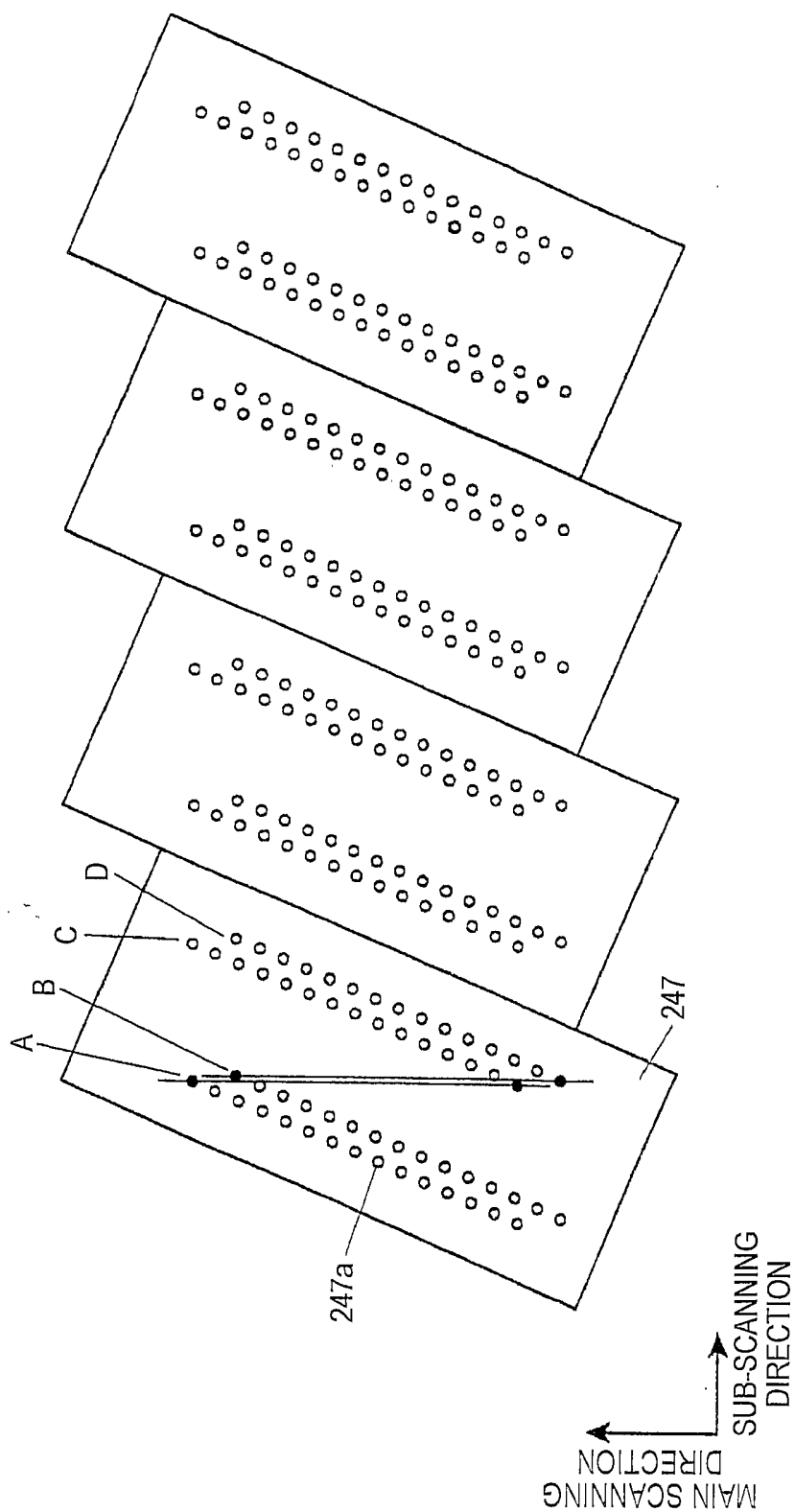


FIG. 21

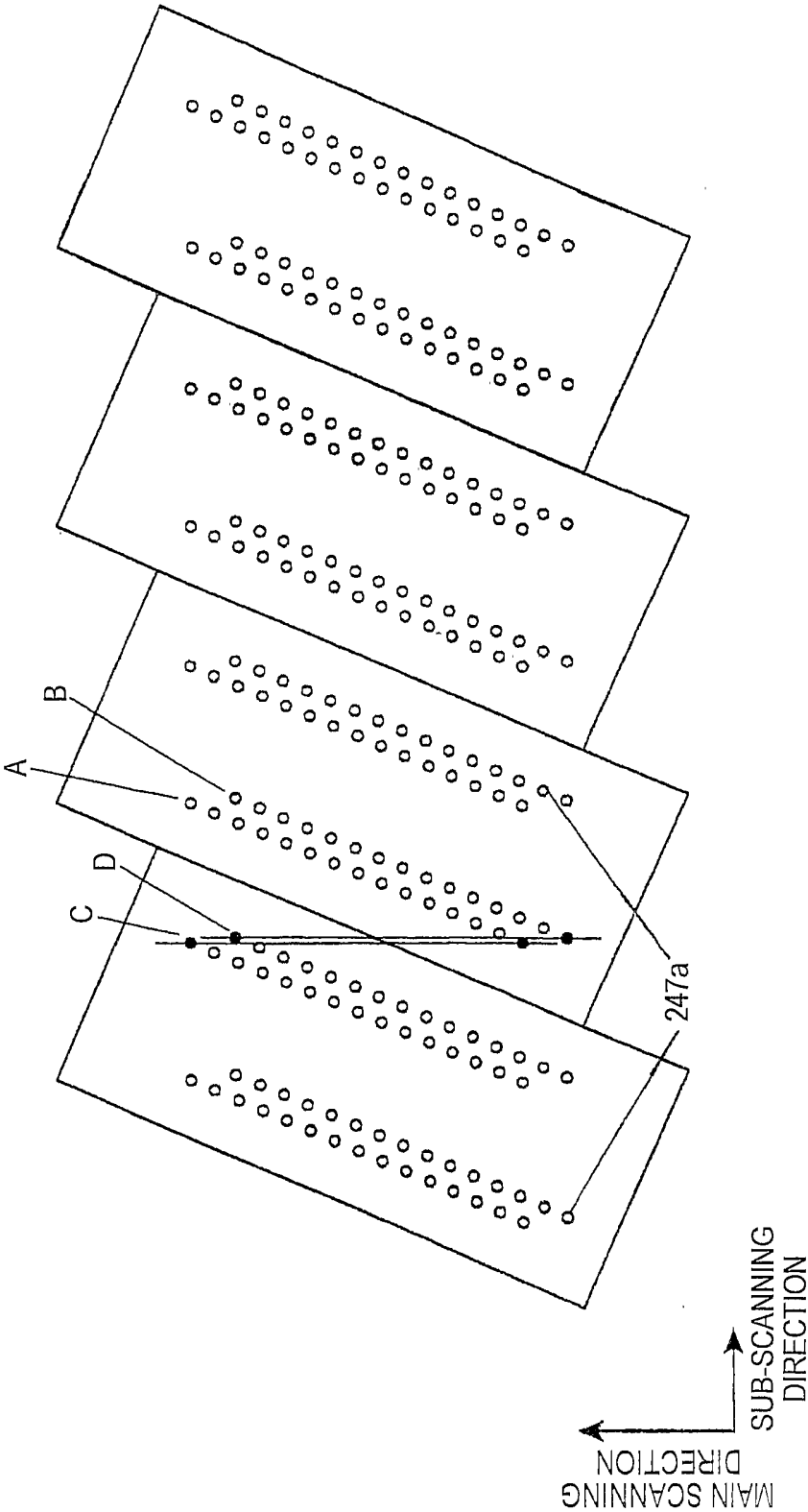


FIG. 22

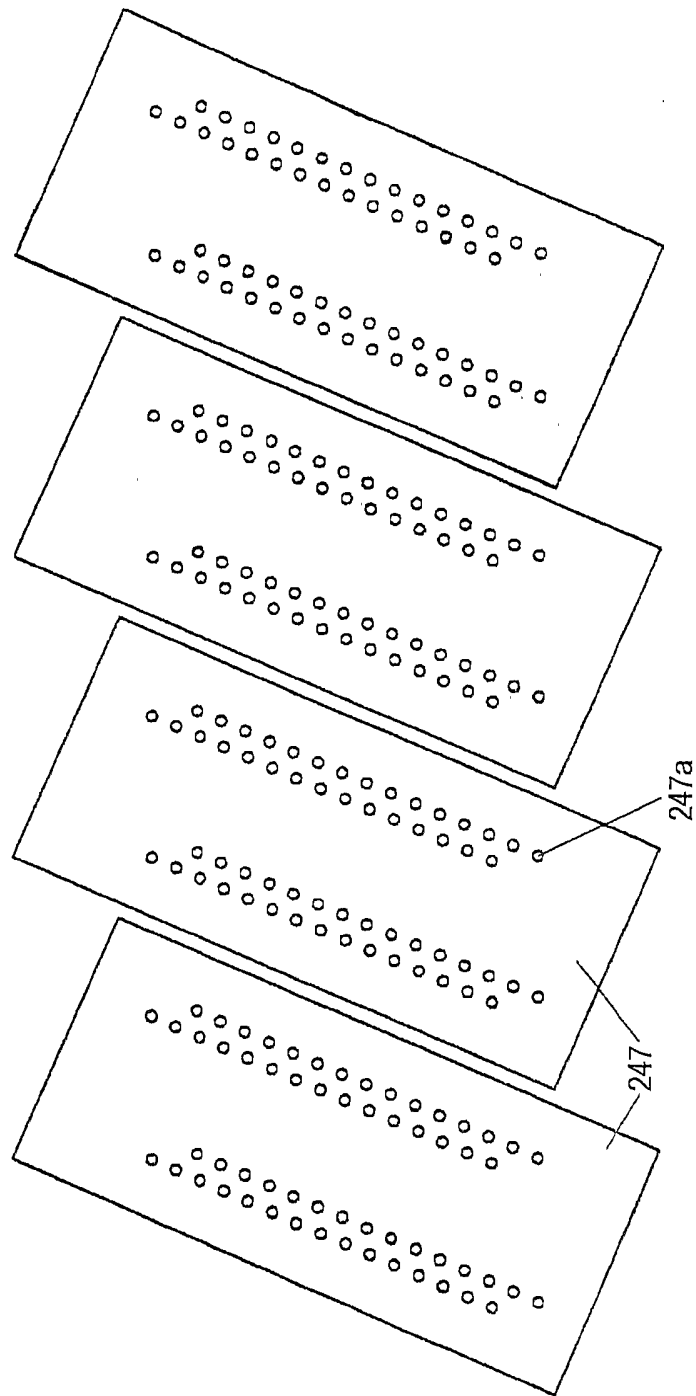


FIG. 23

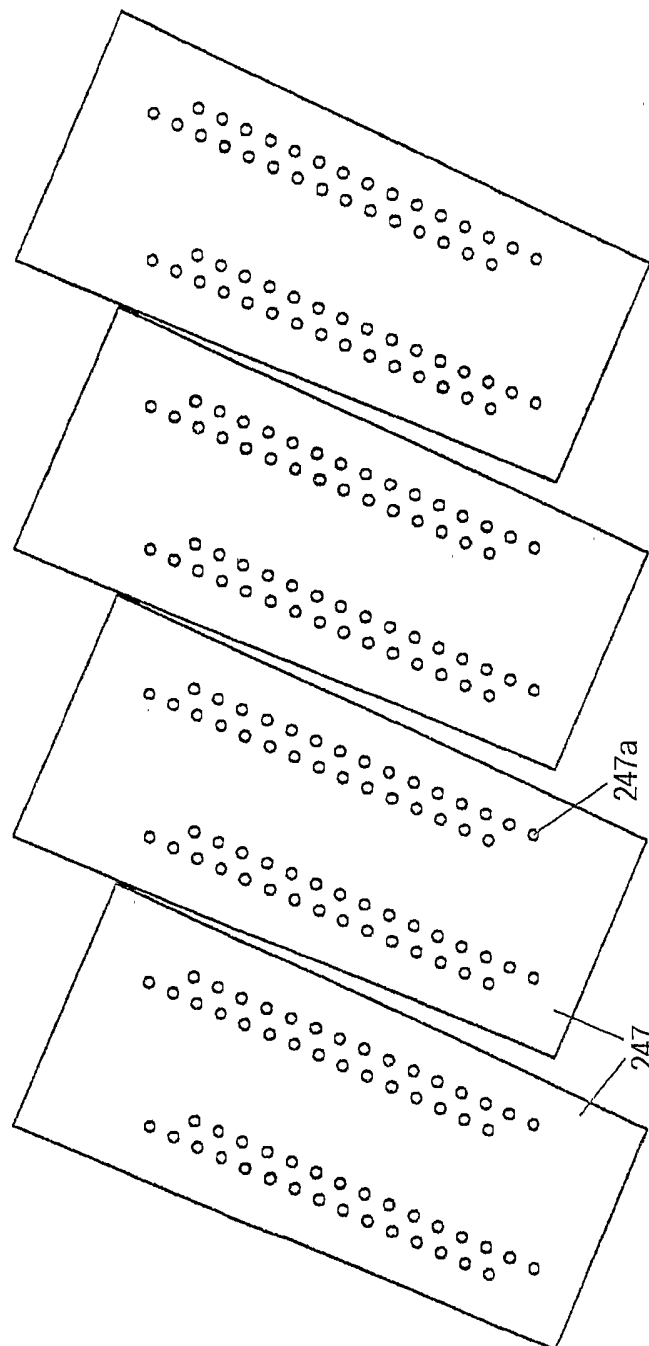


FIG. 24

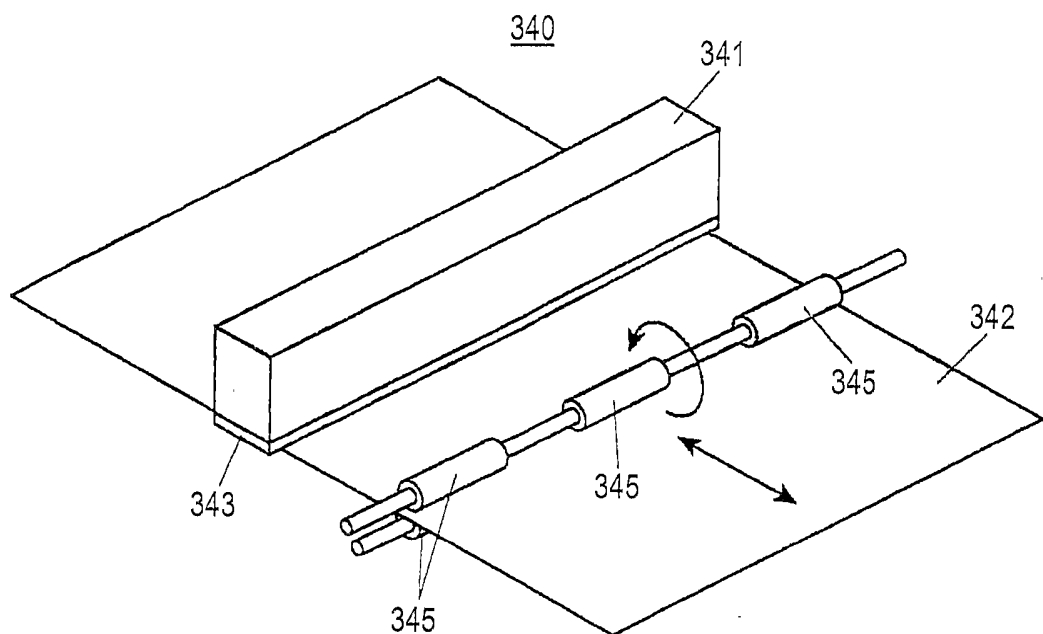
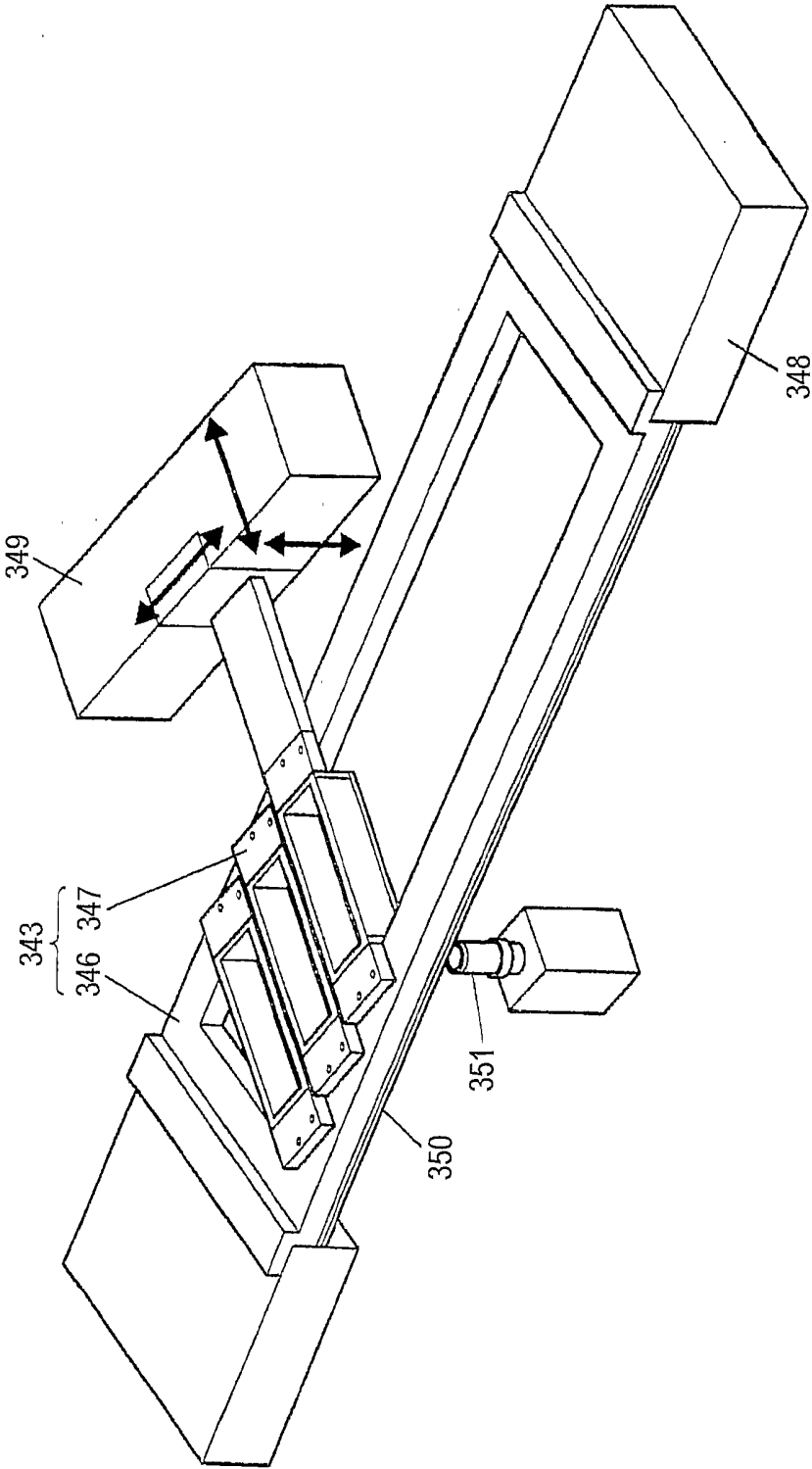


FIG. 25



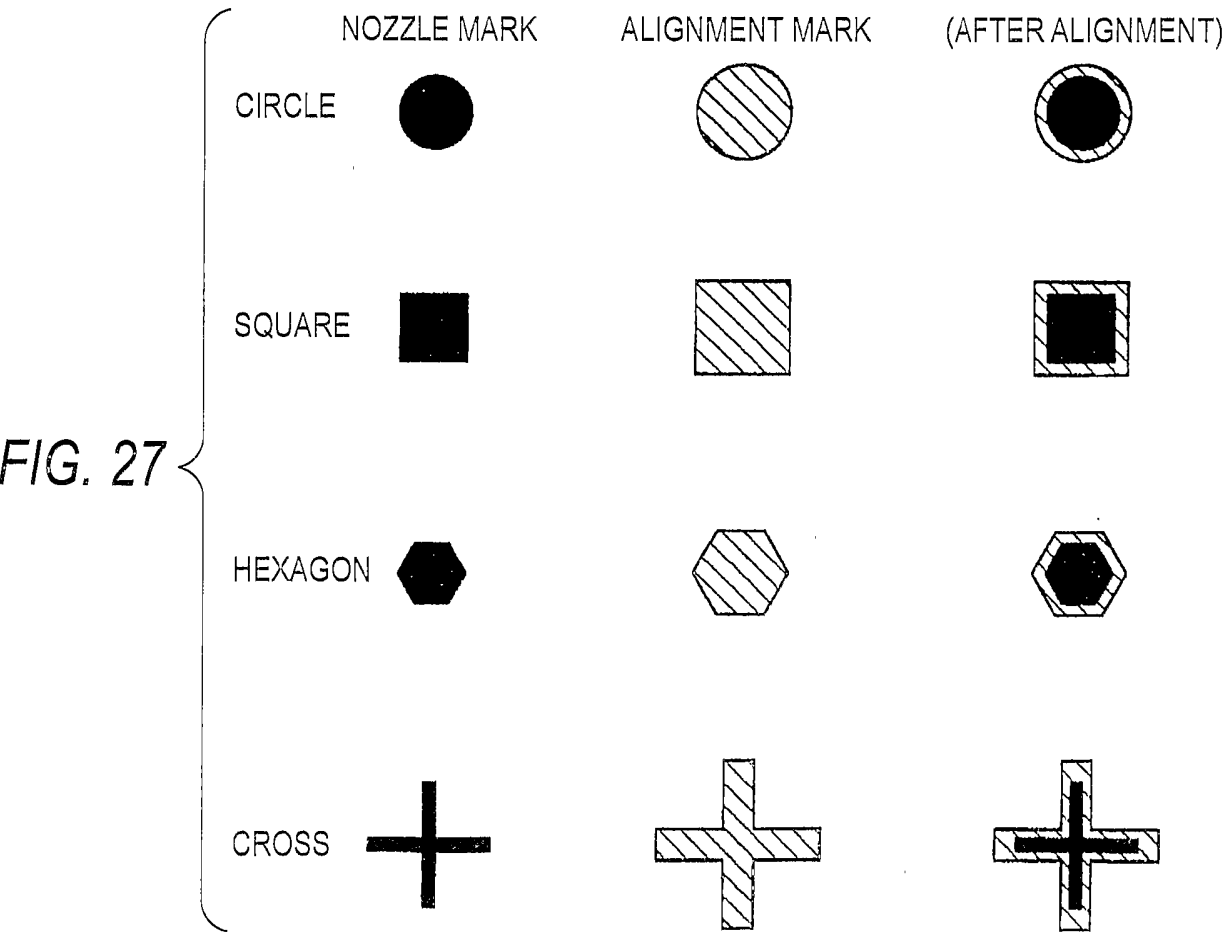
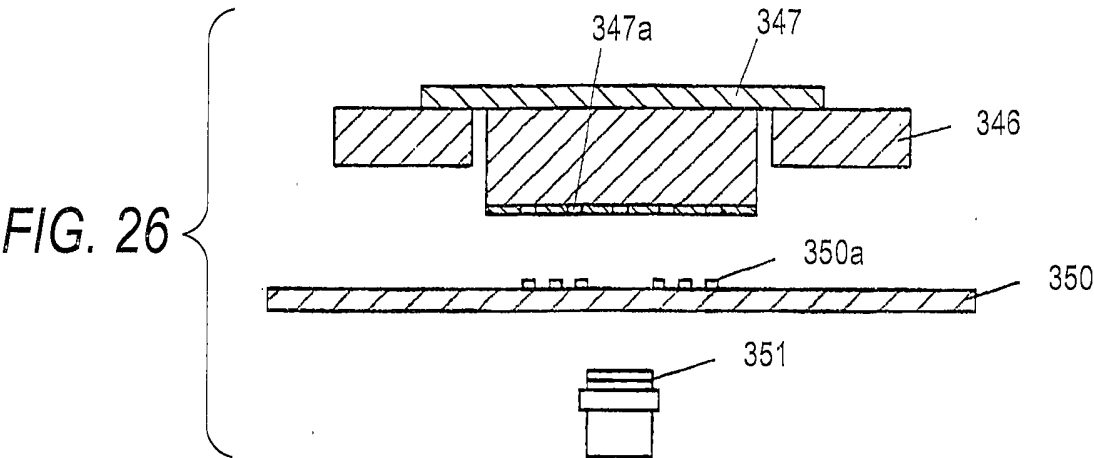
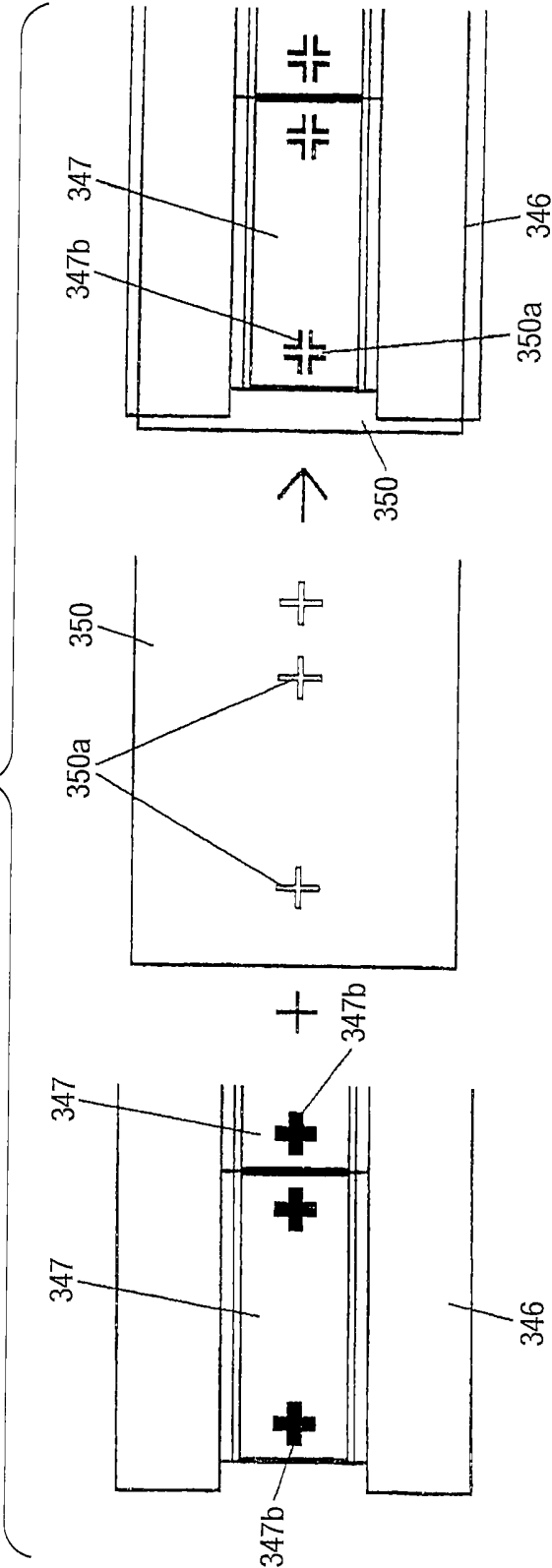
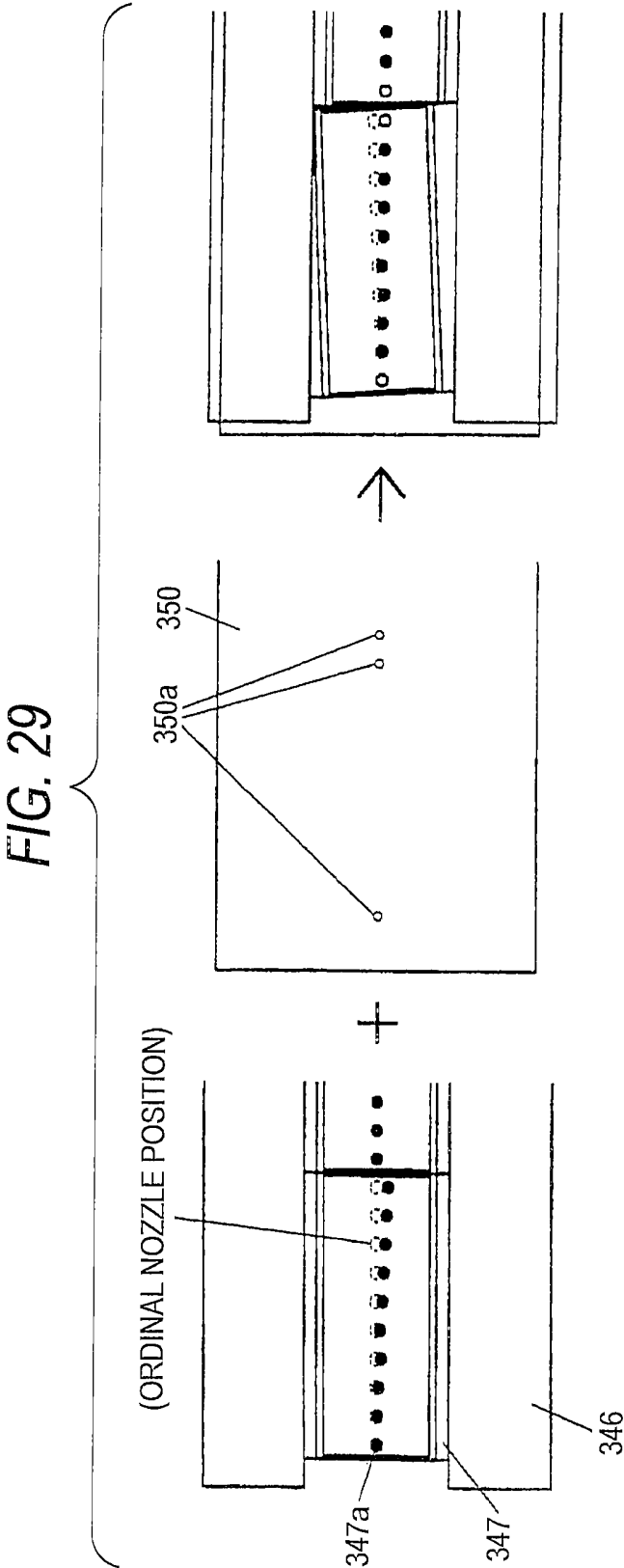


FIG. 28





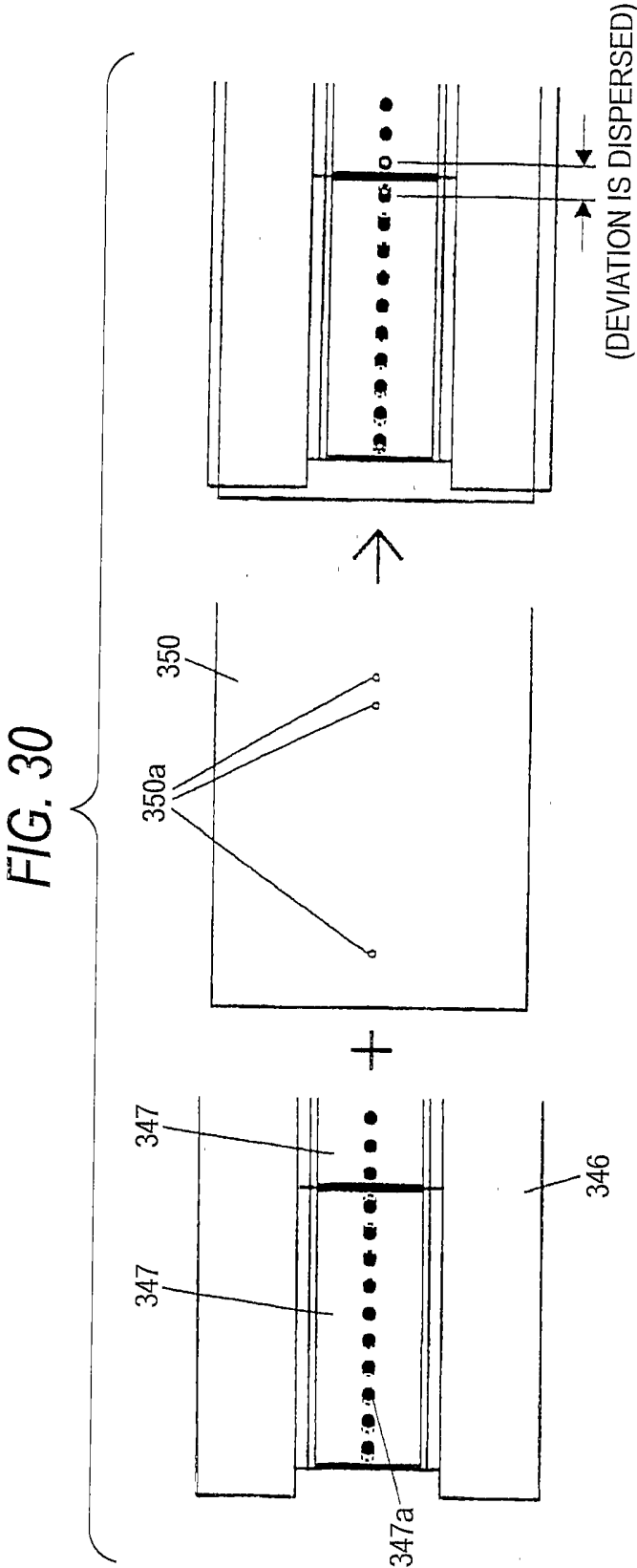


FIG. 31

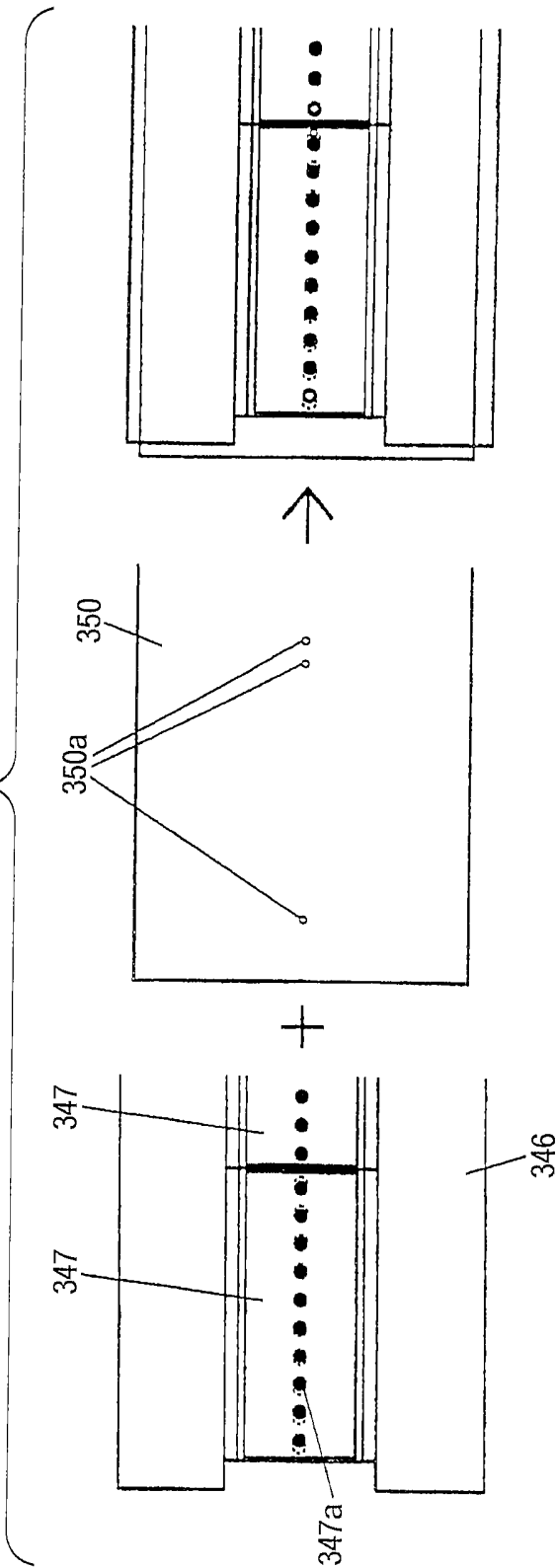


FIG. 32

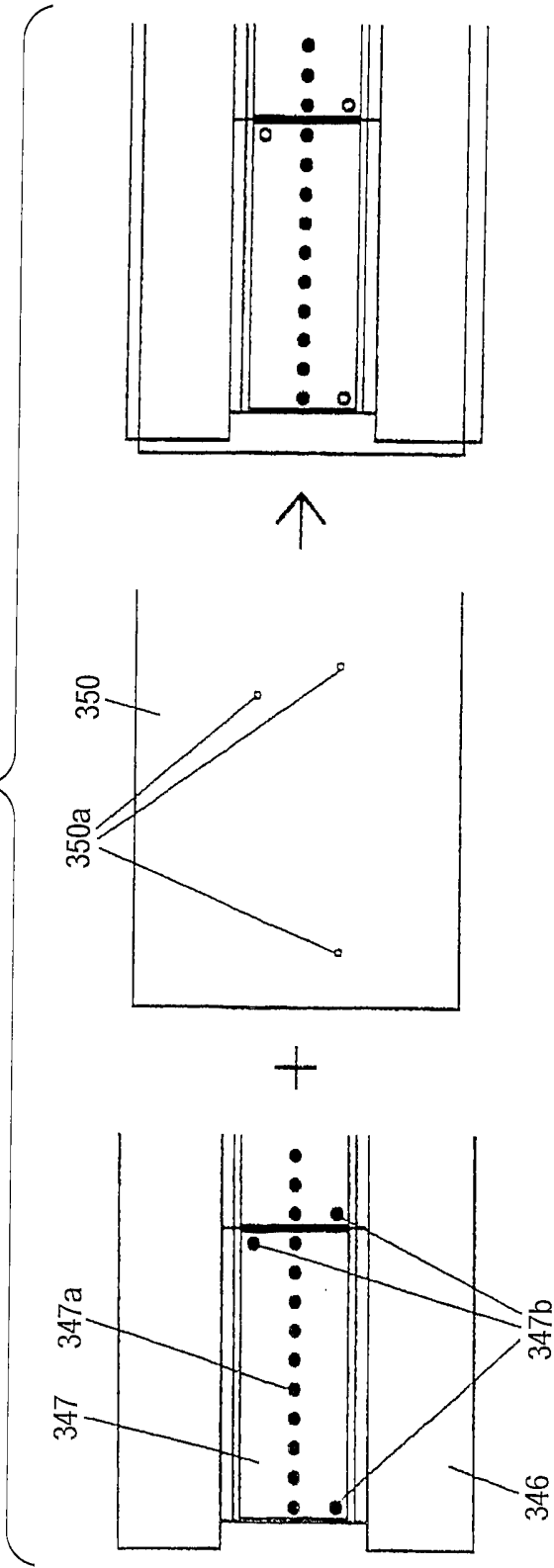


FIG. 33

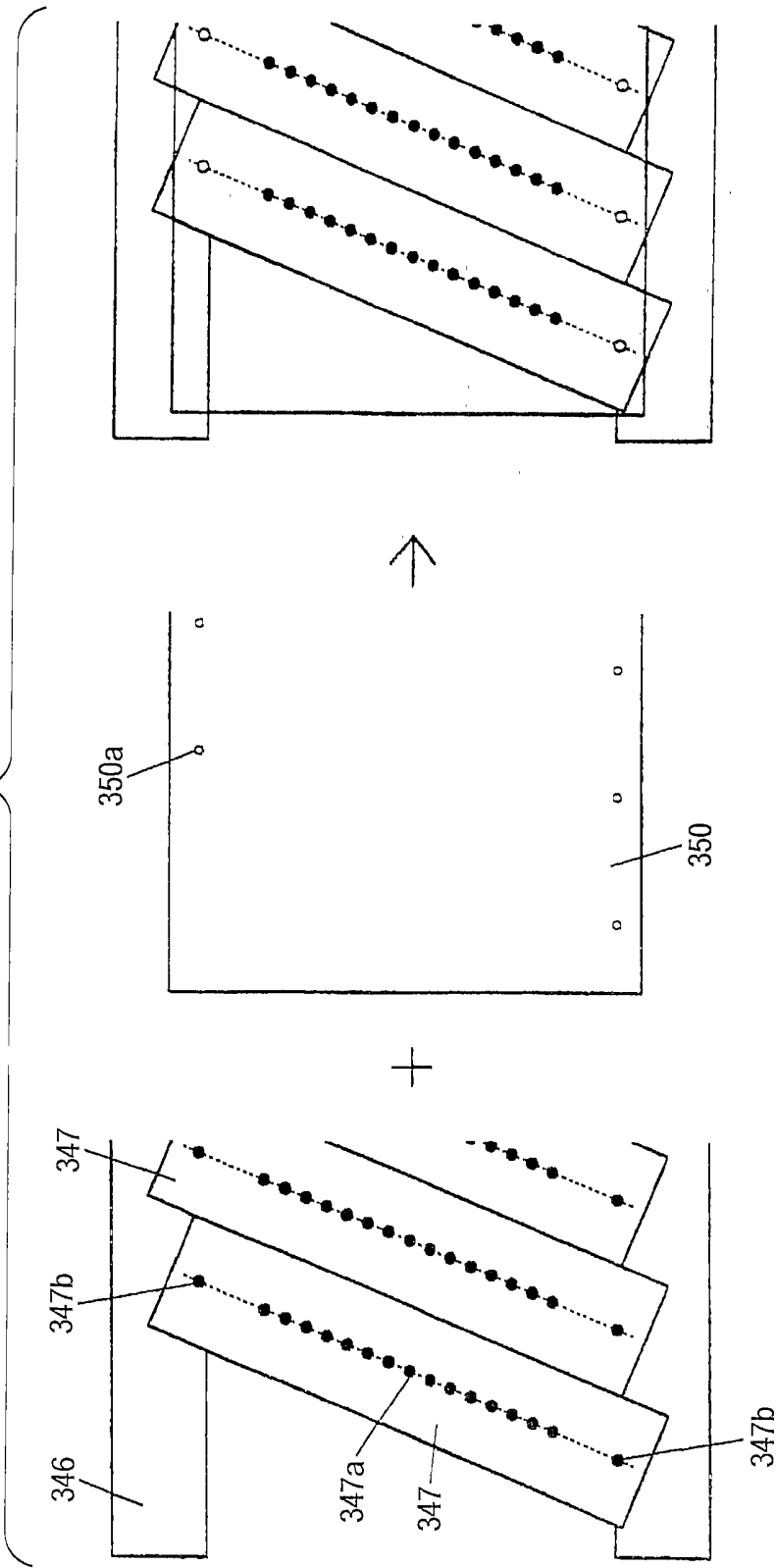


FIG. 34

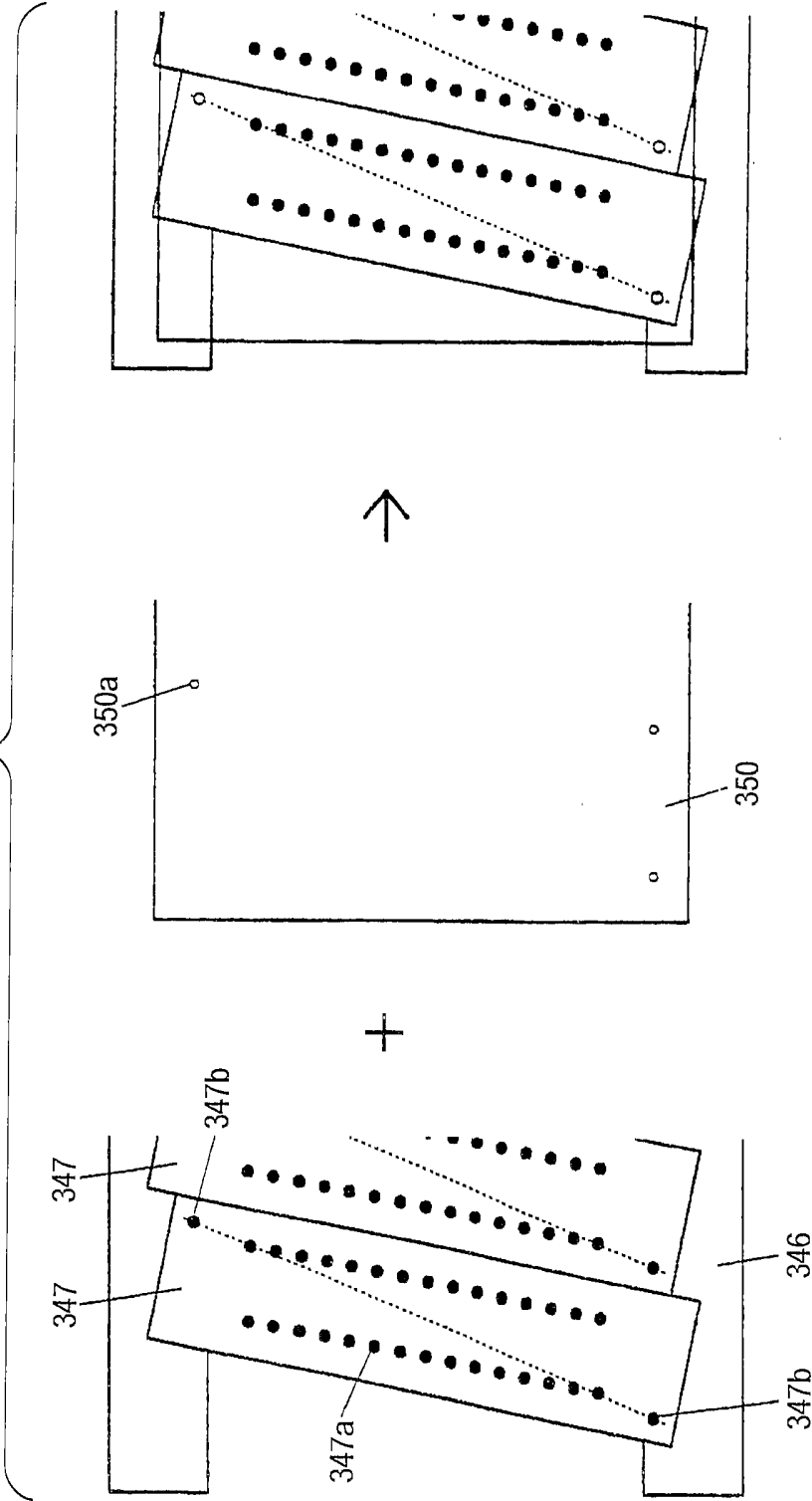


FIG. 35A

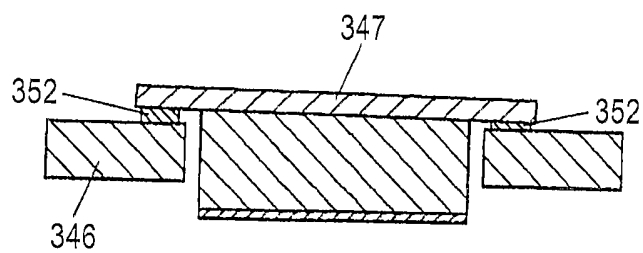


FIG. 35B

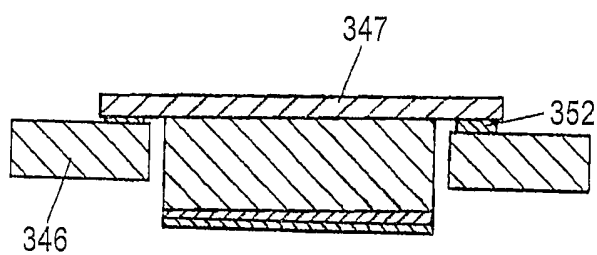


FIG. 36

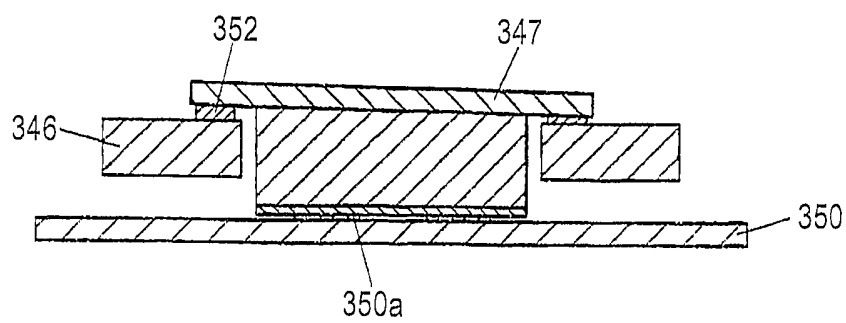


FIG. 38

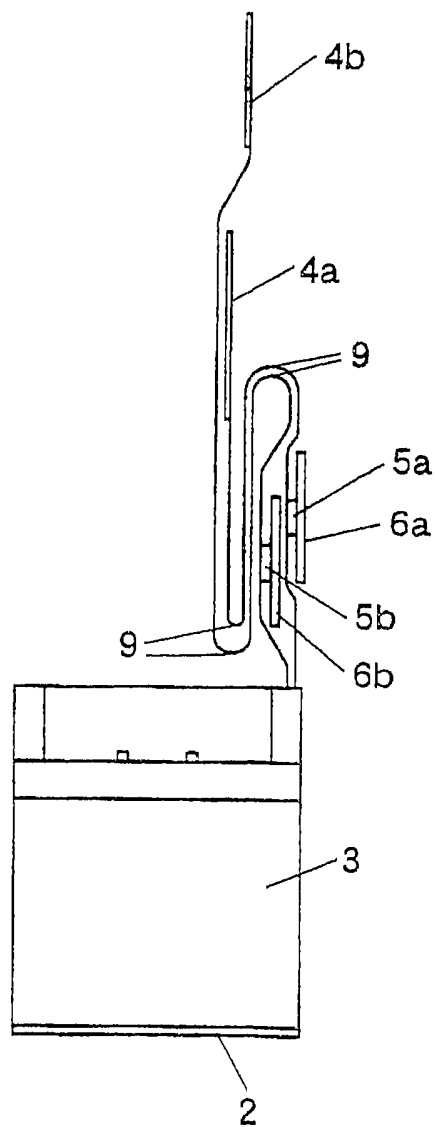


FIG. 39

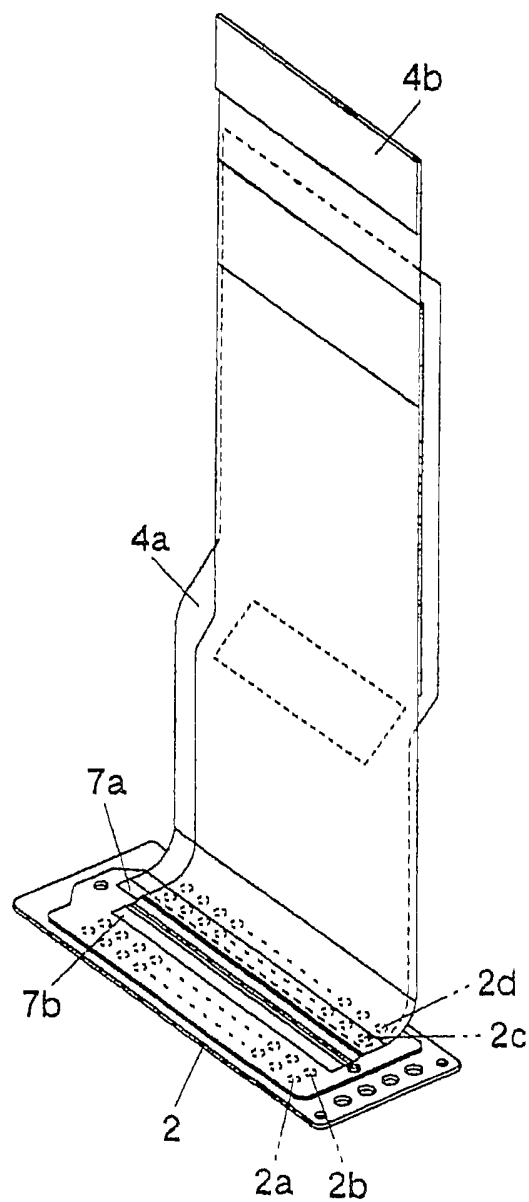


FIG. 40

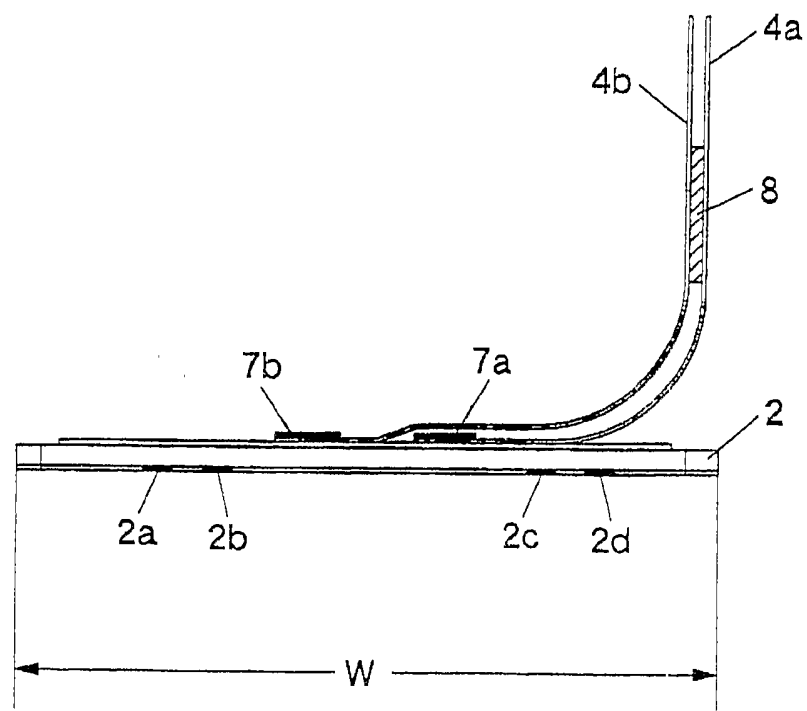


FIG. 41

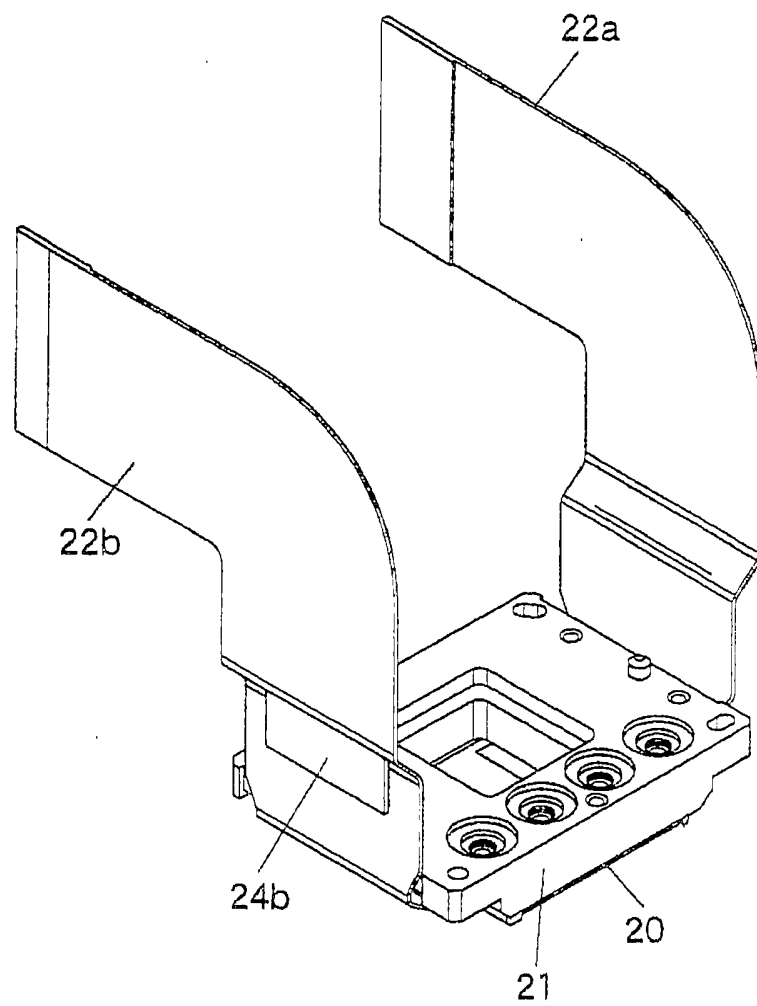
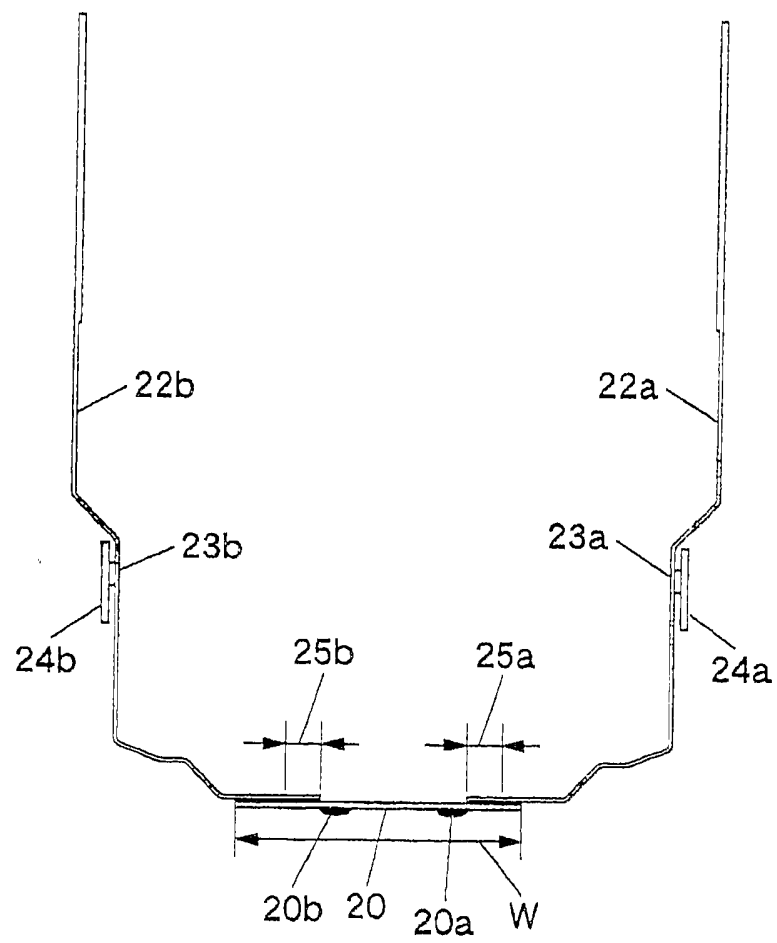


FIG. 42



INTERNATIONAL SEARCH REPORT

International Application No

PCT/JP2004/006089

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 B41J2/14 B41J2/155

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B41J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2002/012029 A1 (MIYATA YOSHINAO) 31 January 2002 (2002-01-31) paragraph '0072! - paragraph '0076!	1-9
A	EP 0 863 007 A (SEIKO EPSON CORP) 9 September 1998 (1998-09-09) column 4, line 35 -column 5, line 33	1-9
A	US 5 912 684 A (KAMISUKI SHINICHI ET AL) 15 June 1999 (1999-06-15) column 39, line 33 - line 48	1-9
A	PATENT ABSTRACTS OF JAPAN vol. 2002, no. 02, 2 April 2002 (2002-04-02) & JP 2001 300421 A (SEIKO EPSON CORP), 30 October 2001 (2001-10-30) abstract	9



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search

14 July 2004

Date of mailing of the international search report

03/08/2004

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Fax: (+31-70) 340-3016

Authorized officer

Urbaniec, T

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/JP2004/006089

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