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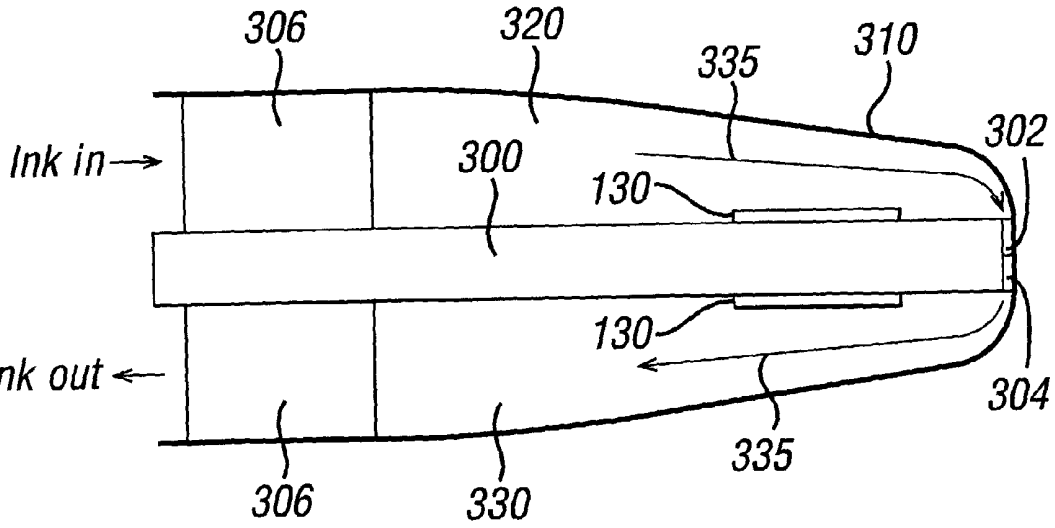
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(54) Title: DROPLET DEPOSITION APPARATUS



(57) Abstract: Droplet deposition apparatus comprises at least one droplet ejection unit (302, 304) comprising a plurality of fluid channels disposed side by side in a row, actuator means, and a plurality of nozzles, said actuator means being actuable to eject a droplet of fluid from a fluid channel through a respective nozzle; a support member (300) for said at least one droplet ejection unit; a first conduit (320) extending along said row and to one side of both said support member and said at least one droplet ejection unit for conveying droplet fluid to each of the fluid channels of said at least one droplet ejection unit; and a second conduit (330) extending along said row and to the other side of both said support member and said at least one droplet ejection unit for receiving droplet fluid from each of the fluid channels of said at least one droplet ejection unit.

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DROPLET DEPOSITION APPARATUS

The present invention relates to droplet deposition apparatus, such as, for example, a drop-on-demand inkjet printer.

In order to increase the speed of inkjet printing, inkjet printheads are typically provided with an increasing number of ink ejection channels. For example, there are commercially available inkjet printheads having in excess of 500 ink ejection channels, and it is anticipated that in future so called "pagewide printers" could include printheads containing in excess of 2000 ink ejection channels.

In at least its preferred embodiments, the present invention seeks to provide droplet deposition apparatus suitable for use in a pagewide printer and having a relatively simple and compact structure.

In a first aspect, the present invention provides droplet deposition apparatus comprising:

at least one droplet ejection unit comprising a plurality of fluid channels disposed side by side in a row, actuator means, and a plurality of nozzles, said actuator means being actuable to eject a droplet of fluid from a fluid channel through a respective nozzle;

a support member for said at least one droplet ejection unit; and

a first conduit extending along said row and to one side of both said support member and said at least one droplet ejection unit for conveying droplet fluid to each of the fluid channels of said at least one droplet ejection unit.

Where the apparatus comprises a plurality of droplet ejection units, the first conduit is preferably configured to convey droplet fluid to each of the fluid channels of said plurality of droplet ejection units. Thus, all of the ink channels

can be supplied with ink from one conduit. This can reduce significantly the number of ink supply channels or conduits required to convey ink to the ink channels, thereby simplifying machining and providing a compact droplet deposition apparatus.

Preferably, the apparatus comprises a second conduit for conveying droplet fluid away from each of the fluid channels of said at least one droplet ejection unit.

In one embodiment, there are a plurality of rows of channels, the droplet ejection units being arranged on the support member such that at least some of the fluid channels of adjacent rows of fluid channels are substantially co-axial. Thus, there may be effectively one fluid inlet and one fluid outlet for a number of coaxial ink channels. This can reduce significantly the size of the printhead in the direction of the paper feed. This can also allow the printheads to be closely stacked in the direction of paper feed, which is advantageous in achieving accurate drop placement, a compact printer and hence a lower cost.

In a preferred arrangement, each fluid channel has a length extending in a first direction and said at least one row extends in a second direction substantially orthogonal to said first direction. With such an arrangement, preferably the at least one droplet ejection unit is arranged on the support member such that there is at least one row of fluid channels extending in the second direction.

The increased density of the components of the apparatus, such as the drive circuitry, can lead to problems associated with overheating. Therefore, preferably at least one of the conduits is arranged so as to transfer a substantial part of the heat generated during droplet ejection to droplet fluid conveyed thereby.

The apparatus may include drive circuit means for supplying electrical signals to the actuator means. The drive circuit means may be in substantial thermal

contact with at least one of the conduits so as to transfer a substantial part of the heat generated in the drive circuit means to the droplet fluid. Arranging the drive circuit means in such a manner can conveniently allow the ink in the printhead to serve as the sink for the heat generated in the drive circuitry. This can substantially reduce the likelihood of overheating, whilst avoiding the problems with electrical integrity that might occur were the integrated circuit packaging containing the circuitry allowed to come into direct contact with the ink. In one arrangement the drive circuit means is mounted on the support member, the support member being in thermal contact with at least one of the conduits. In one embodiment, the support member comprises a substantially U-shaped, or H-shaped, member, the drive circuit means being mounted on at least one of the two facing sides of the arms of the U-shaped, or H shaped, member. With this arrangement, the drive circuit means can be readily physically isolated from the fluid conveyed by the conduits.

Alternatively, the drive circuit means may be mounted on the support member so as to contact droplet fluid being conveyed by at least one of the conduits. With this arrangement it may be necessary to electrically passivate the external surfaces of the drive circuit means.

In one embodiment the apparatus comprises a coolant conveying conduit for conveying a coolant fluid, the drive circuit means being proximate the coolant conveying conduit so as to transfer a substantial part of the heat generated in the drive circuit means to the coolant fluid. Cooling of the drive circuit can thus be achieved with reduced transfer of heat to the droplet ejection units. This can reduce any variation in droplet ejection velocity due to fluctuations in the viscosity of the fluid caused by heating of the droplet fluid by the drive circuit. The drive circuit means is preferably mounted on the support member, the support member being in thermal contact with the third conduit. Preferably, the third conduit comprises an aperture formed in the support member.

Thus, in another aspect the present invention provides droplet deposition

apparatus comprising:

at least one droplet ejection unit comprising a plurality of fluid channels disposed side by side in a row, actuator means, drive circuit means for supplying actuating electrical signals to said actuator means, and a plurality of nozzles, said actuator means being actuable to eject a droplet of fluid from a fluid channel through a respective nozzle;

droplet fluid conveying means for conveying droplet fluid to each of the fluid channels of said at least one droplet ejection unit; and

further coolant conveying means for conveying a coolant fluid, at least one of said drive circuit means and said at least one droplet ejection unit being proximate said coolant conveying means so as to transfer a substantial part of the heat generated during droplet ejection to said coolant fluid.

Preferably at least one of said at least one droplet ejection unit and said drive circuit means is mounted on said coolant conveying means. More preferably, both said at least one droplet ejection unit and said drive circuit means are mounted thereon.

Preferably, the fluid conveying means comprises a conduit extending along said row and to one side of both said coolant conveying means and said at least one droplet ejection unit for conveying droplet fluid to each of the fluid channels of said at least one droplet ejection unit. The fluid conveying means preferably also comprises a second conduit extending along said row and to the other side of both said coolant conveying means and said at least one droplet ejection unit for receiving droplet fluid from each of the fluid channels of said at least one droplet ejection unit.

In an alternative arrangement, there are two rows of fluid channels, each row being arranged on a respective support member having a respective conduit for conveying fluid to that row. Preferably, a further conduit is arranged to convey droplet fluid away from both rows of fluid channels. The second conduit preferably extends between the support members.

In one arrangement, the at least one row extends in a first direction and the channels have a length extending in a second direction substantially coplanar with and orthogonal to the first direction, the support member having a dimension in said second direction which is substantially equal to *n* x the length of a fluid channel in the second direction, where *n* is the number of rows of channels. By reducing the width of the apparatus in the direction of the paper feed, by forming the support member with a thickness substantially equal to the combined lengths of the ink channels in the second direction, improvements in paper/printhead alignment and dot registration can be provided. PZT, from which the ejection units are typically formed, is relatively expensive and so it is advantageous to ensure that a maximum number of channels are provided for a minimum amount of PZT.

Thus, in a further aspect, the present invention provides droplet deposition apparatus comprising:

at least one droplet ejection unit comprising a plurality of fluid channels disposed side by side in a row extending in a first direction, said channels having a length extending in a second direction substantially coplanar with and orthogonal to said first direction, actuator means, and a plurality of nozzles, each nozzle having a nozzle axis extending in a third direction substantially orthogonal to said first and second directions, said actuator means being actuable to eject a droplet of fluid from a fluid channel through a respective nozzle;

means for conveying droplet fluid to said fluid channels; and

a support member for said at least one droplet ejection unit, said at least one droplet ejection unit being arranged on said support member such that there are *n* rows of fluid channels extending in said first direction (*n* being an integral number), said support member having a dimension in said second direction which is substantially equal to *n* x the length of a fluid channel in said second direction.

In an alternative arrangement, the support member may comprise an arm of

a substantially U-shaped member, at least one droplet ejection unit being supported at the end of each of the arms of the U-shaped member.

Preferably, the second conduit extends between the arms of the U-shaped member to convey droplet fluid from the droplet ejection units supported by the arms of the U-shaped member. With such an arrangement, the apparatus may comprise a pair of conduits each for conveying droplet fluid to the or each droplet ejection unit supported by a respective arm, each conduit extending along the external side of the respective arm of the U-shaped member.

In another arrangement, the apparatus comprises a cover member extending over and to the sides of the support member to define with the support member at least part of the conduits.

The support member and the cover member may be attached to a base which defines with the support member and the cover member the conduits. Thus, the number of apparatus components may be reduced, since, for example, the base, cover member and support member perform multiple functions (including the definition of conduits).

In yet another aspect the present invention provides droplet deposition apparatus comprising:

a support member;

at least one droplet ejection unit attached to said support member and comprising a plurality of fluid channels disposed side by side in a row; and

a cover member extending over and to the sides of said support member to define with said support member a first conduit extending along said row for conveying fluid to said fluid channels and a second conduit extending along said row for conveying fluid from said fluid channels.

The or each droplet ejection unit may comprise actuator means and a plurality of nozzles, the actuator means being actuable to eject a droplet of fluid from

a fluid channel through a respective nozzle.

The cover may include apertures for enabling droplets to be ejected from the fluid channels. These apertures are preferably etched in the cover member. In one arrangement the nozzles are formed in the cover. In another arrangement the nozzles are formed in a nozzle plate supported by the cover, each fluid channel being in fluid communication with a respective nozzle via a respective aperture. The use of both a cover member and nozzle plate can provided enhanced tolerance for the laser ablation of the nozzles in the nozzle plate, as precise positioning of the nozzle relative to the ink chamber can become less critical. As the nozzle plate is supported by the cover, it can be made thinner, thereby reducing costs. The cover is preferably formed from a material having a coefficient of thermal expansion which is substantially equal to that of the support member.

The cover is preferably formed from metallic material, for example, from molybdenum or Nilo (a nickel/iron alloy).

The or each droplet ejection unit may comprise a first piezoelectric layer poled in a first poling direction, and a second piezoelectric layer on said first piezoelectric layer and poled in a direction opposite to said first poling direction, said fluid channels being formed in said first and second piezoelectric layers. Thus, the walls of the fluid channels can serve as wall actuators of the so called "chevron" type. These actuators are known to be advantageous because they require a lower actuating voltage to establish the same pressure in the fluid channels during operation than comparable shear mode cantilever type actuators or other conventional piezoelectric drop on demand actuators.

The first piezoelectric layer may be attached directly to said support member. This simple arrangement of the ejection unit can enable the channels to be machined in the first and second piezoelectric layers when the layers are in

situ on the support member, thereby simplifying production. In this arrangement, the support member is preferably formed from ceramic material.

In alternative arrangement, the first piezoelectric layer is formed on a base layer formed from ceramic material, said base layer being attached to said support member.

The axes of the nozzles may extend in a direction substantially orthogonal to the direction of extension of said at least one row. In other words, the droplet ejection unit may be an "edge shooter", with droplets being ejected from the top of the ink channel.

The invention is further illustrated, by way of example, with reference to the accompanying drawings, in which:

Figure 1 represents a perspective view of a module of a droplet ejection unit;

Figure 2 represents a side view of the module shown in Figure 1;

Figure 3 represents a perspective view of the module of Figure 1 with electrodes and interconnection tracks formed thereon;

Figure 4 represents a perspective view of a single drive circuit connected to a droplet ejection module;

Figure 5 represents a perspective view of two drive circuits connected to a droplet ejection module;

Figure 6 represents a perspective view of a first embodiment of an arrangement of a droplet ejection module with fluid conduits attached thereto for the supply of fluid to the module;

Figure 7 represents a perspective view of the arrangement shown in Figure 6 with a heat sink attached thereto;

Figure 8 represents a first array of arrangements shown in Figure 7 in a printhead;

Figure 9 represents a second array of arrangements shown in Figure 7 in a printhead;

Figure 10 represents a third array of arrangements shown in Figure 7 in a printhead;

Figure 11 represents a side view of a second embodiment of an arrangement of a plurality of droplet ejection modules attached to a support member;

Figure 12 represents an exploded perspective view of the embodiment shown in Figure 11 with fluid conduits for the supply of fluid to the modules;

Figure 13 represents a perspective view of the attachment of a nozzle plate to the arrangement shown in Figure 12;

Figure 14 represents a perspective view of a third embodiment of an arrangement of a plurality of droplet ejection modules attached to a support member;

Figure 15 represents a side view of the arrangement shown in Figure 14 with a cover member attached thereto to define fluid conduits for the supply of fluid to the modules;

Figure 16 represents a side view of a portion of the arrangement shown in Figure 15 attached to a base;

Figure 17 represents a perspective view of the arrangement shown in Figure 15 with apertures formed in the cover for the ejection of ink from ink channels;

Figure 18 represents a perspective view of the arrangement shown in Figure 15 with a nozzle plate attached to the cover;

Figure 19 represents a perspective view of a fourth embodiment of an arrangement of a plurality of droplet ejection modules attached to a support member;

Figure 20 represents a side view of a fifth embodiment of an arrangement of droplet ejection modules with fluid conduits for the supply of fluid to the modules; and

Figures 21 to 25 represent cross-sectional views of further embodiments of arrangements of droplet ejection modules with fluid conduits attached thereto.

The present invention relates to droplet deposition apparatus, such as, for example, drop-on-demand inkjet printheads. In the preferred embodiments of the present invention to be described below, the printhead employs a modular layout of droplet ejection modules to provide a pagewide array of droplet ejection nozzles for the ejection of fluid on to a substrate. The manufacture of such a droplet ejection module will first be described.

With reference first to Figures 1 and 2, a droplet ejection module 100 comprises a ceramic base wafer 102 on to which are attached first piezoelectric wafer 104 and second piezoelectric wafer 106. In the preferred embodiment, the base wafer 102 is formed from a glass ceramic wafer having a thermal expansion coefficient C_{TE} between that of the material from which the piezoelectric layers 104, 106 are formed (for example, PZT) and the material from which a support member on to which the base wafer 102 is to be attached are formed. The first piezoelectric wafer 104 is attached to the

base wafer 102 by resilient glue bond material 108. Similarly, the second piezoelectric wafer 106 is attached to the first piezoelectric wafer 104 by resilient glue bond material 110. The combination of the C_{TE} of the base wafer 102 and the resilience of the glue bond material 108, 110 provides a buffer for avoiding the distortion of the module 100 that might otherwise occur as a result of the differing thermal expansion characteristics of the piezoelectric material and the support member. In this preferred embodiment, this is particularly important due to the compactness of the droplet ejection unit, as described in more detail below.

A row of parallel fluid channels 112 are formed in the piezoelectric layers 104, 106. For example, the fluid channels may be provided by grooves formed in the piezoelectric wafers using a narrow dicing blade. As indicated by arrows 114 and 116 in Figure 2, the piezoelectric wafers are poled in opposite directions. As the wafers 104 and 106 are oppositely poled, the walls 118 of the channels serve as wall actuators of the so called "chevron" type, such as are the subject of European Patents No. 0277703 and No. 0278590, the disclosures of which are incorporated herein by reference. These actuators are known to be advantageous because they require a lower actuating voltage to establish the same pressure in the fluid channels during operation.

After forming the channels 112, the wafers are diced to form a module as shown in Figure 1. In the preferred embodiment, the module includes 64 fluid channels, each with a length of 2 mm (approximately equal to 2 x the acoustic length of ink in the channel during operation).

With reference to Figure 3, metallised plating is deposited on the opposing faces of the ink channels 112, where it extends the full height of the channel walls 118 providing actuation electrodes 120 to which a passivation coating may be applied. In one technique for forming the electrodes, a seed layer, such as Nd:YAG, is sputtered over the module 100 and into the channels 112. An interconnect pattern 122 is formed one or both sides 124 of the module

100, for example, by using the well-known laser ablation, photoresist or masking technique. Formation of the interconnect pattern on both sides 124 of the module can halve the density of the tracks of the interconnect pattern, thereby facilitating formation of the interconnect pattern. With the seed layer having been defined, the layer is plated to form the electrode tracks, for example, using an electroless nickel plating process. The tops of the walls 118 separating the channels 112 are kept free of plating metal so that the track and the electrode for each channel are electrically isolated from other channels.

With reference to Figures 4 and 5, each module is connected to at least one associated drive circuitry (integrated circuit ("chip") 130) by means, for example, of a flexible circuit 132. In the arrangement shown in Figure 4, the module 100 has interconnection tracks formed on one side only, and thus only one chip 130 is required to drive the actuators 118. In the Figure 5 arrangement, the module 100 has interconnection tracks formed on both sides of the module, with two chips 130 driving the actuators 118. Via holes 133 may be formed in the flexible circuit 132 to enable the chip to be connected to other components of the drive circuitry, such as resistors, capacitors or the like.

As shown in Figure 5, the module 100 is attached to a support member 140. The drive circuitry 130 may be connected to the module prior to its attachment to the support member, thereby enabling the module to be tested prior to attachment on the support member, or may be connected to the module when it is already attached to the support member 140.

As described in more detail below, in the embodiment shown in Figure 5 the support member 140 is made of a material having good thermal conduction properties. Of such materials, aluminium is particularly preferred on the grounds that it can be easily and cheaply formed by extrusion. In order to reduce the size of the printhead in the direction of paper feed, the support

member 140 has a thickness in the direction of the length of the fluid channels substantially equal to the length of the fluid channels.

Figure 6 illustrates the connection of conduits for conveying ink to and from the module shown in Figure 5 in a first embodiment of a droplet deposition apparatus. The conduits comprise a first ink supply manifold 150 for supplying ink to the module 100 and a second ink supply manifold 152 for conveying ink away from the manifold 152. In the arrangement shown in Figure 6, the manifolds 150, 152 are configured so as to convey ink to and from all of the ink channels of the module 100. The manifolds may be formed from any suitable material, such as plastics material.

With reference to Figure 7, a heatsink 160 is connected to the ink outlet 154 of the second manifold 152. The heatsink is hollow, and is used to convey ink away from the second manifold 152 to an ink reservoir (not shown). As shown in Figure 7, the drive circuits 130 are mounted in substantial thermal contact with the heatsink 160 so as to allow a substantial amount of the heat generated by the circuits during their operation to transfer via the heatsink 160 to the ink. To this end, the heat sink 160 is also formed from material having good thermal conduction properties, such as aluminium. Thermally conductive pads 134, or adhesive, may be optionally employed to reduce resistance to heat transfer between circuits 130 and the heatsink 160.

A nozzle plate 170 is bonded to the uppermost surface of the module 100. The nozzle plate 170 consists of a strip of polymer such as polyimide, for example Ube Industries polyimide UPILEX R or S, coated with a non-wetting coating as provided in US-A-5010356 (EP-B-0367438). The nozzle plate is bonded by application of a thin layer of glue, allowing the glue to form an adhesive bond between the nozzle plate 170 and the walls 118 then allowing the glue to cure. A row of nozzles, one for each ink channel 112, is formed in the nozzle plate, for example by UV excimer laser ablation, the row of nozzles extending in a direction orthogonal to the length of the ink channels 112 so

that the actuators are so called "side shooter" actuators.

The module 100, when supplied with ink and operated with suitable voltage signals via the tracks 124 may be traversed either normally or at a suitable angle to the direction of motion across a paper printing surface to deposit ink on the printing surface. Alternatively, an array of independent modules 100 may be provided. The array layout may take any suitable form. For example, as shown in Figure 8, three 180 dpi resolution modules may be angled to the direction of feed of a printing surface 180 to form a 360 dpi resolution array, whilst Figure 9 shows "3-tier interleaved" array of modules and Figure 10 shows a "2-row interleaved" array of modules 100 for providing the required printhead resolution.

Such a modular array eliminates the need to serially butt together a plurality of modules at facing end surfaces to provide a printhead having the required droplet density. Nonetheless, such modules may be butted together to form a pagewide array of modules.

A second embodiment of droplet deposition apparatus comprising such an arrangement of modules will now be described with reference to Figures 11 to 13.

With reference first to Figure 11, this embodiment comprises a plurality of modules 100, for example, as shown in Figure 4 with drive circuitry attached to one side 124 of the module 100. Each module is mounted on the end of an arm of a substantially U-shaped pagewide support member 200. On each arm, the modules are serially butted together at the edges 126 of the modules 100, as shown in Figure 1, such that there is a single row of fluid channels extending orthogonal to the longitudinal axis, or length, of each of the ink channels 112. The modules may be butted together using glue bond material, and aligned using any suitable alignment technique. Each array of butted modules provides a 180 dpi resolution, and therefore the combination of two

interleaved arrays formed on respective arms of the support member 200 provides a printhead having a 360 dpi resolution.

Similar to the first embodiment, the chips 130 are mounted on the outer surface of the support member 200 so as to lie in substantial thermal contact with the support member 200. As shown in Figure 11, further components 202 of the drive circuitry may be connected to the chip 130 via a printed circuit board 204 mounted on the track using solder bumps 206. Following mounting of the chips on the support member 200, each track 132 is folded in the direction indicated by arrows 208, 210 in Figure 11 so that the printed circuit boards 204 also come into thermal contact with the support member 200.

As described in more detail below, the U-shaped support member 200 acts as an outlet manifold for conveying fluid away from the droplet ejection units. The drive circuits 130 for the modules 100 are mounted in substantial thermal contact with that part of structure 200 acting as the outlet manifold so as to allow a substantial amount of the heat generated by the circuits during their operation to transfer via the conduit structure to the ink. To this end, the structure 200 is made of a material having good thermal conduction properties, such as aluminium.

With reference to Figure 12, ink inlet manifolds 210, 220 extending substantially the entire length of the support member 200 are provided for supplying ink to each of the modules attached to respective arms of the support member (only one module 100 is shown in figure 11 for clarity purposes only). The inlet manifolds 210, 220 may be formed from extruded plastics or metallic materials. As will be appreciated from Figure 12, the inlet manifolds also act to provide external covers to protect the components 202 of the drive circuitry for the modules 100. Endcaps (not shown) are fitted to the ends of the support member 200 and inlet manifolds 210, 220 to form seals to complete the inlet and outlet manifolds and to enclose the drive circuitry.

With reference to Figure 13, similar to the first embodiment a nozzle plate 230 is attached to the tops of the actuator walls 118 and two rows of nozzles formed in the nozzle plate, one row for each of the rows of ink channels. As shown in figure 13, the nozzle plate 230 is additionally supported on each side by portions 240 of the ink inlet manifolds 210, 220. The nozzle plate 230 may be further supported by a support blanking actuator component (not shown) provided at each end of each of the arrays of modules.

An example of another arrangement of butted modules will now be described with reference to Figures 14 to 18, in which the U-shaped support member 200 is replaced by a planar, parallel-sided support member 300.

With reference to Figures 14 and 15, two rows 302, 304 of modules are attached to the support member 300. Whilst Figure 14 shows two rows of four butted modules, any number of modules may be butted together, although it is preferred that the length of each row is substantially equal to the length of a page (typically 12.6 inches (32 cm) for the American "Foolscap" standard).

The support member 300 is preferably formed from ceramic material, such as alumina. This enables the base wafer 102 of the modules 100 to be omitted, thereby reducing further the number of components of the printhead. If so, the first layer 104 of each module is attached directly to the support member 300, for example, using a resilient glue bond. Similar to the module shown in Figure 1, a second piezoelectric layer 106 is attached to the first piezoelectric layer 104.

Similar to the arrangement shown in figure 1, ink channels 112 are formed in the piezoelectric layers 104,106 by, for example, machining and electrodes and interconnect tracks are formed in the channels 112 and on both sides of the support member 300 (only a small number of ink channels and interconnects are shown in Figure 14 for clarity purposes only). The ink

channels are formed such that each ink channel of one row 302 is co-axial with an ink channel of the other row 304.

Drive circuitry, or chips 130, are attached directly to the sides of the support member 300 for supplying electrical pulses to the interconnect tracks to actuate the walls 118 of the channels 112. As the support member is formed from alumina, for example, having a relatively low C_{TE}, this substantially prevents heat generated in the chips 130 from being transferred through the support member to the actuators 118. The drive circuitry may be coated, for example, with parylene.

Housings 306 for housing electrical connections to the chips 130 are also attached to each side of the support member 300. The housings 306 may be conveniently formed from injection moulded plastics material. In addition, a fluid inlet/outlet 308 is also attached to each side of the support member 300. The fluid inlet/outlet may be integral with the adjacent housing 306, and may include a filter, especially at the inlet side, for filtering ink to be supplied to the modules.

A cover 310 extends over the entire length and to both sides of the support member 300. As shown in figure 16, the base of the support member 300 and both ends of the cover 310 are attached to a base plate 315. The cover is preferably formed from a material that is thermally matched to the material of the piezoelectric wafers 104,106. Molybdenum, which has high strength and thermal conductivity in addition to being thermally matched to PZT, has been found to be a particularly suitable material for the cover.

The cover 310 defines with the support member an ink inlet conduit 320 and an ink outlet conduit 330 for conveying ink to and from all of the channels of the two rows 302,304 of modules as indicated by arrows 335 in Figure 15. Endcaps (not shown) are fitted to the ends of the support member 300 and cover 310 to form seals to complete, with the housings 306, the inlet and outlet

conduits and to enclose the electronics.

The co-axial arrangement of the ink channels of the two rows enables ink to flow from the ink inlet conduit 320 into an ink channel of row 302, from that ink channel directly into an ink channel of the other row 304, and from that ink channel to the ink outlet conduit 330. With the arrangement of chips 130 on the sides of the support member 300, heat generated at the surfaces of the chips in thermal contact with the ink carried by the conduits 320,330 is substantially transferred to the ink.

As shown in Figure 17, apertures 340 are formed in the cover 310 to enable ink to be ejected from the modules through the cover 310. The apertures 340 may be formed by any suitable method, for example, UV excimer laser ablation, and may serve as nozzles for the droplet ejection modules. alternatively, as shown in Figure 18, a nozzle plate 350 may be attached to the cover, with nozzles being formed in the nozzle plate 350 such that the nozzles are in fluid communication with the ink channels 112 via the apertures 340. As the nozzle plate 350 is supported by the cover 310, this enables the thickness of the nozzle plate to be reduced. Alternatively, the nozzle plate 350 may be attached directly to the modules, with the cover 310 extending over the nozzle plate with apertures 340 aligned with the nozzles formed in the nozzle plate.

Operation of the third embodiment will now be described.

In its simplest form, when one pair of actuator walls 118 one row, say 304 are required to eject a droplet of fluid from the ink channel 112 between the actuator walls 118, the walls of the ink channel of row 304 which is co-axial with that ink channel may be driven to replicate the acoustics of an ink manifold disposed at the end of that ink channel. In the case of "grey scale" printing, a number of droplets may be ejected from the ink channel of row 302, followed by a similar number of droplets from the co-axial ink channel of row

304. Alternatively, in order to increase the printing speed, a droplet may be fired from each channel in turn. For example, ink can be drawn into one channel followed by (at some specific frequency) by a similar event in the other co-axial channel. This would provide a constant stable acoustic effect within each channel.

Whilst the embodiment shown with reference to Figures 14 to 18 includes two rows of modules, a single row of ink modules may alternatively be used. Such an arrangement is shown in Figure 19. In this embodiment, a single row 402 of modules is attached to the support member 400. Whilst Figure 19 shows four butted modules, any number of modules may be butted together, although it is preferred that the length of each row is substantially equal to the length of a page (typically 12.6 inches (32 cm) for the American "Foolscap" standard). With such an arrangement, the width of the support member may be reduced to substantially the length of a single ink channel 112, and chips 130 connected to one side only of the support member. However, there will, of course, be a reduction in the resolution of the printhead (from 360 dpi to 180 dpi). Resolution may be increased by providing two such arrangements "back to back" with a common ink inlet provided between the rows of modules.

Figure 20 shows a simplified cross-sectional view of a fifth embodiment of an arrangement of droplet ejection modules with fluid conduits for the supply of fluid to the modules. In this embodiment, the support structure 500 comprises a laminated structure of multiple sheets of alumina. In the embodiment shown in figure 20, there are 4 laminated sheets 502, 504, 506, 508 of alumina, although any number of sheets may be used.

The sheets of the support structure 500 are machined or otherwise shaped to define, in the laminated structure, channels 510, 512 for conveying ink towards and away from one or more modules 514 attached to the support structure 500. As shown in Figure 20, channel 510 conveys ink to conduit 516 extending along one side of module 514 for supplying ink to the module 514,

and channel 512 conveys ink away from conduit 518 extending along the other side of module 514.

Conduit 518 is defined by a cover member 520 attached to the top of the module 514 and having apertures 522 such that nozzles 524 of nozzle plate 526 are in fluid communication with the ink channels of the module via the apertures 522, and by end cap 528 attached to the side of the support structure. Whilst conduit 516 may be defined in a similar manner, in the arrangement shown in Figure 20 this conduit is common to two support structures 500, and so alternatively this conduit is defined by the cover member 520 and alumina plate 530 to which the two support structures are attached.

Similar to the previous embodiments, drive circuitry 130 is attached directly to the sides of the support member 500 for supplying electrical pulses to the interconnect tracks to actuate the walls of the channels of the module. As the support member is formed from alumina, for example, having a relatively low C_{TE}, this substantially prevents heat generated in the chips 130 from being transferred through the support member to the actuators. In this embodiment, however, the drive circuitry is not in fluid communication with the ink conveyed to and from the module, but is instead located in a housing formed in the end cap 528.

Figure 21 illustrates a cross-sectional view of a further embodiment of an arrangement of droplet ejection modules with fluid conduits for the supply of fluid to the modules. This embodiment is similar to that of the fifth embodiment, in that a cover extends over and to the sides of the support member 300 to define a first conduit 320 and a second conduit 330 both extending along a row of droplet ejection channels and to the sides of the support member 130. In this embodiment, a single row of modules 302 is mounted on the end of a support member 300, and the first and second conduits 320 and 330 are spaced from the chips 130 mounted on the side of

the support member 300 so as to avoid the need to passivate the surfaces of the chips 130. In order to dissipate heat generated by the chips 130 during operation, the support member 300 is formed from thermally conducting material in order to conduct heat generated by the chips 130 to the fluid conveyed by the conduits 320 and 330.

In the embodiment shown in Figure 22. two rows 302, 304 of ejection units are provided on a substantially U-shaped, or H-shaped, support member 600 comprising a pair of support members 300a, 300b linked by a bridging wall 602. Chips 130 and associated circuitry 602 are mounted on the facing surfaces of the support members 300a, 300b, interconnect tracks 600 being formed on these surfaces for supplying actuating electrical signals to the walls of the ejection units. Fluid is conveyed to and away from the ejection units by conduits 320, 330 defined by cover member 310 and the support member 600, the bridging wall 602 acting to direct fluid from the first row 302 to the second row 304. Heat generated in the chips 130 during operation is conducted by the support members 300a, 300b into fluid carried by the conduits 320, 330.

Figure 23 illustrates an embodiment in which heat generated during operation both by the chips 130 mounted on either side of the support member 650 and by the rows 302, 304 of ejection units mounted on the support member is transferred to a coolant fluid, such as water, conveyed by a conduit 660 passing through the support member 650. The walls 670 of the support member are preferably suitably thin so that heat is conducted to the coolant fluid as quickly as possible. To improve conduction, the walls 670 may be formed from metallic material. The body 675 of the support member may be formed from ceramic material.

In the embodiment shown in Figure 23, there is no recirculation of droplet fluid, in that the conduit 330 simply receives fluid from the ejection units 304 and does not convey fluid back to a reservoir for re-use. Figure 24 illustrates a

modification of this embodiment, in which conduit 330 is configured to convey fluid back to a reservoir for re-use.

Figure 25 illustrates an embodiment in which each row 302, 304 of ejection units is mounted on a respective support member 300. Fluid is conveyed to each row by a respective conduit 320 extending along that row and to one side of the support member on which that row is mounted. Fluid is conveyed away from the rows by a mutual conduit 330 extending between the facing side walls of the two support members 300, heat generated by the chips 130 being transferred to fluid conveyed in the conduit 330. Providing two "inlet" conduits 320 can enable the printhead to be flushed effectively during production to remove dirt. A slow bleed of droplet fluids from one of the conduits 320 can be used to remove air bubbles during printing, whilst a larger flow could be induced during a pause in printing for maintenance purposes.

Each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features.

CLAIMS

1. Droplet deposition apparatus comprising:

at least one droplet ejection unit comprising a plurality of fluid channels disposed side by side in a row, actuator means, and a plurality of nozzles, said actuator means being actuable to eject a droplet of fluid from a fluid channel through a respective nozzle;

a support member for said at least one droplet ejection unit; and

a conduit extending along said row and to one side of both said support member and said at least one droplet ejection unit for conveying droplet fluid to each of the fluid channels of said at least one droplet ejection unit.

2. Apparatus according to Claim 1, comprising a second conduit for conveying droplet fluid away from each of the fluid channels of said at least one droplet ejection unit.

3. Apparatus according to Claim 2, comprising a plurality of droplet ejection units, said conduits being configured to convey droplet fluid to and from each of the fluid channels of said plurality of droplet ejection units.

4. Apparatus according to any preceding claim, wherein each fluid channel has a length extending in a first direction and said row extends in a second direction substantially orthogonal to said first direction.

5. Apparatus according to Claim 4, wherein said at least one droplet ejection unit is arranged on said support member such that there is at least one row of fluid channels extending in said second direction.

6. Apparatus according to any preceding claim, comprising drive circuit means for supplying electrical signals to said actuator means.

7. Apparatus according to Claims 2 and 6, wherein said drive circuit means is in substantial thermal contact with at least one of said conduits so as to transfer a substantial part of the heat generated in said drive circuit means to said droplet fluid.

8. Apparatus according to Claim 7, wherein said drive circuit means is mounted on said support member, said support member being in thermal contact with at least one of said conduits.

9. Apparatus according to Claim 8, wherein said drive circuit means is mounted on said support member so as to contact droplet fluid being conveyed by at least one of said conduits.

10. Apparatus according to Claim 8, wherein said drive circuit means is mounted on said support member so as to be distant from droplet fluid being conveyed by at least one of said conduits.

11. Apparatus according to Claim 10, wherein said support member comprises a substantially U-shaped member, said drive circuit means being mounted on at least one of the two facing walls of the arms of the U-shaped member.

12. Apparatus according to Claim 6, comprising a coolant conveying conduit for conveying a coolant fluid, said drive circuit means being proximate said coolant conveying conduit so as to transfer a substantial part of the heat generated in said drive circuit means to said coolant fluid.

13. Apparatus according to Claim 12, wherein said drive circuit means is mounted on said support member, said support member being in thermal contact with said third conduit.

14. Apparatus according to Claim 13, wherein said third conduit comprises

an aperture formed in said support member.

15. Apparatus according to any preceding claim, wherein there are a plurality of rows of fluid channels, said droplet ejection units being arranged on said support member such that at least some of the fluid channels of adjacent rows of fluid channels are substantially co-axial.

16. Apparatus according to Claim 1, wherein there are two rows of fluid channels, each row being arranged on a respective support member having a respective conduit for conveying fluid to that row.

17. Apparatus according to Claim 16, wherein a further conduit extends between said support members for conveying droplet fluid away from said rows.

18. Apparatus according to any preceding claim, wherein said at least one row extends in a first direction and said channels have a length extending in a second direction substantially coplanar with and orthogonal to said first direction, said support member having a dimension in said second direction which is substantially equal to *n* x the length of a fluid channel in said second direction, where *n* is the number of rows of channels.

19. Droplet deposition apparatus comprising:

at least one droplet ejection unit comprising a plurality of fluid channels disposed side by side in a row extending in a first direction, said channels having a length extending in a second direction substantially coplanar with and orthogonal to said first direction, actuator means, and a plurality of nozzles, each nozzle having a nozzle axis extending in a third direction substantially orthogonal to said first and second directions, said actuator means being actuable to eject a droplet of fluid from a fluid channel through a respective nozzle;

means for conveying droplet fluid to said fluid channels; and

a support member for said at least one droplet ejection unit, said at least one droplet ejection unit being arranged on said support member such that there are *n* rows of fluid channels extending in said first direction (*n* being an integral number), said support member having a dimension in said second direction which is substantially equal to *n* x the length of a fluid channel in said second direction.

20. Apparatus according to any of Claims 1 to 8, wherein said support member comprises an arm of a substantially U-shaped member, at least one droplet ejection unit being supported at the end of each of the arms of the U-shaped member.

21. Apparatus according to Claim 20, comprising a pair of conduits each for conveying droplet fluid to the or each droplet ejection unit supported by a respective arm, each conduit extending along the external side of the respective arm of the U-shaped member.

22. Apparatus according to Claim 21, wherein a further conduit extends between the arms of said U-shaped member to convey droplet fluid from the droplet ejection units supported by the arms of said U-shaped member.

23. Apparatus according to Claim 2, comprising a cover member extending over and to the sides of said support member to define with said support member at least part of said conduits.

24. Droplet deposition apparatus comprising:

a support member;

at least one droplet ejection unit attached to said support member and comprising a plurality of fluid channels disposed side by side in a row; and

a cover member extending over and to the sides of said support member to define with said support member a first conduit extending along said row for conveying fluid to said fluid channels and a second conduit

extending along said row for conveying fluid from said fluid channels.

25. Apparatus according to Claim 23 or 24, wherein said cover includes apertures for enabling droplets to be ejected from said fluid channels.

26. Apparatus according to Claim 24, wherein the or each droplet ejection unit comprises actuator means and a plurality of nozzles, said actuator means being actuable to eject a droplet of fluid from a fluid channel through a respective nozzle.

27. Apparatus according to Claim 23 or 26, wherein said nozzles are formed in said cover.

28. Apparatus according to Claim 27, wherein said nozzles are formed in a nozzle plate supported by said cover, each fluid channel being in fluid communication with a respective nozzle via a respective aperture.

29. Apparatus according to any of Claims 23 to 28, wherein said cover has a coefficient of thermal expansion which is substantially equal to that of said support member.

30. Apparatus according to any of Claims 23 to 29, wherein said cover is formed from metallic material.

31. Apparatus according to Claim 30, wherein said cover is formed from one of molybdenum and Nilo.

32. Apparatus according to any preceding claim, wherein the or each droplet ejection unit comprises a first piezoelectric layer poled in a first poling direction, and a second piezoelectric layer on said first piezoelectric layer and poled in a direction opposite to said first poling direction, said fluid channels being formed in said first and second piezoelectric layers.

33. Apparatus according to Claim 32, wherein the first piezoelectric layer is attached directly to said support member.

34. Apparatus according to Claim 33, wherein said support member is formed from ceramic material.

35. Apparatus according to Claim 32, wherein the first piezoelectric layer is formed on a base layer formed from ceramic material, said base layer being attached to said support member.

36. Apparatus according to any preceding claim, wherein the axes of said nozzles extend in a direction substantially orthogonal to the direction of extension of said at least one row.

37. Droplet deposition apparatus comprising:

at least one droplet ejection unit comprising a plurality of fluid channels disposed side by side in a row, actuator means, drive circuit means for supplying actuating electrical signals to said actuator means, and a plurality of nozzles, said actuator means being actuable to eject a droplet of fluid from a fluid channel through a respective nozzle;

fluid conveying means for conveying droplet fluid to each of the fluid channels of said at least one droplet ejection unit; and

further coolant conveying means for conveying a coolant fluid, at least one of said drive circuit means and said at least one droplet ejection unit being proximate said coolant conveying means so as to transfer a substantial part of the heat generated during droplet ejection to said coolant fluid.

38. Apparatus according to Claim 37, wherein at least one of said at least one droplet ejection unit and said drive circuit means is mounted on said coolant conveying means.

39. Apparatus according to Claim 38, wherein both said at least one droplet

ejection unit and said drive circuit means are mounted on said coolant conveying means.

40. Apparatus according to any of Claims 37 to 39, wherein said fluid conveying means comprises a conduit extending along said row and to one side of both said coolant conveying means and said at least one droplet ejection unit for conveying droplet fluid to each of the fluid channels of said at least one droplet ejection unit.

41. Apparatus according to Claim 40, wherein said fluid conveying means comprises a second conduit extending along said row and to the other side of both said coolant conveying means and said at least one droplet ejection unit for receiving droplet fluid from each of the fluid channels of said at least one droplet ejection unit.

42. Droplet deposition apparatus substantially as herein described with reference to the accompanying drawings.

FIG. 1

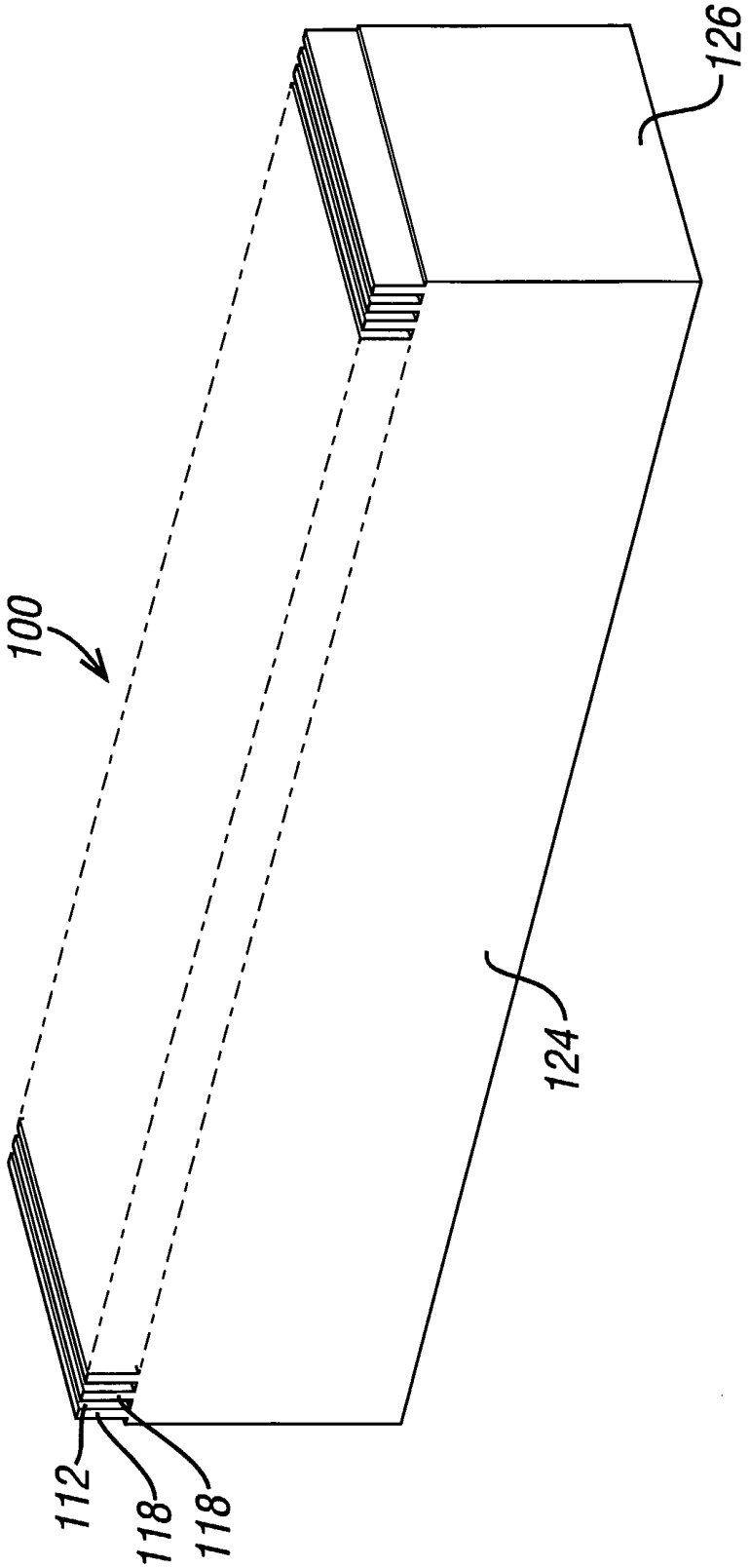


FIG. 2

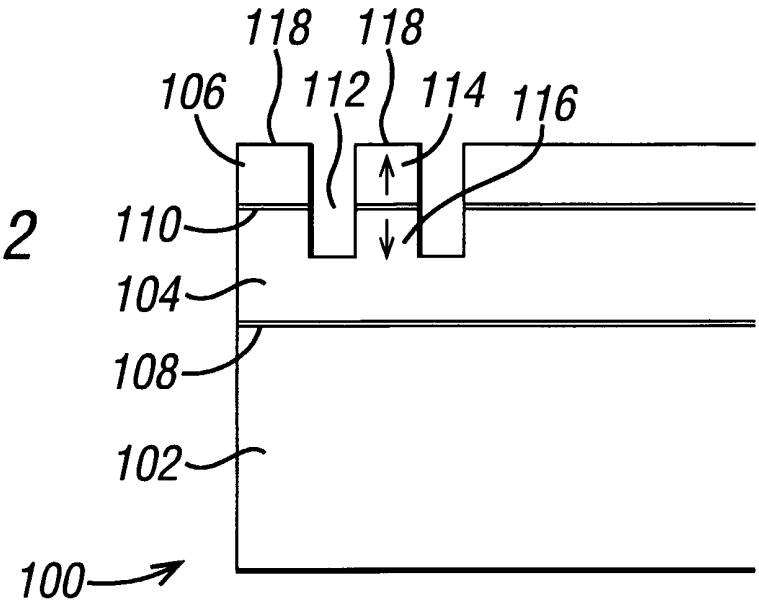


FIG. 3

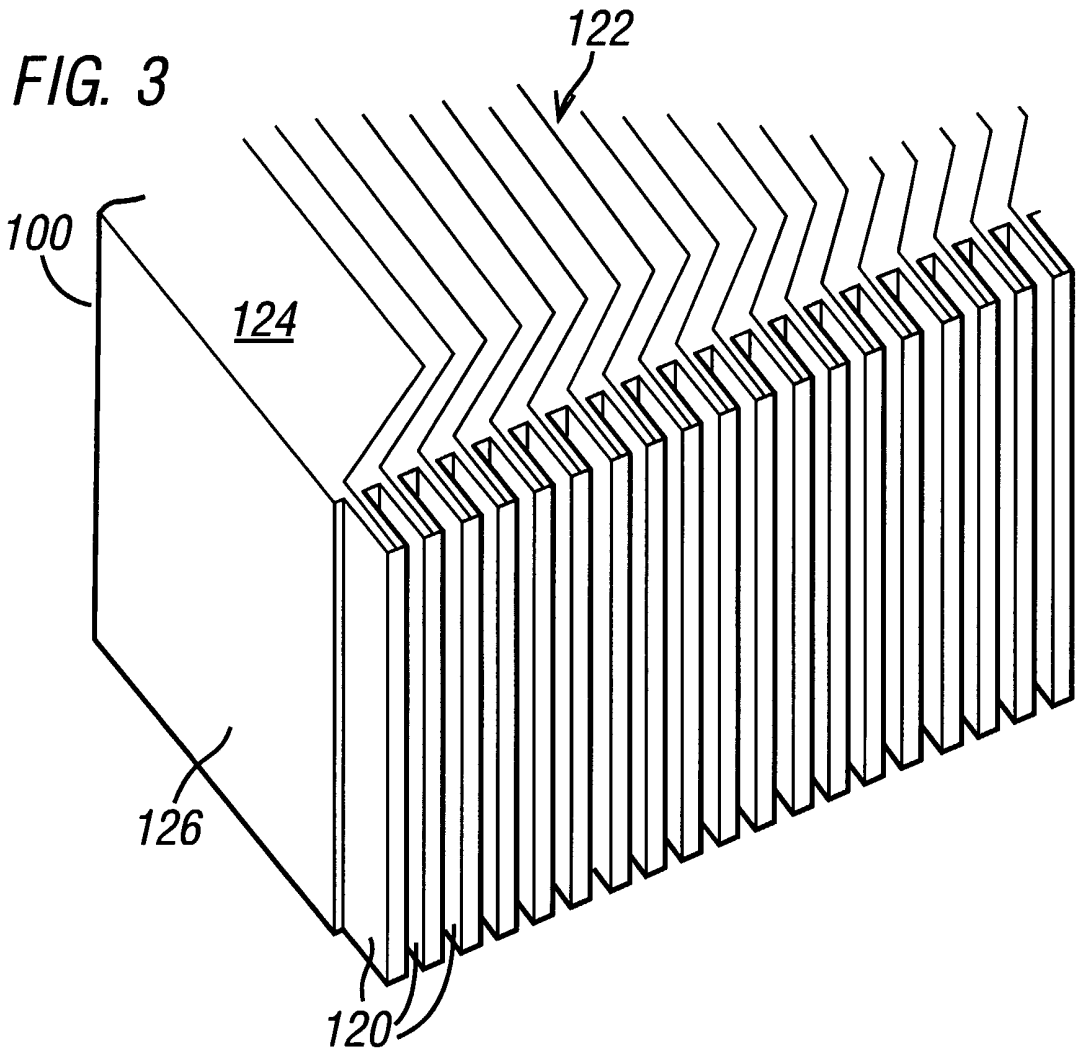


FIG. 4

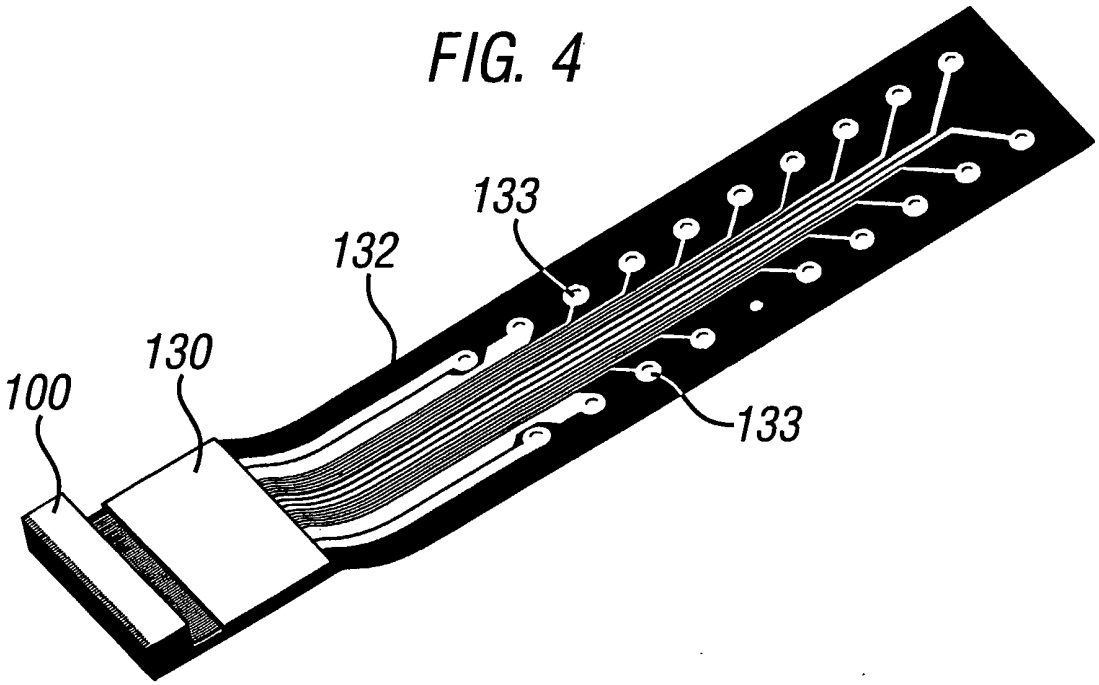


FIG. 5

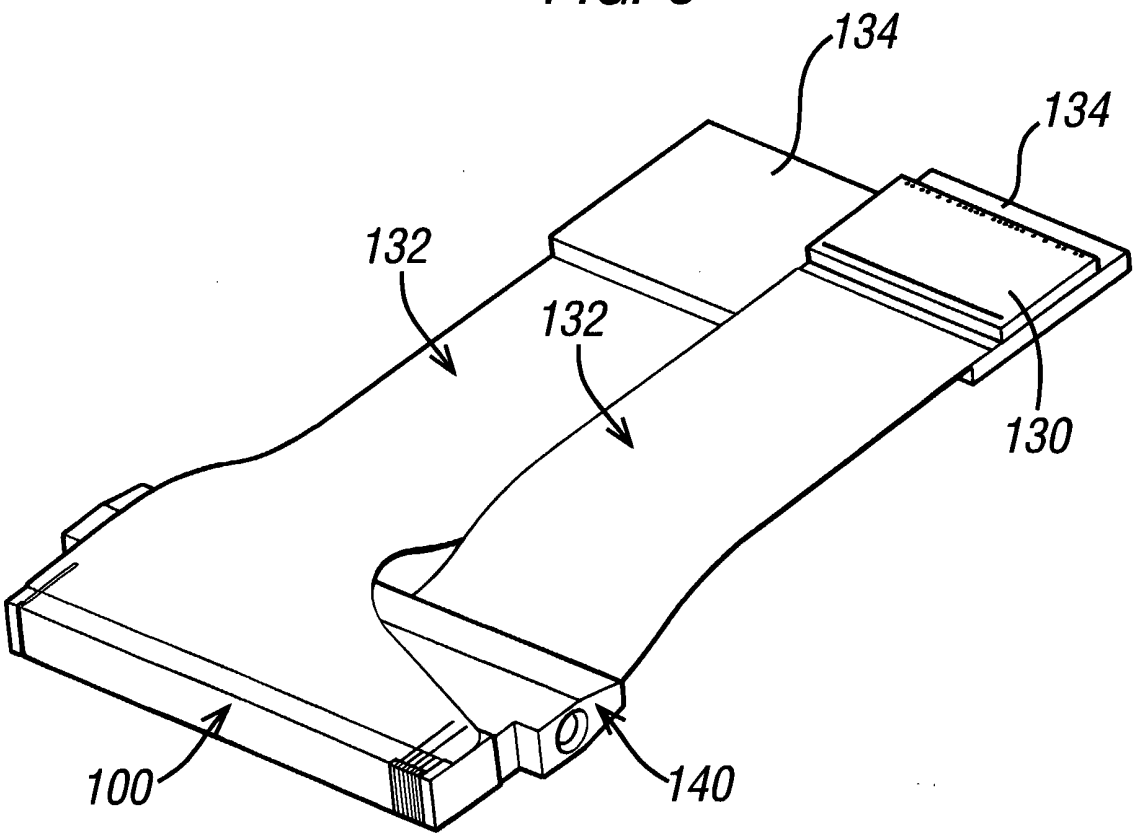


FIG. 6

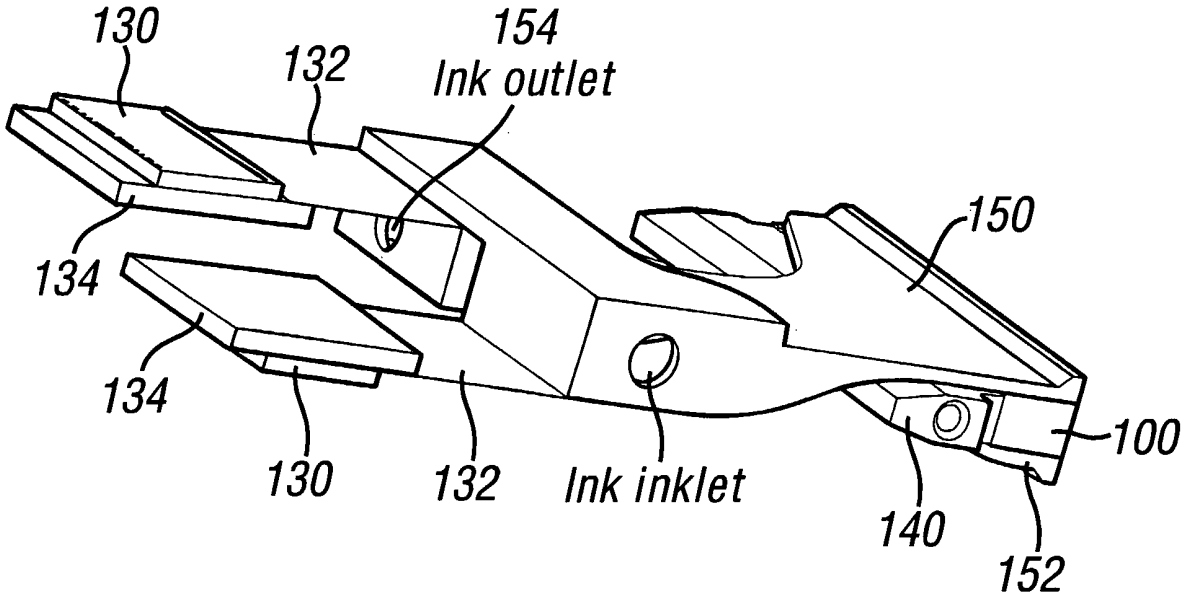

130
132
154
Ink outlet
150
134
134
130
132
Ink inklet
100
140
152

FIG. 7

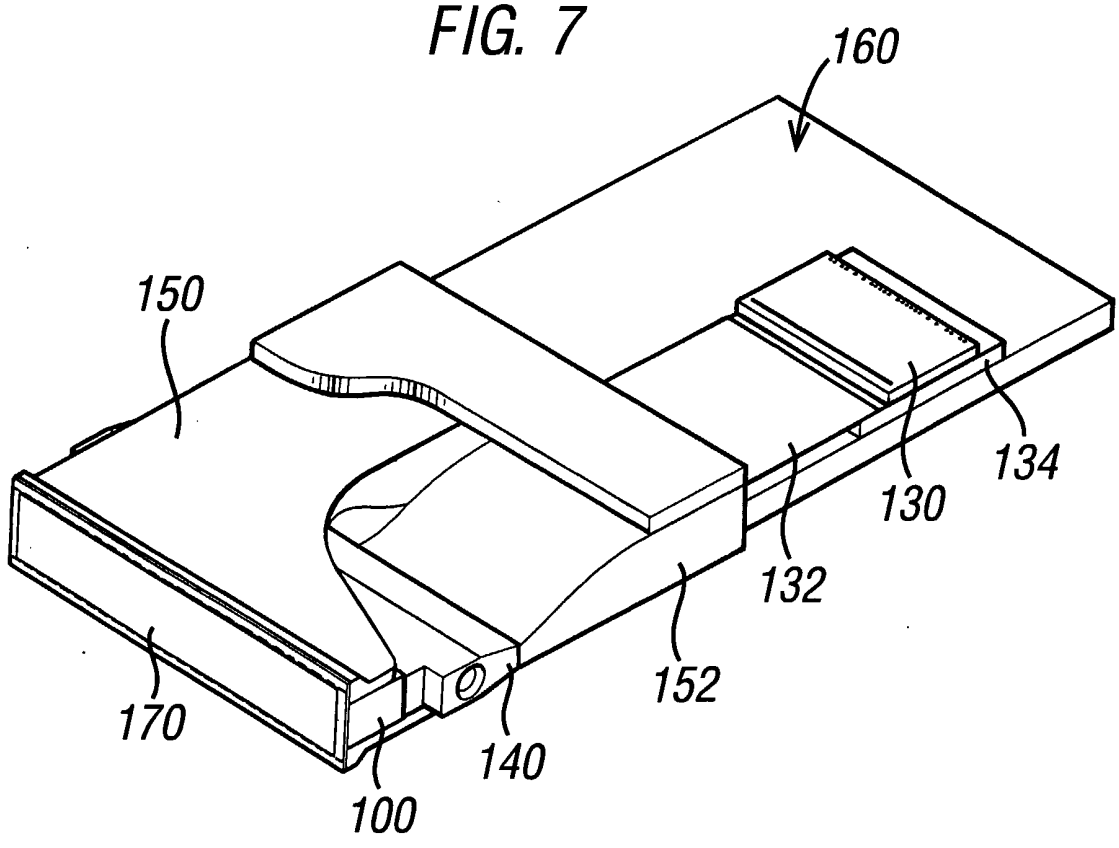

160
150
134
130
132
152
170
140
100

FIG. 8

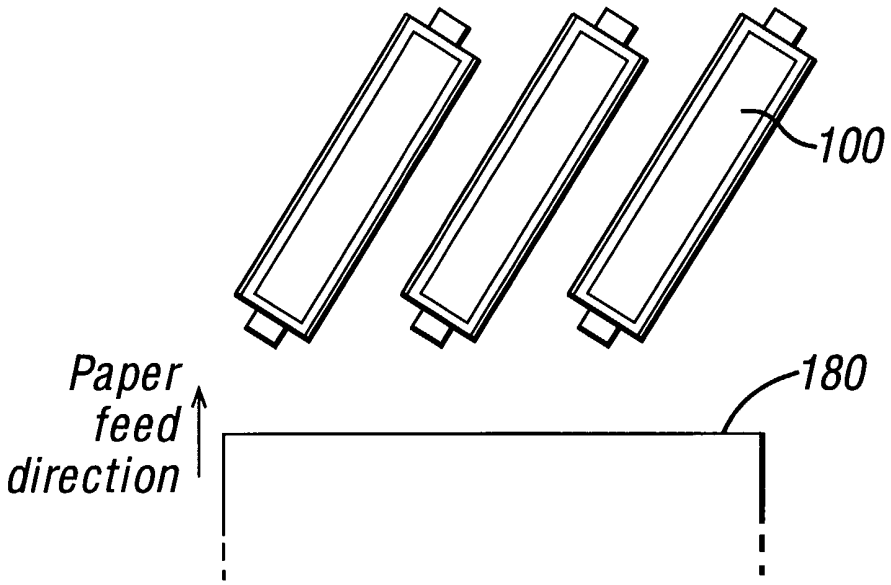


FIG. 9

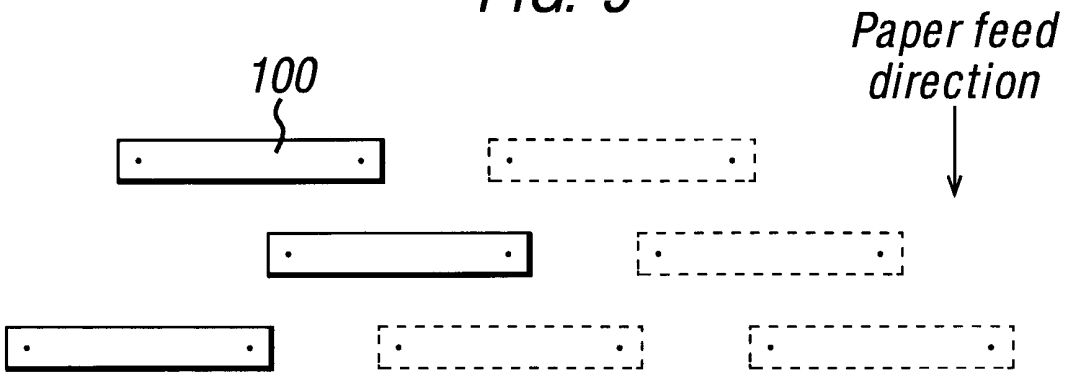


FIG. 10

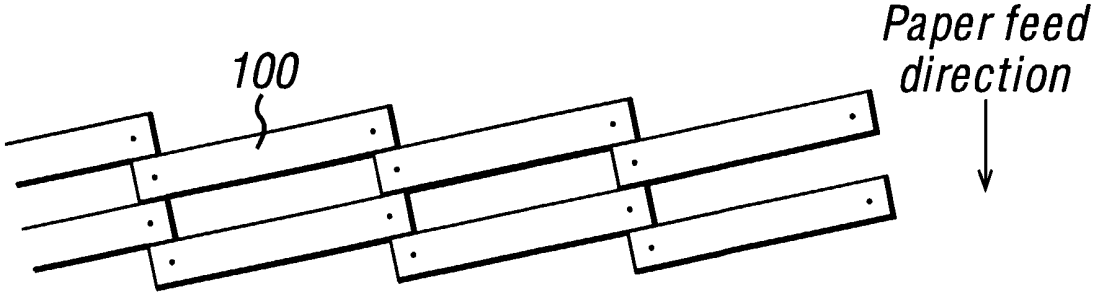


FIG. 11

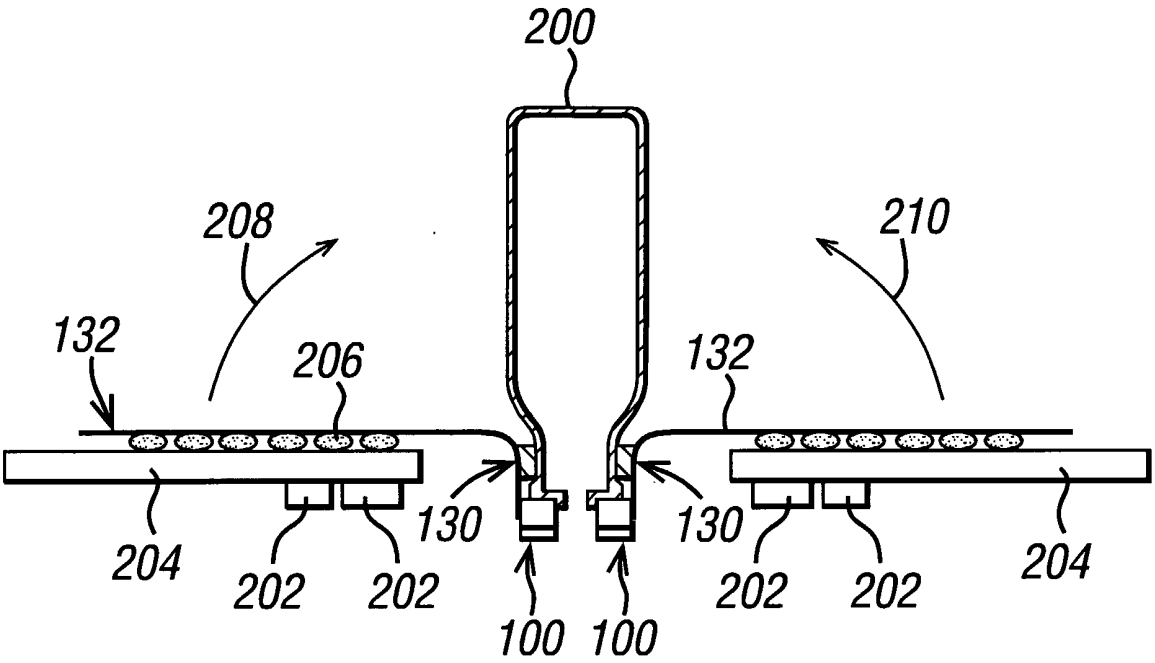

200
208
210
132
206
132
204
202
202
130
130
202
202
204
100
100

FIG. 16

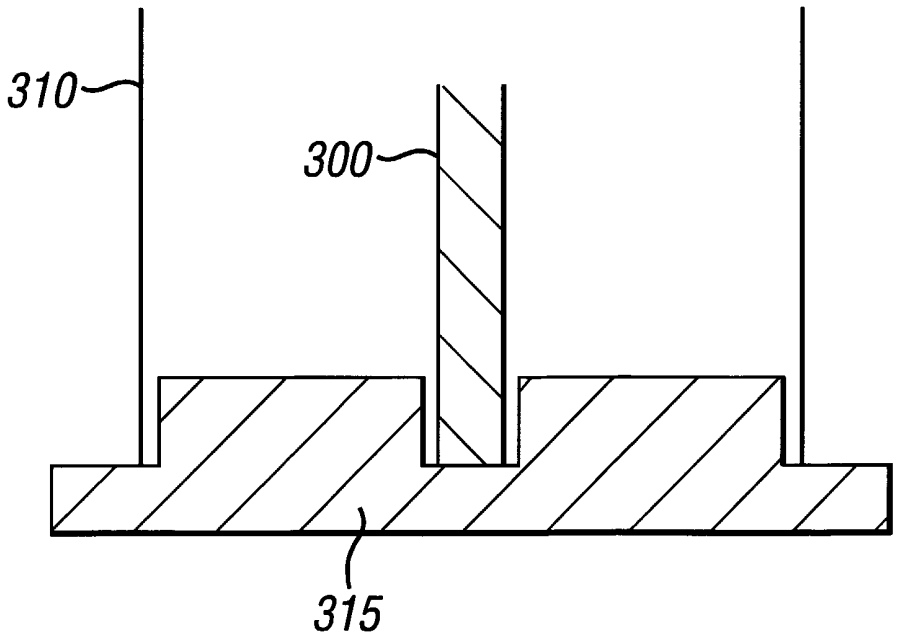

310
300
315

FIG. 12

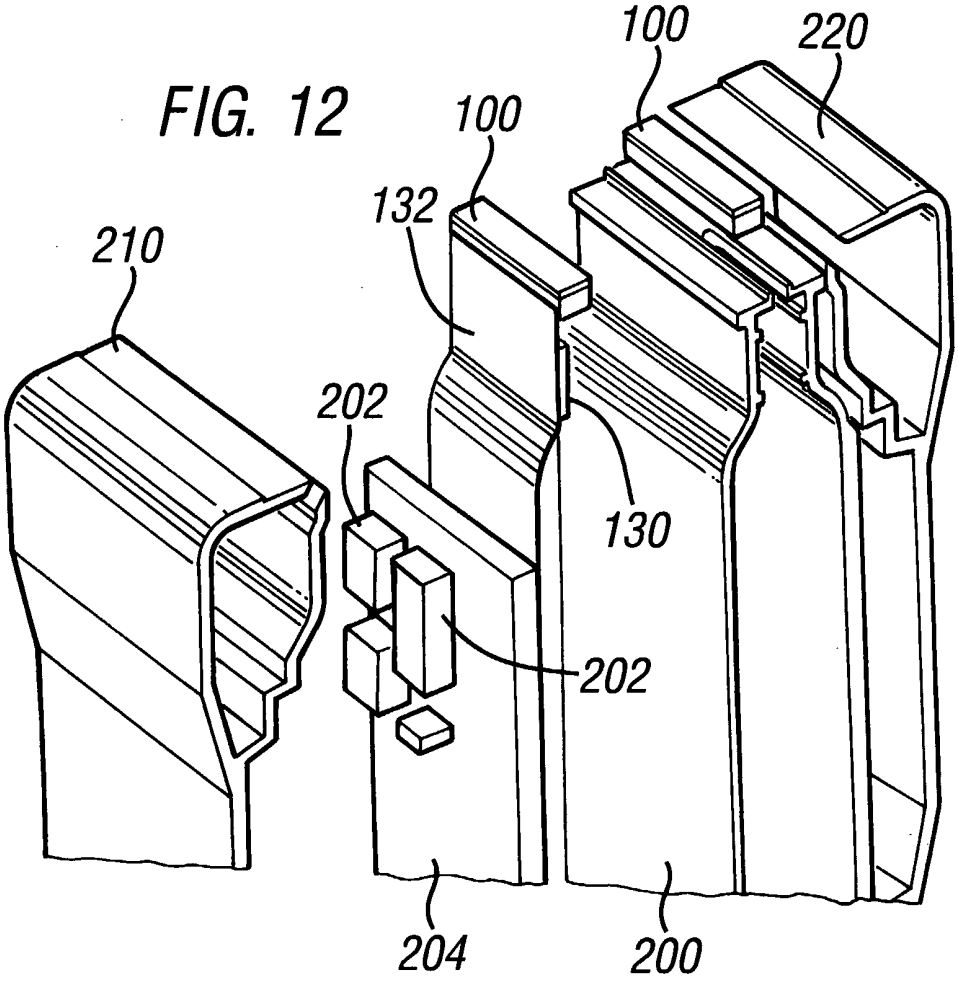


FIG. 13

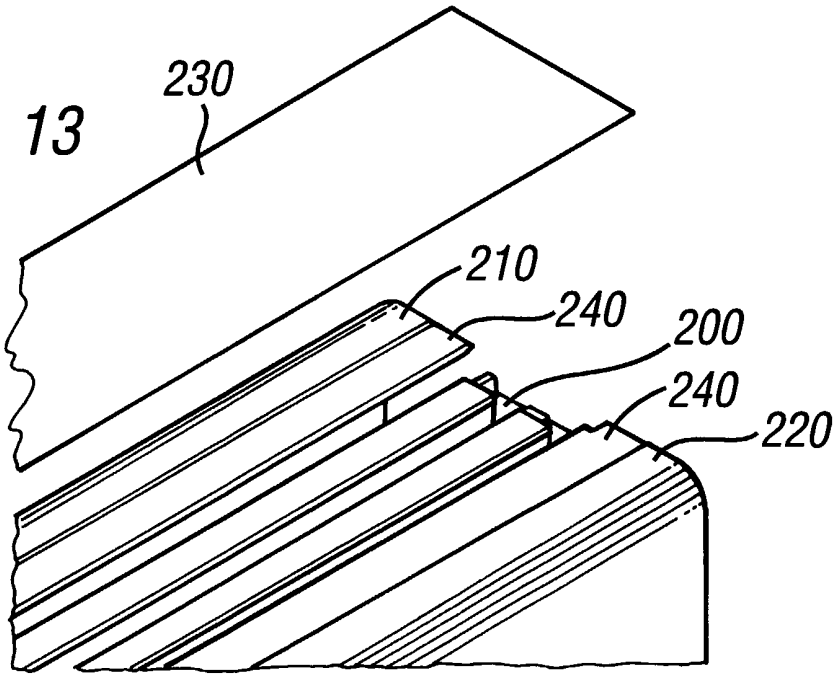


FIG. 14

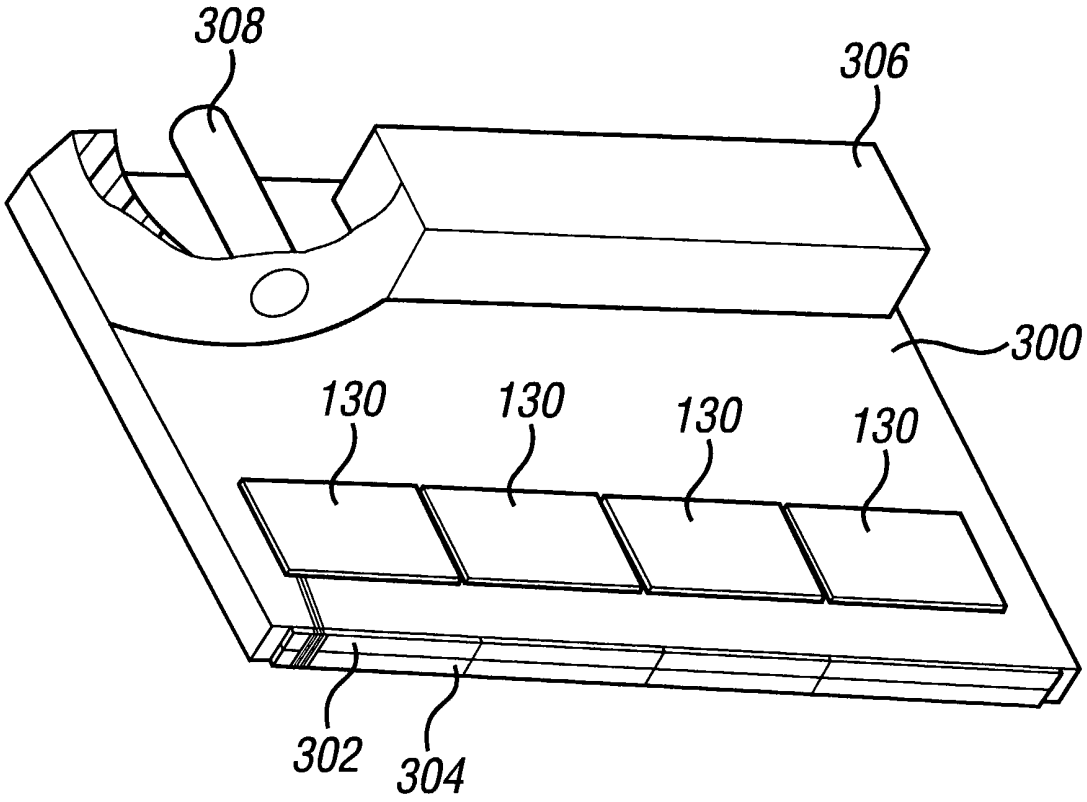

308
306
300
130
130
130
130
302
304

FIG. 15

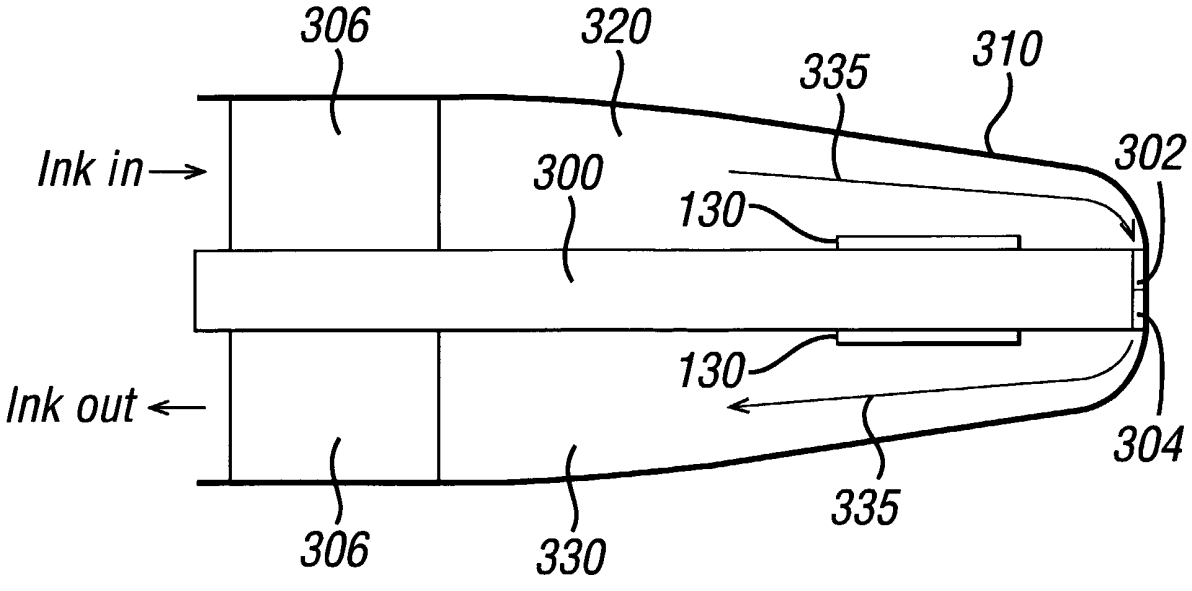

306
320
335
310
Ink in
300
130
302
130
Ink out
304
335
306
330

FIG. 17

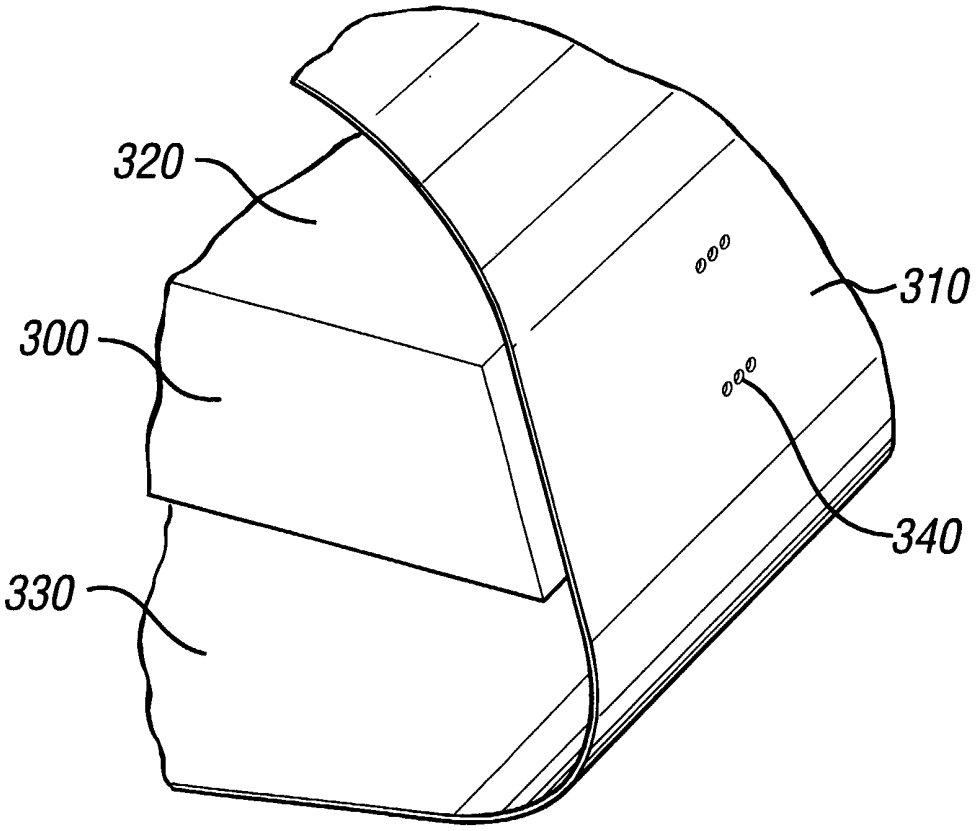
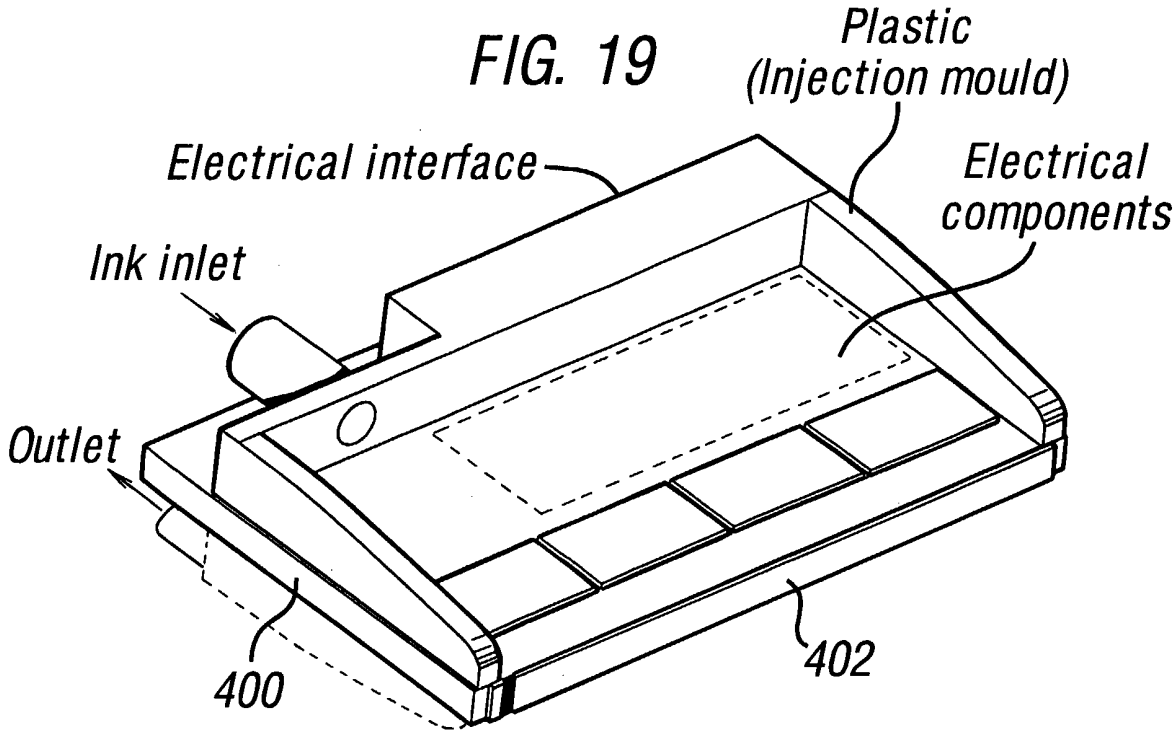

320
310
300
340
330

FIG. 19


Plastic
(Injection mould)
Electrical interface
Electrical
components
Ink inlet
Outlet
400
402

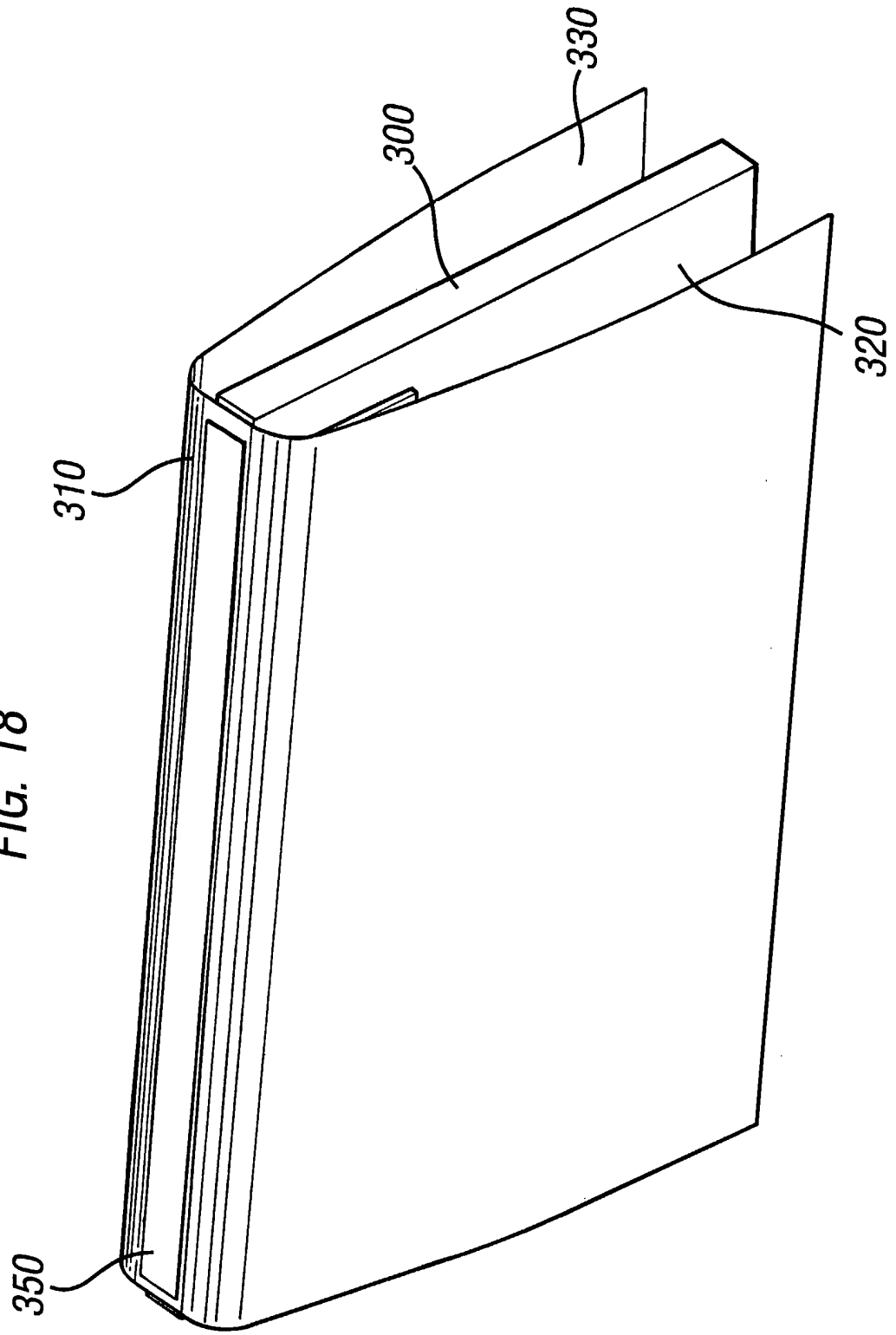


FIG. 18

FIG. 20

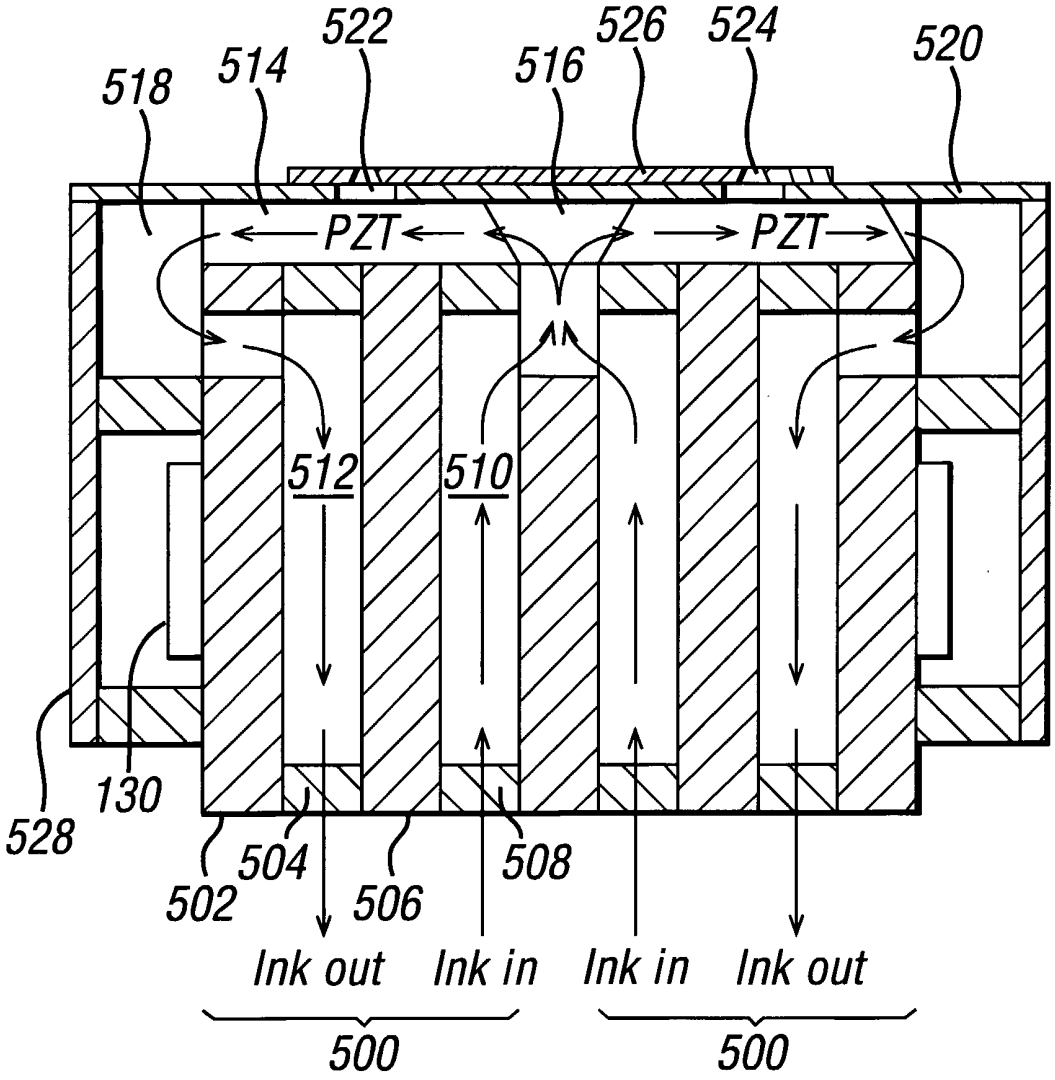

522
526
524
520
518
514
516
PZT
PZT
512
510
528
130
504
502
506
508
Ink out
Ink in
Ink in
Ink out
500
500

FIG. 21

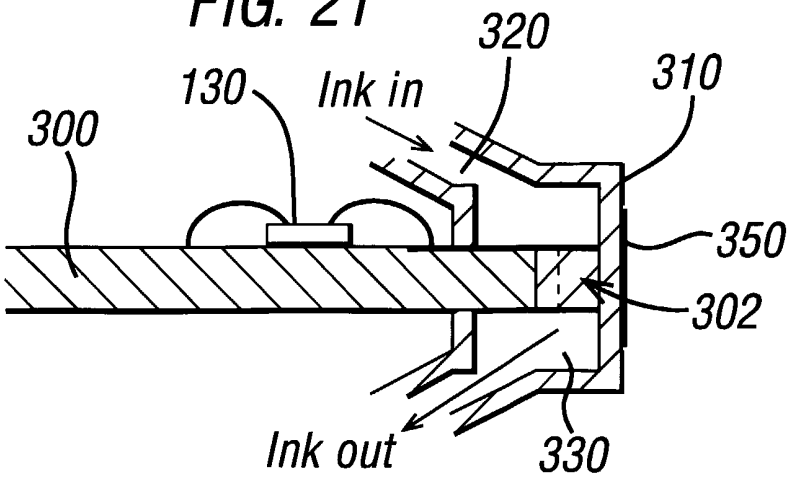

320
130
Ink in
310
300
350
302
Ink out
330

FIG. 22

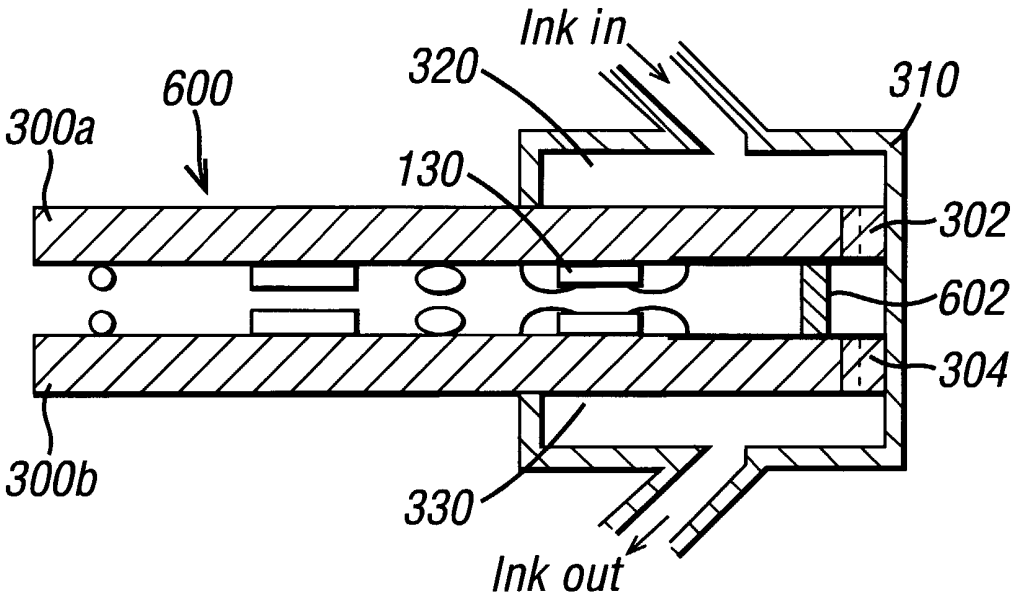

Ink in
320
310
600
300a
130
302
602
304
300b
330
Ink out

FIG. 23

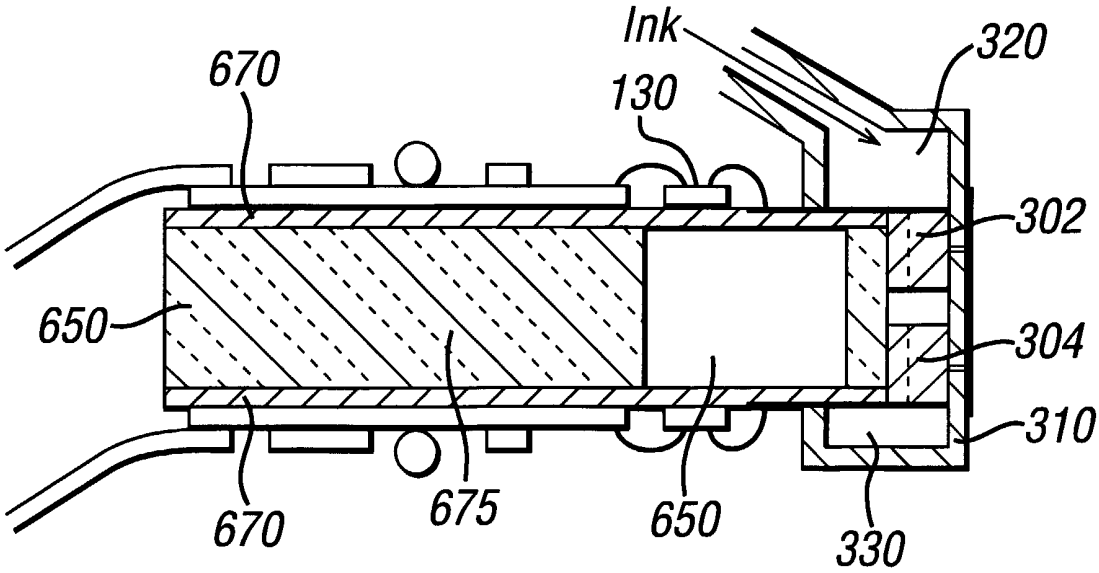

Ink
320
670
130
302
650
304
310
670
675
650
330

FIG. 24

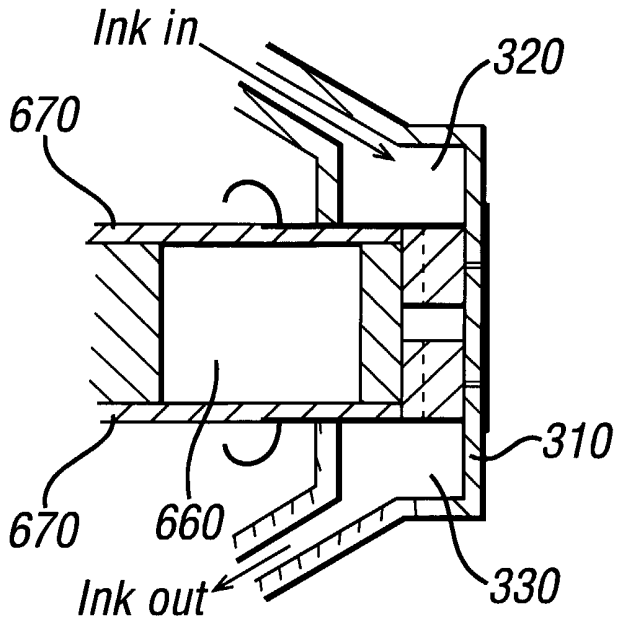
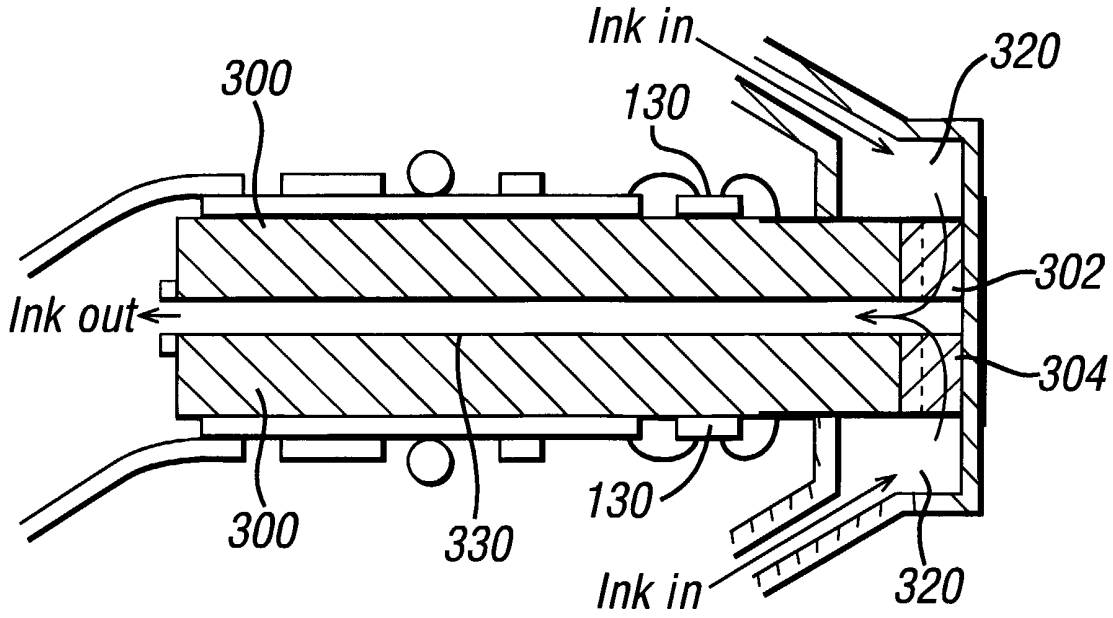

Ink in
320
670
310
670
660
330
Ink out

FIG. 25


Ink in
320
300
130
302
Ink out
304
130
300
330
Ink in
320