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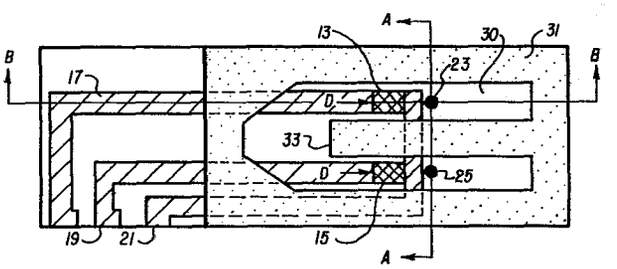
(54) Monolithic ink jet orifice plate/resistor combination.

(57) A monolithic orifice plate/resistor combination (11) is provided for which the active elements can be easily aligned using standard mask aligning equipment. First an orifice plate (27) is formed, typically a flat sheet with orifices (23, 25) therein. A passivating layer (29) is then grown on the sheet, and the resistors (13, 15) and conductors (17, 19, 21) to supply them are deposited onto the passivation layer using standard deposition techniques. A spacer (31) is then attached to the passivation layer to define capillary channels for ink flow and to provide increased hydraulic impedance between resistors, thus, completing the structure for the monolithic orifice plate/resistor combination. A completed print head is then made by attaching a sheet of material to the spacer to supply a back to the device and to form the closure for the capillary channels defined by the spacers.



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MONOLITHIC INK JET ORIFICE PLATE/RESISTOR COMBINATION

This invention relates to a new type of orifice plate/resistor combination for use in bubble-driven ink jet print heads and a method of manufacture.

The background with regard to bubble-driven ink jet printing is adequately represented by U.K. patent application serial No. 8217720 and by U.S. patent nos. 4,243,994; 4,296,421; 4,251,824; 4,313,124; 4,325,735; 4,330,787; 4,334,234; 4,335,389; 4,336,548; 4,338,611; 4,339,762; and 4,345,262. The basic concept there disclosed is a device having an ink-containing capillary, an orifice plate with an orifice for ejecting ink, and an ink heating mechanism, generally a resistor, in close proximity to the orifice. In operation, the ink heating mechanism is quickly heated, transferring a significant amount of energy to the ink, thereby vaporizing a small portion of the ink and producing a bubble in the capillary. This in turn creates a pressure wave which propels an ink droplet or droplets from the orifice onto a closeby writing surface. By controlling the energy transfer to the ink, the bubble quickly collapses before any ink vapor can escape from the orifice.

In each of the above references, however, the construction of the devices is typically of multiple part structures. Generally, a substrate is provided on which resistors and conductors are deposited. Then, a separate orifice plate is attached to the substrate, with meticulous

attention being paid to ensure accurate alignment of the various parts.

The present invention provides a method of making a bubble-driven thermal ink jet print head, comprising selecting a sheet of material for an orifice plate, forming an orifice in said sheet for ejecting droplets of ink, and characterized by the steps of forming a resistor on said orifice plate in close proximity to said orifice, and forming electrical conductors on said orifice plate for supplying power to said resistor.

In carrying out a method as set forth in the last preceding paragraph, it is preferred that a plurality of said orifices is formed in said orifice plate.

In carrying out a method as set forth in the last preceding paragraph, it is preferred that a plurality of said thin film resistors is formed on said orifice plate, each resistor corresponding to a respective orifice.

In carrying out a method as set forth in the last preceding paragraph, it is preferred to include the step of forming hydraulic separators on said orifice plate between adjacent resistors for increasing hydraulic impedance between resistors and for defining ink channels for supplying ink to said resistors.

In carrying out a method as set forth in any one of the last four immediately preceding paragraphs, it is preferred to include the step of attaching said orifice plate to a substrate to form a bubble driven ink jet print head.

In carrying out a method as set forth in the last preceding paragraph, it is preferred that the orifice plate is attached to the substrate in spaced apart manner to permit the flow of ink to the or each resistor and orifice.

In carrying out a method as set forth in any one of the last six immediately preceding paragraphs, it is preferred that a passivation layer is formed on said orifice plate prior to formation of the or each resistor thereon, the

resistors and electrical conductors being formed on said passivation layer.

The present invention further provides an orifice plate for a bubble driven ink jet printer comprising a sheet of material, an opening in said material for permitting the ejection of ink, and characterized by passivation means on said sheet for providing electrical insulation, and heating means located on said passivation layer for creating bubbles in said ink.

In an orifice plate as set forth in the last preceding paragraph, it is preferred that said heating means comprises a plurality of heating sources.

An orifice as set forth in either one of the last two immediately preceding paragraphs may further comprise separator means for distributing said ink to said heating means.

In an orifice plate as set forth in the last preceding paragraph, it is preferred that said separator means comprises a plurality of ink barriers for introducing hydraulic impedance between said heating sources.

In accordance with a preferred embodiment of the invention, a monolithic orifice plate/resistor combination is provided for which the active elements can be easily aligned using standard mask aligning equipment. First, an orifice plate is formed, typically a flat sheet with orifices therein. A passivation layer is then grown on the sheet, and the resistors and conductors to supply them are deposited onto the passivation layer using standard IC techniques. A spacer is then attached to the passivation layer to define capillary channels for ink flow and to provide increased hydraulic impedance between resistors, thus completing the structure for the monolithic orifice plate/ resistor combination. A completed print head is then made by attaching a sheet of material to the spacer to supply a back to the device and to form the closure for the

capillary channels defined by the spacers.

There now follows a detailed description which is to be read with reference to the accompanying drawings, of a method according to the invention; it is to be clearly understood that this method has been selected for description to illustrate the invention by way of example and not by way of limitation.

In the accompanying drawings:-

Figure 1 shows a back view of a preferred embodiment of the invention;

Figure 2 is an isometric view of the orifice plate/resistor combination through a section B-B (shown in Figure 1) at an early stage in its construction;

Figure 3 is an isometric view of the orifice plate/resistor combination after through section B-B upon completion;

Figure 4 shows a top view of a backing plate for the preferred embodiment illustrated in Figure 1;

Figure 5 illustrates a cross-section of the backing plate through a secion A-A shown in Figure 4;

Figure 6 shows a cross-section of the completed ink jet print head according to the invention viewed on the line B-B; and

Figure 7 provides a view of the orifice plate/resistor combination from the front, i.e., from the side where ink is ejected.

In accordance with a preferred embodiment of the invention, shown in Figure 1 is an orifice/resistor combination 11 having monolithic resistors 13 and 15, conductors 17, 19, and 21 and orifice 23 and 25 for use in constructing a bubble-driven ink jet printer. Unlike the construction of the prior art which typically involves forming conductors and resistors on a substrate and then attaching a suitable orifice plate, the present invention begins with an orifice plate, and the resistors and conductors are formed thereon.

Figure 2 illustrates an early stage in the construction of the orifice/resistor combination 11, the view being the cross-section A-A of Figure 1. The construction typically begins with an orifice plate 27 made of a metal which has the orifices 23 and 25 formed therein. Preferably, the orifice plate 27 is made by electroforming, although sheet stock can also be used. Preferable metals for the orifice plate 27 include nickel, copper, beryllium-copper, titanium, molybdenum, 300 series stainless steel, and alloy 42; the most preferable being nickel. Typical thicknesses for the orifice plate 25 range from about 2 to 4 mils (.051 to .102mm). The orifices 23 and 25 can be formed by etching or laser drilling, but more preferably are formed at the same time that the orifice plate is formed by overplating onto a non-conductive barrier which defines the shape of the orifice. (See co-pending patent application no. _____). Following formation of the orifice plate 27, a passivation layer 29 is grown on its surface to provide electrical insulation and to protect the orifice plate from chemical attack from the inks to be used. Typical materials used for the passivation layer 29 include dielectrics such as SiO_2, SiO_xN_y, Al_2O_3 and TiO_2, generally having a thickness in the range of 0.5 to 1.5 microns; the preferred thickness being dependent on the thermal conductivity of the chosen material.

After passivation, the resistors 13 and 15, and the electrical conductors 17, 19, and 21 are formed on the passivation layer 29 according to standard thin film techniques. Typically, there is a wide range of values for the resistance of the resistors 13 and 15, however, the preferred resistance is about 60 ohms and the preferred surface dimensions of the resistors are about 2.5 X 6 mils (.064 x .152mm).

After deposition of the resistors and conductors a second passivation layer 30 is applied to the surface over

the resistors and conductors to provide electrical insulation and cavitation protection according to standard techniques. Then a patterned spacer layer 31 having thickness in the range of 1.5 to 5 mils (.038 x .127mm) (preferably about 2 mils (.051mm)), is applied to the passivation layer 27. (See Figures 1 and 3.) Typical materials for the patterned spacer layer include resists such as Vacrel or Riston (tradenames of Dupont), solder glass, screened glass bead filled epoxy, polyimides, or even electroplated metals.

The purpose of the patterned spacer layer 31 is to provide a capillary channel for directing the flow of ink over the resistors and to provide a measure of hydraulic separation by interposing a system 33 between adjacent orifices to avoid cross-talk during operation. The direction of ink flow is illustrated by the arrows labelled "D" in Figure 1. A suitable back 35, as shown in Figure 4, is then attached firmly to the patterned spacer layer 31 to contain the ink and to provide an ink feed port 37. Typically, for optimum operation the back 35 includes an ink manifold 39 as illustrated in Figures 4 and 5 for providing a closeby volume of ink. Figure 5 shows a cross-section of the back 35 through the section line A-A.

Nearly any material which can be formed and which can be attached to the material chosen for the patterned spacer layer 31 can be used as the back. However, since the preferable construction includes a manifold, materials which are formable are preferred, such as metals and plastics materials. Although the back 35 is shown as a sheet having a uniform thickness, such a uniform thickness is unnecessary and can vary considerably depending on the desired mechanical characteristics, e.g., if it is to serve as a stiffener or pin body.

A cross-section of a completed print head constructed by the above method is illustrated in Figure 6 as it would

appear at the section B-B shown in Figures 1 and 4. Shown therein is the back 35 and the manifold 39, atop the spacer 31 to create an ink capillary 43. The typical distance "L" between the center of the resistor 13 and the closest point of the manifold 39 is about 20 mils (0.51mm), with the typical height "T" of the manifold 39 being in the range of 2-1/2 to 5 mils (.064 to .127mm). Also shown is the distance "F", approximately 10 to 20 mils (.025 to .051mm), corresponding to the distance between the midpoint of the resistor 13 and the center of the orifice 23. The second passivation layer 30 is also best seen from this perspective.

Figure 7 is an illustration of the completed device as it appears from the side where ink is ejected, showing the orifices 23 and 25.

CLAIMS

1. A method of making a bubble-driven thermal ink jet print head, comprising:

selecting a sheet of material for an orifice plate (27);

forming an orifice (23,25) in said sheet for ejecting droplets of ink;

and characterized by the steps of

forming a resistor (13,15) on said orifice plate in close proximity to said orifice; and

forming electrical conductors (17,19,21) on said orifice plate for supplying power to said resistor.

2. A method according to claim 1 characterized in that a plurality of said orifices is formed in said orifice plate.

3. A method according to claim 2 characterized in that a plurality of said thin film resistors is formed on said orifice plate, each resistor corresponding to a respective orifice.

4. A method according to claim 3 characterized by the step of forming hydraulic separators (31) on said orifice plate between adjacent resistors for increasing hydraulic impedance between resistors and for defining ink channels for supplying ink to said resistors.

5. A method according to any one of the preceding claims characterized by the step of attaching said orifice plate to a substrate to form a bubble driven ink jet print head.

6. A method according to claim 5 characterized in that the orifice plate is attached to the substrate in spaced apart manner to permit the flow of ink to the or each resistor and orifice.

7. A method according to any one of the preceding claims characterized in that a passivation layer (29) is formed on said orifice plate prior to formation of the or each resistor thereon;

the resistor(s) and electrical conductors being formed on said passivation layer.

8. An orifice plate for a bubble driven ink jet printer comprising:

a sheet of material (27);

an opening (23,25) in said material for permitting the ejection of ink; and characterized by

passivation means (29,30) on said sheet for providing electrical insulation; and

heating means (13,15,17,19,21) located on said passivation layer for creating bubbles in said ink.

9. An orifice plate according to claim 8 characterrized in that said heating means comprises a plurality of heating sources (13,15).

10. An orifice plate according to either one of claims 8 and 9 further comprising separator means (31) for distributing said ink to said heating means.

11. An orifice plate according to claim 10 characterized in that said separator means comprises a plurality of ink barriers for introducing hydraulic impedance between said heating sources.

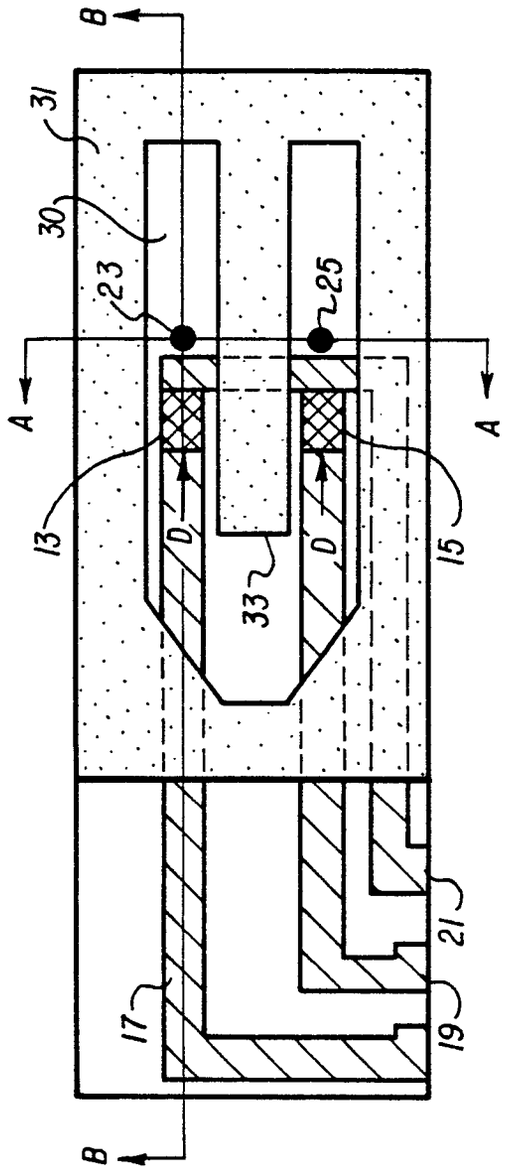

FIG. 1

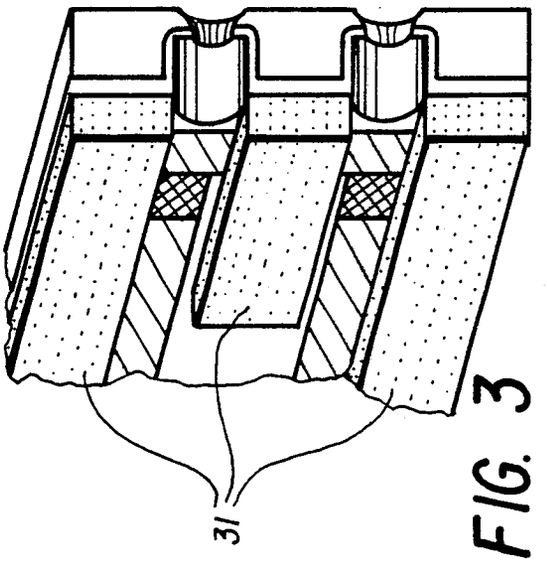

FIG. 3

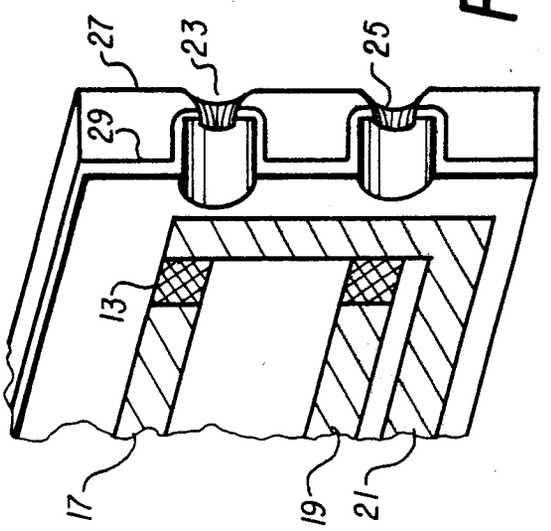

FIG. 2

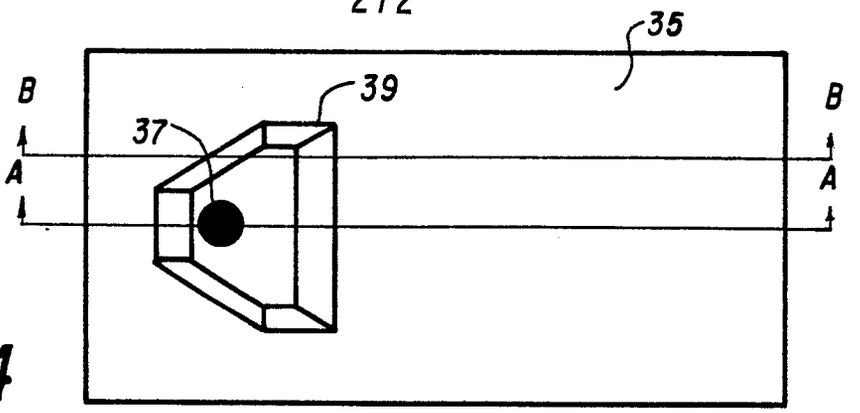

FIG. 4

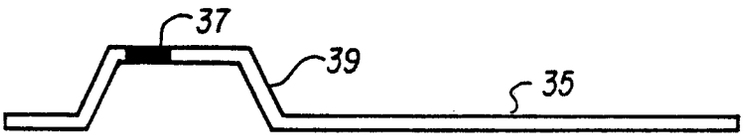

FIG. 5

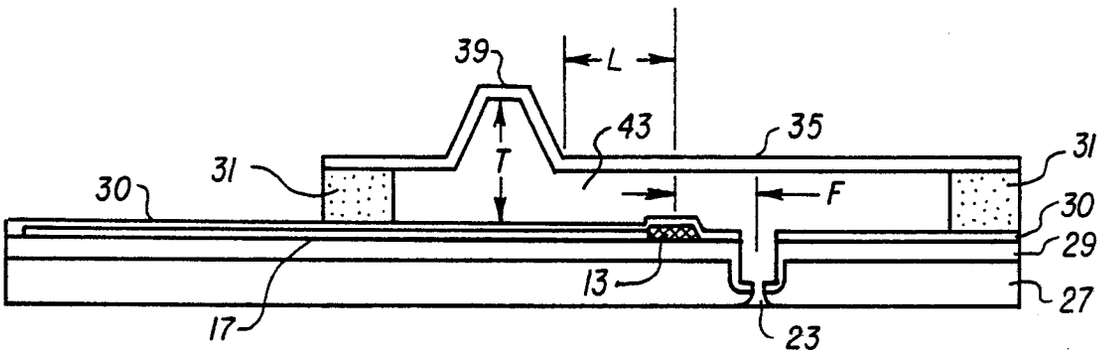

FIG. 6

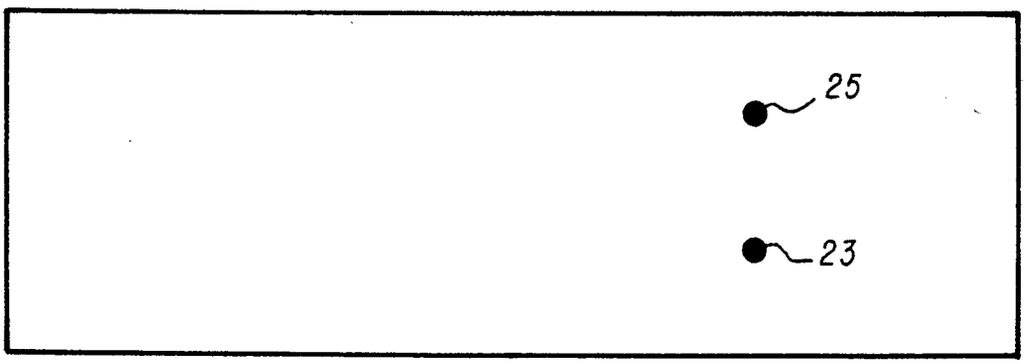

FIG. 7