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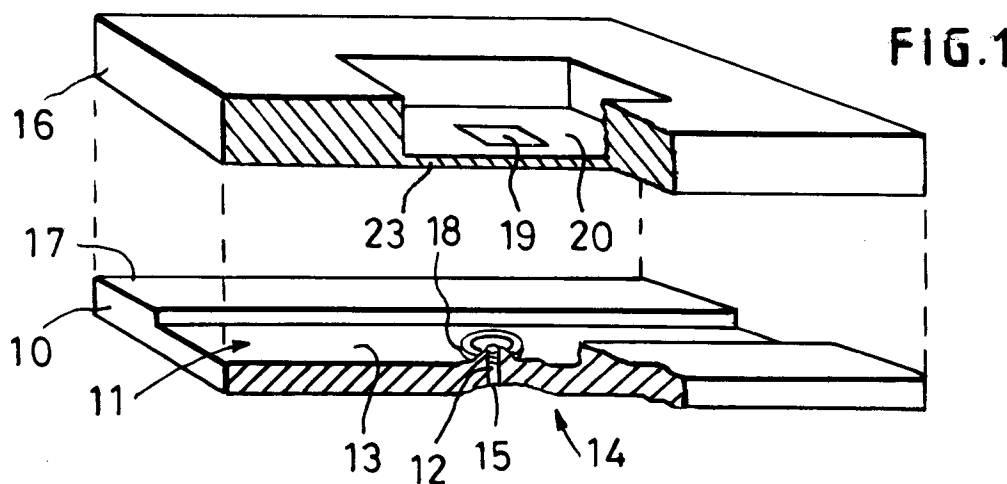
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(54) **Ink jet printing machine.**

(57) An ink jet printing device is formed from silicon or similar material. The device is formed on a first plate (10) having an ink duct groove (11) and ink jet nozzles (15) communicating with the duct (11). The groove is closed by a second plate (16) having diaphragms (23) formed integrally therein, the diaphragms (23) being opposed to passages (12) to the nozzles (15). The diaphragms are movable between positions in which the passages (12) are open and closed respectively by heating of the diaphragms or by heating liquid in a closed reservoir (21) behind each diaphragm.



This invention relates to ink jet printing devices and in particular to the construction of ink jet print heads and the means for controlling ejection of ink therefrom.

Ink jet print heads are known in which drops of ink are selectively ejected from a nozzle toward an ink receiving medium. An ink jet print head may have a plurality of nozzles located in a line and during relative movement between the ink jet print head and an ink receiving medium drops of ink are ejected from selected ones of the nozzles in a series of print cycles to build up line by line a desired print impression on the ink receiving medium. Ejection of ink from a nozzle may be effected by energisation of a piezo electric element to impart pressure to ink contained in the print head immediately adjacent the nozzle. In another known ink jet print head, the ink is ejected by localised heating of the ink such as to vaporise the ink and form a gaseous bubble effective to eject a drop of ink from the nozzle of the print head.

In ink jet print heads in which heating of the ink is utilised to eject drops of ink, the ink needs to be formulated to have thermal properties required to ensure effective ejection of ink drops. However the properties of ink formulated for this reason may be incompatible with formulation of ink to provide required quality of print formation on a print receiving medium.

According to the invention an ink jet printing device includes an ink ejection nozzle; an ink supply duct; a passageway to provide ink flow from said ink supply duct to said ink ejection nozzle; a diaphragm movable between a first state and a second state, said diaphragm when in said first state being spaced from said passageway to permit flow of ink through the passageway from said ink supply duct to said ink ejection nozzle; and heating means to apply heat to cause movement of the diaphragm from one of said first and second states to the other of said states so as to eject a droplet of ink from said nozzle.

Preferably the ink jet printing device includes a first element; a groove in a first face of said first element; a second element secured in sealing engagement with said first face to close said groove and thereby form the ink supply duct; an end of the passageway opening in a wall of the groove opposed to said second element; the diaphragm being formed on said second element at a location corresponding to said end of said passageway.

An embodiment of the invention will now be described by way of example with reference to the drawings in which:-

Figure 1 is a partially cut-away exploded view of an ink jet printing device constructed in accordance with the invention,

Figures 2 and 3 are sectional views illustrating two states of a diaphragm of the printing device; Figure 4 is a partially cut-away exploded view of an alternative construction of ink jet printing de-

vice in accordance with the invention,

Figure 5 is a sectional view of a multi-nozzle printing device, and

Figures 6 and 7 illustrate alternative ways of moving the diaphragm.

Referring first to Figure 1 of the drawings, a first element 10 comprises a substantially planar strip having a groove 11 extending therealong. A passageway 12 is formed in the element 10 such as to extend from the base 13 of the groove 11 to an exterior lower (as shown in the drawing) surface 14 and the opening of the passageway in the surface 14 provides a nozzle 15 for ejection of ink. A seat 18 extends around the passageway on the bottom 13 of the groove. A second element 16 comprising a substantially planar strip extends on the upper surface 17 of the first element to close the groove 11 of the first element and thereby form a duct extending between the elements 10 and 16. The second element is formed with a diaphragm 23 which overlies the nozzle. The diaphragm 23 has a first state, shown in Figure 2, in which the diaphragm 23 sealingly engages the seat 18 to thereby close the passageway and a second state, shown in Figure 3, in which the diaphragm is spaced from the seat 18. Ink is supplied, under pressure, from a source of liquid ink 24 to the groove 11. Normally, with the diaphragm 23 in its first state in sealing engagement with the seat 18, ink is prevented from passing into the passageway 12. By causing the diaphragm to deflect away from its first state in engagement with the seat 18 to its second state ink is permitted to flow from the groove 11 into the passageway 12 and thence to be ejected as a droplet of ink from the nozzle 15. The diaphragm is normally at rest in its first state and deflection of the diaphragm from its first state to its second state may be accomplished by heating the diaphragm by means of an electric current passed through a thin or thick film resistance element 19 deposited on a surface 20 of the diaphragm remote from the groove 11. Alternatively, as shown in Figure 4, a recess 21 in the plate 16 at the rear of the diaphragm 23 may be utilized as a reservoir 21, the diaphragm 23 forming a wall of the reservoir, and filled with liquid. The liquid is retained in the reservoir by means of a third element 22 sealed to the second element 16. The liquid may be heated selectively by means of a resistance element 25 to apply heat to the diaphragm. In this alternative construction the resistance element 25 may be deposited on the third element at a location such that the resistance element is in heat transfer relationship with the liquid in the reservoir. It will be appreciated that heating of the diaphragm is effected only for a very short time period sufficient to eject a droplet of ink from the nozzle. Upon termination of the application of heat to the diaphragm, the diaphragm cools rapidly by conduction of heat to the remainder of the elements 10, 16 which act as heat sinks and, on cooling of the diaphragm, the

diaphragm returns to its original rest state in sealing engagement with the seat 18 thereby terminating the flow of ink to the nozzle.

By using the construction described hereinbefore, a print head having a plurality of nozzles may be fabricated as a single modular unit as shown in Figure 5. The elements 11, 16 and 22 are fabricated of a length sufficient to extend along the length of a required print line and nozzles $15_1 \dots 15_n$ connected by passageways $12_1 \dots 12_n$ to the groove 11 are formed at spaced locations along the length of the element 10. Similarly diaphragms $23_1 \dots 23_n$ corresponding to the nozzles are formed at locations in the second element 16 to control flow of ink into the respective passageways. In a construction of printing device in which the groove 11 extends along the entire length of the device and is utilised to convey ink from an ink supply to all of ink jet nozzles 15, the duct formed by the groove 11 may be incapable of ensuring a sufficient supply of ink to every one of the nozzles even if ink is supplied to both ends of the groove. Accordingly a manifold arrangement 26 may be provided such as to supply ink to the duct at a plurality of locations 27 spaced along the length of the groove 11.

It is preferred to construct the elements 10, 16 of silicon material and to fabricate the elements by the use of techniques as used, or similar to those used, in semiconductor device manufacture.

The construction of ink jet print head described hereinbefore when fabricated of silicon material permits the manufacture of a print head with a plurality of selectively operated ink jet nozzles as a single unit at relatively low cost, the elements 11, 12 being fabricated by etching the silicon material. It is to be understood that electrical conductors are deposited on the element 10, or the element 22, to provide electrical connections to the resistive elements to enable the resistive elements to be energised selectively by electric current by means of a print head control circuit (not shown) connected thereto.

The heating of the diaphragm has been described hereinbefore as being accomplished by an electric current passed through the resistive element 19. However if desired heat may be applied to the diaphragm by other means. For example, a laser beam from a source 28 may be directed at the diaphragm by means 29 as indicated in Figure 6. When liquid is contained in the reservoir 21, it may be heated by the laser beam, the plate 22 being formed of material to permit passage of the laser beam, or the liquid may be heated by an electric current passed between electrodes 30 through the liquid contained in the reservoir 21 as shown in Figure 7.

It is to be understood that the interface between the first and second elements prevents egress of ink from the groove between the cooperating opposed faces of the first and second elements and that the interface between the second and third elements pre-

vents egress of liquid from the reservoir 21. Opposed surfaces of the elements may be fabricated with sufficient precision to prevent egress of ink or liquid therebetween without any other sealing means or a layer of sealing material may be provided between opposed faces.

It will be appreciated that operation of the printing device is effected by means of heating of an element of the print head and does not utilise heating of the ink.

Accordingly the ink may be formulated to provide the required quality of printing independently of any thermal properties the ink may have.

In the construction of ink jet print head described hereinbefore, the diaphragm 23 when at rest in its first state is in sealing engagement with the seat 18 and is deflected away from the seat to its second state to permit flow of ink by application of heat to the diaphragm. However if desired, the diaphragm may have a rest position in which it is spaced from the seat 18 thereby permitting flow of ink to the passageway and the diaphragm is formed so as to be deflectable toward the seat. The print device may be operated as described hereinbefore with the ink supplied under pressure to the duct formed by the groove 11 and the diaphragm having a state in which it is in sealing engagement with the seat 18 preventing flow of ink via the passageway to the nozzle and the pressure of the ink supply being such as to cause ejection of an ink droplet from the nozzle when the diaphragm is in a state permitting ink flow to the nozzle.

In an alternative manner of operating the print device, the ink may be supplied under only sufficient pressure as to ensure a flow of ink to the device and the diaphragm having a rest state spaced from the seat 18 permitting flow of ink to the passageway 12, the pressure being insufficient to flow of ink out of the nozzle. When ejection of an ink droplet from the nozzle is desired, the diaphragm is heated rapidly to cause the diaphragm to move rapidly toward the seat 18 such as to produce a pressure pulse applied to the ink in the passageway. This pressure pulse is effective to eject an ink droplet from the nozzle. Upon cooling of the diaphragm, the diaphragm moves away from the seat 18 and permits flow of ink into the passageway to replenish ink lost from the passageway in the ejected ink droplet. It will be appreciated that movement of the diaphragm towards the seat 18 produces the pressure pulse in the passageway and that it is not necessary, with this manner of operating the print device, for the diaphragm to move into sealing engagement with the seat 18. Accordingly the end of the passageway need not be provided with a seat and the passageway may be formed such as to cooperate with the diaphragm to produce the pressure pulse required to eject the ink droplet.

Deflection of the diaphragm from its rest state may be accomplished as described hereinbefore by

the application of heat to the diaphragm so that thermal distortion of the diaphragm results in deflection of the diaphragm from its rest state. Alternatively, expansion and contraction of the liquid in the reservoir may be utilised to deflect the diaphragm between its first and second states. With the reservoir filled with liquid, heating of the liquid results in expansion of the liquid and expansion of the liquid causes the diaphragm to be deflected into engagement with the seat 18. When the liquid cools and contracts the diaphragm returns to its rest state. Thus it is to be understood that heat may be applied either directly to the diaphragm or to an intermediate material, i.e. the liquid in the reservoir, to cause deflection of the diaphragm from one of its states to the other of its states.

Claims

1. An ink jet printing device including an ink ejection nozzle (15); an ink supply duct (11); a passageway (12) to provide ink flow from said ink supply duct (11) to said ink ejection nozzle (15) characterised by a diaphragm (23) movable between a first state and a second state, said diaphragm (23) when in said first state being spaced from said passageway (12) to permit flow of ink through the passageway from said ink supply duct to said ink ejection nozzle; heating means (19; 28; 30) to apply heat to cause movement of the diaphragm (23) from one of said first and second states to the other of said states so as to eject a droplet of ink from said nozzle (15).

2. An ink jet printing device as claimed in claim 1 including a first element (10); a groove (11) in a first face (17) of said first element; a second element (16) secured in sealing engagement with said first face (17) to close said groove (11) and thereby form the ink supply duct; an end of the passageway (12) opening in a wall of the groove (11) opposed to said second element (16); the diaphragm (23) being formed on said second element at a location corresponding to said end of said passageway (12).

3. An ink jet printing device as claimed in claim 2 wherein the first and second elements (10, 16) comprise silicon material etched to form the groove (11), passageway (12), ink ejection nozzle (15) and diaphragm (23).

4 An ink jet printing device as claimed in claim 1, 2 or 3 including a resistive heating element (19) deposited in heat transfer engagement with the diaphragm.

5. An ink jet printing device as claimed in claim 1, 2 or 3 wherein the means (19; 28; 30) to apply heat includes a laser source (28) and means (29) to direct a laser beam from said laser source onto the diaphragm (23).

6. An ink jet printing device as claimed in claim 1, 2 or 3 including a reservoir (21) containing liquid, the

diaphragm (23) extending between the liquid reservoir (21) and the ink supply duct (11); and means to apply heat (19; 28; 30) to said liquid contained in said reservoir (21).

7. An ink jet printing device as claimed in claim 6 wherein heating of the liquid in the reservoir (21) causes expansion of the liquid effective to act on and move the diaphragm (23) from one of its states to the other of its states.

8. An ink jet printing device as claimed in claim 6 or 7 including means (30) to pass electric current through the liquid to cause heating of said liquid.

9. An ink jet printing device as claimed in claim 6 or 7 wherein the means to apply heat includes a laser source (28) and means (29) to direct a laser beam from said laser source to the liquid in the reservoir (21).

10. An ink jet printing device as claimed in any preceding claim wherein the diaphragm (23) when in the second state is effective to close the passageway (12) from the ink supply duct (11) to prevent flow of ink therethrough of ink from the ink supply duct (11) to the nozzle (15).

11. An ink jet printing device as claimed in any preceding claim wherein ink is supplied from a source (24) to the duct (11) under pressure.

12. An ink jet printing device as claimed in any preceding claim wherein movement of the diaphragm (23) toward the end of the passageway (12) from the first state to the second state produces a pressure pulse in ink lying in the passageway (12) effective to eject a droplet of ink from the nozzle (15).

13. An ink jet printing device as claimed in any preceding claim including a plurality of ink ejection nozzles (15₁...15_n); a plurality of passageways (12₁...12_n) for ink from the supply duct (11) to corresponding ink ejection nozzles; and a plurality of diaphragms (23₁...23_n) corresponding respectively to said passageways.

14. A method of manufacturing an ink jet printing device as claimed in claim 2 characterised by the steps of forming the first and second elements (10, 16) by etching silicon material to form the groove (11), passageway (12), ink ejection nozzle (15) and diaphragm (23).

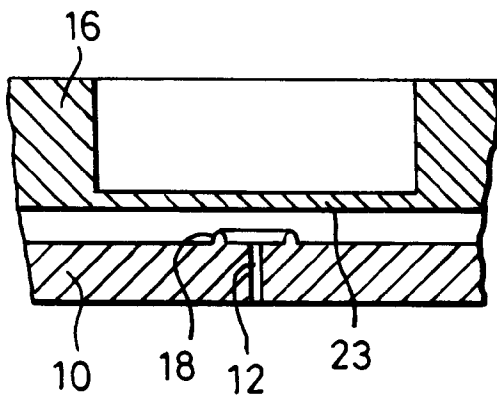
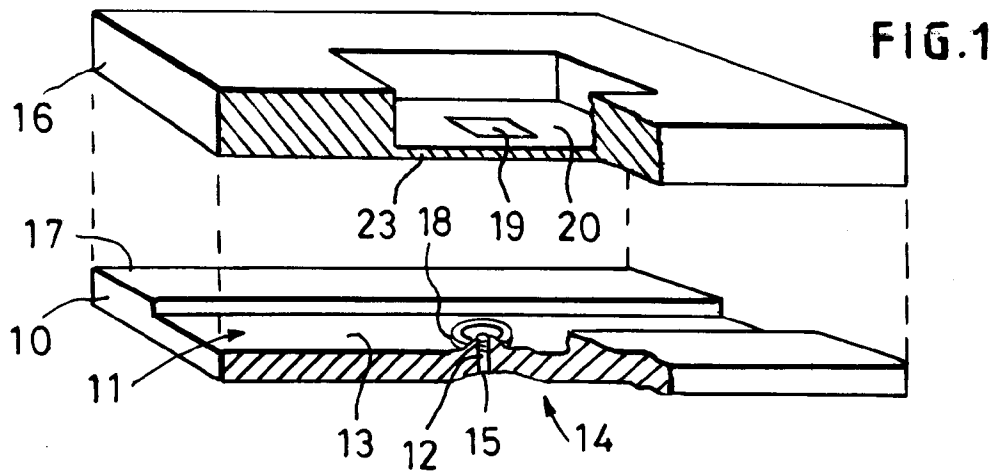


FIG. 2

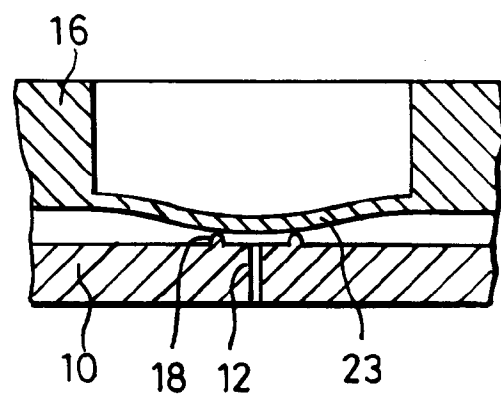
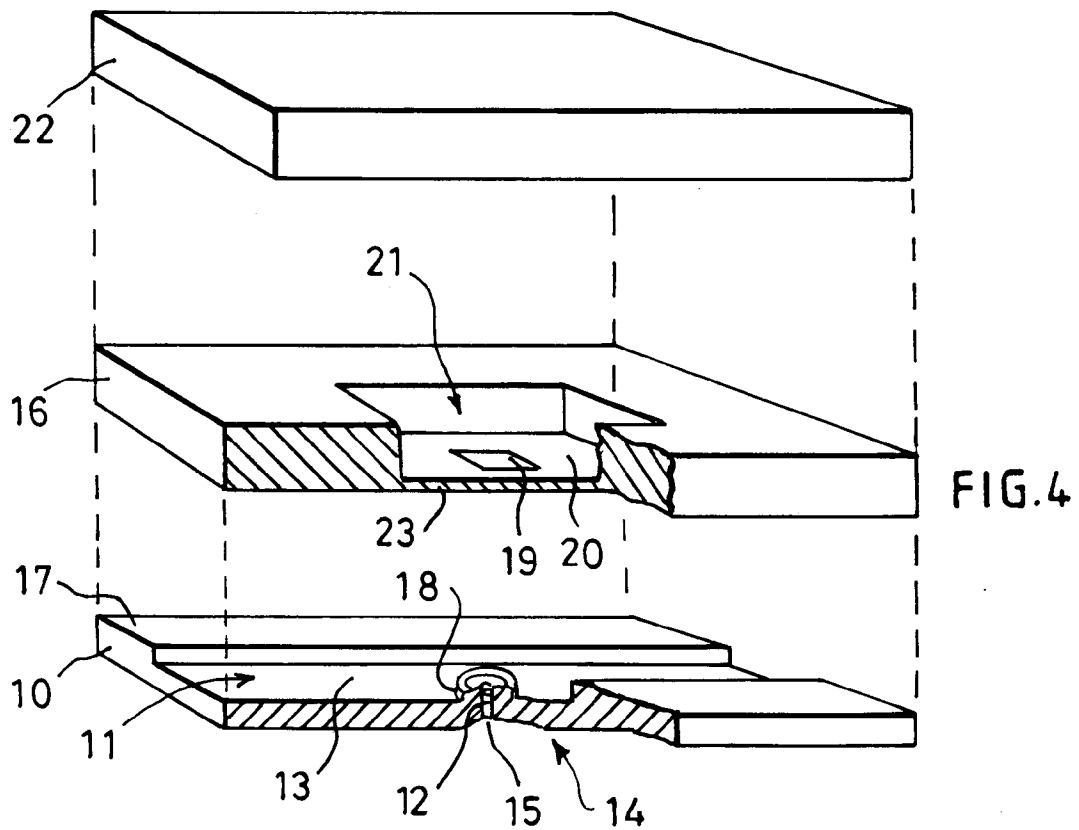


FIG. 3



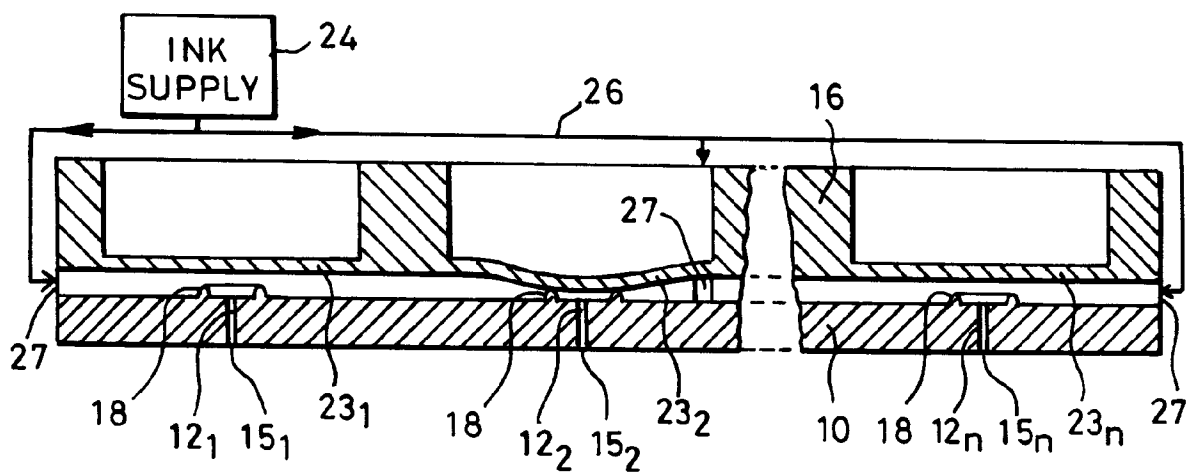


FIG.5

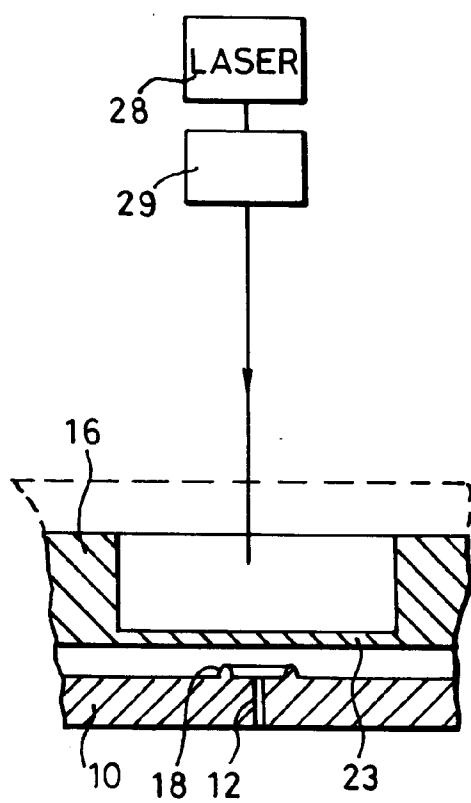


FIG.6

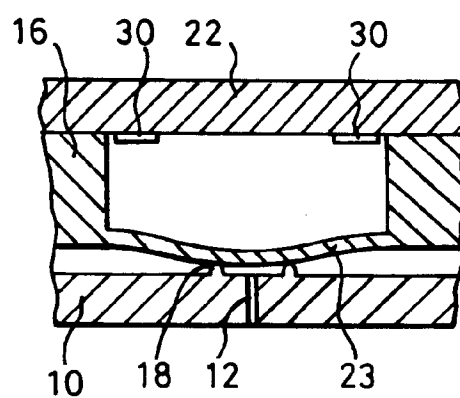


FIG. 7