

Description

This invention relates to electrically pulsed, droplet deposition apparatus and more particularly to such apparatus in the form of a high density multi-channel array. A familiar use to which apparatus of this kind is put is as a drop-on-demand ink jet printhead.

A high density array printhead should clearly have the property that each channel can be actuated separately and that a minimum of the energy applied to one channel is coupled into neighbouring channels. Energy coupling between channels is termed, "crosstalk".

In EP-A-0 277 703 and EP-A-0 278 590, there are disclosed ink jet printheads having a multiplicity of parallel channels mutually spaced in an array direction normal to the length of said channels which employ shear mode actuators which occupy side walls of the channels as the means of expelling droplets from nozzles respectively communicating with the channels. Shear mode actuators were chosen to avoid one kind of crosstalk, namely that arising from elastic interaction from stress waves through the piezo-electric material of the printhead caused by volume changes in the actuators. Shear mode actuators when actuated do not experience a volume change, for example, a change in length or height thereof.

Actuation of two groups respectively of odd and even numbered channels, alternately is a further feature of shared, shear mode wall actuators as disclosed in EP-A-0 278 590. Actuation of pressure p in a selected channel induces pressure $-p/2$ in the immediate neighbouring channels which cannot therefore be actuated at the same time as the selected channel. Pressure crosstalk namely energy coupling into the next but one, next but three etc., channels, i.e. the neighbouring channels of the same group, also occurs when compliant channel wall actuators of the selected channel are actuated. This can be avoided by means of the offset form of channel arrangement disclosed in the said co-pending European application.

Although crosstalk reduction has been effected in the ways described for the forms of crosstalk referred to, a further source of crosstalk has been identified which is troublesome and requires a different approach to accomplish its reduction. The shear mode wall actuators of a printhead of the kind referred to, when actuated, are subject to respective fields normal to electrodes on opposite sides of channel facing walls which comprise the actuators. These fields give rise to fringe fields which in the vicinity of the roots of the wall actuators have significant components parallel to the poling direction so that the piezo-electric material in these regions is volumetrically distorted rather

than being deflected in shear.

The overall effect of these fringe fields is to deflect the base material at the roots of the wall actuators to induce crosstalk into the neighbouring channels and at the same time to reduce significantly the wall actuator deflection. It is a principal object of the present invention, therefore, to provide a high density, multi-channel array, electrically pulsed droplet deposition apparatus in which cross talk attributable to fringe field effects arising upon actuation of shear mode channel actuators is minimised.

The present invention consists in a high density multi-channel array, electrically pulsed droplet deposition apparatus, comprising a bottom sheet of piezo-material poled in a direction normal to said sheet and formed with a multiplicity of parallel, open topped channels mutually spaced in an array direction normal to the length of the channels and defined each by facing side walls and a bottom surface extending between said side walls, a top sheet facing said bottom surfaces of said channels and bonded to said side walls to close said channels at the tops thereof, respective nozzles communicating with said channels for the ejection of droplets of liquid therefrom, connection means for connecting said channels with a source of droplet deposition liquid and electrodes provided on opposite sides of each of at least some of said side walls to form shear mode actuators for effecting droplet expulsion from the channels associated with said actuators, each electrode extending substantially along the length of the corresponding side wall in that each electrode extends over an area so spaced from the bottom surface of the channel in which the electrode is disposed that when a potential difference is applied between the electrodes on opposite sides of a wall, the resulting electrical field is confined substantially to that wall, leaving substantially free from piezo-electric distortion that region of the bottom sheet beneath the bottom surface of each of the channels adjoining the wall.

Preferably, each electrode extends over an area of the side wall on which it is provided from an edge of said side wall adjoining said top sheet.

Advantageously, each channel is formed with a forward part of uniform depth between said bottom surface and said top sheet, and a part rearwardly of the forward part of lesser depth than said forward part, said rearward part being formed on the facing side wall and bottom surfaces thereof with an electrically conductive coating in electrical contact with the electrodes on the facing side walls of the forward part of the channel.

In one form of the invention the electrodes on the facing walls of the forward part of each channel are formed in one with the electrically conductive

coatings on the channel part rearwardly of said forward part.

Suitably, the depth of the coating on the side walls is approximately half the depth of the forward part of the channel and covers the bottom part of the channel rearwardly of said forward part.

In another form of the invention said top sheet is formed in generally like manner to said bottom sheet, of piezo-electric material with channels corresponding to said channels of said bottom sheet and with electrodes on side walls of channels thereof corresponding with the side walls of said bottom sheet which are provided with electrodes, said top sheet being disposed in inverted relation to said bottom sheet and secured thereto so that each pair of said corresponding channels of the sheets together form a single composite channel extending within each of said sheets and said nozzles are provided in a nozzle plate secured to said sheets to provide respective nozzles at an end of said composite channels.

In an alternative way of achieving a similarly functioning apparatus, said bottom sheet comprises an integral sheet of piezo-electric material having oppositely poled regions respectively in upper and lower parts of each channel side walls and said electrodes extend on opposite sides of each of some at least of the said channel side walls from the top of said side walls, each said electrode covering said region in the upper part and a substantial part of said region in the lower part of the corresponding channel side wall. In this arrangement the top sheet is made of insulating material.

The invention further consists in the method of making a high density, multi-channel array pulsed droplet deposition apparatus, characterised by forming a bottom sheet with a layer of piezo-electric material poled normal to said layer, forming a multiplicity of parallel, open topped, droplet liquid channels in said bottom sheet which extend partially through said layer of piezo-electric material to afford walls of piezo-electric material between successive channels, forming electrodes on respective opposite sides of some at least of said walls so that an electric field can be applied to effect shear mode displacement of said walls provided with electrodes in a direction transversely to said channels, connecting electrical drive circuit means to said electrodes, securing a top sheet to said walls to close said channels and providing nozzles and droplet liquid supply means for said channels, said electrodes being formed on a substantial length of said walls characterised in that each electrode extends over an area so spaced from the bottom surface of the channel in which the electrode is disposed that when a potential difference is applied between the electrodes on opposite sides of a wall, the resulting electrical field is confined substantially

to that wall, leaving substantially free from piezo-electric distortion that region of the bottom sheet beneath the bottom surface of each of the channels adjoining the wall.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

FIGURE 1 is a fragmentary diagrammatic sectional view to an enlarged scale of a high density, multi-channel array, electrically pulsed, droplet deposition apparatus in the form of an ink jet printhead which illustrates the problem addressed by the present invention;

FIGURE 2 is a view, similar to Figure 1, showing an ink jet printhead according to the invention;

FIGURE 3 is a fragmentary longitudinal sectional view of an ink channel of one form of ink jet printhead according to the invention;

FIGURES 4(a) and 4(b) are fragmentary sectional views taken on the lines (a)-(a) and (b)-(b) of Figure 3;

FIGURE 5 is a view similar to Figure 3, of another form of ink jet printhead according to the invention;

FIGURE 6 is a view similar to Figure 2 showing a further form of ink jet printhead according to the invention;

FIGURE 7 is a view similar to Figures 2 and 6 showing a further form of ink jet printhead according to the invention; and;

FIGURE 8 is a view of an alternative form of a component used in the embodiments of the invention shown in Figures 2 and 7.

In the drawings, like parts are given the same reference numerals.

Referring to Figure 1, an ink jet printhead 10 comprises a multiplicity of parallel ink channels 12 forming an array in which the channels are mutually spaced in an array direction perpendicular to the length of the channels. The channels are formed at a density of two or more channels per mm. in a sheet 14 of piezo-electric material, suitably PZT, poled in the direction of arrows 15 and are defined each by side walls 16 and a bottom surface 18, the thickness of the PZT being greater than the channel depth. The channels 12 are open topped and in the printhead are closed by a top sheet 20 of insulating material - shown in Figure 2, but not in Figure 1 where it is omitted to make clearer the problem associated with the arrangement of Figure 1 - which is thermally matched to the sheet 14 and is disposed parallel to the surfaces 18 and bonded by a bonding layer 21 to the tops 22 of the walls 16. The channels 12 on their side wall and bottom surfaces are lined with a metallised electrode layer 24. It will be apparent therefore that when a potential difference of similar magnitude but opposite sign is applied to the elec-

trodes on opposite faces of each of two adjacent walls 16, the walls will be subject to electric fields indicated by lines of flux density 26 in opposite senses normal to the poling direction 15. The walls are in consequence deflected in shear mode, and in the absence of a top sheet 20 are displaced to the positions indicated by the broken lines 28. However at the roots of the side walls, the electric fields 26 exhibit fringe effects such that the lines of force have substantial components in the direction of poling. Where in piezo-electric material the electric field lies in the direction of poling i.e. the 3 direction, the material suffers an elongation or contraction both in the 3-3 direction along and in the 3-1 and 3-2 directions normal to the poling direction. In contrast a shear mode deflection arises when the electric field in the 1 direction is perpendicular to the direction of poling where the 1-5 deflection is rotational in character and is normal to both the field and the poling axes and is not accompanied by any change in height or length of the side walls thus deflected. The chain dotted lines 32 show a swelling caused by the fringe field lines 26 in the piezo-electric material which is a maximum at the mid-channel locations of those channels which are electrically activated and a contraction which is a maximum in the middle of those channels adjacent the activated channels.

In a printhead as described the channels are arranged in two groups of odd and even numbered channels and selected channels of each group are activated simultaneously and alternately with the channels of the other group. The fringe fields then give rise to distortions in the base sheet 14. These reduce the shear mode deflection of the walls 16 and generate stresses which are elastically propagated and develop crosstalk in the adjacent channels.

Alternatively, the channels may be arranged in three or more groups of interleaved channels with selected channels of one group being simultaneously actuated in sequence with selected channels of the other groups. Whether arranged in two or more groups it will be apparent that between actuated channels there are a number of unactuated channels which is at least one less than the number of channel groups. Cross-talk is then substantially reduced but the loss of shear mode wall deflection in the root of the wall remains significant.

Referring now to Figures 2 and 3, the channels 12 therein are provided on facing walls 16 thereof with metallised electrodes 34 which extend from the edges of the tops 16 of the walls down the walls to a location well short of the bottom surface 18 of the channels. There is an optimum metallisation depth which gives maximum wall displacement at about the mid-height of the walls depending on the distribution of wall rigidity. The virtue of

this design is that the fringe fields damp out rapidly within the walls 16 where they generate stresses but no resultant deflection in the walls. At the roots of the walls there are no fringe fields so that there are no field components in the poling direction and therefore no distortion of the kind shown by the line 32 in Figure 1 takes place.

In Figure 3, it will be seen that the channels 12 comprise a forward part 36 of uniform depth which is closed at its forward end by a nozzle plate 38 having formed therein a nozzle 40 from which droplets of ink in the channel are expelled by activation of the facing actuator walls 16 of the channel. The channel 12 rearwardly of the forward part 36 also has a part 42 of lesser depth extending from the tops 22 of the walls 16 than the forward part 36. The metallised plating 34 which is on opposed surfaces of the walls 16 occupies a depth approximately one half that of the channel side walls but greater than the depth of the channel part 42 so that when plating takes place the side walls 16 and bottom surface 18 of the channel part 42 are fully covered whilst the side walls in the forward part 36 of the channel are covered to approximately one half the channel depth in that part. A suitable electrode metal used is an alloy of nickel and chromium, i.e. nichrome. It has been found that for satisfactory actuation of the actuator walls 16 the compliance of the bond layer 22 which is $\frac{hE}{H}$ where h is the height of the bond layer 22, e is the modulus of elasticity of that layer, H is the height of the walls 16 and E the elastic modulus thereof, should be less than 1 and preferably less than 0.1.

It will be noted that a droplet liquid manifold 46 is formed in the top sheet 20 transversely to the parallel channels 12 which communicates with each of the channels 12 and with a duct 48 which leads to a droplet liquid supply (not shown).

Cutting of the channels 12 in the sheet 14 is effected by means of grinding using a dicing cutter of the kind disclosed in EP-A-0 309 148 or EP-A-0 398 571. The cutter is rotated at high speed and is mounted above a movable bed to which a number of the poled PZT sheets are secured. The bed is movable with respect to the horizontal rotary axis of the cutter in parallel with that axis and in two mutually perpendicular axes a vertical and a horizontal axis both at right angles to the horizontal axis parallel with the cutter axis. The pitch of the cutter blades is greater than the pitch required for the channels 12 so that two or more passes of the cutter are needed to cut the channels 12. At each cut the forward channel sections 36 are first cut and the bed is then lowered so that the sections 42 of the channels are cut to the lesser depth required. The minimum concave radius at rear end of section 36 of the channels is determined by the

radius of the cutter blades.

Referring now to Figures 4(a) and 4(b) in connection with which the manner of depositing the metal, suitably nichrome, electrodes 34 is described: For this operation a collimated beam 60 of evaporated metal atoms is derived from an electron beam which is directed on a metal source located about 0.5 to 1.0 metres from the jig holding the PZT sheets 14 in which the channels 12 have been cut. The PZT sheets 14 contained in the jig are located with respect to the metal vapour beam so that the vapour emission makes an angle of $+\delta$ with the longitudinal vertical central plane of the channels 12. In this way metal deposition takes place on one side wall 16 of each channel to a depth, determined by the angle δ which is approximately half the depth of the section 36 of the channel but greater than the depth of the channel sections 42. The coating of a side wall 16 in each of the channel sections 36 is accompanied by coating of the corresponding wall in the sections 42 and of the greater part of the bottom surface of each of those sections. A second stage of the coating to complete the metal deposition is effected by turning the sheets 14 through 180° so that the incident angle of the metal vapour is now $-\delta$, and the walls 16 facing those already coated are treated and the coating of bottom surfaces of channel sections 42 is also completed. Excess metal on the tops and ends of the channel walls is removed by lapping. Instead of reversing the sheets 14 two sources of metal vapour may be used in succession to effect the metal coatings.

After plating of the channels 12 is effected and before connection thereof to a suitable driver chip, an inert inorganic passivant is coated on the walls of the channel sections 36 and 42. The passivant coating is chosen to have a high electrical resistivity and is also resistant to migration of ion species from the droplet fluid, in the case of a printer, the ink, to be employed, under the shear mode actuator field. A plurality of passivant layers may be needed to obtain the requisite electrical properties. Alternating films of Si_3N_4 and SiON are suitable for the averred purpose.

Figure 5 shows an alternative design to that of Figure 3 in which a thinner sheet 14 of PZT is employed which is laminated by a bond layer 51 to a base layer 50 suitably of glass thermally matched to the sheet 14. The base layer here contains an ink manifold 52 communicating with the channels and with a source of droplet liquid supply. The channels 12 are formed a little less deep than the PZT sheet to help stiffen the bond layer 51 in the forward part 36 i.e. the active part of the channels.

Referring now to Figure 6, the invention is illustrated as applied to the form of printhead 10, described with reference to Figures 2(a) to (d) in

EP-A-0 278 590. Thus, similar upper and lower sheets 14 of piezo-electric material are formed with corresponding channels 12 provided with metalised electrodes 34 and are secured together by inverting the upper sheet with respect to the lower sheet and providing the bond layer 22 between the tops of the corresponding channel side walls. In this form of actuation, because the directions of poling are opposed in the sheets the channel side walls are deflected into chevron form.

The electrodes 34 stop short of the bottom of the channels, as in the case of the embodiment of the invention illustrated in Figure 2, so that fringe field effects producing field components in the direction of poling are reduced, if not eliminated.

It will be apparent that manufacture is facilitated by making the sheets 14 of identical form.

Referring now to the embodiment illustrated in Figure 7, a sheet 14 is employed therein having upper and lower regions poled in opposite senses as indicated by the arrows 15. The electrodes 34 are deposited so as to cover the facing channel side walls from the tops thereof down to a short distance from the bottoms of the channels so that a region of each side wall extending from the top of the channel and poled in one sense and a substantial part of a lower region of the side wall poled in the reverse sense are covered by the relevant electrode. Thus, it will be appreciated that the arrangement described operates to deflect the channel side walls into chevron form as in the case of the embodiment of the invention described with reference to Figure 6, though in the case of the presently described embodiment the chevron deflection occurs in a monolithic sheet of piezo-electric material rather than two such sheets bonded on or near the plane containing the channel axes. The manner of poling of a sheet 14 of piezo-electric material transversely thereto with regions of opposed polarity at opposite sides of the sheet is described in EP-A-0 309 147.

Figure 8 illustrates a sheet 20' of insulating material which can be employed as an alternative to sheet 20 of the embodiments of the invention illustrated in Figures 2 and 3, 5, 6 and 7. Sheet 20' is formed with shallow channels 12' which correspond to the channels 12 of sheet 14 and is bonded after inversion thereof to the sheet 14, the bond layer 22 being formed between the tops of the corresponding channel side walls in the sheets 14 and 20'.

It will be noted that, as described in connection with Figure 5, a sheet 50' of glass or other insulating material is employed as a stiffening means for the sheet 14 of piezo-electric material. Such a stiffening sheet can also be employed to stiffen the sheet 14 in the arrangements of Figures 2 and 3 and to stiffen both sheets 14 in the arrangement of

Figure 6.

Claims

1. A high density multi-channel array, electrically pulsed droplet deposition apparatus, comprising a bottom sheet (14) of piezo-material poled in a direction normal to said sheet and formed with a multiplicity of parallel, open topped channels (12) mutually spaced in an array direction normal to the length of the channels and defined each by facing side walls (16) and a bottom surface (18) extending between said side walls, a top sheet (20) facing said bottom surfaces (18) of said channels and bonded to said side walls (16) to close said channels (12) at the tops thereof, respective nozzles (40) communicating with said channels for the ejection of droplets of liquid therefrom, connection means (46,48) for connecting said channels with a source of droplet deposition liquid and electrodes (34) provided on opposite sides of each of at least some of said side walls to form shear mode actuators for effecting droplet expulsion from the (12) channels associated with said actuators, each electrode (34) extending substantially along the length of the corresponding side wall, characterised in that each electrode (34) extends over an area so spaced from the bottom surface (18) of the channel (12) in which the electrode is disposed that when a potential difference is applied between the electrodes (34) on opposite sides of a wall (16), the resulting electrical field is confined substantially to that wall (16), leaving substantially free from piezo-electric distortion that region of the bottom sheet (14) beneath the bottom surface (18) of each of the channels (12) adjoining the wall (16).
2. A high density multi-channel array, electrically pulsed droplet deposition apparatus as claimed in Claim 1, wherein each electrode (34) extends over an area of the side wall (16) on which it is provided from the edge of said side wall adjoining said top sheet (20).
3. A high density multi-channel array, electrically pulsed droplet deposition apparatus as claimed in Claim 2, wherein said area is rectangular.
4. A high density multi-channel array, electrically pulsed droplet deposition apparatus as claimed in any preceding claim, wherein the electrodes (34) extend from an end of said channels adjacent the nozzles (40).
5. The apparatus of Claim 2 or 3, wherein each of said channels (12) is formed with a forward part (36) of uniform depth between said bottom surface (18) and said top sheet (20) in which said electrodes (34) are provided and a part (42) rearwardly of said forward part of lesser depth than said forward part.
6. The apparatus of Claim 5, wherein the electrodes (34) provided on the facing walls of each of said forward parts (36) have a depth which is greater than the depth of said rearward parts (42) but less than the depth of said channels.
7. The apparatus of Claim 6, wherein each of said rearward parts (42) is formed with an interior electrically conductive coating (34) which is in electrical contact with the electrodes (34) on the facing side walls (16) of the forward parts (36) of said channels (12).
8. The apparatus of Claim 5, wherein the electrodes (34) on the facing walls (16) of the forward part (36) of each channel (12) are formed in one with the electrically conductive coatings (34) on the rearward channel part (42).
9. Apparatus as claimed in any preceding claim, wherein said electrodes (34) are provided on respective facing side walls (16) of each of said channels (12).
10. Apparatus as claimed in Claim 9, wherein electrical connections to said electrodes (34) of each of said channels (12) are provided to enable operation of said channels in a plurality of groups of interleaved channels, selected channels of each of said groups being simultaneously actuated in sequence with selected, simultaneously actuated channels in the other or each of the others of said groups so that between any two actuated channels there is disposed at least one unactuated channel.
11. Apparatus as claimed in Claim 10, wherein electrical connections to said electrodes (34) of each of said channels (12) are provided to enable operation of said channels in two groups of interleaved alternating channels, selected channels of one of said groups being simultaneously actuated in sequence with selected, simultaneously actuated channels in the other of said groups.
12. Apparatus as claimed in any preceding claim, wherein said top sheet (14) is formed in gen-



Figure 6.

Claims

1. A high density multi-channel array, electrically pulsed droplet deposition apparatus, comprising a bottom sheet (14) of piezo-material poled in a direction normal to said sheet and formed with a multiplicity of parallel, open topped channels (12) mutually spaced in an array direction normal to the length of the channels and defined each by facing side walls (16) and a bottom surface (18) extending between said side walls, a top sheet (20) facing said bottom surfaces (18) of said channels and bonded to said side walls (16) to close said channels (12) at the tops thereof, respective nozzles (40) communicating with said channels for the ejection of droplets of liquid therefrom, connection means (46,48) for connecting said channels with a source of droplet deposition liquid and electrodes (34) provided on opposite sides of each of at least some of said side walls to form shear mode actuators for effecting droplet expulsion from the (12) channels associated with said actuators, each electrode (34) extending substantially along the length of the corresponding side wall, characterised in that each electrode (34) extends over an area so spaced from the bottom surface (18) of the channel (12) in which the electrode is disposed that when a potential difference is applied between the electrodes (34) on opposite sides of a wall (16), the resulting electrical field is confined substantially to that wall (16), leaving substantially free from piezo-electric distortion that region of the bottom sheet (14) beneath the bottom surface (18) of each of the channels (12) adjoining the wall (16).
2. A high density multi-channel array, electrically pulsed droplet deposition apparatus as claimed in Claim 1, wherein each electrode (34) extends over an area of the side wall (16) on which it is provided from the edge of said side wall adjoining said top sheet (20).
3. A high density multi-channel array, electrically pulsed droplet deposition apparatus as claimed in Claim 2, wherein said area is rectangular.
4. A high density multi-channel array, electrically pulsed droplet deposition apparatus as claimed in any preceding claim, wherein the electrodes (34) extend from an end of said channels adjacent the nozzles (40).
5. The apparatus of Claim 2 or 3, wherein each of said channels (12) is formed with a forward part (36) of uniform depth between said bottom surface (18) and said top sheet (20) in which said electrodes (34) are provided and a part (42) rearwardly of said forward part of lesser depth than said forward part.
6. The apparatus of Claim 5, wherein the electrodes (34) provided on the facing walls of each of said forward parts (36) have a depth which is greater than the depth of said rearward parts (42) but less than the depth of said channels.
7. The apparatus of Claim 6, wherein each of said rearward parts (42) is formed with an interior electrically conductive coating (34) which is in electrical contact with the electrodes (34) on the facing side walls (16) of the forward parts (36) of said channels (12).
8. The apparatus of Claim 5, wherein the electrodes (34) on the facing walls (16) of the forward part (36) of each channel (12) are formed in one with the electrically conductive coatings (34) on the rearward channel part (42).
9. Apparatus as claimed in any preceding claim, wherein said electrodes (34) are provided on respective facing side walls (16) of each of said channels (12).
10. Apparatus as claimed in Claim 9, wherein electrical connections to said electrodes (34) of each of said channels (12) are provided to enable operation of said channels in a plurality of groups of interleaved channels, selected channels of each of said groups being simultaneously actuated in sequence with selected, simultaneously actuated channels in the other or each of the others of said groups so that between any two actuated channels there is disposed at least one unactuated channel.
11. Apparatus as claimed in Claim 10, wherein electrical connections to said electrodes (34) of each of said channels (12) are provided to enable operation of said channels in two groups of interleaved alternating channels, selected channels of one of said groups being simultaneously actuated in sequence with selected, simultaneously actuated channels in the other of said groups.
12. Apparatus as claimed in any preceding claim, wherein said top sheet (14) is formed in gen-



- erally like manner to said bottom sheet (14), of piezo-electric material with channels (12) corresponding to said channels (12) of said bottom sheet and with electrodes on side walls of channels thereof corresponding with the side walls of said bottom sheet which are provided with electrodes, said top sheet (14) being disposed in inverted relation to said bottom sheet (14) and secured thereto so that each pair of said corresponding channels of the sheets together form a single composite channel (12) extending within each of said sheets and said nozzles (40) are provided in a nozzle plate (38) secured to said sheets to provide respective nozzles at an end of said composite channels.
13. Apparatus as claimed in Claim 12, wherein said top and bottom sheets are of identical form.
14. Apparatus as claimed in Claim 12 or Claim 13, wherein said top and bottom sheets are bonded to respective stiffening layers (50) of insulating material.
15. Apparatus as claimed in any one of Claims 1 to 11, wherein said bottom sheet comprises an integral sheet of piezo-electric material (14) having oppositely poled regions respectively in upper and lower parts of each channel side walls (16) and said electrodes (34) extend on opposite sides of each of at least some of the said channel side walls from the top (22) of said side walls, each said electrode covering said region in the upper part and a substantial part of said region in the lower part of the corresponding channel side wall.
16. Apparatus as claimed in any one of Claims 1 to 11 and 15, wherein said bottom sheet (14) is bonded to a stiffening layer (50) of insulating material.
17. Apparatus as claimed in any one of Claims 1 to 11 and 15 and 16, wherein said top sheet (20) is formed with channels (12) corresponding with said channels (12) of said bottom sheet and said top sheet (20) is bonded to said bottom sheet (14) so that each pair of corresponding channels of the sheets together form a single composite channel.
18. The method of making a high density, multi-channel array pulsed droplet deposition apparatus, by forming a bottom sheet (14) with a layer of piezo-electric material poled normal to said layer, forming a multiplicity of parallel, open topped, droplet liquid channels (12) in

said bottom sheet which extend partially through said layer of piezo-electric material to afford walls (16) of piezo-electric material between successive channels, forming electrodes (34) on respective opposite sides of some at least of said walls so that an electric field can be applied to effect shear mode displacement of said walls provided with electrodes in a direction transversely to said channels, connecting electrical drive circuit means to said electrodes, securing a top sheet (20) to said walls to close said channels and providing nozzles (40) and droplet liquid supply means (46,48) said channels, said electrodes being formed on a substantial length of said walls characterised in that each electrode (34) extends over an area so spaced from the bottom surface (18) of the channel (12) in which the electrode is disposed that when a potential difference is applied between the electrodes (34) on opposite sides of a wall (16), the resulting electrical field is confined substantially to that wall (16), leaving substantially free from piezo-electric distortion that region of the bottom sheet (14) beneath the bottom surface (18) of each of the channels (12) adjoining the wall (16).

19. The method claimed in Claim 18, comprising the step of forming said electrodes by deposition of metal from metal vapour beams directed towards said walls at an angle to channel facing surfaces thereof.

Patentansprüche

1. Hochauflösende, vielkanalige Anordnung zum elektrisch gepulsten Niederschlag von Tröpfchen mit einer Bodenplatte (14) aus Piezomaterial, das in eine Richtung gepolt ist, die senkrecht zu besagter Platte ist, und die mit einer Vielfachheit paralleler, oben offener Kanäle (12) ausgebildet ist, die jeweils mit Zwischenraum in einer Anordnungsrichtung angeordnet sind, die senkrecht zur Längsrichtung der Kanäle ist und die jeweils durch gegenüberliegende Seitenwände (16) und eine Bodenfläche (18), die sich zwischen den besagten Seitenwänden erstreckt, definiert sind, einer Deckplatte (20), die besagten Bodenflächen (18) der besagten Kanäle gegenüberliegt und mit besagten Seitenwänden (16) verbunden ist, um besagte Kanäle (12) an ihren oberen Enden zu schließen, entsprechenden Düsen (40), die mit besagten Kanälen zum Ausstoßen von Flüssigkeitströpfchen aus diesen kommunizieren, Verbindungseinrichtungen (46, 48) zur Verbindung besagter Kanäle mit einer Tröpfchennieder-



schlagsflüssigkeitsquelle und Elektroden (34), die auf gegenüberliegenden Seiten von jeweils mindestens einigen der besagten Seitenwände vorgesehen sind, um Schermodusbetätigungsorgane zur Bewirkung des Tröpfchenausstoßes aus den Kanälen (12), die mit besagten Betätigungsorganen verbunden sind, zu bilden, wobei sich jede Elektrode (34) im wesentlichen längs der Längserstreckung der entsprechenden Seitenwand erstreckt, dadurch gekennzeichnet, daß

jede Elektrode (34) sich über einen Bereich so räumlich beabstandet von der Bodenfläche (14) des Kanals (12), in dem die Elektrode angeordnet ist, erstreckt, daß, wenn eine Potentialdifferenz zwischen den Elektroden (34) auf gegenüberliegende Seiten einer Wand (16) gegeben wird, das resultierende elektrische Feld im wesentlichen auf diese Wand (16) beschränkt ist, und diese Region der Bodenplatte (14) unter der Bodenfläche (18) jedes der Kanäle (12), die an die Wand (16) angrenzen, im wesentlichen frei von piezoelektrischer Verformung hält.

2. Hochauflösende, vielkanalige Anordnung zum elektrisch gepulsten Niederschlag von Tröpfchen gemäß Anspruch 1, in der sich jede Elektrode (34) über einen Bereich der Seitenwand (16) erstreckt, auf der sie von dem Rand der besagten Seitenwand, die an besagte Deckplatte (20) angrenzt, vorgesehen ist.
3. Hochauflösende, vielkanalige Anordnung zum elektrisch gepulsten Niederschlag von Tröpfchen gemäß Anspruch 2, in der besagter Bereich rechteckig ist.
4. Hochauflösende, vielkanalige Anordnung zum elektrisch gepulsten Niederschlag von Tröpfchen gemäß einem der vorangegangenen Ansprüche, in der sich die Elektroden (34) von einem Ende der besagten Kanäle, das an die Düsen (40) angrenzt, erstrecken.
5. Anordnung gemäß Anspruch 2 oder 3, in der jeder der besagten Kanäle (12) mit einem vorwärtigen Teil (36) gleichförmiger Tiefe zwischen besagter Bodenfläche (18) und besagter Deckplatte (20), in der die besagten Elektroden (34) vorgesehen sind und einem Teil (42) hinter dem besagten vorwärtigen Teil geringerer Tiefe als besagter vorwärtiger Teil gebildet wird.
6. Anordnung gemäß Anspruch 5, in der die Elektroden (34), die auf den Stirnwänden jeder der besagten vorwärtigen Teile (36) vorgesehen

sind, eine Tiefe haben, die größer ist als die Tiefe der besagten rückwärtigen Teile (42), aber kleiner ist als die Tiefe der besagten Kanäle.

7. Anordnung gemäß Anspruch 6, in der jeder der besagten rückwärtigen Teile (42) mit einer inneren elektrisch leitfähigen Beschichtung (34) ausgebildet ist, die in elektrischem Kontakt mit den Elektroden (34) auf den Stirnseitenwänden (16) der vorwärtigen Teile (36) der besagten Kanäle (12) ist.
8. Anordnung gemäß Anspruch 5, in der die Elektroden (34) auf den Stirnwänden (16) des vorwärtigen Teils (36) jedes Kanals (12) in einem mit den elektrisch leitenden Beschichtungen (34) auf dem rückwärtigen Kanalteil (42) ausgebildet sind.
9. Anordnung gemäß einem der vorangehenden Ansprüche, in der besagte Elektroden (34) auf den entsprechenden Stirnseitenwänden (16) jedes der besagten Kanäle (12) vorgesehen sind.
10. Anordnung gemäß Anspruch 9, in der elektrische Verbindungen mit besagten Elektroden (34) jedes der besagten Kanäle (12) vorgesehen sind, um den Betrieb der besagten Kanäle in einer Vielzahl von Gruppen abwechselnder Kanäle zu ermöglichen, wobei die ausgewählten Kanäle jeder der besagten Gruppen gleichzeitig in Reihe mit ausgewählten, gleichzeitig betätigten Kanälen in der anderen oder jeder der anderen der besagten Gruppen betätigt werden, so daß zwischen beliebigen zwei betätigten Kanälen mindestens ein nicht betätigter Kanal angeordnet ist.
11. Anordnung gemäß Anspruch 10, in der die elektrischen Verbindungen mit besagten Elektroden (34) jeder der besagten Kanäle (12) vorgesehen sind, um den Betrieb der besagten Kanäle in zwei Gruppen von abwechselnd alternierenden Kanälen zu ermöglichen, wobei die ausgewählten Kanäle einer der besagten Gruppen gleichzeitig in Reihe mit den ausgewählten und gleichzeitig betätigten Kanälen in den anderen der besagten Gruppen betätigt werden.
12. Anordnung gemäß einem der vorangegangenen Ansprüche, in der die besagte Deckplatte (14) in allgemein ähnlicher Art wie die besagte Bodenplatte (14) aus piezoelektrischem Material mit Kanälen (12), die den besagten Kanälen (12) der besagten Bodenplatte entsprechen,



- und mit Elektroden auf den Seitenwänden der Kanäle dieser, die den Seitenwänden der besagten Bodenplatte entsprechen, die mit Elektroden versehen sind, ausgebildet ist, die besagte Deckplatte (14) in einer umgekehrten Beziehung zur besagten Bodenplatte (14) angeordnet und mit dieser so befestigt ist, daß jedes Paar der besagten entsprechenden Kanäle der Platten gemeinsam einen einzelnen Verbundkanal (12) bildet, der sich innerhalb jeder der besagten Platten erstreckt und besagte Düsen (40) in einer Düsenplatte (38) vorgesehen sind, die mit besagten Platten fest verbunden ist, um entsprechende Düsen an einem Ende der besagten Verbundkanäle zu schaffen.
13. Anordnung gemäß Anspruch 12, in der besagte Deck- und Bodenplatten von identischer Form sind.
14. Anordnung gemäß Anspruch 12 oder 13, in der besagte Deck- und Bodenplatten mit den entsprechenden versteifenden Schichten (50) isolierenden Materials verbunden sind.
15. Anordnung gemäß einem der vorangegangenen Ansprüche 1 bis 11, in der die besagte Bodenplatte eine einstückige Platte piezoelektrischen Materials (14) umfaßt, das entgegengesetzte Regionen in den oberen bzw. unteren Teilen jeder der Kanalseitenwände (16) aufweist und besagte Elektroden (34) sich auf gegenüberliegenden Seiten von jeweils wenigstens einigen der besagten Kanalseitenwände von dem oberen Ende (22) der besagten Seitenwände erstrecken, wobei jede besagte Elektrode die besagte Region in dem oberen Teil und einem wesentlichen Teil der besagten Region in dem unteren Teil der entsprechenden Kanalseitenwand bedeckt.
16. Anordnung gemäß einem der Ansprüche 1 bis 11 und 15, in der die besagte Bodenplatte (14) mit einer versteifenden Schicht (50) isolierenden Materials (50) verbunden ist.
17. Anordnung gemäß einem der Ansprüche 1 bis 11 und 15 und 16, in der die besagte Deckplatte (20) mit Kanälen (12), die den besagten Kanälen (12) der besagten Bodenplatte entsprechen, gebildet ist und die besagte Deckplatte (20) mit der besagten Bodenplatte (14) derart verbunden ist, daß jedes Paar der entsprechenden Kanäle der Platte gemeinsam einen einzigen Verbundkanal bilden.
18. Verfahren zur Herstellung einer hochauflösenden, vielkanaligen Anordnung zum elektrisch gepulsten Niederschlag von Tröpfchen, bei dem eine Bodenplatte (14) mit einer Schicht piezoelektrischen Materials, das senkrecht zu besagter Schicht gepolt ist, gebildet wird, eine Vielfachheit paralleler, oben offener Tröpfchenflüssigkeitskanäle (12) in besagter Bodenplatte gebildet wird, die sich zum Teil durch besagte Schicht piezoelektrischen Materials erstrecken, um Wände (16) piezoelektrischen Materials zwischen aufeinanderfolgenden Kanälen zu schaffen, Elektroden (34) auf entsprechenden gegenüberliegenden Seiten von wenigstens einigen der Seitenwände gebildet werden, so daß ein elektrisches Feld angelegt werden kann, um eine Schermodusverschiebung der besagten Wände, die mit Elektroden in einer Richtung quer zu den Kanälen versehen sind, zu bewirken, eine elektrische Steuerschaltkreisvorrichtung mit besagten Elektroden verbunden wird, eine Deckplatte (20) mit besagten Wänden fest verbunden wird, um besagte Kanäle zu schließen und Düsen (40) und Tröpfchenflüssigkeitsversorgungsanordnungen (46,48) für besagte Kanäle vorgesehen werden, wobei die besagten Elektroden auf einer beträchtlichen Länge der besagten Wände gebildet werden, dadurch gekennzeichnet, daß jede Elektrode (34) sich über eine Fläche erstreckt, die so räumlich von der Bodenfläche (18) des Kanals (12), in der die Elektrode angeordnet ist, angeordnet ist, daß, wenn eine Potentialdifferenz zwischen die Elektroden (34) auf gegenüberliegenden Seiten einer Wand (16) gegeben wird, das resultierende elektrische Feld im wesentlichen auf diese Wand (16) beschränkt ist, wobei diese Region der Bodenplatte (14) unter der Bodenfläche (18) jedes der Kanäle (12), die an die Wand (16) angrenzen, im wesentlichen frei von piezoelektrischer Verformung gelassen wird.
19. Verfahren gemäß Anspruch 18, das den Schritt der Bildung besagter Elektroden durch Ablagerung von Metall aus einem Metaldampfstrahl, der auf besagte Wände in einem Winkel zu den dem Kanal zugewandten Flächen gerichtet ist, gebildet wird, umfaßt.

Revendications

1. Appareil de dépôt de gouttelettes par impulsions électriques comportant un ensemble de canaux multiples de haute densité, qui comprend une feuille inférieure (14) en matière piézoélectrique polarisée dans une direction perpendiculaire à ladite feuille et dans laquelle



sont formés une multiplicité de canaux parallèles ouverts vers le haut (12), mutuellement espacés dans une direction d'agencement perpendiculaire à la longueur des canaux et définis chacun par des parois latérales en regard (16) et une surface inférieure (18) s'étendant entre lesdites parois latérales, une feuille supérieure (20) prévue en face desdites surfaces inférieures (18) desdits canaux et liée auxdites parois latérales (16) de manière à fermer lesdits canaux (12) à leurs sommets, des buses respectives (40) qui communiquent avec lesdits canaux pour l'éjection de gouttelettes de liquide à partir de ces canaux, des moyens de connexion (46,48) pour connecter lesdits canaux à une source de liquide de dépôt de gouttelettes, et des électrodes (34) prévues sur les faces opposées de chacune d'au moins certaines desdites parois latérales pour constituer des actionneurs en mode de cisaillement afin d'effectuer l'expulsion de gouttelettes, à partir des canaux (12) associés auxdits actionneurs, chaque électrode (34) s'étendant sensiblement tout le long de la paroi latérale correspondante, caractérisé en ce que chaque électrode (34) s'étend sur une région espacée de la surface inférieure (18) du canal (12) dans lequel l'électrode est disposée d'une manière telle que, lorsqu'une différence de potentiel est appliquée entre les électrodes (34) sur les faces opposées d'une paroi (16), le champ électrique résultant est confiné sensiblement à cette paroi (16) et laisse sensiblement exempte de distorsion piézo-électrique la région de la feuille inférieure (14) située au-dessous de la surface inférieure (18) de chacun des canaux (12) adjacents à la paroi (16).

2. Appareil de dépôt de gouttelettes par impulsions électriques comportant un ensemble de canaux multiples de haute densité suivant la revendication 1, dans lequel chaque électrode (34) s'étend sur une région de la paroi latérale (16) sur laquelle elle est placée, à partir du bord de ladite paroi latérale adjacent à la dite feuille supérieure (20).

3. Appareil de dépôt de gouttelettes par impulsions électriques comportant un ensemble de canaux multiples de haute densité suivant la revendication 2, dans lequel ladite région est rectangulaire.

4. Appareil de dépôt de gouttelettes par impulsions électriques comportant un ensemble de canaux multiples de haute densité suivant une quelconque des revendications précédentes, dans lequel les électrodes (34) s'étendent à

partir d'une extrémité desdits canaux adjacente aux buses (40).

5. Appareil suivant la revendication 2 ou 3, dans lequel chacun desdits canaux (12) comporte une partie avant (36) de profondeur uniforme entre ladite surface inférieure (18) et ladite feuille supérieure (20), dans laquelle sont placées lesdites électrodes (34), et une partie (42) située vers l'arrière de ladite partie avant et de moindre profondeur que ladite partie avant.

6. Appareil suivant la revendication 5, dans lequel les électrodes (34) prévues sur les parois en regard de chacune desdites parties avant (36) ont une profondeur qui est plus grande que la profondeur des dites parties arrière (42) mais plus petite que la profondeur des dits canaux.

7. Appareil suivant la revendication 6, dans lequel chacune des dites parties arrière (42) comporte un revêtement intérieur électriquement conducteur (34) qui est en contact électrique avec les électrodes (34) placées sur les parois latérales en regard (16) des parties avant (36) desdits canaux (12).

8. Appareil suivant la revendication 5, dans lequel les électrodes (34) placées sur les parois en regard (16) de la partie avant (36) de chaque canal (12) sont formées en un seul élément avec les revêtements électriquement conducteurs (34) sur la partie arrière des canaux (42).

9. Appareil suivant une quelconque des revendications précédentes, dans lequel lesdites électrodes (34) sont prévues sur des parois latérales en regard respectives (16) de chacun desdits canaux (12).

10. Appareil suivant la revendication 9, dans lequel les connexions électriques auxdites électrodes (34) de chacun desdits canaux (12) sont prévues de manière à permettre le fonctionnement desdits canaux dans une pluralité de groupes de canaux imbriqués, des canaux choisis de chacun de ces groupes étant simultanément actionnés en séquence avec des canaux choisis actionnés simultanément de l'autre ou de chacun des autres desdits groupes de sorte que, entre deux canaux actionnés quelconques, il y a au moins un canal non actionné.

11. Appareil suivant la revendication 10, dans lequel les connexions électriques auxdites électrodes (34) de chacun desdits canaux (12) sont prévues de manière à permettre le fonctionne-



- ment desdits canaux en deux groupes de canaux imbriqués en alternance, des canaux choisis d'un desdits groupes étant simultanément actionnés en séquence avec des canaux choisis actionnés simultanément de l'autre desdits groupes.
12. Appareil suivant une quelconque des revendications précédentes, dans lequel ladite feuille supérieure (14) est formée de manière sensiblement identique à ladite feuille inférieure (14) de matière piézoélectrique, avec des canaux (12) correspondant auxdits canaux (12) de ladite feuille inférieure et avec des électrodes sur des parois latérales des canaux de la feuille supérieure qui correspondent aux parois latérales de la dite feuille inférieure qui portent des électrodes, la dite feuille supérieure (14) étant inversée par rapport à ladite feuille inférieure (14) et fixée à celle-ci de sorte que chaque paire de dits canaux correspondants des feuilles définisse un canal composite unique (12) s'étendant dans chacune des dites feuilles, lesdites buses (40) étant prévues dans une plaque à buses (38) fixée auxdites feuilles de manière à présenter des buses respectives à une extrémité desdits canaux composites.
13. Appareil suivant la revendication 12, dans lequel lesdites feuilles supérieure et inférieure sont de forme identique.
14. Appareil suivant la revendication 12 ou la revendication 13, dans lequel lesdites feuilles supérieure et inférieure sont liées à des couches de raidissement respectives (50) en matière isolante.
15. Appareil suivant une quelconque des revendications 1 à 11, dans lequel ladite feuille inférieure comprend une feuille intégrale de matière piézoélectrique (14) ayant des régions polarisées en opposition respectivement dans des parties supérieures et inférieures des parois latérales (16) de chaque canal et lesdites électrodes (34) s'étendent sur des faces opposées de chacune d'au moins certaines desdites parois latérales des canaux à partir du sommet (22) desdites parois latérales, chaque dite électrode couvrant ladite région dans la partie supérieure et une portion substantielle de ladite région dans la partie inférieure de la paroi latérale de canal correspondante.
16. Appareil suivant une quelconque des revendications 1 à 11 et 15, dans lequel ladite feuille inférieure (14) est liée à une couche de raidissement (50) en matière isolante.
17. Appareil suivant une quelconque des revendications 1 à 11 et 15 et 16, dans lequel ladite feuille supérieure (20) comporte des canaux (12) en correspondance desdits canaux (12) de ladite feuille inférieure et ladite feuille supérieure (20) est liée à ladite feuille inférieure (14) de sorte que chaque paire de canaux correspondants des feuilles définisse un canal composite unique.
18. Méthode de fabrication d'un appareil de dépôt de gouttelettes par impulsions comportant un ensemble de canaux multiples de haute densité, par formation d'une feuille inférieure (14) avec une couche de matière piézoélectrique polarisée perpendiculairement à ladite couche, formation d'une multiplicité de canaux de liquide de gouttelettes, parallèles et ouverts à la partie supérieure (12) dans ladite feuille inférieure, ces canaux s'étendant partiellement à travers ladite couche de matière piézoélectrique pour présenter des parois (16) de matière piézoélectrique entre canaux successifs, formation d'électrodes (34) sur les faces opposées respectives d'au moins certaines desdites parois de sorte qu'un champ électrique puisse être appliqué pour engendrer un déplacement en mode de cisaillement desdites parois pourvues d'électrodes, dans une direction transversale auxdits canaux, connexion de circuits d'excitation électriques aux dites électrodes, fixation d'une feuille supérieure (20) aux dites parois pour fermer lesdits canaux, et création de buses (40) et de moyens (46,48) d'amenée de liquide de gouttelettes auxdits canaux, lesdites électrodes étant formées sur une longueur substantielle desdites parois, caractérisée en ce que chaque électrode (34) s'étend sur une région espacée de la surface inférieure (18) du canal (12) dans lequel l'électrode est disposée de sorte que, lorsqu'une différence de potentiel est appliquée entre les électrodes (34) sur les faces opposées d'une paroi (16), le champ électrique résultant est confiné sensiblement à cette paroi (16) et laisse sensiblement exempte de distorsion piézoélectrique la région de la feuille inférieure (14) qui est au-dessous de la surface inférieure (18) de chacun des canaux (12) adjacents à la paroi (16).
19. Méthode suivant la revendication 18, comprenant l'étape de formation desdites électrodes par dépôt de métal au moyen de faisceaux de vapeur de métal dirigés vers lesdites parois suivant un angle par rapport à leurs surfaces en regard des canaux.