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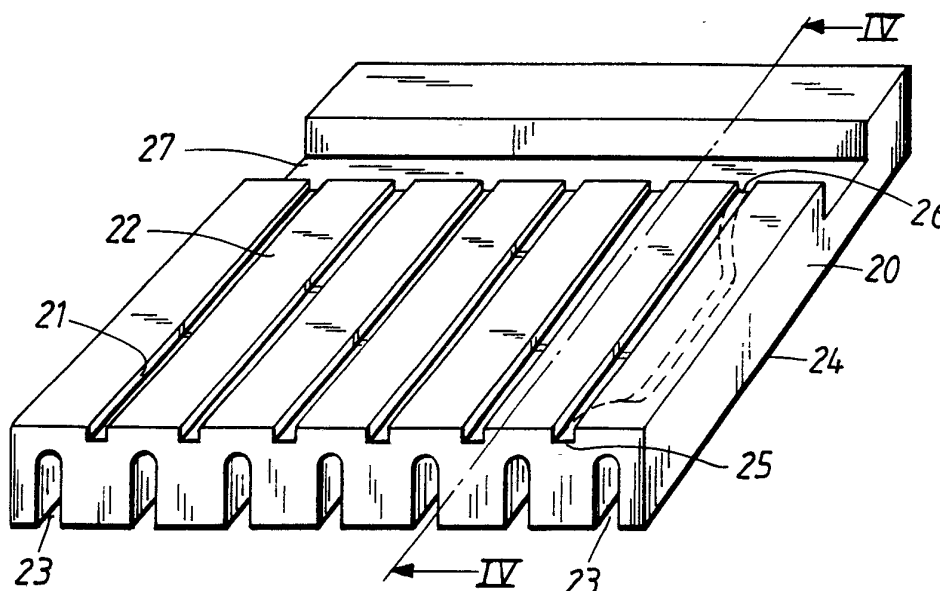
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(54) Title: DROP-ON-DEMAND LIQUID EJECTOR ARRANGEMENT



(57) Abstract

A droplet ejector arrangement, particularly for an ink-jet printer, is formed in at least one piezoelectric, preferably piezoceramic, wafer (20). Grooves formed in one side of the wafer act as ejector channels (21), with each ejector channel having a nozzle (25). The characteristics of the droplet ejector, i.e. the result of the effect of the ejector channels (21) on the liquid in terms of size, velocity and rate of emerging droplets, can be imparted to the channels during manufacture by selecting the appropriate length, depth and width of the channel (21), together with the length, depth and width of the nozzle (25). Flow characteristics of the liquid through each channel are optimized by providing regions with varying cross-sectional area in the channels (21).

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TITLE: DROP-ON-DEMAND LIQUID EJECTOR ARRANGEMENT

TECHNICAL FIELD:

The present invention relates to a drop-on-demand liquid ejector arrangement according to the preamble of claim 1 and to a method of manufacturing such an ejector arrangement according to the preamble of claim 16.

BACKGROUND:

The invention is particularly suited for use in ink-jet printing devices. In such devices, a plurality of droplet ejectors are arranged in a print head so that strings of text or other patterns can be deposited on a recording medium passing in front of the ejectors. Such droplet ejectors have a nozzle which communicates with a fluid chamber fed from a reservoir. A piezoelectric transducer acts on said chamber to rapidly vary the pressure therein and, as a consequence, the volume thereof in response to signals in the form of electrical pulses, whereby fluid droplets, whose velocity and volume depend on the electrical energy of the applied pulses, are ejected from the nozzle. In order that a recording can be made in as few passages as possible, it is desirable that the text be formed simultaneously in columns. Thus, the outlets of the droplet ejectors are arranged in a straight line perpendicular to the recording direction, as described in US-A-3 946 398 to Kyser et al.

Clearly, if high resolution for the recorded medium is required, then the nozzles of the droplet ejectors accordingly have to be spaced closer together and it is the size of the transducer and its arrangement which limits the possibilities to closely arrange the nozzles in a straight line perpendicular to the recording direction.

For applications where acceptable text can be formed using, say, eight to ten droplet ejectors, the fluid chamber and associated piezoelectric transducer of each droplet ejector can

be connected to its nozzle by a conduit, with the conduits of all the ejectors fanning towards their respective nozzles arranged in a straight line. A radial array of such an assembly is described in US-A-3 747 120 to Stemme whilst a substantially longitudinal array is described in US-A-4 158 847 to Heinzl et al. Arrays of this type suffer from the disadvantage that the ejectors require long conduits which affect the control of the droplets. Furthermore, the conduits are of differing lengths which impart non-uniform characteristics to the droplets.

In order to achieve higher resolution for the recorded medium without needing to reduce the spacing between droplet ejectors, a linear array is disclosed in US-A-4 459 601 to Hawkins in which the nozzles lie along a line which slopes with respect to the recording direction. Thus, in order to achieve a vertical line on the recording medium, the droplets are ejected with an increasing time delay along the array. Such an arrangement has the advantage that it can easily be expanded by adding more ejectors to the array. However, the need to calculate the required time delay before firing is an expensive complication.

Clearly, in order to achieve a high definition linear array with as low an angle of slope with respect to the print columns on the recording medium as possible, the droplet ejectors must be as narrow as possible. Up until now, one of the most compact arrangements has been disclosed in US-A-4 367 478 to Larsson. A pulse drop ejector is described therein having a substantially linear edge of a substantially rectangular transducer arranged abaxially along a channel which is caused to compress ink in the channel to eject a drop. Since this device utilizes a linear edge of a transducer abaxially along a channel, more transducers and nozzles can be placed in a smaller area than with previous designs. The major disadvantage with this design is, however, the complicated assembly of a large number of components.

More recently, as described in US-A-4 842 493 to Nilsson, a multi-channel droplet ejector, or piezoelectric pump, has been proposed in which a piezo wafer has grooves or channels sawn in

from the upper side and the under side. The grooves, which extend through the entire length of the wafer, lie offset relative to one another and their depths partially overlap. The piezo wafer is metallized over its entire surface, though the metal layer in the channels on one side of the wafer is removed. The discrete layers of metal on this side form individual electrodes for each channel, whilst the layer of metal on the other side serves as a common electrode for all the channels. The region of piezoelectric material between each individual electrode and the common electrode serves as a transducer for each pump channel. Such a pump allows 4-5 channels per millimetre to be formed in the wafer. Due to the extremely small structures, by blocking off a region of a opening to each pump channel, the remaining open area can itself serve as a nozzle.

PROBLEM AND SOLUTION:

Whilst the above-described piezoelectric pump offers considerable advantages over previous droplet ejector assemblies, a need still exists for a more versatile system in which the characteristics of the droplet ejector can be easily altered by selecting optimal shape parameters of transducer, nozzle and other channels so as to achieve the desired size, velocity and rate of droplets for each application and each type of liquid that is to be used, and also to provide a droplet ejector which fills easily without trapping air bubbles and which operates over a large range of driving pulses without entrapment of air during meniscus retractions.

Thus, it is an object of the present invention to provide a droplet ejector arrangement which needs fewer components, which is easier to manufacture and whose characteristics can be readily provided for during its manufacture.

This object is achieved by a droplet ejector arrangement according to claim 1 and which can be made according to the method of manufacture of claim 16.

Further advantageous embodiments of the invention are given in the respective dependent claims.

Other advantages and problems which the present invention addresses will become apparent in the following description of preferred embodiments of the invention, by way of example only, with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS:

- Fig. 1 is a schematic, perspective view of a prior art multi-channel droplet ejector;
- Fig. 2 is a section through a channel of the prior art droplet ejector along line II-II of Fig. 1;
- Fig. 3 is a schematic, perspective view of a multi-channel droplet ejector according to the present invention;
- Fig. 4 is a section along line IV-IV of Fig. 3;
- Fig. 5 is a view similar to Fig. 4, though with a cover plate in place;
- Fig. 6 is a partial view in the direction of arrow A in Fig. 5;
- Fig. 7 is a section along a channel of another embodiment of the invention;
- Fig. 8 is a section along a channel of a further embodiment of the invention;
- Fig. 9 is a section along a channel of a modification of the embodiment of Fig. 8;
- Fig. 10 is a section along a channel of a modification of the embodiment of Fig. 9;

Fig. 11 is a section along a channel of a further embodiment of the invention;

Fig. 12 is a schematic, perspective view of another embodiment according to the invention;

Fig. 13 is a front elevation in the direction of the nozzle openings of an additional embodiment of the present invention, and

Figs. 14, 15 and 16 are sections along coaxially arranged channels according to three further embodiments of the invention.

BEST MODE OF CARRYING OUT THE INVENTION:

With reference to Figures 1 and 2, a multi-channel droplet ejector of the type disclosed in US-A-4 842 493 is shown, which comprises a piezoceramic wafer 10 into which grooves 11, 12 have been sawn from the upper side and lower side. The grooves 11 serve as pump channels when an electrical pulse is applied to electrodes formed on the upper and lower surfaces of the wafer. To provide a nozzle 13 in each channel 11, a part of the piezoceramic is ground off in the region of the front openings of the channels and a cover plate 14 comprising a projection 15 is placed on the wafer so that the channels' openings are partially blocked, thereby forming the nozzles. The cover plate 14 is also provided with a channel 16 which extends transversely relative to the pump channels and via which all channels can be connected to a fluid reservoir. The channels may also be blocked off at the rear openings by inserts.

Whilst the above-described pump can be made to function reasonably well, high precision is required for obtaining an accurate fit and good sealing of the projection 15 with the ground-off region, as well as for the individual blocking inserts. Furthermore, the cover plate 14 needs to be machined to form the fluid supply channel 16. Since this channel 16 feeds the pump channels 11 transversely with no restrictor means across the openings into the pump channels, it will serve

as a passage for undesired coupling between pump channels. Also there is no means for restricting flow backwards during pump action.

An embodiment of a droplet ejector arrangement according to the present invention is shown in Fig. 3. Reference numeral 20 denotes a piezoceramic wafer with ejector channels 21 on one side 22 and corresponding separation grooves 23 on the other side 24. For reasons of clarity, a cover plate has not been shown. Whilst the term "piezoceramic" has been used herein, it is to be understood that any material possessing piezoelectric properties may be used.

As can more clearly be seen from Fig. 4, the ejector channels 21 do not extend throughout the entire length of the ceramic wafer 20. Instead, the channels 21 are formed by, for example, a circular diamond saw blade SB whose centre follows the locus of points indicated by the letters LP in Fig. 4. The channels, as well as the separation grooves, may of course be formed by other means, such as milling, moulding, pressing, grinding or cutting in any way.

Thus, the nozzle 25 is a part of the ejector channel 21 and may be formed by removing a slight amount of piezoceramic material. The length of the nozzle section is determined in this instance by the length of pass of the circular saw along the wafer 20 at that depth. The pumping region of the channel is formed by lowering the saw blade deeper into the material. In this respect, it is often advantageous to form a flat region along the base of the channel. As with the nozzle 25, a restrictor 26 can also be formed as a part of the channel in the wafer by raising the saw to a suitable height then progressing horizontally through the wafer. The restrictor 26 connects the remainder of the channel 21 with a transverse, fluid supply conduit 27 which serves as a manifold and to which fluid from a not-shown reservoir is fed. The width of the nozzle, and of course the restrictor, can be varied with respect to the pumping region of the channel by, in this case, using a narrower saw blade.

The separation grooves 23 adjacent to the ejector channels 21 are shown in Fig. 3 as extending from the front surface of the wafer 20. Naturally, to prevent these grooves 23 breaking through into the fluid supply conduit 27, the grooves 23 terminate a little way before the said conduit 27. By allowing the grooves 23 to pass through the front surface of the wafer 20, a gas, preferably air, may be arranged to flow along and out of these thus formed channels. The gas can be used to help form and control the droplets emerging from the nozzles 25 of the ejector channels 21. Such an arrangement is commonly referred to as "air-assistance".

If air assistance is not required, then the grooves 23 may have a similar trough-like form to the ejector channels 21.

The advantages of the arrangement according to Figures 3 and 4 are many. Firstly, the transducer and essentially all (or most) of the fluidic channels are located in a single piece of piezoelectric ceramics. Secondly, the layout is such that transducer and groove parameters can be selected more or less independently to optimize the characteristics of the ejector. Furthermore, the cross section along the ejector channel from the fluid supply conduit up to the nozzle can be varied in such a way as to achieve a streamlined flow-through design in order to avoid air entrapment. A restriction inbetween the fluid supply conduit and the ejector channel can be arranged not only to optimize the ejector characteristics, but also to prevent fluidic coupling to other ejectors in the same ceramic piece.

As is shown in Figs. 5 and 6, the channels can be covered by a thin planar sheet of ceramics, glass, metal or similar which requires no projections thereon or recesses therein. This embodiment closely corresponds to that shown in Figs. 3 and 4, and so the same figure reference numerals have been used where possible, though with the suffix " ' ". Apart from having a cover plate 28' in situ, the main difference between the two embodiments is that the side walls of the ejector channels 21' and the separation grooves 23' are oblique. Thus, the width of each channel and groove is greatest at its respective planar

surface 22', 24'. As is clearly visible in Fig. 6, the nozzle 25' may be narrower than the width of the ejector channel 21' at the region where the nozzle opens into said channel.

The position of the nozzle can be varied with respect to the ejector channel by forming the nozzle in a part distinct from the wafer, as shown in Figures 7 to 10.

With reference to Fig. 7, a plurality of ejector channels 31 are formed in a wafer 30. The ejector channels 31 extend up to, and partially through, the front surface of the wafer. Adjacent to this surface is positioned an end-plate 32 with at least one nozzle 33 cooperating with each ejector channel 31. With such an arrangement, the location of the nozzle 33 with respect to the ejector channel, as well as its shape and size, can be varied.

In Fig. 8, a wafer 40 is shown with a cover plate 42 lying over ejector channels 41 and the fluid supply conduit 45. The ejector channels 41 are formed so that no break-through occurs in the front surface of the wafer. To allow liquid to be ejected from the ejector channels 41, a cavity 43 is provided above each channel in a cover plate 42. A nozzle 44 leads from the cavity to the surroundings.

Although in Fig. 8 the nozzle 44 is shown exiting in the same longitudinal direction as the ejector channel 41, it is of course feasible that the nozzle exits in a direction more or less perpendicular to that shown, i.e. through the upper surface of the cover plate 42. Such an arrangement is shown in Fig. 9. In this instance, no cavity is required and the nozzle 44 can extend through the entire thickness of the cover plate 42. It should be noted that the angle of exit of the nozzle 44 need not necessarily be a right-angle, but may be inclined as required.

A modification of the embodiment according to Fig. 9 is shown in Fig. 10. In this embodiment, two fluid supply conduits 45' for each ejector channel are formed in the piezo wafer 40', one

at either end of the channel 41'. In this case, the nozzle 44', or nozzles, of each ejector channel may be arranged in the cover plate 42' at any location along the longitudinal axis of the channel.

A further embodiment is shown in Fig. 11. Here, the assembly has been shown inverted with respect to the previous figures. This is to emphasize that the orientation of the assembly is not important for the present invention. A wafer 50 is provided with a plurality of ejector channels 51. A cover plate 52 is positioned adjacent the wafer 50 as shown, with a nozzle 53 for each ejector channel being provided in the wafer in a manner similar to that shown in Fig. 4. The position of a restrictor can be varied with respect to the ejector channels, especially when it is made up of a plurality of micro-channels, by forming the restrictor in a part distinct from the wafer. Thus, in this instance, a through-bore 54, which serves as a fluid supply conduit, is provided in the cover plate 52, and the restrictor is in the form of a microfilter 55, schematically shown in Fig. 11 covering the through-bore 54. Microfilters can of course be used with any of the embodiments described herein.

In Fig. 12, a droplet ejector arrangement is shown in which a pair of ejector channels 61 on one side 62 of the piezo wafer 60 are non-parallel and meet in the vicinity of their nozzles 65 to form a common nozzle in the front face of the wafer. Of course, more than one pair of ejector channels may be provided and it is feasible to have more than two ejector channels which converge together. Separation grooves 63 are provided on the other side 64 of the wafer. Although not shown in the drawing, at least one separation groove 63 also lies between the ejector channels 61. Whilst the nozzles 65 of the channels 61 are shown as meeting within the wafer 60, it is also to be understood that each nozzle may penetrate the front face of the wafer 60 such that the droplets emerging from said nozzles 65 meet at a point remote from said wafer.

For some applications, a greater ejector channel density than that attainable with the droplet ejectors described above is

desirable. Thus, according to a further embodiment of the present invention, greater channel density is obtained by providing a piezoceramic wafer of the type shown for example in Fig. 4 on either side of a separation plate, as shown in Fig. 13. The channel density is thus hereby effectively doubled. Another possibility is to operate the separation grooves as additional ejector channels. In Fig. 13, the wafers 20 are positioned on the separation plate 28 such that the nozzles 25 in one wafer are offset from the nozzles in the other wafer. The separation distance S between the sets of nozzles is governed by the thickness of the separation plate 28. To reduce this distance, the separation plate 28 may be provided with a cavity and a nozzle for each ejector channel 21, similar to that shown in Fig. 8, but with cavities opening into the ejector channels in both wafers.

Ultimately, the separation plate 28 can be totally excluded, with the wafers 20 being directly affixed to each other. As well as the nozzles then being substantially linearly arranged, a further advantage is obtained, that being that a common liquid supply conduit may be used.

Another possibility for varying the arrangement of nozzles with respect to each other is to provide at least two longitudinally coaxially arranged ejector channels in the one face of a piezo wafer. Such a possibility is shown in Figs. 14, 15, and 16.

In Fig. 14, the two longitudinally coaxially arranged ejector channels 71 are formed in a piezo wafer 70 and are in communication with one another. Fluid is supplied to the ejector channels 71 via three fluid supply conduits 75 extending transversely to the longitudinal axis of the channels 71. One of said supply conduits is arranged between the two ejector channels and serves as a common fluid supply conduit, whilst the remaining two supply conduits are in communication with the opposite end of each respective ejector channel 71. During operation, droplets are ejected via nozzles 74 provided at desired locations in a cover plate 72 which delimits the longitudinal opening of each ejector channel.

In Figs. 15 and 16, the ejector channels 71' are discrete, i.e. no common fluid supply conduit is provided. Instead, there is one fluid supply conduit 75' for each ejector channel 71'. In Fig. 15, the said supply conduits 75' feed the left-hand end of the ejector channels 71', as drawn, whilst in Fig. 16 the ends of the channels 71' lying furthest away from each other are fed. As in Fig. 14, nozzles 74' for the ejector channels 71' are provided in a cover plate 72'. The arrangements according to Figs. 15 and 16 have the advantage that a different fluid can be provided in each supply conduit 75', thereby permitting for example a multicoloured image to be generated.

In order to manufacture the droplet ejector arrangement according to the present invention, a plurality of grooves are formed on both sides of a non-polarized piezoceramic wafer as described above in connection with Figures 3 and 4. Such a wafer may typically be made from standard piezoceramic material in the approximate form of a cuboid having the dimensions 30 x 20 x 1 mm. If a circular saw blade is utilized to form the grooves, since all the grooves on one side of the wafer are identical, a plurality of such blades may be connected together for simultaneous cutting of the grooves. The cutters are numerically controlled by a microprocessor or similar to which parameters for the desired width, depth and length for each groove, nozzle and restrictor have been inputted. Thus, for different applications, the characteristics of the droplet ejector can be easily altered. Clearly, if the grooves are formed by, say, moulding or pressing, then it is the moulds or presses which are machined in a numerically controlled manner in order to create grooves of the desired shape and size.

Once the ejector channels and separation grooves have been formed, the entire surface of the piezoceramic wafer is coated with a conductive material in order to form electrodes for the ejector channels. If it is desired to have a fluid supply conduit within the wafer, this can be formed either before coating of the wafer or afterwards. The coating should preferably have the following advantages; it should be conductive, chemically resistant to various liquids and

particularly inks, easy to bond to and have good adherence to ceramics.

The wafer can be coated in several ways, though the preferred method in this instance is to use chemical vapour deposition (CVD) of silicon. CVD can provide a chemically resistant, thin layer with a very accurate control of the thickness, and the silicon is receptive to doping to enhance the conductivity. Such a formed coating can also be bonded extremely well to several materials. Coating methods other than CVD which may be used include nickel plating, gold sputtering, plasma vapour deposition, etc.

To form discrete electrodes for each ejector channel, the electrode layer at the floor of the separation grooves and on the front and rear faces of the wafer is removed. Thus, the electrode layer on the surface in which the ejector channels are formed acts as a common electrode for all the ejector channels. As is known per se, discrete electrodes can be formed by masking those areas on which no coating is required.

As is taught in the above-mentioned US-A-4 842 493, after the above manufacturing stages have been carried out, the transducer for each ejector channel formed in the piezoceramic wafer is polarized by applying a voltage between its electrodes.

In conclusion, it can be said that the present invention offers flexibility of design of droplet ejectors which, up until now, has not been available. Since the cross-sectional area of the ejector channels can be varied along its length, the channels can be optimized for each application.

It will be apparent to the skilled man that the droplet ejector according to the present invention may be operated on the so-called fire-before-fill or the fill-before-fire principle.

Naturally, the present invention is not restricted to the above described embodiments, but may be varied within the scope of

the appended claims. By way of example, more than one nozzle can be provided for each ejector channel. Similarly, more than one restrictor passage can also be provided for each channel. Furthermore, the planar faces of the wafer need not be parallel as shown in the drawings, but can also slope so as to form a wedge-shaped wafer.

Claims

1. A droplet ejector arrangement comprising at least one piezoelectric, preferably piezoceramic, wafer (20,30,40,50,60,70) having planar, opposite first and second faces (22,22',62;24,24',64) with at least one longitudinally extending groove (21,21',23,23',31,41,41',51,61,63,71,71') extending inwardly therein, such that the groove or grooves of the first face lie offset relative to the groove or grooves of the second face, with said grooves partially overlapping in the direction of their depth, whereby each groove (21,21',31,41,41',51,61,71,71') of one of said faces (22,22',62) forms an ejector channel having a nozzle (25,25',33,44,44',53,65,74,74') at one end, characterized in that the cross-sectional area of regions of said ejector channel (21,21',31,41,41',51,61,71,71') varies along the length of the channel up to said nozzle (25,25',33,44,44',53,65,74,74').
2. A droplet ejector arrangement according to claim 1, characterized in that the cross-sectional area of said ejector channel (21,21',31,41,41',51,61,71,71') is varied by providing regions of differing depth in said channel, measured from the planar face (22,22',62) in which said channel extends.
3. A droplet ejector arrangement according to claim 1 or 2, characterized in that at the end of each ejector channel (21,21',31,41,41',61,71,71') remote from the nozzle (25,25',33,44,44',65,74,74'), a restrictor (26) is provided in said wafer for communication with a supply of liquid for the ejector.
4. A droplet ejector arrangement according to claim 3, characterized in that said liquid is supplied to said restrictor (26) via a fluid supply conduit

(27,45,45',75,75') which extends inwardly from the same face (22,22',62) as the ejector channel or channels (21,31,41,41',61,71,71').

5. A droplet ejector arrangement according to any of claims 2-4, characterized in that the nozzle (25,25',53,65) for each ejector channel is an extension of said ejector channel and is integrally formed in said wafer (20,50,60) to a depth which is less than the maximum depth of said channel (21,21',51,61).
6. A droplet ejector arrangement according to any of claims 2-4, characterized in that each nozzle (33) is formed in an end-plate (32) which delimits the end of each channel remote from said restrictor.
7. A droplet ejector arrangement according to any of claims 2-4, characterized in that each nozzle (44,44') is formed in a cover plate (42,42') which delimits the longitudinal opening of each ejector channel (41,41').
8. A droplet ejector arrangement according to claim 2, characterized in that liquid is supplied to said ejector channel (51) via at least one bore (54) in a cover plate (52).
9. A droplet ejector arrangement according to claim 1 and 7, characterized in that the nozzle (44') in the cover plate (42') is positioned part way along the length of the ejector channel, and liquid is supplied to said ejector channel (41') via two liquid supply conduits (45'), with one conduit at either end of said channel (41').
10. A droplet ejector arrangement according to claim 7, characterized in that at least two ejector channels (71;71') are longitudinally coaxially arranged in said first face.

11. A droplet ejector arrangement according to any of claims 1 to 7, characterized in that two piezoelectric wafers (20) are arranged such that the faces of said wafers having the ejector channels (21) therein lie one above the other and face each other, with the ejector channels (21) of one wafer being offset relative to the respective ejector channels (21) of the other wafer.
12. A droplet ejector arrangement according to claim 11, characterized in that a separation plate (28) is provided between the two wafers (20).
13. A droplet ejector arrangement according to claim 12, characterized in that the nozzles (25) for the ejector channels (21) are provided in the separation plate (28).
14. A droplet ejector arrangement according to any of the preceding claims, characterized in that a plurality of ejector channels (61) are formed in said first face (62), and at least pairs of said channels are non-parallel and converge towards the nozzle ends of each other.
15. A droplet ejector arrangement according to any of the preceding claims, characterized in that said ejector channel (21, 21', 31, 41, 41', 51, 61, 71, 71') is provided with a flat region along its base.
16. A method of manufacturing a droplet ejector arrangement comprising
1. forming at least one longitudinally extending groove which is intended to serve as an ejector channel for a liquid in a first planar face of a piezoelectric, preferably piezoceramic, wafer, regions of which wafer serve as a transducer for the ejector channel, and, if a plurality of grooves are formed in the first face, forming grooves in a second planar face of said wafer opposite said first face such that said latter grooves lie offset relative to the ejector channels in said

first face and partially overlap therewith in the direction of their depth, said ejector channel or channels being provided with a nozzle or nozzles at one end thereof;

2. coating the entire surface of said wafer with a conductive material to form a conductive layer;
3. removing regions of the conductive layer at the base of the groove or grooves formed in the other face of the wafer, and on the front and rear faces of said wafer;
4. polarizing each transducer by applying a voltage pulse between its electrodes ,

c h a r a c t e r i z e d by forming said grooves in said wafer by using means responsive to commands from a microprocessor or similar having predetermined parameters of length, depth and width for all the grooves inputted therein to create regions of varying cross-sectional area along the length of the ejector channel or channels up to said nozzle or nozzles.

17. A method of manufacturing a droplet ejector arrangement according to claim 16, c h a r a c t e r i z e d in that if a single ejector channel is formed in said first planar face, at least one groove is formed in said second face substantially parallel with, though offset relative to, said ejector channel.

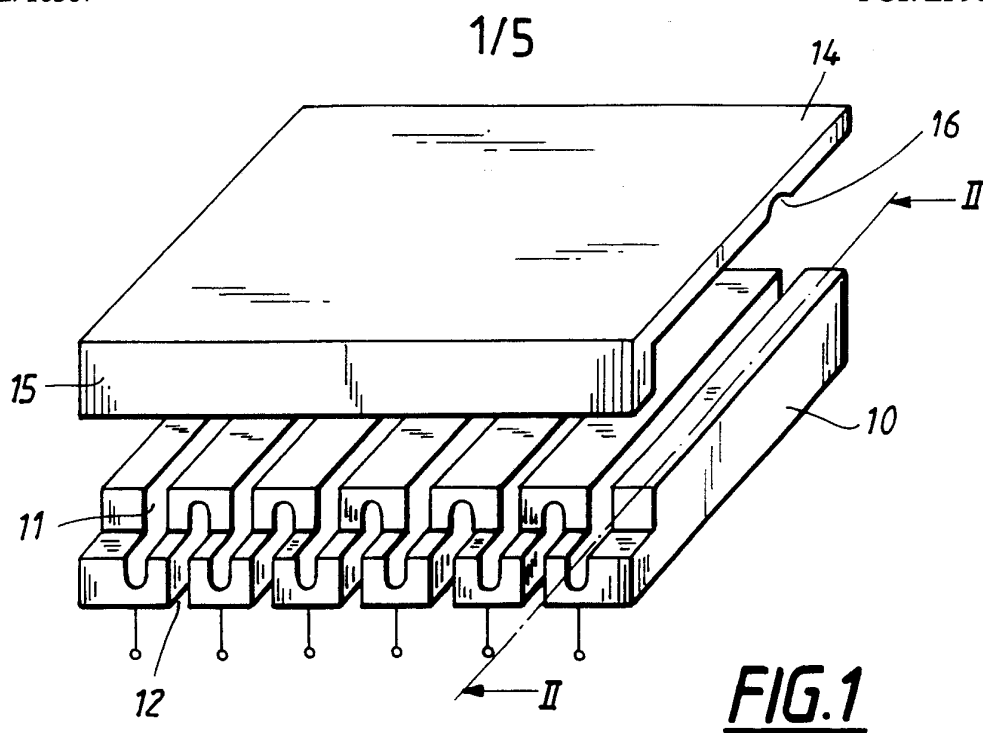
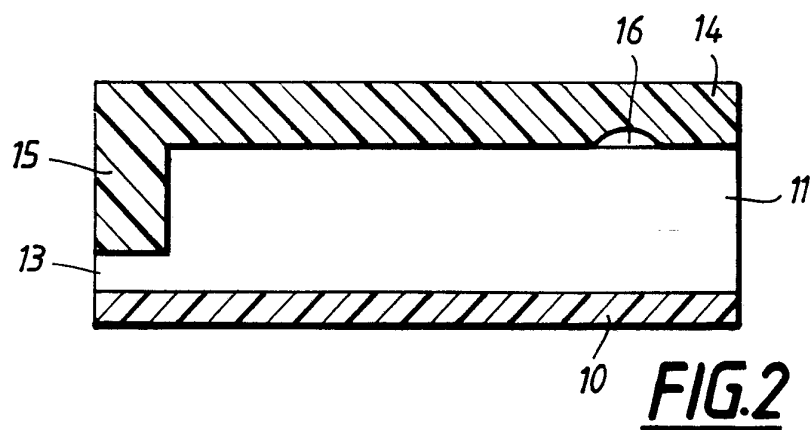
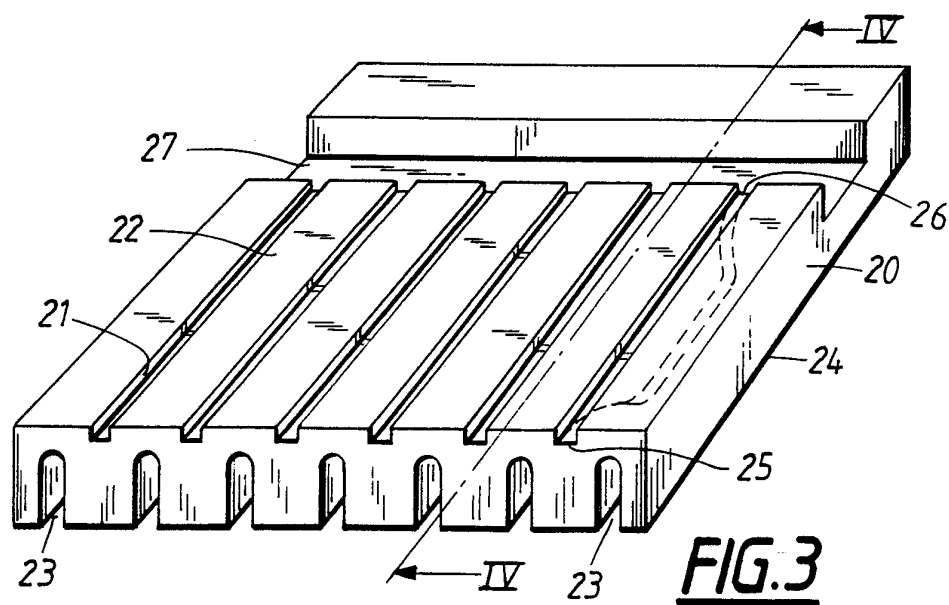
18. A method of manufacturing a droplet ejector arrangement according to claim 16 or 17, c h a r a c t e r i z e d in that in order to vary the cross-sectional area of regions in said ejector channel or channels, the insert depth of that which is used to form the channel or channels is accordingly varied along the length of said channel or channels .

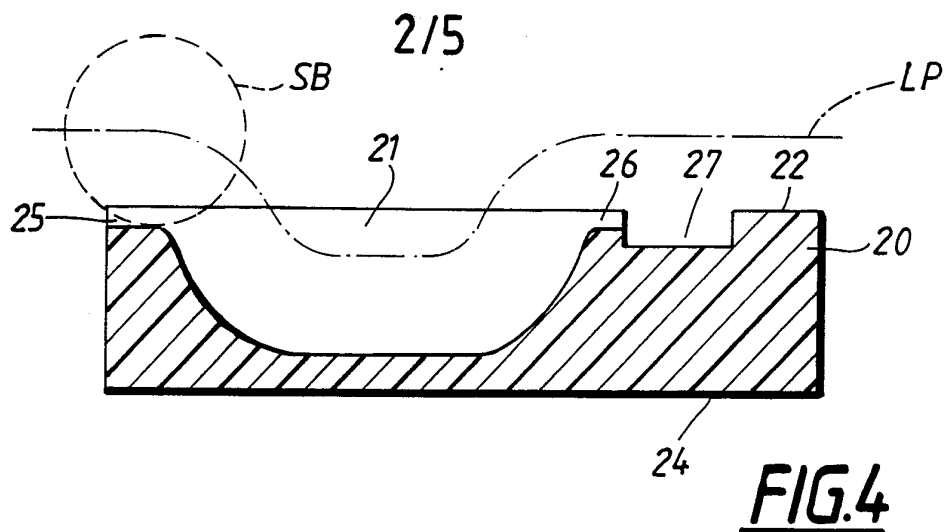
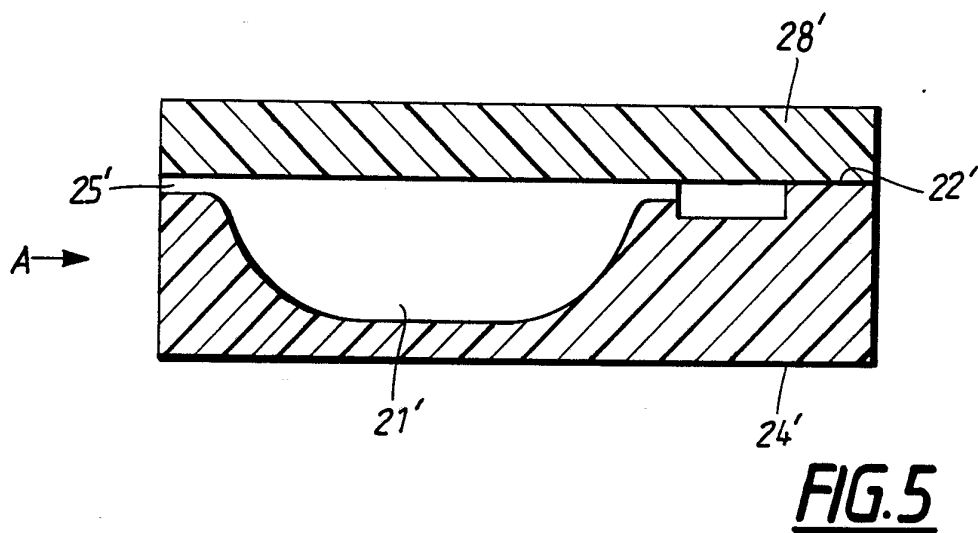
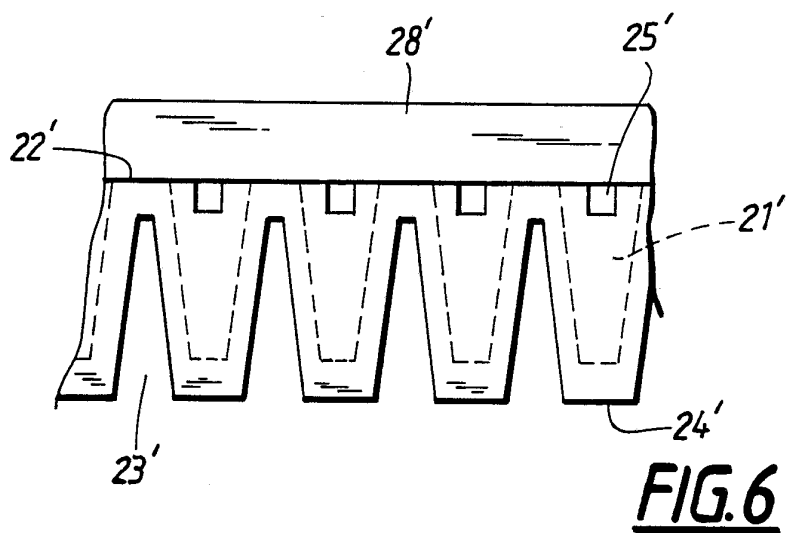
19. A method of manufacturing a droplet ejector arrangement according to any of claims 16 to 18, c h a r a c t e r i z e d by removing or forming piezoelectric material to a depth which is less than the maximum depth of said ejector channel at one end of said channel to provide a nozzle for each ejector channel and/or by removing or forming material to a lesser

depth than the maximum depth of said ejector channel at the other end to provide a restrictor for each ejector channel.

20. A method of manufacturing a droplet ejector arrangement according to claim 16 to 18, c h a r a c t e r i z e d by removing or forming material to a depth which is less than the maximum depth of said ejector channel at both ends of said channel to provide a restrictor at both ends thereof, each restrictor being in communication with a source of liquid, with the nozzle for said channel being provided in a cover plate which delimits the longitudinal opening of said channel.

21. A method of manufacturing a droplet ejector arrangement according to any of claims 16 to 20, c h a r a c t e r i z e d in that coating is achieved by chemical vapour deposition and conductivity in desired regions is obtained by doping.





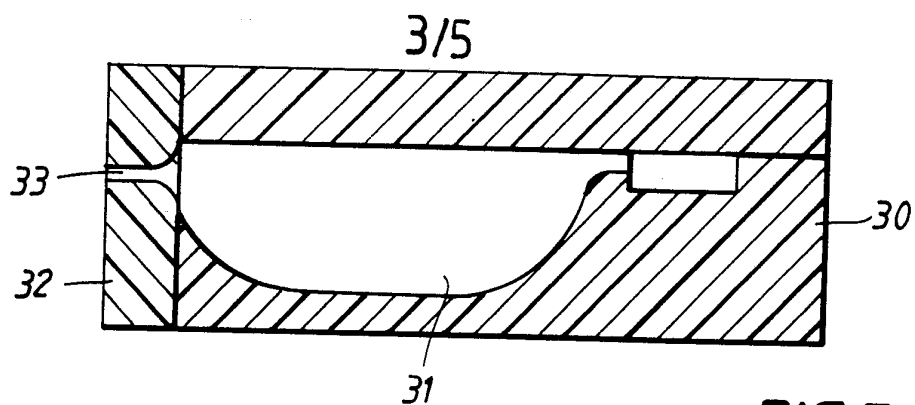


FIG. 7

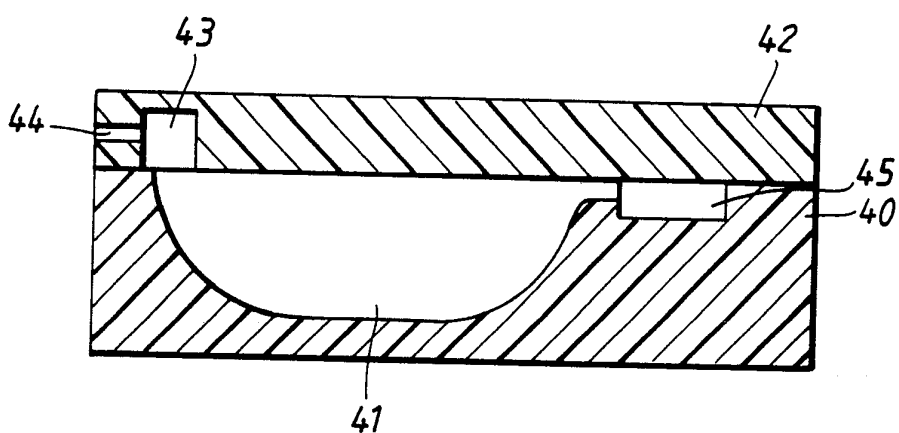


FIG. 8

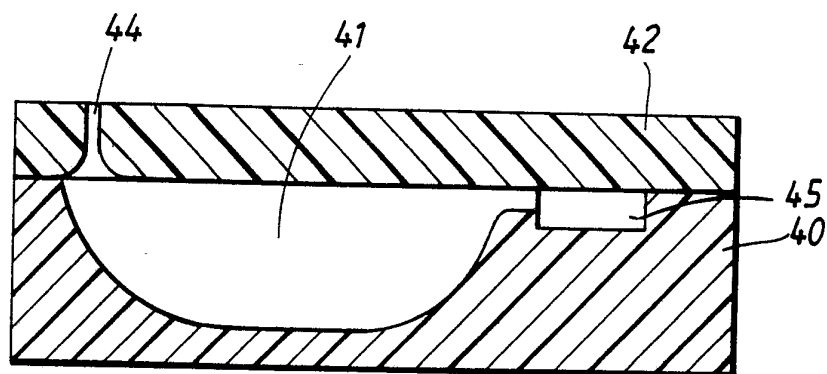


FIG. 9

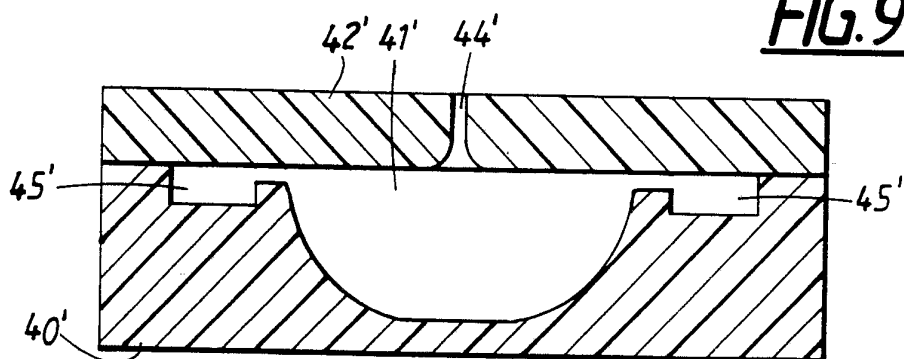


FIG. 10

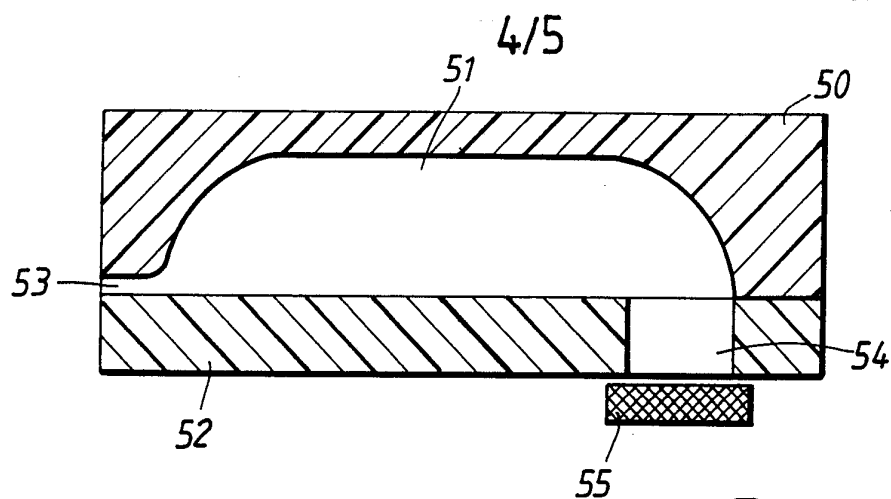


FIG. 11

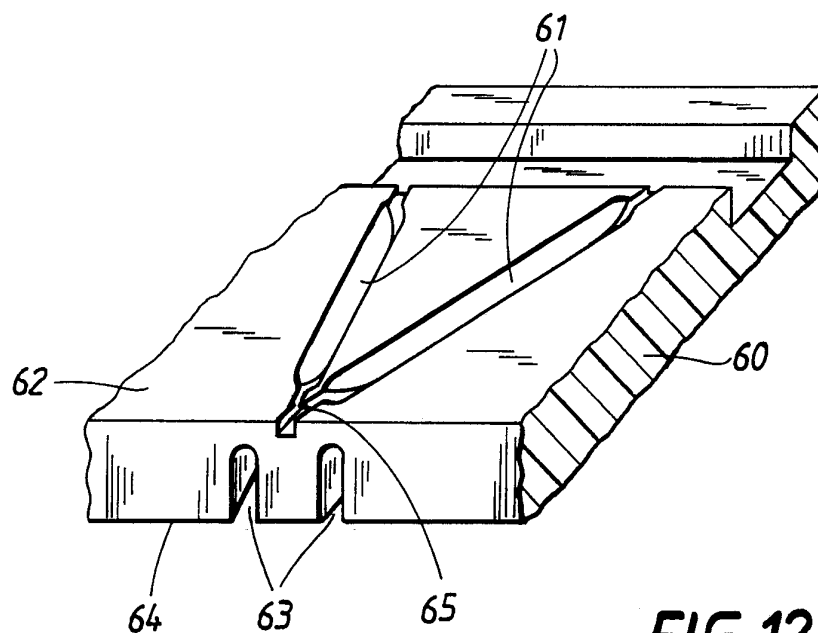


FIG. 12

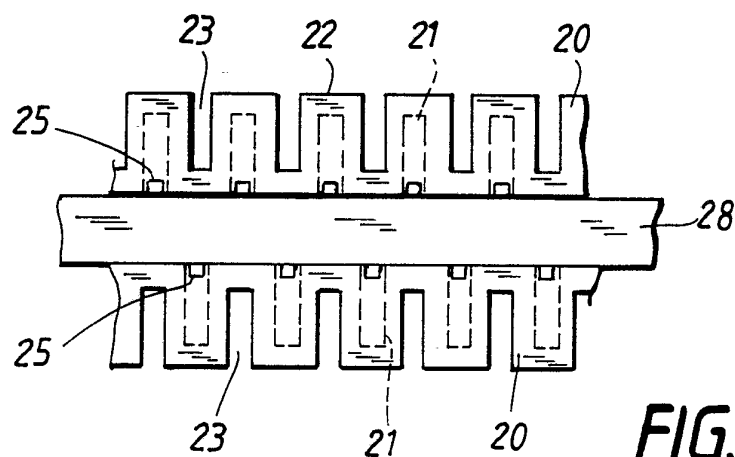


FIG. 13

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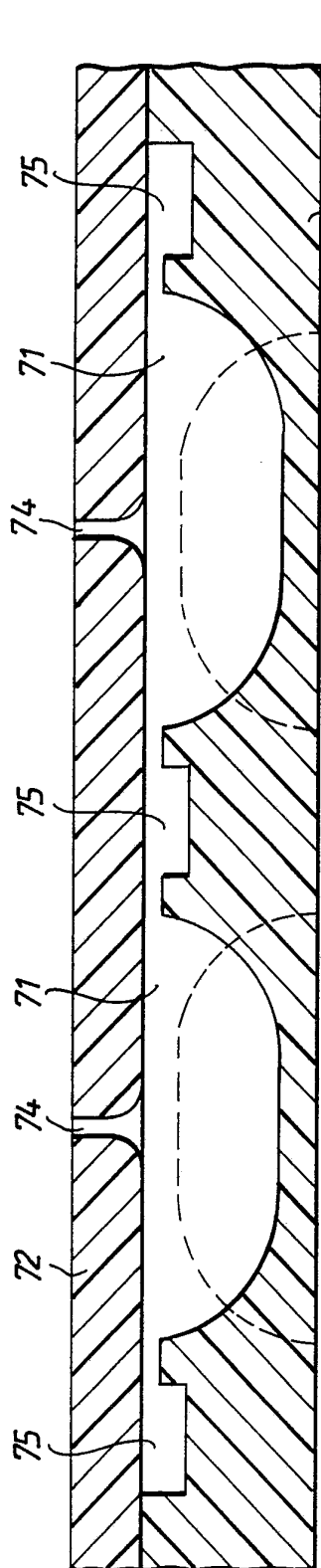


FIG. 14

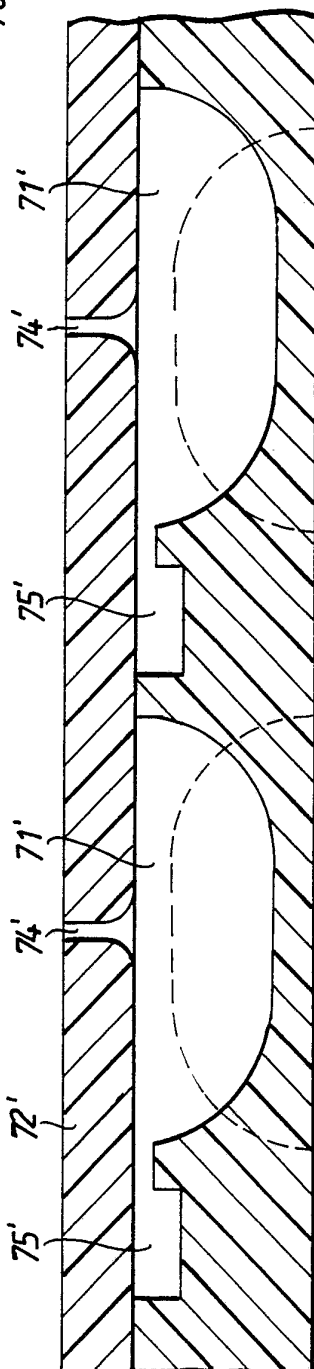


FIG. 15

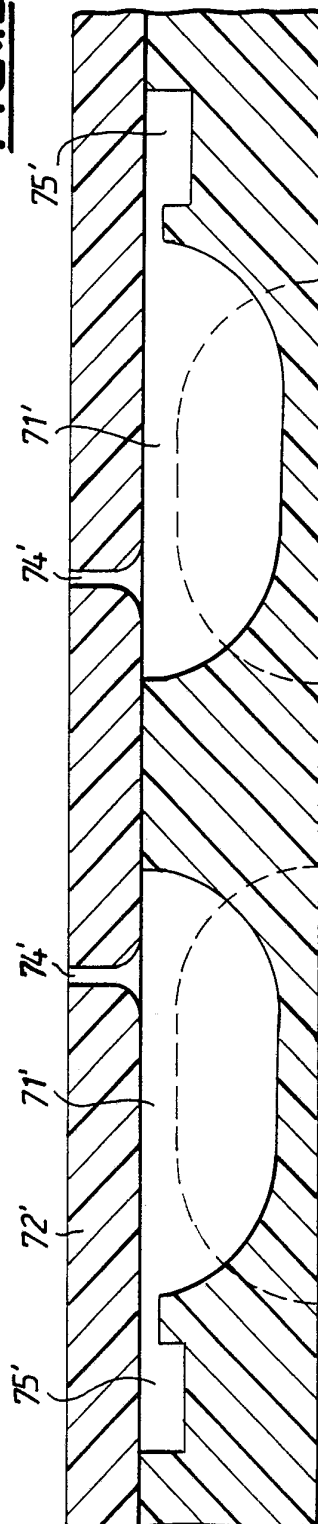
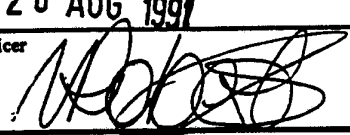


FIG. 16

INTERNATIONAL SEARCH REPORT

PCT/EP 90/02119

International Application No

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 B41J2/16		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.Cl. 5	B41J	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ^o	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	US,A,4819014 (TAKESHI YASUHARA ET AL) 04 April 1989 see abstract; figures 10, 12a-13c, 29 see column 6, lines 25 - 31 see column 12, line 59 - column 13, line 11 ---	1-6, 8, 15-20
A	EP,A,0037624 (SHINSU SEIKI KABUSHIKI KAISHA) 14 October 1981 see abstract; figures 3, 9, 11, 13a see page 9, line 11 - page 10, line 1 ---	1, 2, 4, 5, 8 11-13, 15, 16, 18, 19, 21
A	DE,A,3820082 (FUJI ELECTRIC CO. LTD.) 29 December 1988 see abstract; figures 1-3c see column 3, lines 30 - 68 ---	1-5, 8, 11, 12 15-20
-/--		
^o Special categories of cited documents : ¹⁰ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
07 AUGUST 1991	20 AUG 1991	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	ROBERTS N. 	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	EP,A,0364136 (AM INTERNATIONAL INCORPORATED) 18 April 1990 see abstract; figures 3, 5 see column 2, line 18 - column 3, line 3 see column 6, lines 13 - 52 ---	1-6, 8, 15, 16 18-21
A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 36 (M-664)(2883) 03 February 1988, & JP-A-62 189168 (HIROMICHI FUKUCHI ET AL) 18 August 1987, see the whole document ---	1, 2, 3, 5, 8, 15, 16, 18-20
A	US,A,4842493 (KENTH NILSSON) 27 June 1989 see abstract; figures 5, 8, 9-14 see column 5, line 3 - column 6 (cited in the application) ---	1, 3, 4, 14, 15

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.**

EP 9002119

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

07/08/91

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