(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 921 003 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
09.06.1999 Bulletin 1999/23

(51) Int. Cl.[6]: **B41J 2/155**

(21) Application number: **98204010.7**

(22) Date of filing: **27.11.1998**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **03.12.1997 EP 97203798**

(71) Applicant: **Océ-Technologies B.V.**
5914 CC Venlo (NL)

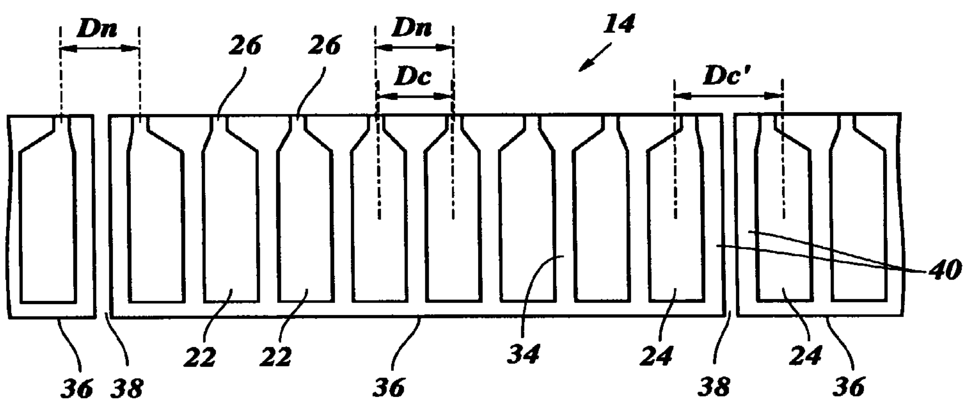
(72) Inventors:
- **Blom, Franciscus Richard**
5731 MK Mierlo (NL)
- **Ellenkamp, Hendrik Willem**
5913 CA Venlo (NL)

(74) Representative:
Hanneman, Henri W., Dr. et al
Océ-Technologies B.V.
Patents & Information
St. Urbanusweg 43
P.O. Box 101
5900 MA Venlo (NL)

(54) **Ink-jet array printhead**

(57) Ink jet array printhead comprising a channel plate (14) composed of a plurality of channel plate elements (36), wherein each channel plate element has formed therein a plurality of parallel channels (22, 24; 50) separated from one another by partition walls (34), each channel has an open end forming a nozzle (26; 52), and the channel plate elements are arranged side by side so that the nozzles form a linear array, characterized in that the width of the channels (22, 24; 50) is smaller than that of the nozzles (26; 52), and the channels of each channel plate element (36) are arranged with a constant effective pitch (Dc) which is smaller than that (Dn) of the nozzles.

Fig. 2



Printed by Xerox (UK) Business Services
2.16.7/3.6

Description

[0001] The invention relates to an ink jet array printhead and methods for manufacturing the same.

[0002] US-A-5 410 340 discloses an ink jet array printhead comprising a channel plate composed of a plurality of channel plate elements, wherein each channel plate element has formed therein a plurality of parallel channels separated from one another by partition walls, each channel has an open end forming a nozzle, and the channel plate elements are arranged side by side so that the nozzles form a linear array.

[0003] This known device is a so-called bubble jet printhead in which a heating element is associated with each of the channels in order to temporarily heat the ink in the channel, thereby to create a bubble in the ink and to generate a pressure sufficient for expelling an ink droplet out of the nozzle. The manufacturing process for this printhead includes the steps of forming heating elements arranged in a row on the surface of a silicon wafer, dicing the wafer into tiles which have the same size as the channel plate elements, and sandwiching the tiles and the channel plate elements so that the positions of the heating elements coincide with those of the channels. In order to provide sufficient space for the dicing cuts and to avoid any damage to the heating elements adjacent to these dicing cuts, at least the first and the last heating element of each tile are slightly displaced inwardly so that they are slightly offset from the center of the corresponding channel.

[0004] EP-A-0 402 172 discloses an array printhead in which the necessary pressure for expelling ink droplets is generated by means of piezoelectric actuators. The actuators are respectively disposed above the ink channels with the interposition of a flexible plate which flexes in accordance with the expansion and retraction strokes of the piezoelectric actuators so that pressure waves are generated in the ink volume in the channels. In this type of printhead the width of the end of the channel forming the nozzle should be reduced so that the width of the channel itself is larger than the width of the nozzle.

[0005] As similar device is disclosed in applicant's copending European Patent Application No. 96 202 043.4 filed on July 18, 1996.

[0006] It is of course desirable that the nozzles of the linear array are arranged with a constant pitch throughout the printhead. When the channel plate has a one-piece construction, this can easily be achieved by forming the channels and the nozzles according to a regular pattern. In order to achieve a high image resolution it is further desirable that the pitch of the nozzles is made as small as possible. As a result, the width of the channels and, in particular, the width of the partition walls separating the same has to be made very small. In a practical example, the width of the partition walls is only in the order of 40 μm. In the production of such minute structures it is inevitable that, occasionally, manufacturing errors occur which make the whole device unusable. When the number of channels is increased the likelihood of such errors is also increased and, accordingly, the production yield becomes lower. For manufacturing a large array printhead, e.g. a printhead extending over the whole width of a page to be printed, it would therefore be desirable to divide the channel plate into a plurality of separate channel plate elements so that, in case of a defect, it is sufficient to replace the defective element rather than discarding the whole channel plate.

[0007] The channel plate elements have to be butted appropriately in order to achieve a continuous nozzle array with constant pitch. This, however, leads to the problem that only a limited space is available for outer walls limiting the channels adjacent to the butted edges of the channel plate elements. The thickness of these outer walls could not be larger than half the thickness of the partition walls separating the individual channels within the channel plate. Since the thickness of the partition walls is comparatively small already, it would be problematic to manufacture outer walls having only half this thickness, and this would again increase the likelihood of defects.

[0008] It is an object of the present invention to provide an ink jet array printhead the channel plate of which is composed of a plurality of channel plate elements and the nozzles of which are nevertheless arranged at a constant pitch also across the boundaries of the channel plate elements, and which can be manufactured with high production yield.

[0009] This object is achieved with the features indicated in claim 1.

[0010] Suitable methods for manufacturing such a printhead are indicated in claims 7 and 8.

[0011] According to the invention, the channels of each channel plate element are arranged with a constant pitch which is smaller than that of the nozzles.

[0012] As a result, the positions of the nozzles relative to the channels vary over the width of the nozzle plate element. In general, there will be a zone in the central part of the nozzle plate element, where the nozzle is disposed near the widthwise center of the associated channel, whereas in other zones of the channel plate element the nozzle will be laterally offset from the center of the channel. This offset increases proportionally with the distance from the zone where the nozzle is centered on the channel. Thus, if the width of the channel plate element were infinite, there would occur "blind channels" which are skipped in the sequence of nozzles and do not overlap with any nozzle. The locations of these "blind channels" are suitable for placing dicing cuts separating the channel plate into individual channel plate elements, thereby providing enough space for making the outer walls of the adjacent channels thicker.

[0013] More specific features of the printhead according to the invention are indicated in the dependent claims.

[0014] In a preferred embodiment the thickness of the outer walls adjacent to the edges of the channel plate elements have the same thickness as the partition walls. This eliminates variations in the droplet generation processes in the various channels which might otherwise be caused by differences in the mechanical strength of the walls limiting the channels.

[0015] If the printhead is of a type employing piezoelectric actuators, these actuators may be arranged with the same constant pitch as the channels. It is preferable that the actuators are integrated into a number of actuator members each comprising a plurality of actuators. The boundaries between the actuator members may then coincide with the boundaries between the channel plate elements.

[0016] The center to center distance between two channels situated on either side of a boundary between two channel plate elements may be twice the pitch of the channels within the channel plate elements. This has the advantage that the actuator members can be dimensioned and arranged regardless of the boundaries between the channel plate elements, because the pitch of the actuators will always fit with the pitch of the channels. The actuators that are located at the boundaries of the channel plate elements and accordingly have no channel associated therewith, will of course not be actuated and may serve as support members for bearing the reaction forces generated by the active actuators.

[0017] One method of manufacturing the printhead according to the invention comprises the steps of forming channels and nozzles in the surface of a wafer such that the pitch of the channels is smaller than that of the nozzles, and cutting the wafer at appropriate positions in order to obtain a plurality of channel plate elements from one and the same wafer.

[0018] When the nozzles are formed in the surface of the wafer, the center to center distance of the two nozzles positioned on either side of the location of a dicing cut may be equal to the pitch of the other nozzles but may also be smaller or larger than this pitch. These differences can be compensated either by leaving an appropriate gap between the adjacent channel plate elements or, when the distance is larger than the regular pitch, by increasing the width of the dicing cut, so that the channel plate elements can then be brought closer together.

[0019] An alternative method of manufacturing a printhead according to the invention comprises the steps of forming channels in the surface of a wafer, dicing the wafer into a plurality of channel plate elements, arranging the channel plate elements side by side to form the complete channel plate, preparing a nozzle plate with orifices defining the nozzles arranged with pitch different from that of the channels and mounting the nozzle plate in front of the channel plate so that each nozzle falls within the cross section of an open end of one of the channels.

[0020] In this case the nozzle plate may be divided into several elements according to the same pattern as the channel plate or according to a different pattern.

[0021] Preferred embodiments of the invention will now be explained in detail in conjunction with the accompanying drawings, in which:

- Fig. 1 is a cross-sectional view of a part of a printhead according to a first embodiment of the invention;
- Fig. 2 is a plan view of a channel plate of the printhead shown in Fig. 1;
- Fig. 3 is a plan view of a wafer from which the channel plate shown in Fig. 2 is made;
- Fig. 4 is a cross-sectional view of essential parts of a printhead according to another embodiment of the invention;
- Fig. 5 is a horizontal cross-section of a printhead according to yet another embodiment of the invention; and
- Fig. 6 is a plan view of a wafer from which the channel plate of the printhead shown in Fig. 5 is made.

[0022] The printhead 10 shown in Fig. 1 has a layered structure and comprises a support plate 12, a channel plate 14, a flexible plate 16, an actuator system 18 and a backing plate 20.

[0023] As can be seen more clearly in Fig. 2, a plurality of parallel channels 22, 24 are formed in the top surface of the channel plate 14 which is preferably made of graphite. The rear ends of the channels 22, 24, as viewed in Fig. 1, are formed as nozzles 26. The open top sides of the channels 22, 24 and the nozzles 26 are covered by the flexible plate 26, e.g. a thin glass plate. The actuator system 18 is formed by a plurality of piezoelectric actuator members 28 which have a comb-like structure and each comprise a number of parallel fingers 30, 32 the lower ends of which are bonded to the flexible plate 16. The top ends of the fingers are connected by a bridge portion of the actuator member, and the backing plate 20 is fixed to the top surfaces of the bridge portions of the various actuator members 28.

[0024] The fingers 30, 32 are aligned in parallel with channels 22, 24. The piezoelectric material of the fingers 30 is polarized so that these fingers serve as piezoelectric actuators. These actuators are arranged in pairs, and the fingers 32 are interposed between the actuators 30 of each pair and serve as support members for bearing the reaction forces of the actuators.

[0025] As is shown in Fig. 1, each of the actuators 30 is disposed above one of the channels 22, 24, whereas the support members 32 are disposed directly above partition walls 34 separating the individual channels.

[0026] The printhead 10 further comprises an ink supply system for supplying liquid ink to each of the channels 22, 24 as well as electrodes and electronic control means for energizing the actuators 30 individually. These components are generally known in the art and are therefore not shown and described here. When, in operation, one of the actuators 30 is energized, it first performs a retraction stroke so that the portion of the flexible plate 16 connected to this actuator is flexed upwardly and additional ink is sucked into the associated channel. Then, the actuator performs an expansion stroke so that the flexible plate 16 is flexed downwardly into the channel, and the liquid in this channel is pressurized so that an ink droplet is expelled from the nozzle 26.

[0027] The channel plate 14 is composed of a plurality of separate channel plate elements 36 only one of which is shown in its entirety in Fig. 1. The channel plate elements 36 are arranged side by side, and the boundaries between these elements are designated by reference numerals 38.

[0028] As is shown in Fig. 2, the nozzles 26 are arranged at a constant pitch Dn throughout the printhead, i.e. the distance between two adjacent nozzles belonging to the same channel plate element 36 is the same as the distance between two nozzles disposed on either side of a boundary 38. Thus, when a sheet of printing paper is moved past the printhead 10 in the direction orthogonal to the row of nozzles 26, and all actuators are energized periodically at the same timing, a regular matrix pattern of dots will be printed on the paper. In a practical application an ink jet printer will comprise several printheads 10 which are staggered appropriately and will fire at appropriate timings so that additional dots are printed in the gaps between the nozzles 26 of the other printheads, so that a higher resolution is achieved.

[0029] For illustration purposes the channel plate element 36 in Figs. 1 and 2 is shown to comprise only eight channels 22, 24. In practice, however, the number of channels per channel plate element may be considerably larger, e.g. 150 or more. The channels 22, 24 belonging to the same channel plate element 36 are also arranged with a constant pitch Dc. However, as is shown in Fig. 2, this pitch Dc is slightly smaller than the pitch Dn of the nozzles 26. The width of the nozzles 26 is considerably smaller than the width of the channels 22, 24. In a practical example the width of the nozzles may be 40 μm whereas the width of each channel may be approximately 300 μm. In case of the channels 22 located in the central portion of the channel plate element 36, the nozzles 26 are positioned substantially at the center of the channel, whereas, the more one approaches to the lateral ends of the channel plate element, the more the nozzle is offset outwardly from the center of the channel. As a result, the center to center distance Dc' of the two channels 24 situated on either side of a boundary 38 is considerably larger than the regular pitch Dc of the channels. This has the advantage that, in spite of the constant pitch Dn of the nozzles, the channels 24 adjacent to the boundary 38 can be limited by outer walls 40 which have the same thickness as the partition walls 34 between the channels 22 within the channel plate element.

[0030] In the shown embodiment the individual channel plate elements 36 are so positioned on the support plate 12 that the distance between the nozzles of the channels 24 adjacent to the boundary 38 is equal to Dn, and a small gap is formed between the channel plate elements. As an alternative, this gap may be filled with an appropriate spacer element or the outer walls 40 may be made thicker so that the channel plate elements 36 can directly be butted against each other.

[0031] In the embodiment shown in Figs. 1 and 2 there is a one-two-one relationship between the channel plate elements 36 and the actuator members 28. In a modified embodiment there may be provided larger actuator members which extend over the boundaries between the channel plate elements 36. In this case it may be preferable to make the distance Dc' equal to 2 Dc, so that the actuator member can have a uniform pattern of fingers 30, 32 regardless of the boundaries 38 of the channel plate elements.

[0032] A plurality of channel plate elements 36 can efficiently be manufactured by forming the channels 22, 24 and the nozzles 26 in the surface of a larger wafer 42 a portion of which is shown in plan view in Fig. 3, and then performing dicing cuts 44 to form the individual channel plate elements. When the channels 22, 24 are formed on the wafer, the distance between the channels 24 can be selected appropriately in view of the width of the dicing cut 42. If desired, the thickness of the outer walls 40 can be made either larger or smaller than that of the partition walls 34. It is preferable, however, that the thickness of the outer walls 40 is larger than half the thickness of the partition walls 34.

[0033] Since there is a one-two-one correspondence between the actuator members 28 and the channel plate elements 36, and the actuators 30 are arranged in pairs in the embodiment shown in Fig. 1, each channel plate element 36 has an even number of channels.

[0034] In order to avoid sharp bends in the flexible plate 26 when the same is displaced by the actuators, it is desirable that the actuators 30 are sufficiently spaced away from the partition walls 34 and the outer walls 40 of the channels. This is why, in Fig. 1, the fingers 30 and 32 are arranged in a non-regular pattern, which may however be problematic from the viewpoint of manufacturing.

[0035] Fig. 4 illustrates a modification in which all the fingers 30 and 32 of the actuator member 28 are arranged with equal spacings. In this case, the channels 46, 48 of the channel plate 14 are arranged in pairs corresponding to the pairs of actuators 30. A sufficient spacing of the actuators from the partition walls and end walls of the channels is achieved by slightly displacing the two channels 46 and 48 of each pair outwardly relative to the associated support finger 32. Thus, strictly speaking, the channels 46, 48 of the channel plate element 36 are no longer arranged with a constant pitch. It is possible however to define an effective pitch Dc as one half of the distance between two adjacent pairs of channels 46, 48. This effective pitch Dc is then constant over the whole channel plate element 36.

[0036] In the embodiments described above the nozzles 26 are formed in the channel plate 14 by converging the channels in the end portion forming the nozzle. Figs. 5 and 6 show an embodiment in which the channels 50 are formed by straight grooves, and the nozzles 52 are defined by orifices formed in a separate nozzle plate 54 which is fixed to the front face of the channel plate 14, the flexible plate 16, etc.. The channel plate elements 36 according to this embodiment can simply be manufactured by cutting a regular pattern of straight grooves into the surface of the wafer 42, regardless of the boundaries between the channel plate elements to be formed therefrom. Then, dicing cuts 44 are formed along the center lines of some of the grooves 50' which will thereby be removed.

Claims

1. Ink jet array printhead comprising a channel plate (14) composed of a plurality of channel plate elements (36), wherein each channel plate element has formed therein a plurality of parallel channels (22, 24; 50) separated from one another by partition walls (34), each channel has an open end forming a nozzle (26; 52), and the channel plate elements are arranged side by side so that the nozzles form a linear array, characterized in that the width of the channels (22, 24; 50) is larger than that of the nozzles (26; 52), and the channels of each channel plate element (36) are arranged with a constant effective pitch (Dc) which is smaller than that (Dn) of the nozzles.

2. Ink jet array printhead according to claim 1, wherein the channels (24) adjacent to boundaries (38) between different channel plate elements (36) are limited by outer walls (40) the thickness of which is larger than half the thickness of the partition walls (34).

3. Ink jet array printhead according to claim 2, wherein the thickness of the outer walls (40) is larger than or equal to the thickness of the partition walls (34).

4. Ink jet array printhead according to any of the preceding claims, wherein the center to center distance (Dc') between two channels (24) on either side of a boundary (38) between different channel plate elements (36) is equal to twice the pitch (Dc) of the channels within the channel plate element.

5. Ink jet array printhead according to any of the preceding claims, wherein each of the channels (22, 24; 50) is associated with a piezoelectric actuator (30) for pressurizing liquid ink contained within said channel.

6. Ink jet array printhead according to any of the preceding claims, wherein the nozzles (52) are defined by orifices formed in a nozzle plate (54).

7. Method of manufacturing an ink jet array printhead according to any of the claims 1 to 5, comprising the steps of:

   - forming parallel channels (22, 24) in the surface of a wafer (42), each channel having a reduced end forming a nozzle (26), said channels (22, 24) being arranged in groups in which the nozzles (26) have a constant pitch (Dn) and the channels (22, 24) have a constant pitch (Dc) which is smaller than that of the nozzles, so that the nozzles (26) are outwardly offset relative to the widthwise center of the channel, and this offset increases towards both ends of the group,
   - performing dicing cuts (44) between the channels (24) defining the ends of each group, thereby to form a plurality of channel plate elements (36), and
   - positioning the channel plate elements (36) side by side so that the nozzles (26) of the various channel plate elements (36) form an array with constant pitch (Dn).

8. Method of manufacturing a printhead according to claim 6, comprising the steps of:

   - forming parallel straight channels (50,50') in the surface of a wafer (42), said channels having an open end and being arranged in groups within which the pitch (Dc) of the channels is constant,
   - performing dicing cuts (44) in the wafer, thereby separating the groups form each other and forming separate channel plate elements (36),
   - positioning the channel plate elements (36) side by side,
   - forming a linear array of nozzle orifices (52) in a nozzle plate (54), the pitch (Dn) of the nozzle orifices being larger than that (Dc) of the channels, and
   - mounting the channel plate (54) in front of the open ends of the channels (50) of the nozzle plate elements (36) so that each nozzle orifice (52) communicates with one of the channels.

9. Method according to claim 8, wherein all the channels (50,50') formed in the wafer (42) have a constant pitch and some (50') of the channels are at least partly removed by performing the dicing cuts (44).

Fig. 1

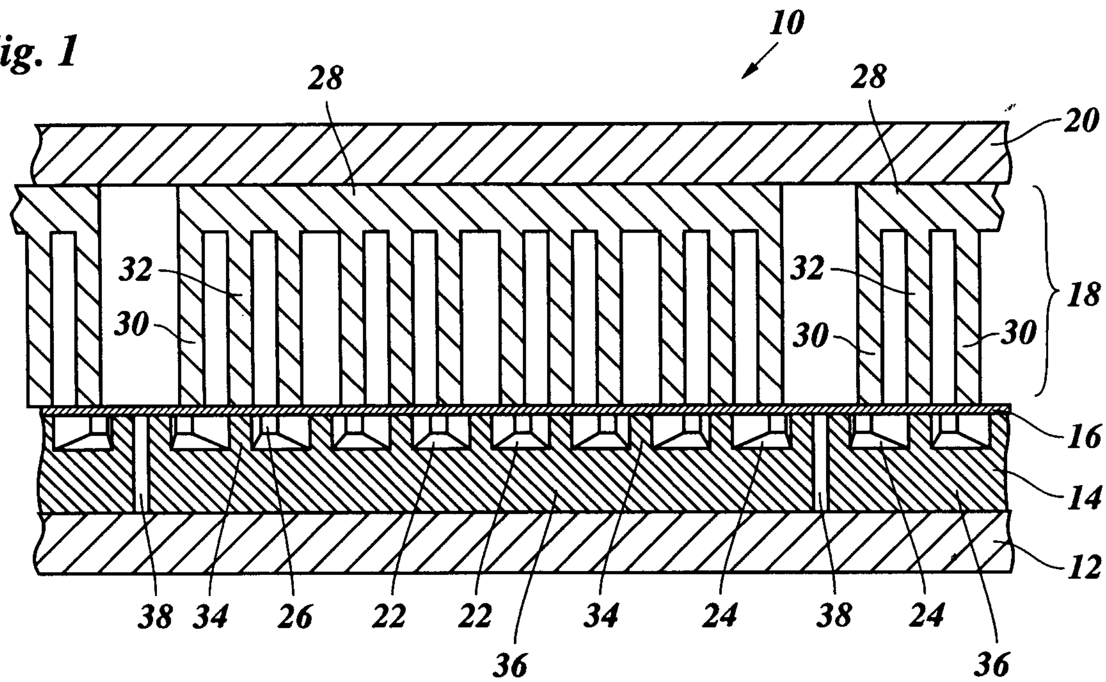


Fig. 2

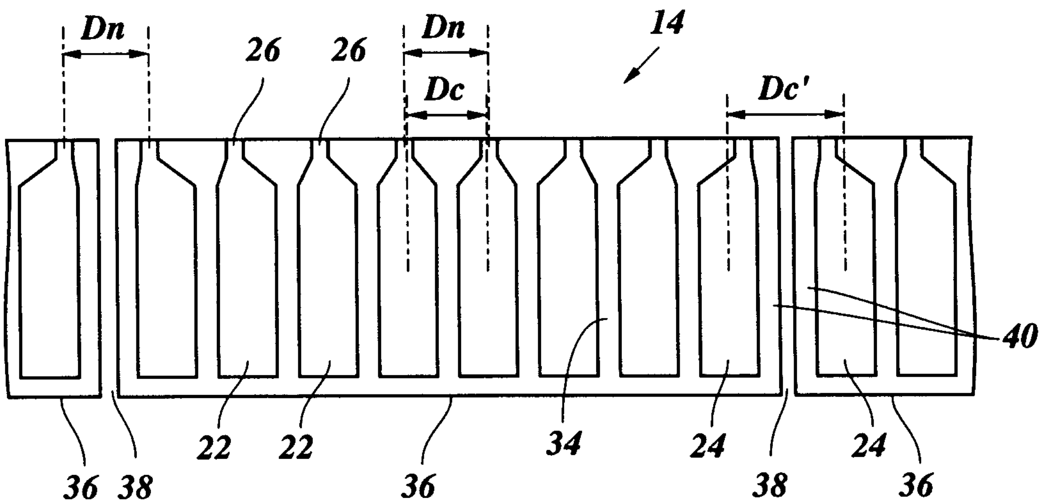


Fig. 3

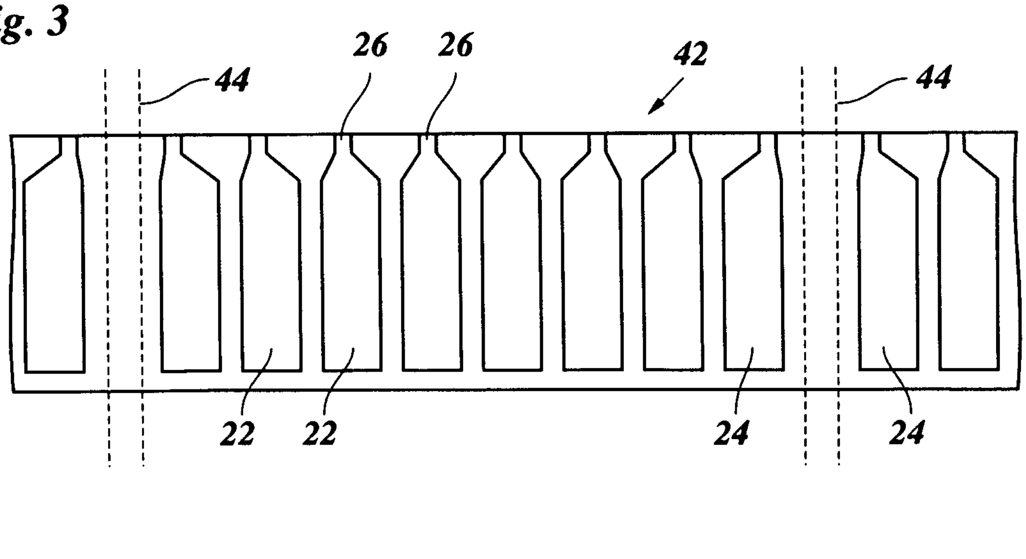


Fig. 4

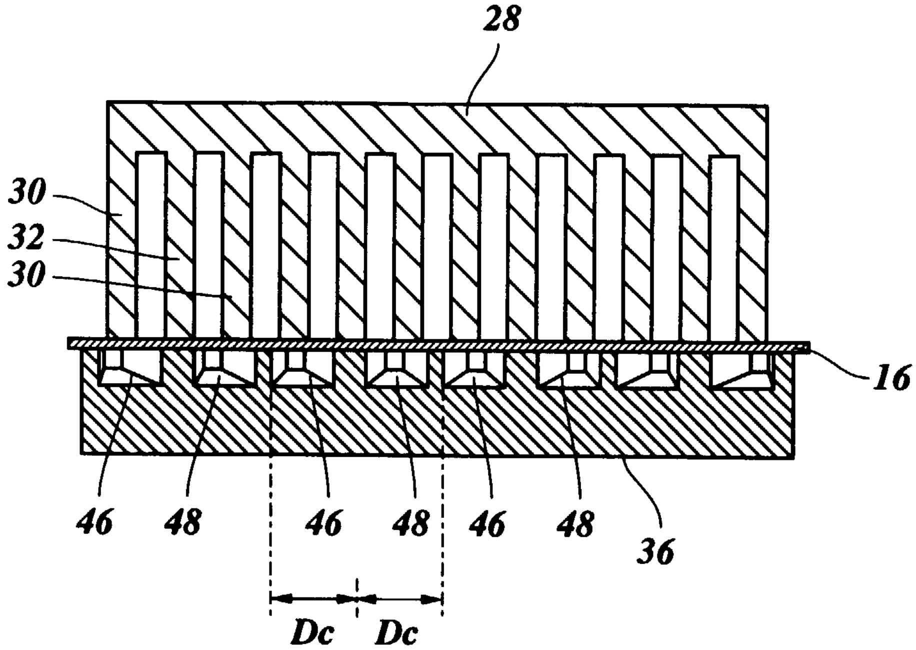


Fig. 5

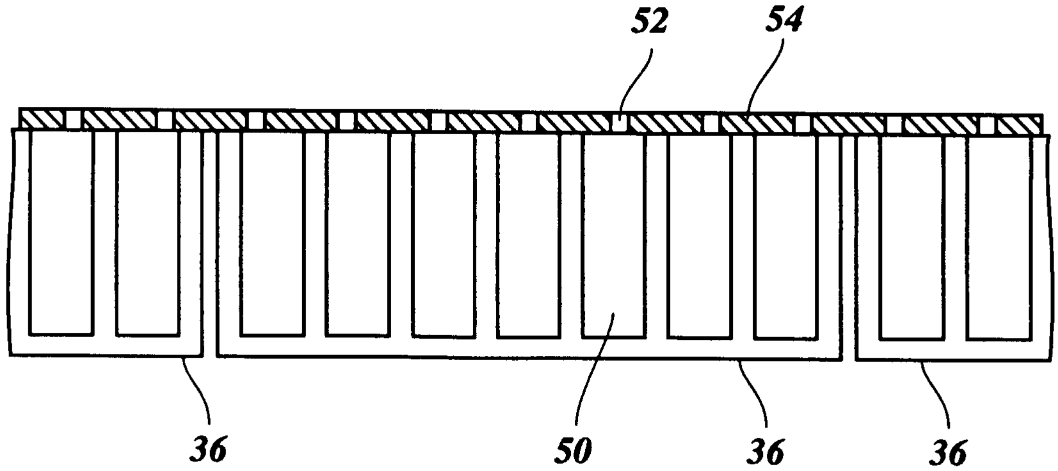
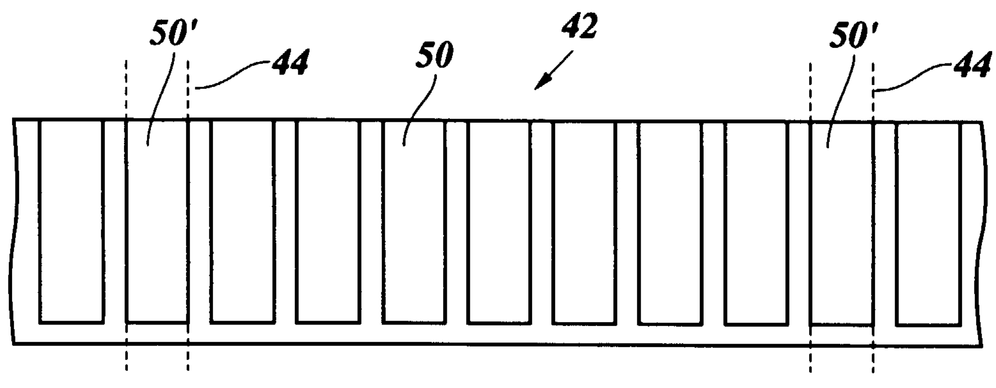


Fig. 6



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 20 4010

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	EP 0 755 791 A (SEIKO EPSON CORP) 29 January 1997 * column 3, line 19 - column 4, line 44 * * column 5, line 24 - column 7, line 20; figures 7,8 *	1	B41J2/155
A	EP 0 670 222 A (CANON KK) 6 September 1995 * page 8, line 50 - page 9, line 22; figures 9,10 *	1	
A	EP 0 615 845 A (COMPAQ COMPUTER CORP) 21 September 1994 * column 3 - column 6 *	1	
D,A	US 5 410 340 A (DRAKE DONALD J ET AL) 25 April 1995 * column 6; figure 7 *	1	
A	EP 0 707 965 A (CANON KK) 24 April 1996		
A	PATENT ABSTRACTS OF JAPAN vol. 004, no. 125 (M-030), 3 September 1980 -& JP 55 084678 A (RICOH CO LTD), 26 June 1980 * abstract *		TECHNICAL FIELDS SEARCHED (Int.Cl.6) B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	1 March 1999	Van Oorschot, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 98 20 4010

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European 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.

01-03-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0755791 A	29-01-1997	EP 0785071 A	23-07-1997
		WO 9703836 A	06-02-1997
		JP 9187931 A	22-07-1997
		JP 9131868 A	20-05-1997
EP 0670222 A	06-09-1995	JP 7266566 A	17-10-1995
		JP 7309012 A	28-11-1995
		CA 2143896 A	05-09-1995
		SG 44309 A	19-12-1997
		CN 1110945 A	01-11-1995
EP 0615845 A	21-09-1994	US 5365645 A	22-11-1994
		AT 153916 T	15-06-1997
		DE 69403520 D	10-07-1997
		DE 69403520 T	18-12-1997
US 5410340 A	25-04-1995	JP 7186387 A	25-07-1995
EP 0707965 A	24-04-1996	JP 8118642 A	14-05-1996

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82