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(54) **MODULAR MEMS INKJET PRINT HEAD**

(57) An inkjet print head comprises a nozzle plate substrate having arranged therein an array of through holes extending from a first surface of the nozzle plate substrate to an opposite second surface of the nozzle plate substrate; and at least two inkjet print head MEMS chips, wherein each inkjet print head MEMS chip comprises at least two droplet ejection units, each droplet ejection unit comprising a liquid supply port, a pressure chamber, a liquid outlet port and an actuator for generating a pressure change in a liquid arranged in the pressure chamber. The liquid outlet port of the droplet ejection unit is in fluid communication with at least one of the through holes of the nozzle plate substrate and the at least one through hole thereby forms a nozzle of the corresponding droplet ejection unit such that upon pressure change in the liquid in the corresponding pressure chamber a droplet of the liquid is expelled through said at least one through hole.

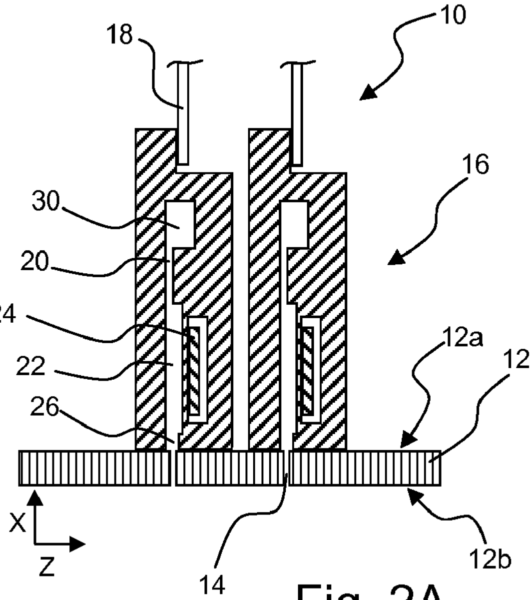

Fig. 2A

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Description

FIELD OF THE INVENTION

[0001] The present invention generally pertains to an inkjet print head comprising multiple inkjet print head chips and a method for manufacturing such an inkjet print head.

BACKGROUND ART

[0002] Inkjet print heads comprising one or multiple inkjet print head chips are well known in the art. In particular, such inkjet print head chips may employ different methods for generating a droplet of a liquid supplied to the inkjet print head chips. For example, a thermal actuation technique may be used, wherein a heater generates a gas bubble in the liquid near a nozzle orifice such that the expansion from liquid to gas pushes a droplet of liquid through the nozzle orifice. Another known technique is the application of an electromechanical transducer such as, for example, a piezo-electric actuator or an electrostatic actuator. With such an actuation technique, a pressure chamber is filled with the liquid and a flexible wall is actuated to change a volume of the pressure chamber. Upon suitable volume change, a droplet of the liquid is expelled through a nozzle that is in fluid communication with the pressure chamber.

[0003] The above known inkjet print head chips are commonly manufactured by application of MEMS (Micro Electro-Mechanical Systems) technology, which includes the use of lithographic techniques to etch structures in a substrate, usually a silicon substrate. The structures may have dimensions as small as one micrometer and even smaller. With such inkjet print head chips it is possible to generate very small droplets with a droplet volume of several picoliters or even a volume of less than a picoliter.

[0004] Such small droplets allow forming very small dots on a recording medium and thus allow providing an image on a recording medium with a very high image resolution (i.e. number of dots per unit length, e.g. number of dots per millimeter). A high image resolution provides for sharpness, for example, and is thus advantageous. Still, to harvest such advantage, the dot placement needs to be very accurate, since inaccurate dot placement inevitably negatively affects the image quality.

[0005] Due to manufacturing limitations, the inkjet print head chips are usually relatively small compared to a size of a recording medium, which means that multiple inkjet print head chips are needed to span a recording medium width. Thus, it is well known to arrange multiple inkjet print head chips in an array to form an inkjet print head that spans the recording medium width. In view of the desired image quality, the inkjet print head chips need to be arranged accurately relative to each other such that the nozzles of the separate inkjet print head chips align accurately to ensure that the dots of the separate inkjet print head chips are accurately positioned on the recording medium relative to each other in order to really harvest the potential of the small droplets.

[0006] Commonly, near the edge of the inkjet print head chips, no nozzles can be provided. Consequently, the inkjet print head chips need to be staggered to mutually align the nozzles. Accurately staggering the inkjet print head chips is however in practice not so simple and not so accurate. As a result, in the resulting image on the recording medium, chip transitions (also known as stitching errors) are visible and may be seen as a banding phenomenon.

[0007] In order to improve the resulting image quality, it is desired to provide for an inkjet print head comprising multiple inkjet print head chips and having accurately mutually aligned nozzles.

SUMMARY OF THE INVENTION

[0008] In an aspect of the present invention, an inkjet print head is provided. The inkjet print head comprises a nozzle plate substrate and at least two inkjet print head MEMS chips. The nozzle plate substrate has arranged therein an array of through holes extending from a first surface of the nozzle plate substrate to an opposite second surface of the nozzle plate substrate, wherein the array comprises at least two rows of through holes extending in a width direction of the nozzle plate substrate and positioned staggered with respect to one another. Each inkjet print head chip comprises at least two droplet ejection units, wherein each droplet ejection unit comprises a liquid supply port, a pressure chamber, a liquid outlet port and an actuator for generating a pressure change in a liquid arranged in the pressure chamber. In the inkjet print head according to the present invention, the liquid outlet port of the droplet ejection unit is in fluid communication with at least one of the through holes of the nozzle plate substrate, whereby the at least one through hole forms a nozzle of the corresponding droplet ejection unit such that upon pressure change in the liquid in the corresponding pressure chamber a droplet of the liquid is expelled through said at least one through hole.

[0009] In the inkjet print head according to the present invention, an array of nozzles is provided. Separate inkjet print head chips are provided without nozzles, but with liquid outlet ports. The liquid outlet ports are aligned and in fluid communication with the nozzles such that the position of the nozzles in the nozzle plate substrate determines the relative positioning of the nozzles in the array. With MEMS-processing technology, it is simple and cost-effective to provide for an accurate array of nozzles (through holes) in the nozzle plate substrate. With the nozzles accurately positioned, the droplets expelled through the nozzles will result in accurately positioned dots.

[0010] In an embodiment, the inkjet print head MEMS chips are positioned on the nozzle plate staggered with respect to one another, such that the inkjet print head

MEMS chips are offset with respect to one another in a thickness direction and partially overlap when viewed in the thickness direction of the nozzle plate substrate perpendicular to the width direction. The thickness direction Z and the width direction Y define the main or largest plane of the nozzle plate substrate. In the thickness direction Z, the MEMS chips are positioned after or next to one another, such that the MEMS chips do not overlap when viewed along the width direction Y. When viewing along the thickness direction Z, the adjacent edges of the two MEMS chips do overlap. The number of liquid outlet ports of each inkjet print head MEMS chip is equal to the number of nozzles in the respective row of through holes in the nozzle plate substrate over which row the MEMS chip is positioned. The through holes are aligned on the nozzle plate on at least two lines extending in the width direction. These parallel lines are spaced apart from one another in the thickness direction. Through holes are grouped together in relatively short rows, each row being aligned on one of the lines. Rows one the same line are preferably spaced apart by a distance similar to the width of a row on the other of the at least two lines, wherein the latter row is substantially in between the former two rows when viewed in the thickness direction.

[0011] In an embodiment, the inkjet print head MEMS chips are formed from thin slices of silicon, and wherein the liquid outlet ports of each inkjet print head MEMS chips are arranged in a row in the width direction, such that the at least two rows of liquid outlet ports are positioned staggered in corresponding overlap with the staggered rows of through holes on the nozzle plate substrate. Each inkjet print head MEMS chip preferably contains a straight row of a predetermined number of liquid outlet ports. The width of the liquid outlet port row is similar to the width of the corresponding row of through holes over which the MEMS chip is mounted.

[0012] In an embodiment, neighboring through holes in each row are spaced apart from one another by a predetermined first pitch, and wherein at least one through hole in a first one of the rows is spaced apart in de width direction from a neighboring though hole in second one of the rows by said predetermined first pitch. Preferably, when viewed in the width direction neighboring through holes have the same pitch spacing regardless of which row their direct or nearest neighbor in the width direction is in. For example, a through hole at an end of a row has a first neighbor (through hole) on a first side, which neighbor is positioned in the same row at a distance of the predetermined first pitch in the width direction. This through hole has a second neighbor on the other side, which neighbor is positioned in a different row, but spaced apart from the through hole by the same first pitch when measured in the width direction. The through hole and the second neighbor are however spaced apart in the thickness direction, whereas the through hole and its first neighbor are aligned along the width direction (i.e. have the same relative position on the thickness axis). This provides a very uniform nozzle density over the full printing width.

[0013] In an embodiment, the nozzle plate comprises a silicon wafer with lithographically etched through-holes. Using MEMS technology to produce the nozzle plate helps to accurately achieve a fine nozzle density, thereby improving the print quality.

[0014] In an embodiment, each droplet ejection unit is configured for ejecting picoliter sized droplets. The present invention provides an increased nozzle density and thus allows for the use of very small droplets volume. Thereby, a high quality image may be formed.

[0015] In an embodiment, a cross-sectional area of the liquid outlet port is larger than a cross-sectional area of the corresponding through hole in the nozzle plate substrate, which corresponding through hole is in fluid communication with said liquid outlet port. For example, presuming the liquid outlet port has a circular cross-section having an outlet port diameter and presuming the through hole has a circular cross-section having a through hole diameter, the liquid outlet port diameter may be larger than the through hole diameter. In such an embodiment, with the liquid outlet port having a larger cross-sectional area than the through hole forming the nozzle, the positioning of the inkjet print head chip relative to the nozzle plate substrate becomes easier. Minor deviations in the relative positioning do not affect the alignment of the liquid outlet port and the corresponding through hole. This further alleviates the requirements on the manufacturing accuracy for the inkjet print head chips, which reduces costs and increases a manufacturing yield.

[0016] In an embodiment, presuming that each inkjet print head chip has a length in an X direction, a width in an Y direction and a thickness in an Z direction, the liquid outlet ports are arranged in an outlet port side of the inkjet print head chip, wherein outlet port side extends perpendicular to the X direction. Further, the first surface and the second surface of the nozzle plate substrate extend perpendicular to the X direction. Then, in this embodiment, the inkjet print head chips are arranged with their respective outlet port sides on the first surface of the nozzle plate substrate. The arrangement of inkjet print head chips relative to the nozzle plate substrate allows, *inter alia*, for a dense chip arrangement. For example, a first inkjet print head chip and a second inkjet print head chip may be arranged with a side surface, other than a surface of the outlet port side, against each other. Alignment relative to each other is not relevant, provided that the separate inkjet print head chips are well enough aligned with the associated through holes. Stitching errors are prevented due to the alignment of the through holes during manufacturing of the nozzle plate substrate.

[0017] In an embodiment, the first inkjet print head chip and the second inkjet print head chip each comprise a liquid supply channel, wherein the liquid supply ports of the droplet ejection units are fluidly coupled between such liquid supply channel and the respective pressure chambers. Each such liquid supply channel has a first channel port arranged in a first channel port side of the inkjet print head chip, the first channel port side being different from the outlet port side, and each such liquid supply channel has a second channel port arranged in a second channel port side of the inkjet print head chip, the second channel port side being different from the outlet port side. Further, in this embodiment, one of the first channel port side and the second channel port side of the first inkjet print head chip is arranged opposing one of the first channel port side and the second channel port side of the second inkjet print head chip with the respective channel ports aligned with respect to each other such that the respective liquid supply channels are fluidly coupled. For example, the liquid supply channel may extend in parallel to the nozzle plate substrate. In this embodiment, a dense inkjet print head chip arrangement is achieved, while enabling to easily and cost-effectively supply liquid to each inkjet print head chip.

[0018] In another embodiment, a first inkjet print head chip is configured to eject droplets of an ink having a first color and a second inkjet print head chip is configured to eject droplets of an ink having a second color different from the first color. Thus, it is possible to provide for a multi-color inkjet print head with accurately aligned nozzles.

[0019] In an embodiment, the actuator is a piezo-electric transducer arranged on a flexible wall of the pressure chamber, the flexible wall of the pressure chamber extending perpendicular to the outlet side of the inkjet print head chip, which provides for a simple arrangement and construction.

[0020] In another aspect, the present invention provides for a method of manufacturing an inkjet print head, the method comprising the steps of providing a nozzle plate substrate; providing, in the nozzle plate substrate, an array of through holes extending from a first surface of the nozzle plate substrate to an opposite second surface of the nozzle plate substrate; providing at least two inkjet print head chips, wherein each inkjet print head chip comprises at least two droplet ejection units, each droplet ejection unit comprising a liquid supply port, a pressure chamber, a liquid outlet port and an actuator for generating a pressure change in a liquid arranged in the pressure chamber; and arranging the liquid outlet port of the droplet ejection unit in fluid communication with at least one of the through holes of the nozzle plate substrate, the at least one through hole thereby forming a nozzle of the corresponding droplet ejection unit such that upon pressure change in the liquid in the corresponding pressure chamber a droplet of the liquid is expelled through said at least one through hole.

[0021] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating embodiments of the invention, are given by way of illustration only, since various changes and modifications within the scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying schematical drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

Fig. 1A is a bottom view of a first embodiment of an inkjet print head according to the present invention;
Fig. 1B is a top view of the first embodiment of an inkjet print head according to the present invention;
Fig. 1C is a side view of the first embodiment of an inkjet print head according to the present invention;
Fig. 1D is a perspective view of the first embodiment of an inkjet print head according to the present invention;
Fig. 2A is a cross-sectional view of a second embodiment of an inkjet print head according to the present invention;
Fig. 2B is a cross-sectional view of a third embodiment of an inkjet print head according to the present invention;
Fig. 2C is a bottom view of a fourth embodiment of an inkjet print head according to the present invention;
Fig. 2D is a bottom view of a fifth embodiment of an inkjet print head according to the present invention;
Fig. 3 is a cross-sectional view of a sixth embodiment of an inkjet print head according to the present invention; and
Fig. 4 is a cross-sectional view of a seventh embodiment of an inkjet print head according to the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

[0023] The present invention will now be described with reference to the accompanying drawings, wherein the same reference numerals have been used to identify the same or similar elements throughout the several views.

[0024] Figs. 1A - 1D illustrate a first embodiment of an inkjet print head 10 according to the present invention. In Fig. 1A, a second surface 12b of a nozzle plate substrate 12 is shown with four rows of nozzles 14, which are formed as through holes through the nozzle plate substrate 12. In a Y-direction, the nozzles 14 are all arranged at a same pitch. In particular, a first pitch P1 between nozzles 14 in a same row is identical to a second pitch P2 between the nozzles 14 at each end of two adjacent rows.

[0025] In operation, a recording medium may be transported along the inkjet print head 10 in a Z-direction. With the same pitches P1, P2 in the Y-direction, virtually, a single row of nozzles at a constant pitch and extending in the Y-direction is available for providing dots on the recording medium.

[0026] In Fig. 1B, a first surface 12a of the same nozzle plate substrate 12 is seen, wherein the nozzles 14 are shown in dotted lines as they are actually not visible in this view. In this view, MEMS-manufactured inkjet print head chips 16 are arranged over the nozzles 14. Usually, the MEMS-manufactured print heads are formed by lithographic techniques, including etching, performed on silicon wafers, forming mechanical structures with dimensions in a micrometer range and sometimes even in a sub-micrometer range.

[0027] Further, electrically conductive leads may be provided to electromechanical transducer structures, such as an electrostatic actuator or a piezo-electric actuators, arranged in the mechanical structure such that an electric signal may induce a mechanical movement for operation. A well-known example of such a MEMS structure is a piezo-electric actuated inkjet print head. As such inkjet print heads are well known in the art and thus apparent to those skilled in the art, these print heads, their way of functioning and their method of manufacturing are not further described in much detail herein.

[0028] As compared to the well-known MEMS inkjet print heads, the inkjet print head 10 according to the present invention shares a single nozzle plate substrate 12 with multiple MEMS inkjet print head chips 16. For dot positioning on a recording medium, the positions of the nozzles 14 relative to each other is important. With each inkjet print head chip 16 having its own nozzles, as in the prior art, results in a high dependency on the inkjet print head chip 16 positioning relative to each other. In the inkjet print head 10 according to the present invention, the nozzle plate substrate 12 may be processed such that all through holes forming the nozzles 14 are accurately positioned relative to each other. Then, later in the manufacturing process, the inkjet print head chips 16 are arranged on the first surface 12a of the nozzle plate substrate 12 such that an outlet port of each ejection unit is aligned with one of the through holes, which is described hereinbelow *inter alia* in relation to Fig. 2A.

[0029] The nozzle plate substrate 12 may for example be manufactured by MEMS processing, wherein a highly accurate lithographic mask may be employed to etch the through holes in a silicon wafer. However, other suitable materials and processing methods may be employed as well, if such materials and processes provide for a sufficiently accurate positioning of the nozzles 14.

[0030] In the first embodiment illustrated in the Figs. 1A - 1D and with particular reference to Fig. 1C and Fig. 1D, the MEMS-manufactured inkjet print head chips 16 are arranged against each other, whereby such arrangement provides for a dense arrangement of nozzles 14 and further provides for additional strength and stiffness to the inkjet print head chips 16 when arranged in the inkjet print head 10. It should be born in mind that the inkjet print head chips 16 may be formed from thin slices of silicon and thus may have a thickness (dimension in the illustrated Z-direction) that may not exceed one millimeter. Of course, in another embodiment, a support structure may be provided on the first surface 12a of the nozzle plate substrate 12 to support the inkjet print head chips 16. Further, other structures such as a liquid supply structure for supplying liquid to each inkjet print head chip 16 may as well function as a support for the inkjet print head chips16.

[0031] In Fig. 2A, a second embodiment of the inkjet print head 10 is shown in cross-section, wherein two inkjet print head chips 16 are arranged on a single nozzle plate substrate 12 and each show a droplet ejection unit. The droplet ejection unit comprises a liquid supply port 20, a pressure chamber 22 and an outlet port 26. In this illustrated embodiment, a piezo-electric actuator 24 is arranged on a flexible wall of the pressure chamber 22 such that the actuator 24 is arranged for changing a volume of the pressure chamber 22 when an electric signal is applied. A liquid supply channel 30 is in fluid communication with the liquid supply port 20. Further, an electrical conductive member 18, e.g. a cable, is electrically connected for supplying said electric signal to the actuator 24. As apparent to those skilled in the art, a suitable signal generating circuitry is connected to another end of the electrical conductive member 18.

[0032] Note that, in this embodiment, a cross-sectional area of the outlet port 26 is larger than a cross-sectional area of the nozzle 14, wherein both cross-sectional areas are perpendicular to an X-direction. The X-direction is a direction in which the through holes forming the nozzles 14 extend from the first surface 12a to the second surface 12b. Further, in this second embodiment, the two illustrated inkjet print head chips 16 are not arranged against each other, leaving space to position the inkjet print head chips 16 relative to the nozzle plate substrate 12 independent from each other. Thus, inaccuracies in the position of the outlet ports 26 may be compensated by positioning the inkjet print head chip 16 relative to the nozzle plate substrate 12 such that the larger outlet port 26 is arranged over the smaller nozzle 14.

[0033] It is noted that the nozzle 14 is an essential part of the inkjet print head 10. The acoustics of the fluidic system for droplet formation are affected by a shape of the nozzle 14, as well known in the art. In other words, a through hole in the nozzle plate substrate 12 that does not affect the droplet formation, e.g. because its cross-sectional area is significant larger than the cross-sectional area of the outlet port 26, is not within the scope of the present invention. Moreover, such a through hole is not considered to form a nozzle of an inkjet print head, since in such a case the position of the through holes would not contribute to an improved dot positioning.

[0034] The liquid supply channel 30 extends in a width direction of the inkjet print head 10 (cf. Y-direction in Fig. 1A and 1B). It may extend from end to end or may be an internal channel having a separate channel port in a side of the inkjet print head chip 16 for receiving liquid in the liquid supply channel 30. The liquid thus supplied is supplied to the droplet ejection units through the liquid supply channel 30, which is in fluid communication with the respective liquid supply ports 20.

[0035] In a third embodiment, as shown in Fig. 2B, the liquid supply channel 30 is provided with two channel ports, i.e. first channel port 32 and second channel port 34. In this particular embodiment, the first channel port 32 and the second channel port 34 are each arranged in a respective side of the inkjet print head chip 16 such that the liquid supply channel 30 extends from a first side to a second side of the inkjet print head chip 16, thereby providing a through-flow channel. Positioning two or more inkjet print head chips 16 against each other, for example the first embodiment of Figs. 1A - 1D, allows to provide an extended liquid supply channel 30 running through multiple inkjet print head chips 16 and thereby simplifying a liquid supply connection to all inkjet print head chips 16 as compared to individual liquid supply connections for each inkjet print head chip 16 in view of the desired high density of inkjet print head chips 16.

[0036] Referring to Figs. 2C and 2D (Fig. 2B could be considered to be a cross-section of Figs. 2C and 2D along lines I-I and II-II, respectively), it is noted that the nozzles 14 of two adjacent inkjet print head chips 16 may be arranged next to each other as seen in the Z-direction (Fig. 2C) or the nozzles 14 may be staggered (Fig. 2D). Arranged next to each other, redundancy is provided in the Z-direction and, presuming that the Z-direction is a recording medium transport direction, a failing nozzle may be replaced by its adjacent nozzle. In another embodiment, these adjacent nozzles may be used to increase an amount of liquid (ink) applied per position on the recording medium, for example for increasing an optical density of such a dot or a diameter of such a dot. Arranging the nozzles in a staggered way decreases an overall dot pitch. Using ink of a same color thus provides for an increased dot resolution (more dots per unit length). Using ink of different colors enables to position dots of different colors next to each other instead of overlapping over each other. Of course, as apparent to those skilled in the art, other reasons may apply for selecting either of the above configurations or selecting yet another configuration, depending on the envisaged application. It is believed to lie within the ambit of the skilled person to select a suitable configuration and therefore designing and selecting an application-suitable configuration is not further elucidated herein.

[0037] Fig. 3 illustrates a further embodiment, in which a recess is provided in the first surface 12a of the nozzle plate substrate 12. Such a recess may assist in positioning the inkjet print head chips 16.

[0038] Fig. 4 illustrates another embodiment, wherein the through holes in the nozzle plate substrate 12 have a tapered cross-section such that a diameter in the first surface 12a is larger than a diameter in the second surface 12b. This enables to provide for a relatively large diameter in the first surface 12a for ease of positioning of the outlet ports 26 in the inkjet print head chips 16, while enabling to provide for a relatively small nozzle 14 for ejecting relatively small droplets.

[0039] Detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. In particular, features presented and described in separate dependent claims may be applied in combination and any advantageous combination of such claims is herewith disclosed.

[0040] Further, it is contemplated that structural elements may be generated by application of three-dimensional (3D) printing techniques. Therefore, any reference to a structural element is intended to encompass any computer executable instructions that instruct a computer to generate such a structural element by three-dimensional printing techniques or similar computer controlled manufacturing techniques. Furthermore, such a reference to a structural element encompasses a computer readable medium carrying such computer executable instructions.

[0041] Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the invention. The terms "a" or "an", as used herein, are defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language). The term coupled, as used herein, is defined as connected, although not necessarily directly.

[0042] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. An inkjet print head (10) comprising:

- a nozzle plate substrate (12) having arranged therein an array of through holes (14) extending from a first surface of the nozzle plate substrate (12) to an opposite second surface of the nozzle plate substrate (12), wherein the array comprises at least two rows of through holes (14) extending in a width direction (Y) of the nozzle plate substrate (12) and positioned staggered with re-

spect to one another; and
• at least two inkjet print head MEMS chips (16), wherein each inkjet print head MEMS chip (16) comprises at least two droplet ejection units, each droplet ejection unit comprising a liquid supply port (20), a pressure chamber (22), a liquid outlet port (26) and an actuator (24) for generating a pressure change in a liquid arranged in the pressure chamber (22),

wherein the liquid outlet ports (26) of the droplet ejection units of each inkjet print head MEMS chip (16) are in fluid communication with a respective row the through holes (14) of the nozzle plate substrate (12), the at least one through hole (14) thereby forming a nozzle (14) of the corresponding droplet ejection unit such that upon pressure change in the liquid in the corresponding pressure chamber (22) a droplet of the liquid is expelled through said at least one through hole (14).

2. The inkjet print head (10) according to claim 1, wherein the inkjet print head MEMS chips (16) are positioned staggered with respect to one another, such that the inkjet print head MEMS chips (16) are offset with respect to one another in a thickness direction (Z) and partially overlap when viewed in the thickness direction (Z) of the nozzle plate substrate (12) perpendicular to the width direction (Y).

3. The inkjet print head (10) according to claim 2, wherein the inkjet print head MEMS chips (16) are formed from thin slices of silicon, and wherein the liquid outlet ports (26) of each inkjet print head MEMS chip (16) are arranged in a row in the width direction (Y), such that the at least two rows of liquid outlet ports (26) are positioned staggered in corresponding overlap with the staggered rows of through holes (14) on the nozzle plate substrate (12).

4. The inkjet print head (10) according to any of the preceding claims, wherein neighboring through holes (14) in each row are spaced apart from one another by a predetermined first pitch (P1), and wherein at least one through hole (14) in a first one of the rows is spaced apart in de width direction (Y) from a through hole (14) in the second one of the rows by a second pitch (P2), which second pitch (P2) is equal to said predetermined first pitch (P1).

5. The inkjet print head (10) according to any of the preceding claims, wherein the nozzle plate substrate (12) comprises a silicon wafer with lithographically etched through-holes (14).

6. The inkjet print head (10) according to any of the preceding claims, wherein each droplet ejection unit is configured for ejecting picoliter sized droplets.

7. The inkjet print head (10) according to any of the preceding claims, wherein a cross-sectional area of the liquid outlet port (26) is larger than a cross-sectional area of the corresponding through hole (14) in the nozzle plate substrate (12), which corresponding through hole (14) is in fluid communication with said liquid outlet port (26).

8. The inkjet print head (10) according to claim 7, wherein the liquid outlet port (26) has a circular cross-section having an outlet port diameter and the through hole (14) has a circular cross-section having a through hole diameter and wherein the liquid outlet port diameter is larger than the through hole diameter.

9. The inkjet print head (10) according to any of the preceding claims, wherein

• each inkjet print head MEMS chip (16) has a length in an X direction, a width in an Y direction and a thickness in an Z direction;
• the liquid outlet ports (26) are arranged in an outlet port side of the inkjet print head MEMS chip (16), which outlet port side extends perpendicular to the X direction;
• the first surface and the second surface of the nozzle plate substrate (12) extend perpendicular to the X direction; and
• the inkjet print head MEMS chips (16) are arranged with their respective outlet port sides on the first surface of the nozzle plate substrate (12).

10. The inkjet print head (10) according to claim 9, wherein a first inkjet print head MEMS chip (16) and a second inkjet print head MEMS chip (16) are arranged with a side surface, other than a surface of the outlet port side, against each other.

11. The inkjet print head (10) according to claim 10, wherein

• the first inkjet print head MEMS chip (16) and the second inkjet print head MEMS chip (16) each comprise a liquid supply channel, the liquid supply ports of the droplet ejection units being fluidly coupled between the liquid supply channel and the respective pressure chambers,
• each liquid supply channel has a first channel port arranged in a first channel port side of the inkjet print head MEMS chip, the first channel port side being different from the outlet port side;
• each liquid supply channel has a second channel port arranged in a second channel port side of the inkjet print head MEMS chip, the second channel port side being different from the outlet port side;

wherein one of the first channel port side and the second channel port side of the first inkjet print head MEMS chip is arranged opposing one of the first channel port side and the second channel port side of the second inkjet print head MEMS chip with the respective channel ports aligned with respect to each other such that the respective liquid supply channels are fluidly coupled.

12. The inkjet print head (10) according to claim 11, wherein the liquid supply channel extends in parallel to the nozzle plate substrate (12).

13. The inkjet print head (10) according to any of the preceding claims, wherein a first inkjet print head MEMS chip is configured to eject droplets of an ink having a first color and a second inkjet print head MEMS chip is configured to eject droplets of an ink having a second color different from the first color.

14. The inkjet print head (10) according to any of the preceding claims, wherein the actuator is a piezo-electric transducer arranged on a flexible wall of the pressure chamber, the flexible wall of the pressure chamber extending perpendicular to the outlet side of the inkjet print head MEMS chip.

15. A method of manufacturing an inkjet print head (10), the method comprising the steps of

- providing a nozzle plate substrate (12);
- providing, in the nozzle plate substrate (12), an array of through holes (14) extending from a first surface of the nozzle plate substrate (12) to an opposite second surface of the nozzle plate substrate (12), wherein the array comprises at least two rows of through holes (14) extending in a width direction (Y) of the nozzle plate substrate (12) and positioned staggered with respect to one another;
- providing at least two inkjet print head MEMS chips (16), wherein each inkjet print head MEMS chip (16) comprises at least two droplet ejection units, each droplet ejection unit comprising a liquid supply port (20), a pressure chamber (22), a liquid outlet port (26) and an actuator (24) for generating a pressure change in a liquid arranged in the pressure chamber (22);
- mounting the inkjet print head MEMS chips (16) staggered with respect to one another on the nozzle plate (12), thereby arranging the liquid outlet port (26) of the droplet ejection unit in fluid communication with at least one of the through holes (14) of the nozzle plate substrate (12), the at least one through hole (14) thereby forming a nozzle (14) of the corresponding droplet ejection unit such that upon pressure change in the liquid in the corresponding pressure chamber (22) a droplet of the liquid is expelled through said at least one through hole (14).

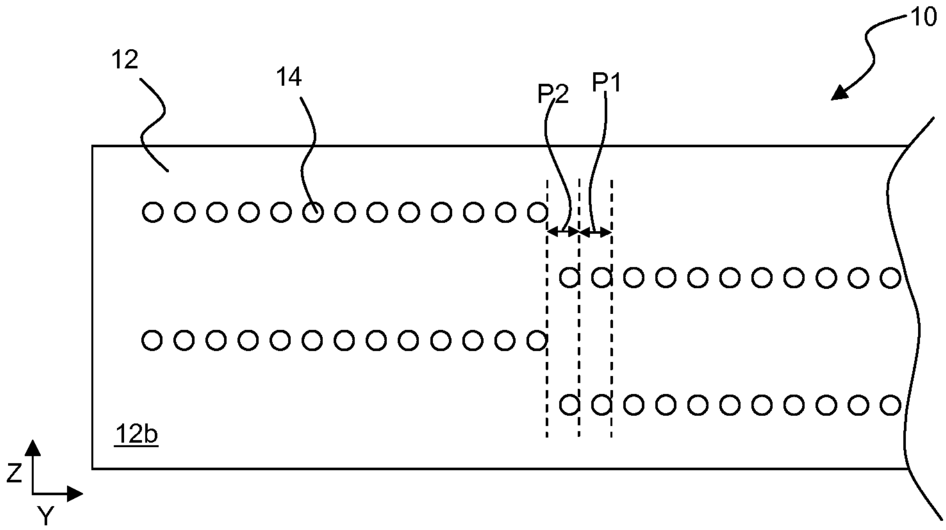

Fig. 1A

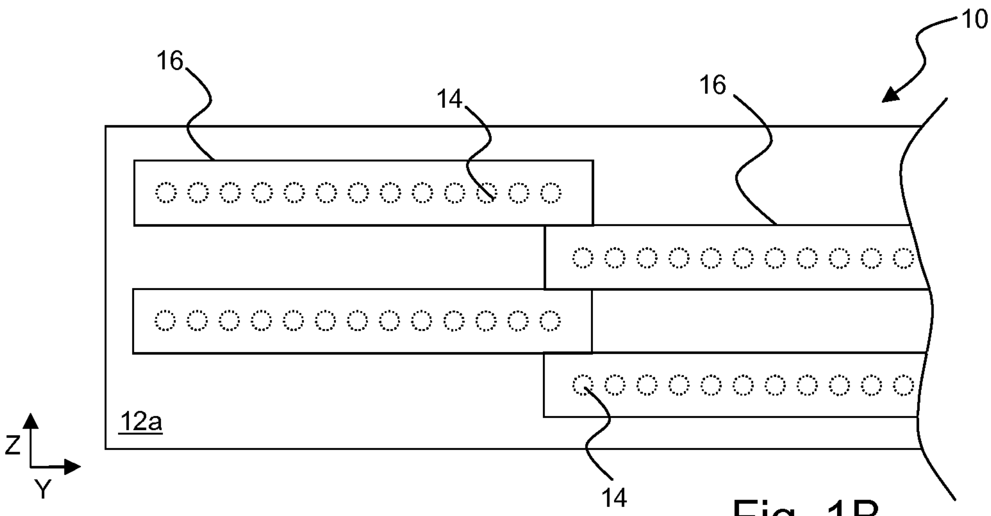

Fig. 1B

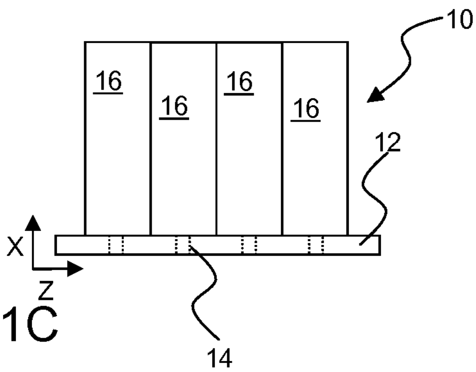

Fig. 1C

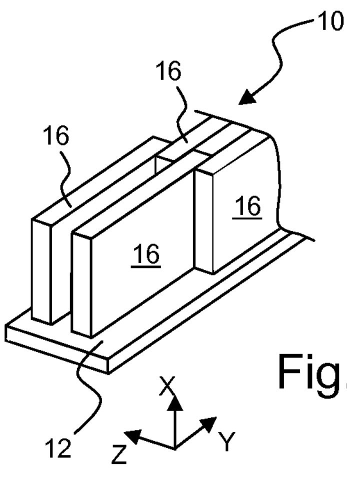

Fig. 1D

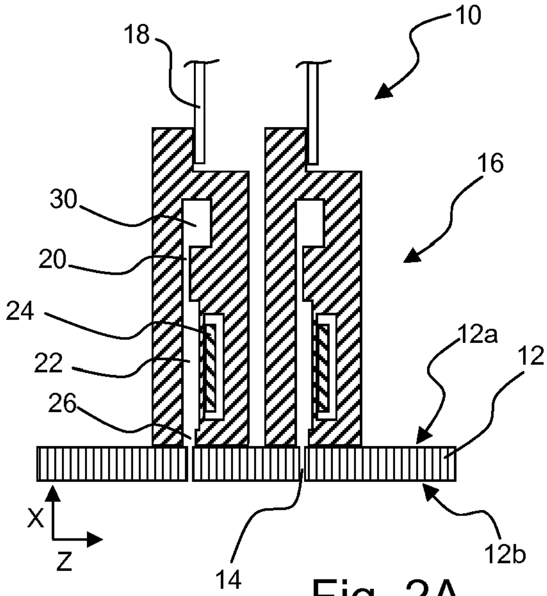

Fig. 2A

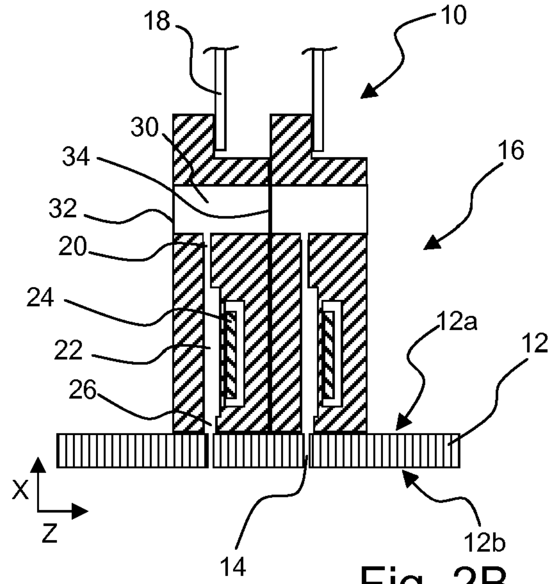

Fig. 2B

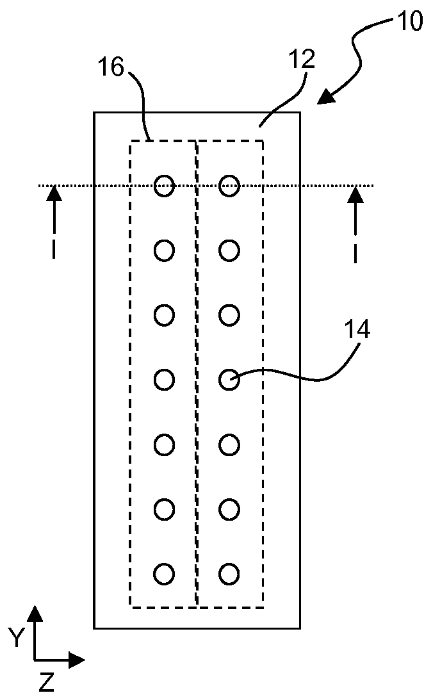

Fig. 2C

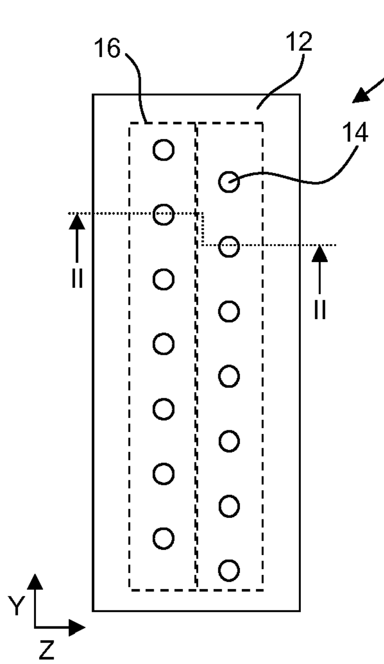

Fig. 2D

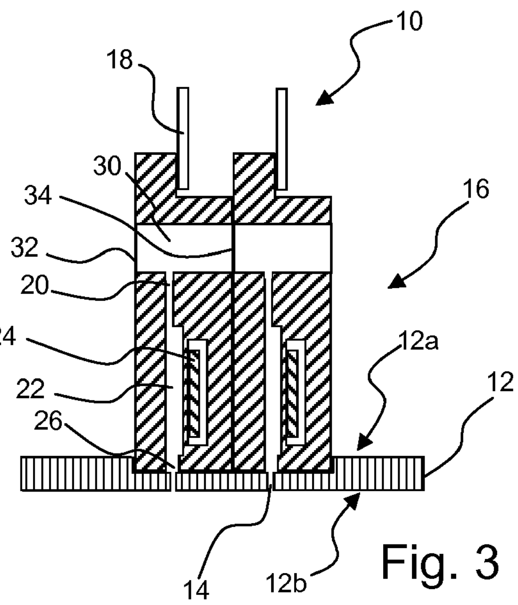
10
18
30
34
32
20
24
22
26
16
12a
12
14
12b

Fig. 3

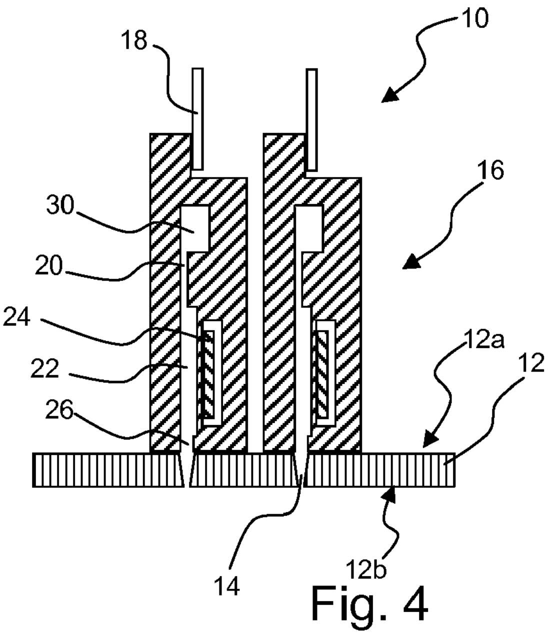
10
18
30
20
24
22
26
16
12a
12
14
12b

Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 18 15 9447

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
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