



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.03.2015 Bulletin 2015/10

(51) Int Cl.:
B41J 2/14 (2006.01)

(21) Application number: **13425119.8**

(22) Date of filing: **29.08.2013**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **IN.TE.SA. S.p.A.**
40026 Imola (Bologna) (IT)

(72) Inventor: **Guidotti, Gian Mario**
41124 Modena (IT)

(74) Representative: **Casadei, Giovanni**
Bugnion S.p.A.
Via Vellani Marchi, 20
41124 Modena (IT)

(54) **Printheads for decorating ceramic substrates**

(57) A printhead (20) comprising: a chamber (22); an actuator element (30) located outside the chamber (22), wherein the actuator element (30) is coupled to an obturator (31); and a separator element (26) located between the chamber (22) and the actuator element (30), characterized in that a portion of the obturator (31) is located

within the chamber (22) and operable to move from a first position inside the chamber (22) to a second position inside the chamber (22) on actuation of the actuator element (30), whereby the actuator element is isolated from the fluid chamber during printing.

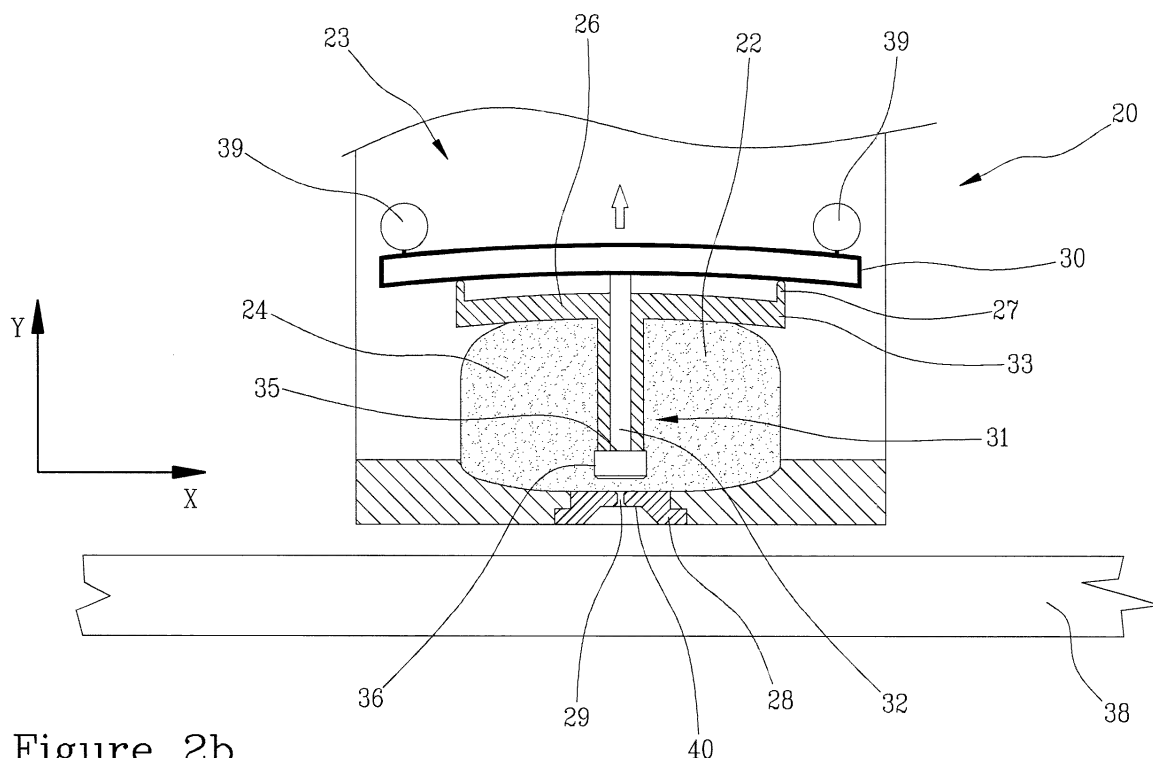


Figure 2b

Description

[0001] The present invention relates to ink jet print-heads and, particularly, but not exclusively, it relates to improvements to printheads for decorating ceramic substrates.

[0002] Decoration of ceramic substrates, for example ceramic tiles involves depositing a glaze or engobe on the surface of the tile. The glaze generally comprises an aqueous or solvent based ceramic solution or suspension, or a suspension within a solution, made up of a liquid part having a quantity of mineral particulates/powders dispersed therein, whereby the specific glaze formulation is dependent on the requirements of the end user.

[0003] Common techniques such as silk screening, rotary printing, flexography, and curtain printing or curtain bell deposition are used to deposit the glaze on the surface of the tile. However, it is difficult to achieve controlled local effects on the tile using the above mentioned techniques; in addition it is difficult and time consuming to change over from one design to the next. Texture and decorative effects at present can be achieved by using for example intaglio printing, involving rollers with a textured elastomeric coating, relying on printing onto a virtually smooth surface. However, the rollers are expensive, require storage space and cannot only be used for one specific design. In addition, tiles are never flat enough to enable easy control of roller pressure for even contact between tile and roller, essential for a consistent finish that at the same time does not break the tile.

[0004] Inkjet printing poses an attractive technique to deposit glaze addressing the above issues. In a digital inkjet printhead, glaze in a chamber of the printhead is ejected from the printhead through a nozzle, by an actuator located inside the printhead. In addition to glaze, digital printing of engobe, typically an aqueous clay suspension, enables printing of texture effects that would otherwise only be possible during the pressing stage of the tile. However, conventional inkjet printers use nozzle diameters $\varnothing < 50\mu\text{m}$, which are not suitable for glaze or engobe, which are powder suspensions, or suspensions within solutions, as these typically have particle sizes of 10s of microns as well as high weights per volume far exceeding 100g per square meter, and more typically requiring up to 1 kg per square meter to be deposited.

[0005] EP1972450B discloses an example of a conventional printhead 1 used to print glaze as shown in section in Figure 1. The printhead 1 comprises a fluid chamber 2, having a fluid inlet (not shown) and fluid outlet (not shown), whereby the glaze 4 flows through the chamber 2 from the input to the output under a pressure of e.g. 1 Bar.

[0006] The printhead 1 comprises an actuator 6 in the form of a piezoelectric bar having an obturator 7 coupled thereto and located inside the chamber 2, whilst the printhead 1 further comprises a nozzle portion 8 having a surface 5 inside the chamber 2 and having at least one

through-hole nozzle 9 therein providing a flow pathway from inside the chamber 2 to a substrate 10 through the nozzle 9.

[0007] An obturator is any mechanical element which is operable to engage with the nozzle portion 8 to provide a mechanical seal at the entrance to the nozzle 9, thereby preventing/reducing the flow of glaze into the nozzle 9. Such an obturator may form part of an obturator assembly comprising an obturator.

[0008] As the obturator 7 is coupled to the actuator 6, it moves in the same direction of deflection of the actuator 6, and is configured to engage with the surface 5 to block the nozzle 9 when the actuator 6 is in a non-deflected position, and to disengage from the surface 5 thereby uncovering the nozzle 9, when the actuator is in a deflected position.

[0009] An electronic control unit (not shown), is used to drive the actuator with a certain voltage waveform e.g. to drive the actuator 6 such that it deflects in an oscillatory manner at a certain frequency e.g. 1 kHz. By oscillating the actuator 6 it is possible to control the ejection of the fluid from the nozzle 9 in the form of droplets.

[0010] The chamber is provided with a seal(s) 12 e.g. a gasket, to prevent the glaze exiting the chamber 2 at any point other than the nozzle 9, and though the fluid inlet and outlet.

[0011] One problem with the conventional printhead 1 is that glaze or engobe, over time, damage the actuating element 6 located inside the chamber 2, the obturator 7, surface 5 and/or the seal(s) 12, thereby significantly reducing the lifetime of the printhead 1 by resulting in leakage from the chamber and/or causing pressure issues within the chamber.

[0012] A further problem with conventional printheads is that they are generally only compatible with solvent based glazes, which are costly, and can be highly toxic, and require a furnace to burn the solvent after deposition. However, using water based glazes in conventional printheads results in clogged nozzles, and increased wear on the internal components within the printhead.

[0013] It would therefore be advantageous to provide an improved printhead which addresses the aforementioned disadvantages.

[0014] In a first aspect there is provided a printhead comprising: a chamber; an actuator element located outside the chamber, wherein the actuator element is coupled to an obturator; and a separator element located between the chamber and the actuator element, **characterized in that** a portion of the obturator is located within the chamber and operable to move from a first position inside the chamber to a second position inside the chamber on actuation of the actuator element.

[0015] Preferably, the actuator element comprises piezoelectric material. Preferably, the separator element comprises a flexible portion.

[0016] Preferably, the chamber is a fluid-chamber.

[0017] Preferably, the actuator element is mechanically coupled to the obturator, wherein the fluid chamber

comprises at least one nozzle, and wherein the obturator is operable to close or open the inlet of the at least one nozzle on actuation of the actuator element.

[0018] Preferably, the obturator is part of an obturator assembly.

[0019] In a second aspect there is provided a printer having a printhead comprising: a chamber; an actuator element located outside the chamber, wherein the actuator element is coupled to an obturator; and a separator element located between the chamber and the actuator element, **characterized in that** a portion of the obturator is located within the chamber and operable to move from a first position inside the chamber to a second position inside the chamber on actuation of the actuator element.

[0020] Preferably, the method comprising using the printer of claim 10 to deposit a fluid on the substrate, wherein the fluid comprises a glaze., wherein the fluid is an aqueous glaze, or wherein the fluid comprises engobe.

[0021] In a third aspect there is provided a separator element, for separating a fluid chamber of a print head and a compartment for retaining an actuator element, the separator element comprising a flexible portion, and **characterised in that** the separator element is operable to provide movement of an obturator located inside the fluid chamber on actuation of the actuator element in the compartment.

[0022] Preferably the separating element is engageable with a portion of the fluid chamber, wherein the separator element is further engageable with the obturator, wherein the separator element is further engageable with a connecting element coupled between the obturator and the actuator element, wherein the flexible portion is an elastomeric material, wherein the elastomeric material is nitrile butadiene rubber.

[0023] Preferably the connecting element is a connecting rod, and preferably an elongated connecting rod.

Figure 1 shows in section an example of a conventional printhead of the prior art used to print glaze; Figure 2a shows, in section, a printhead according to a first embodiment of the present invention, whereby glaze is prevented from flowing through the nozzle;

Figure 2b shows in section the printhead of Figure 2a, whereby glaze is not prevented from flowing through the nozzle;

Figure 3 shows in graphical form, an example waveform of the voltage applied to an actuator of Figures 2a and 2b;

Figure 4 shows in perspective view a cross section of a printhead of a second embodiment of the present invention;

Figure 5a shows a printer system having a printhead formed by a plurality of individual printheads according to a third embodiment of the present invention; and

Figure 5b, shows a printer system, having a plurality

of nozzles formed within a single fluid chamber.

Figure 2a shows, in section, a printhead 20, whereby glaze is prevented from flowing through a nozzle 29 in a nozzle portion 28, whilst Figure 2b shows in section the printhead 20 whereby glaze is not prevented from flowing through the nozzle 29.

[0024] Whilst the operation of the printhead is described hereinafter using glaze, it will be appreciated that any suitable fluid could be used depending on the specific application e.g. methyl ethyl ketone or acetone based ink for printing on cardboard/paper/food packaging or polymer/metallic based ink for 3D-printing, or engobe.

[0025] The glaze itself may contain pigment to provide colour after firing, and have other additives such as clay to provide different finishes such as glossy, matt, opaque finishes that may be combined on the same surface, as well as special effects such as metallic tones and lustre. Texture or relief structures can be provided by printing a solution containing predominantly engobe. An exemplary digital glaze composition is disclosed in ES2386267. Particle sizes within the glaze are generally in the range of between 0.1µm - 50µm, and preferably up to 30µm, but will vary dependent on the specific formulation.

[0026] Alternatively engobe may be used in the printhead, whereby engobe is used for priming of ceramic tiles, to make the tile water permeable after pressing; or for printing raised features on the tile for wood, stone effects.

[0027] Engobe is a clay particle suspension, whilst glaze generally comprises an aqueous or solvent based glass frit suspension, or a suspension within a solution, made up of a liquid part having a quantity of mineral particulates/powders dispersed therein, whereby the specific glaze formulation is dependent on the requirements of the end user. A matt glaze may also contain engobe.

[0028] The body of the printhead 20 is formed of a robust material which has mechanical and chemical resistance to the specific fluids used for a particular printing application. One suitable material is polyether ether ketone (PEEK) e.g. Victrex PEEK 150GL30, which has suitable mechanical and chemical resistance properties for both organic and aqueous fluids including aqueous based glaze.

[0029] The printhead 20 comprises a fluid chamber 22, having a fluid inlet (not shown) and fluid outlet (not shown), whereby the glaze 24 flows through the chamber 22 from the inlet to the outlet under a substantially constant pressure above atmospheric pressure e.g. 1 bar. The inlet and outlets are fluidly connected to a closed circuit glaze supply system. The closed-circuit supply system (CCSS) having a supply channel to supply the glaze to the inlets and outlets, a discharge channel and means for moving and pressurizing the glaze in the conduit e.g. pumps, whereby the CCSS is controlled by e.g. an electronic ink supply system, as known in the art.

[0030] The printhead 20, further comprises a flexible separation member 26 e.g. formed of nitrile butadiene

rubber (NBR) 70 Shore A, which is operable to seal a top portion of the chamber 22, thereby providing a sealed separation between the chamber 22 and a compartment 23 of the printhead 20. The compartment 23 is provided with an actuator 30 located therein.

[0031] The separation member 26 is retained in position, and provides a sealing functionality by means of formations 27 formed thereon which form a mechanical engagement with reciprocal formations formed in the printhead 20, thereby retaining the sealing means in position. A sealant and/or adhesive may also be used to ensure the flexible separation member 26 is retained in position and/or to improve the seal at the interface 33 between the flexible separation member 26 and the printhead 20.

[0032] In the present embodiment the separation member 26 is formed of a resilient material, but it is not limited to being resilient.

[0033] The actuator 30 is operable to deflect from a first position as shown in Figure 2a, whereby the actuator 30 is not deflected, to a second position as shown in Figure 2b, whereby the actuator 30 deflects in a direction away from the nozzle portion 28 (in the y-plane) upon application of an electric field thereto (e.g. a voltage across electrodes of the actuator). Actuator retaining elements 39 are used to retain the actuator in position relative to the chamber 22, such that the deflection of the actuator 30 relative to the chamber 22 is maximized.

[0034] In a preferred embodiment, the actuator 30 is formed of a piezoelectric element formed, for example, of lead zirconate titanate (PZT) but may be formed of barium titanate, potassium sodium niobate (KNN) and/or bismuth sodium titanate (BNT) or any suitable material.

[0035] The functionality of piezoelectric elements is well known, whereby the piezoelectric elements are deflected on the application of an electric field thereto e.g. by applying a voltage differential across the layer(s) of the element.

[0036] In a preferred embodiment, the actuator 30 is a piezoelectric element, in the form of a substantially flat rectangular plate comprising one or more piezoelectric layers, configured to function as a bimorph, whereby the driving and contraction of the ceramic element creates a bending moment that converts a transversal change in length into a large bending displacement perpendicular to the contraction. Such functionality is obtained using known piezoelectric elements, for example, a PICMA[®] Bender Piezoelectric actuator (e.g. PL112-PL140), which allows for full differential control of the displacement. It will be appreciated that the shape of the element is not restricted to being a rectangular plate, but may be square, disc or any suitable polygonal shape.

[0037] The actuator 30 has at least two electrodes or terminals associated with, for each piezoelectric layer, whereby the electrodes are configured for allowing the supply of a controllable electric field to the actuator 30. In a preferred embodiment, deflection in bending mode of approximately 30 μm is provided. However, the amount

of deflection required will be dependent on the specific application but in general deflection will be in the order of 600 μm . Preferably, elements capable of deflection of at least 20 μm to 60 μm will be used. Such deflection can be obtained by applying an appropriate voltage differential across the layer(s) of the piezoelectric element for example, up to approximately 600V, but preferably voltage differentials of up to between 20V to 60V will be applied between layer(s) of the piezoelectric element, and preferably up to 30V.

[0038] It will also be appreciated that whilst the actuator 30 is operable to deflect in a direction away from the nozzle portion 28 on application of an electric field thereto i.e. in the Y-plane, as demonstrated by the arrow 40, in alternative embodiments, the actuator 30 may be arranged to deflect in a direction towards the nozzle portion 28 on application of an electric field thereto.

[0039] An obturator assembly 31 is attached to the actuator 30 using a suitable adhesive which will not degrade in the presence of the glaze e.g. Loctite 438. The obturator assembly 31 is operable to engage the nozzle portion 28, to close/open the inlet to a nozzle 29 formed therein.

[0040] The obturator assembly 31 comprises a connecting element, wherein, in the present embodiment, the connecting element is a connecting rod 23, which is secured to the actuator 30.

[0041] It will be apparent to a skilled person having knowledge of this specification that the connecting element can take any suitable form to connect an obturator assembly to the actuator.

[0042] The connecting rod 32 protrudes through the flexible separation member 26 into the chamber 22, whilst a seal is formed between the flexible separation member 26 and the obturator assembly 31 thereby maintaining the seal between the chamber 22 and the compartment 23. The connecting rod 32 is fabricated using a material having mechanical and chemical properties resistant to glaze or any other fluids used in the particular printing applications required by a user e.g. Polyetherimide (PEI) such as Ultem 1000, or polyether ether ketone (PEEK) etc.

[0043] In general, the nozzle portion 28 refers to a surface having a nozzle 29 formed therein. The nozzle portion 28 is formed of any suitable material e.g. PEEK (KETRON), PEI, Stainless Steel (LS316) or Silicon, whereby the nozzle 29 is formed therein by a suitable manufacturing technique e.g. by micro electrical discharge machining (EDM)/laser machining/chemical etching etc.

[0044] In the preferred embodiments below, the nozzle has a diameter substantially equal to 400 μm . When printing with glaze or engobe the nozzle preferably has a diameter between 100 μm - 600 μm , and substantially between 375 μm - 425 μm , and preferably substantially the diameter is 400 μm to ensure that nozzle does not become blocked by the particles in the glaze.

[0045] The nozzle portion 28 may be formed integral to the chamber 22 during fabrication of the chamber 22,

or may be a separate element which is assembled into the chamber 22 during manufacture of the printhead 1, and secured in place using a suitable adhesive e.g. Loc-tite 438.

[0046] In a preferred embodiment, the distal end 35 of the connecting rod 32 is inserted into a valve head 36 inside the chamber 22, whereby the valve head 36 is formed to engage the substantially flat surface of the nozzle portion 28 when the actuator 30 is in the first position. With the actuator in the first position, the valve head 36 is engaged with an area surrounding the inlet of the nozzle 29 of the nozzle portion 28 such that no pathway exists for fluid to flow from the chamber 22 into the nozzle 29.

[0047] It will be seen that in order to close off the inlet to the nozzle, the valve head 36 engages with the nozzle portion 28. Therefore, in order to reduce wear on the valve head 36, the valve head 36 is formed of a durable material, e.g. NBR 70 Shore A or Titanium Grade 5, which is capable of withstanding repeated exposure to cavitation and abrasion caused by being driven towards or against the nozzle portion 28. Similar considerations are also taken into account when selecting the material used for the nozzle portion 28, which may comprise a hard component in the form of a valve seat insert made out of titanium to achieve good durability.

[0048] In alternative embodiments, the valve head 36 may be absent and the connecting rod 32 or the separation member 26 may be adapted to engage the surface surrounding the area of the inlet of the nozzle 29 to prevent/restrict fluid flow therein from the chamber 22 when the actuator is in the first position.

[0049] Providing a suitable voltage differential across the piezoelectric actuator 30 causes the actuator 30 to deflect to the second position, thereby causing the obturator assembly 31 attached to the actuator 30, and the separation member 26 attached thereto, to move in the direction of deflection of the actuator 30, such that the valve head 36 disengages from surface surrounding the area of the inlet of the nozzle 29, whereby a pathway is formed such that glaze flows from the chamber 22 and into the nozzle 29 i.e. thereby filling the nozzle 29.

[0050] Subsequent removal of the voltage differential across the actuator 30 results in the actuator 30 returning to the first position from the second position in the compartment 23, which in turn results in the valve head 36 returning to engage the surface surrounding the area of the inlet of the nozzle 29 in the chamber 22. During the return of the actuator 30 to the first position, the downward movement of the valve head 36 with respect to the nozzle 29 assembly impedes the flow of fluid into the nozzle 29, and effects ejection of the glaze from the nozzle 29 towards a substrate 38 located beneath an outlet of nozzle 29 on the exterior of the printhead 20.

[0051] An electronic control unit (not shown), is used to provide the actuator 30 with a voltage differential waveform e.g. to drive the actuator such that it deflects in an oscillatory manner at a certain frequency, e.g. 1 kHz. By

driving the actuator 30 in such a manner it is possible to control the ejection of the fluid from the nozzle 29 in the form of droplets.

[0052] It will be seen that the flexible separation member 26 allows for deflection of the actuator 30 in the compartment 23 to effect movement of the valve head 36 inside the chamber 22, such that drops of glaze can be deposited on the substrate 38 through the nozzle 29 in a controlled manner, without risk of the actuator 30 coming into contact with the glaze.

[0053] Figure 3 shows in graphical form, an example waveform of the voltage differential across a piezoelectric actuator 30, whereby the element is arranged to deflect on application of the voltage differential thereto.

[0054] At time 90, the voltage differential (ΔV) across the actuator 30 is increased from V0 (e.g. 0V) to V1 (e.g. 30V). During this time the actuator 30 will deform and deflect (e.g. 30 μ m) from the first position as shown at Figure 2a to the second position as shown in Figure 2b, resulting in a separation of the valve head 36 from the nozzle portion 28.

[0055] During the period 92, the voltage differential is maintained on the piezoelectric actuator 30, thereby maintaining the actuator in the second position, such that glaze enters the nozzle 29, whereby the time 92 that the voltage differential is maintained across the actuator 30 is proportional to the desired drop volume of ink entering the nozzle 29, and therefore of the printed drop.

[0056] At time 94, the voltage differential across the actuator 30 is reduced to V0 and the actuator 30 returns to the first position as shown at Figure 2a. During the return to the first position, the bottom surface 40 of the valve head 36 blocks the nozzle 29 and a drop is ejected from the nozzle towards the substrate 38 during the time 94.

[0057] For the present embodiment, the waveform shown in Figure 3 is repeated at a frequency of 1 kHz, for as long as drops are required to be ejected from the nozzle. The frequency/drive time (90, 92, 94) may be increased or decreased as required by a user e.g. to increase or decrease the volume of the printed drop, or to increase the frequency of drop ejection from the printhead 20. When a drop is not required to be printed, the differential is held substantially at V0.

[0058] The print head 20 of the present invention comprises the advantage of being both mechanically and electronically adjustable, so that the print head 20 is flexible and versatile, and adaptable to various desired applications, and to various ceramic glazes e.g. aqueous based and solvent based glazes. It will also be appreciated that a variety of different inks with different fluid properties could be used by modifying various parameters of the printhead 20 e.g. deflection of the actuator, the nozzle diameter, drive voltage etc. as required.

[0059] It will be appreciated that the values used for the above embodiments take the deflection of the piezoelectric elements to be proportional to variations in the applied voltage/voltage differential, i.e. approximately

1 μm deflection per 1V differential, but, as will be appreciated by the skilled person, the relationship and the specific values used will vary depending dependent on a number of factors including the material and specific crystalline structure/poling of the piezoelectric element and the geometry of the actuator device e.g. length/width/height of the piezoelectric layers. Furthermore, there is no requirement for the relationship between deflection and applied electric field to be linear.

[0060] Figure 4 shows in perspective view a cross section of a printhead 50. The printhead 50 comprises a fluid chamber 52 having a flexible separation member in the form of a diaphragm 53, a side wall 54, a top-wall 59 and a nozzle portion 56.

[0061] The side wall 54 comprises a glaze inlet 55 in fluid connection with a glaze manifold (not shown), through which glaze enters the chamber 52 from the manifold, and a glaze outlet (not shown) in fluid connection with the manifold, through which fluid leaves the chamber 52 into the manifold.

[0062] The nozzle portion 56 is formed of KETRON®PEEK 100 NATURAL and is arranged to sealably fit into the housing of the chamber 52. A nozzle 60 having a diameter $\varnothing$ of approximate $400\mu\text{m}$ is provided in the nozzle portion 56. The nozzle 60 provides a fluid pathway from the chamber 52 to atmosphere 51.

[0063] It will be appreciated that the specific diameter $\varnothing$ of the nozzle is chosen dependent for example on the specific fluid properties and the desired drop volume range.

[0064] However, dependent on the specific application and/or the glaze or engobe used, the diameter may be in the range of $80\mu\text{m}$ - $1000\mu\text{m}$, whilst for applications using ink solutions e.g. MEK based or Acetone ink, the diameter may be in a much smaller range e.g. in the order of $10\text{-}60\mu\text{m}$.

[0065] In the present embodiment, the diaphragm 53 is formed as an annular structure of NBR 60 Shore A and is arranged to seal the top wall of the chamber 52 from an actuator compartment 63, having a piezoelectric actuator 64 located therein. The diaphragm 53 comprises at least one formation 62 formed around the diaphragm 52 and which engages with at least one formation 65 provided on the inside of the chamber 52.

[0066] During assembly, an adhesive e.g. Loctite 438 is provided around the formation 62, and when the diaphragm is inserted into the chamber 52, the formation 62 engages with formation 65, and the adhesive retains the diaphragm 53 in position relative to the chamber 52, thereby providing a sealing functionality between the chamber 52 and the compartment 63. The diaphragm 53 locates within a central aperture of the top wall 59.

[0067] The diaphragm 53 is further provided with a central aperture 66 through which an elongated connecting rod 68, formed e.g. of Ultem 1000, is inserted. A formation 70 along the inner diameter of the central aperture 66 such as lip, which may comprise a recess(es) or a protrusion(s), engages with the connecting rod 68, which

may have suitable features to receive the recess(s) or protrusion(s) of the arrangement 70, to seal the aperture 66 such that glaze does not leak from the chamber 52 into the compartment 63. The formation may be secured relative to the elongated connecting rod 68 using e.g. Loctite 438.

[0068] A first end of the elongated connecting rod 68 is secured to the actuator 64 using a suitable adhesive e.g. Loctite 438.

[0069] In the present embodiment, the valve head 76 is formed as a cylindrical structure having a closed end 78 and an open end 80, whereby the open end 80 is formed to receive the distal end of the elongated connecting rod 68.

[0070] The distal end of the connecting rod 68 is inserted into the valve head 76 and secured relative thereto using a suitable adhesive e.g. Loctite 438. The valve head 76 is formed of a material having a high mechanical resistance to wear e.g. NBR 70 Shore A or Titanium Grade 5, although using a deformable material for the valve head 76 such as NBR allows for reduced contact energy because the valve head 76 will deform to correct for nonplanar alignment between valve head and valve seat such the overall impact energy is reduced.

[0071] In a preferred embodiment, the open end 80 of the valve head 76 is also formed to engage with a diaphragm 88 e.g. an elastomeric 'O'-ring to seal the connecting rod 68 from the inside of the chamber 52 and to ensure that glaze does not leak from the chamber 52 into the compartment 63. Furthermore, in the present embodiment, a valve seat 82 is provided atop the nozzle portion 56 around the entrance to the nozzle 60 inside the chamber 52. The valve seat 82 is formed as an annular insert which engages with the nozzle portion 56; such that the top surface of the valve seat 82 is flush with the entrance 83 to the nozzle 60.

[0072] The valve seat 82 may be formed of a material which has a good mechanical resistance to wear e.g. Titanium Ti-6Al-4V grade 5. Furthermore, in order to prevent the valve seat 76 becoming dislodged in operation, it may be secured relative to the nozzle portion 56 using a suitable adhesive e.g. Loctite 438, or it may be a friction fit e.g. "click-fit." The bottom surface 79 of the valve head 76 is operable to engage with the valve seat 82 to seal/close the inlet 83 to the nozzle 60, such that when the valve head 76 is in contact with the valve seat 82 the entrance 83 to the nozzle 60 is sealed relative to the chamber 52, such that glaze is prevented/restricted from flowing from the chamber 52 into the nozzle 60, whilst when there is no contact between the valve head 76 and the valve seat 82, the nozzle 60 is not sealed relative to the chamber 52, and glaze is not prevented/restricted from flowing from the chamber 52 into the nozzle 60.

[0073] In the printhead shown in Figure 4, deflection of the actuator 64 occurs in the y-plane Two elastomeric retaining elements 86 are used to retain the actuator 64 in position relative to the chamber 52, such that the deflection of the actuator 64 relative to the chamber 52 is

maximized, although the number of retaining elements 86 is dependent on specific user requirements and is not limited to two, and is not limited in its specific design to allow it to provide retention and allow maximum deflection.

[0074] The operation of the printhead 50 is similar to the operation of the printhead 20, and a similar waveform as shown in Figure 3 can be applied to the actuator 64. When a voltage differential is applied across the actuator 64, the actuator 64 deflects in the Y-direction from a first non-deflected position to a second deflected position.

[0075] The elongated connecting rod 68 is secured relative to the actuator 64, whilst the valve head 76 is secured relative to the connecting rod 68 at a distal end 89 thereof, and, therefore, the elongated connecting rod 68 and the valve head 76 will deflect inside the chamber 52 in the same direction as the actuator 64, which is located outside of the chamber in the compartment 63.

[0076] Such functionality is obtained by using the flexible diaphragm 53. Whilst the flexible separation members 26 and 53 are described as substantially annular components in the embodiments above, it will be appreciated that the components are not limited to being annular and may be any suitable shape, for example it may be square, rectangular, cylindrical etc.

[0077] For example, the flexible separation member 26 of the first embodiment forms substantially the whole top wall of the chamber 22. However, it may be that the separation member 26 is an element which does not form substantially the whole of a wall, but for example, may simply be a rubber 'O' ring(s) insertable into an annular groove in a diametric aperture of a non-flexible top wall of the chamber 22, through which the connecting rod 32 is inserted, whereby the 'O'-ring(s) is in contact with the separation member 26.

[0078] In such an embodiment, the 'O' - ring(s) allows for the same functionality as discussed above, in that the connecting rod, coupled to a valve head in a chamber and to an actuator outside the chamber, is caused to deflect by deflection of the actuator thereby closing/opening the nozzle inlet accordingly, whilst the 'O' - ring located in contact with the connecting rod provides a sealing functionality between the fluid chamber and the actuator, whilst also allowing the actuator effect movement of the valve head..

[0079] It will be seen that when the actuator 64 is in the deflected position, glaze can flow from the chamber 52 into the nozzle 60. When the actuator 64 subsequently returns to the first position, the inlet to the nozzle 60 is closed relative to the chamber 52, whilst the glaze in the nozzle 60 is ejected from the nozzle onto a substrate (not shown)

[0080] In the present embodiment a deflection of up to 20-60 μ m's is desirable, such that a separation of approximately 20-60 μ m is provided between the bottom surface of the valve head 76 and the valve seat 82 when the actuator is deflected. Such a separation is sufficient for the water-based glaze to pass from the chamber 52 into

the nozzle 60. However, whilst the actuator 64 is deflected by approximately 20-60 μ m in the present embodiment, deflection of approximately 30 μ m is preferred, but it will be seen that deflection of up to 600 μ m could be used in operation, depending on the specific properties of the fluid to be printed, and the specific application. For example MEK based inks are less viscous than glaze, and have a smaller particle size distribution, and so will flow more easily through a smaller separation than the glaze. The printhead comprises a fluid chamber, designed to contain the glaze to be deposited on a substrate, whereby the glaze is supplied to the chamber 52 from a controlled glaze supply system via an inlet and an outlet at a pressure of e.g. 0.1Bar - 10Bar, and preferably, wherein the pressure is preferably between 0.5 and 1.5Bar, and preferably substantially equal to 1Bar.

[0081] An electronically controlled closed fluid supply system 103 as shown in Figures 5a and 5b, having e.g. pressure monitoring equipment 104, valves 105 etc. enables a modification of the speed of circulation of the glaze internally of the conduit; and maintains a constant flow of glaze around the system at a controlled pressure e.g. 1Bar. The continuous and controlled flow of the glaze prevents sedimentation of the -components contained in the suspension, a vital condition for good functioning of the head, and provides for consistent pressure in the printhead.

[0082] Figure 5a shows a printer 100 having a printhead 101 formed by several discrete printheads 102, arranged side by side. The printheads 102 are as described above in relation to Figures 2a, 2b and 4. The printheads 102 are arrayed and may be angled to the direction of substrate travel, so as to adjust the distance between the nozzles 29 of adjacent printheads 102. It will also be seen, that fewer or more printheads 102 can be added to the printhead 101.

[0083] In such an array, the individual heads may be designed to interlock such as to provide a continuous fluid flow through each head by providing means that connect the fluid inlets and fluid outlets of neighboring chambers, so that the fluid flow through all heads can be controlled by the same closed circuit supply system.

[0084] Alternatively, as demonstrated in Figure 5b, a single printhead 101, having a plurality of nozzles 29 formed within a single chamber is also achievable, whereby a single fluid chamber having a plurality of obturators (not shown) to close/open the nozzles 29 is provided, whereby the obturators are each controllable by respective actuators located outside of the chamber, in the manner as described above.

[0085] Furthermore, it will be appreciated that the individual printheads 102 are independently addressable, such that they can be controlled, to e.g. provide multi-sized droplets from a single print pass e.g. by controlling the time the nozzles 29 are filled with glaze while the inlet to the nozzle 29 is open relative to the chamber.

[0086] The printheads 101, 102 described above can be advantageously used not only for decoration, finishing

and texturing of ceramic tiles, but as a result of the size of the drops of glaze which can be obtained it can also be employed in full-surface glazing.

[0087] Using such functionality as described above, glaze can be ejected from the printhead in a controlled manner. Unlike the conventional printheads, water-based glaze can be deposited using the printhead 50.

[0088] Furthermore, it will also be appreciated that adjusting the parameters of the printhead can influence the final graphic effect, and improve the functionality and performance of the head. For example, on a printhead design level, the diameter of the nozzle 29 can be varied to provide access to different ranges of drop volumes and ejection frequencies.

[0089] The benefits of depositing of a larger diameter particles and high solid content fluids such as glaze and engobe are apparent. In addition, the ability to add large size pigment particles of 20-30 μm to a glaze results in a high colour density and full flexibility to apply colour glaze digitally. This is not possible to achieve with printheads having a nozzle diameter of $< 50 \mu\text{m}$ where the pigment diameter has to be kept low. Further, by controlling the closed circuit supply system 103, the pressure at which the glaze is maintained in circulation internally of the printhead is adjustable in a controlled manner according to the density and viscosity of the glaze. In this way the quantity of glaze exiting from the nozzle can be controlled e.g. whilst maintaining a constant drive waveform, the volume of the printed drops will increase by increasing the pressure in the system, whilst the volume of the drops will be decreased by decreasing the pressure in the system.

[0090] Such functionality is also obtainable by maintaining a constant pressure and modifying the drive waveform. For example, reducing the time for which the V1 drive voltage is applied to the actuator (Time 92 in Figure 3) to open the inlet to the nozzle results in a reduced drop volume because the amount of fluid flowing into the nozzle and available for ejection is limited to the time the nozzle is being filled.

[0091] In alternative embodiments it will also be seen that using actuators other than piezoelectric actuators could be used to provide the same driving functionality to effect droplet ejection, for example electrostatic actuators, magnetic actuators, electrostrictive actuators, Thermal uni/bi morph elements, solenoids, shape memory alloys etc. could readily be used to provide the functionality described above whilst obtaining the desirable functionality as will be apparent to the skilled person upon reading the above specification.

Claims

1. A printhead (20) comprising:

a chamber (22);
an actuator element (30) located outside the

chamber (22), wherein the actuator element (30) is coupled to an obturator (31); and
a separator element (26) located between the chamber (2) and the actuator element (30),
characterized in that a portion of the obturator (31) is located within the chamber (22) and operable to move from a first position inside the chamber (22) to a second position inside the chamber (22) on actuation of the actuator element (30).

2. The printhead according to Claim 1, wherein the actuator element comprises piezoelectric material.
3. The printhead according to any preceding claim, wherein the separator element comprises a flexible portion.
4. The printhead according to any preceding claim, wherein the chamber is a fluid-chamber.
5. The printhead according to any preceding claim, wherein the actuator element is mechanically coupled to the obturator.
6. The printhead according to any of Claims 4 or 5, wherein the fluid chamber comprises at least one nozzle.
7. The printhead according to Claim 6, wherein the obturator is operable to partially close or open the inlet of the at least one nozzle on actuation of the actuator element.
8. The printhead according to any preceding claim, wherein the obturator is part of an obturator assembly.
9. A printer having a print head of any of Claims 1 to 8.
10. A method of inkjet printing, the method comprising using the printer of claim 10 to deposit a fluid on the substrate.
11. The method of inkjet printing according to Claim 10, wherein the fluid comprises a glaze.
12. The method of inkjet printing according to Claim 11, wherein the fluid is an aqueous glaze.
13. The method of inkjet printing according to Claim 10, wherein the fluid comprises engobe.
14. A separator element (26), for separating a fluid chamber (22) of a print head (20) and a compartment (23) for retaining an actuator element (30), the separator element (26) comprising a flexible portion, and **characterised in that** the separator element (26) is

operable to provide movement of an obturator (31) located inside the fluid chamber (22) on actuation of the actuator element in the compartment (23).

15. A separator element as claimed in Claim 14, wherein the separating element is engageable with a portion of the fluid chamber. 5
16. A separator element as claimed in any of Claims 14 or 15, wherein the separator element is further engageable with the obturator. 10
17. A separator element as claimed in any of Claims 14 or 15, wherein the separator element is further engageable with a connecting element coupled between the obturator and the actuator element. 15
18. A separator element as claimed in any of Claims 14 to 17, wherein the flexible portion is an elastomeric material. 20
19. A separator element as claimed in Claim 18, wherein the elastomeric material is nitrile butadiene rubber. 25

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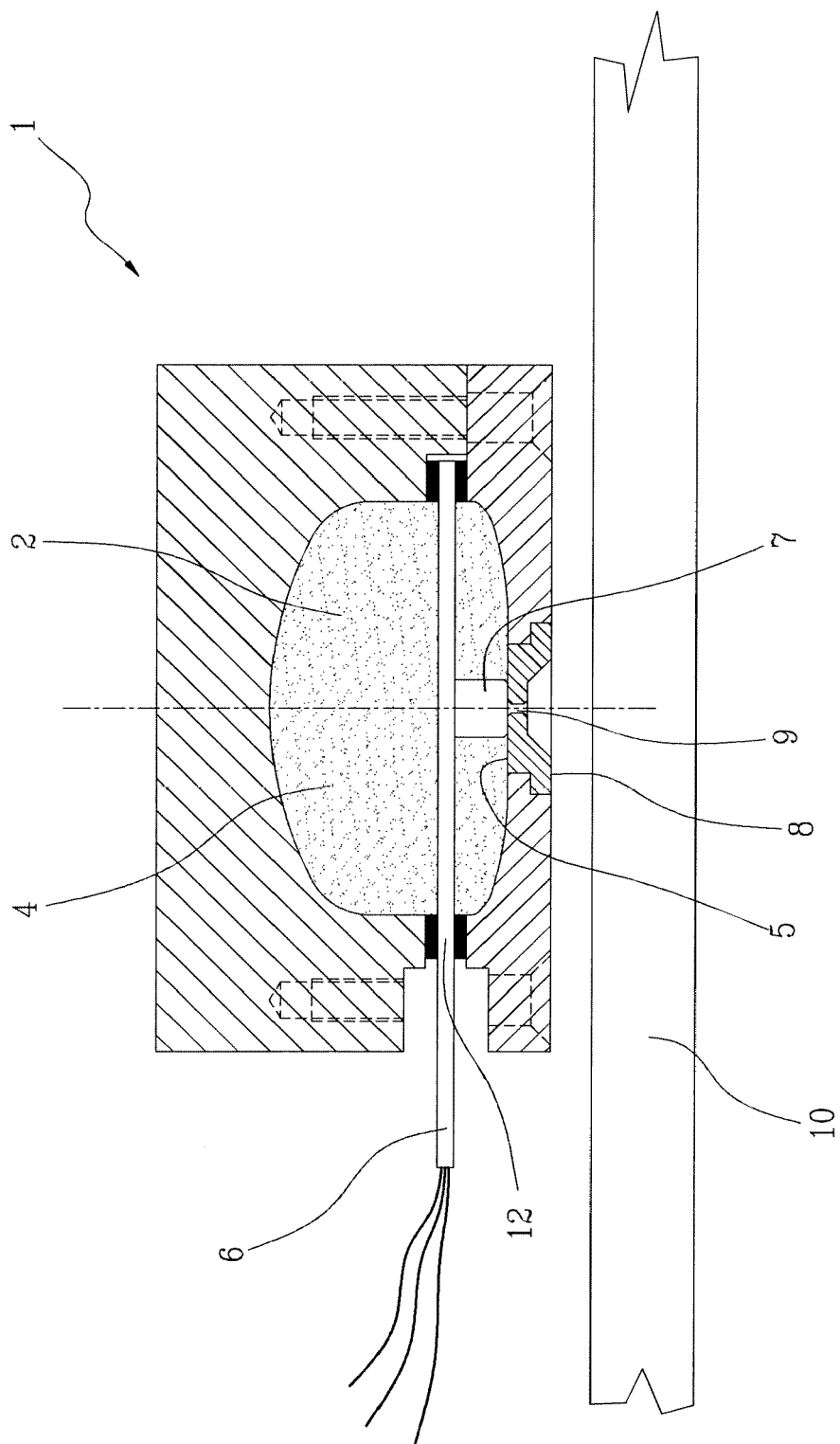
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Figure 1 (Prior Art)



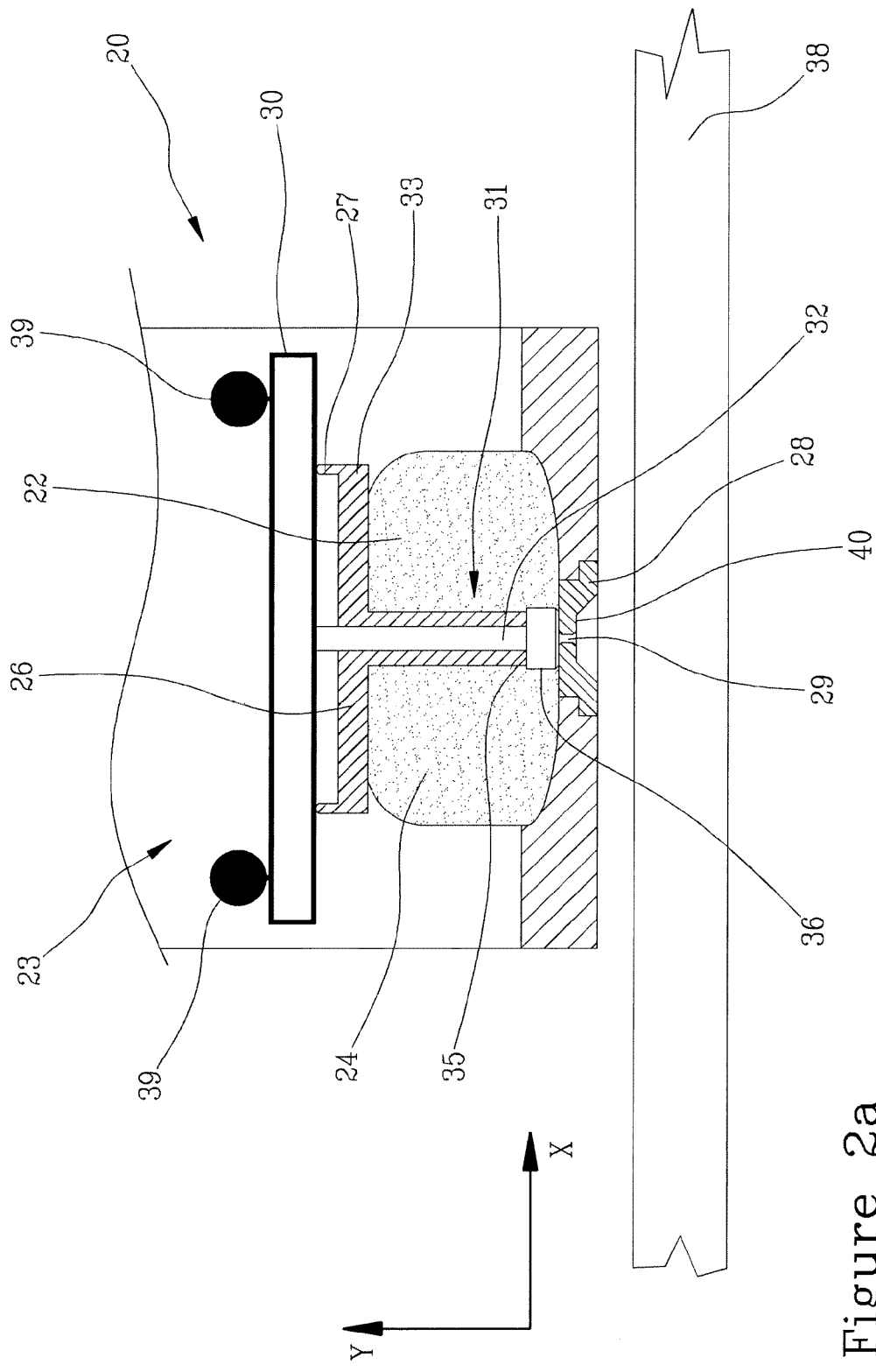


Figure 2a

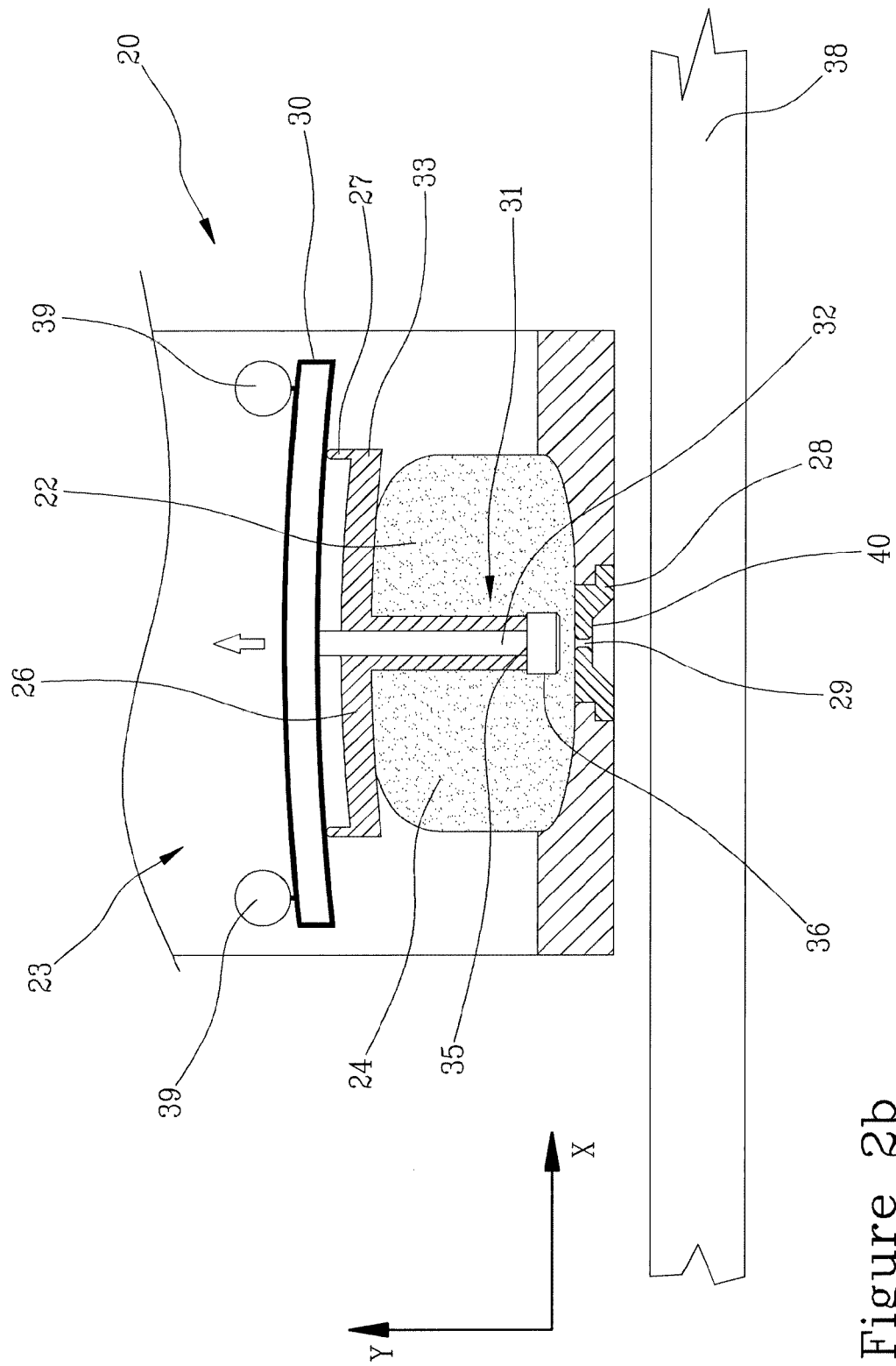


Figure 2b

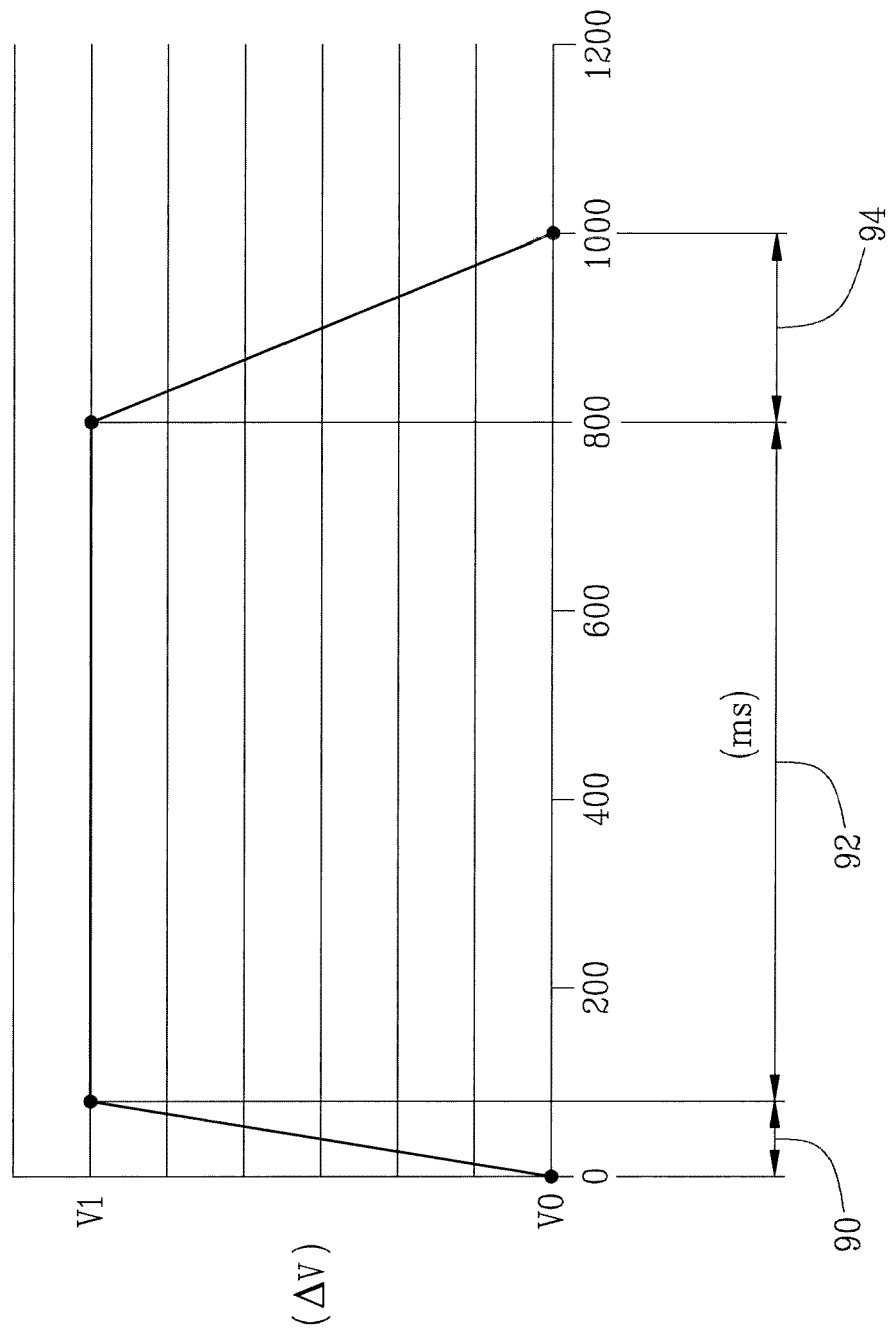


Figure 3

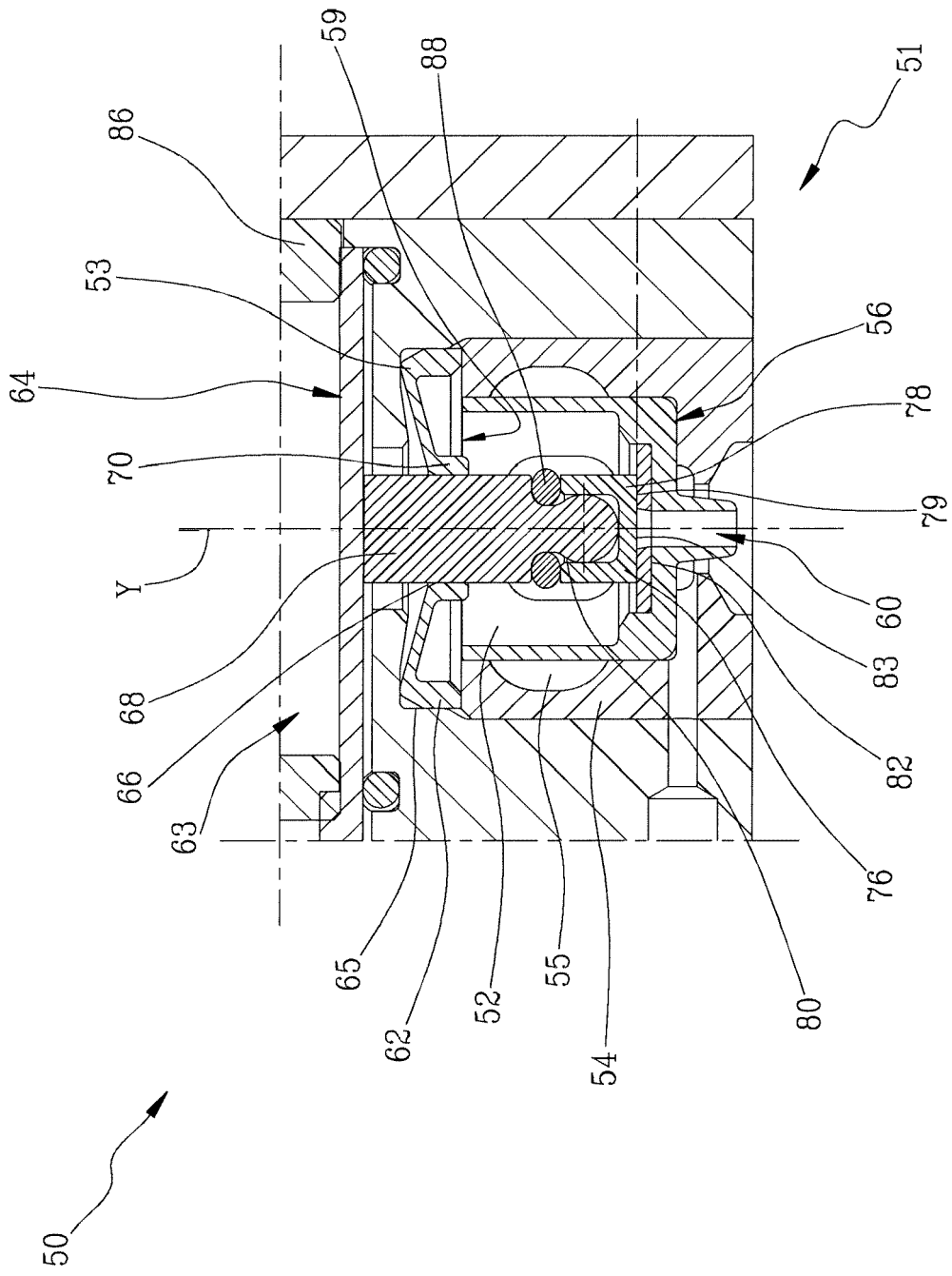


Figure 4

Figure 5a

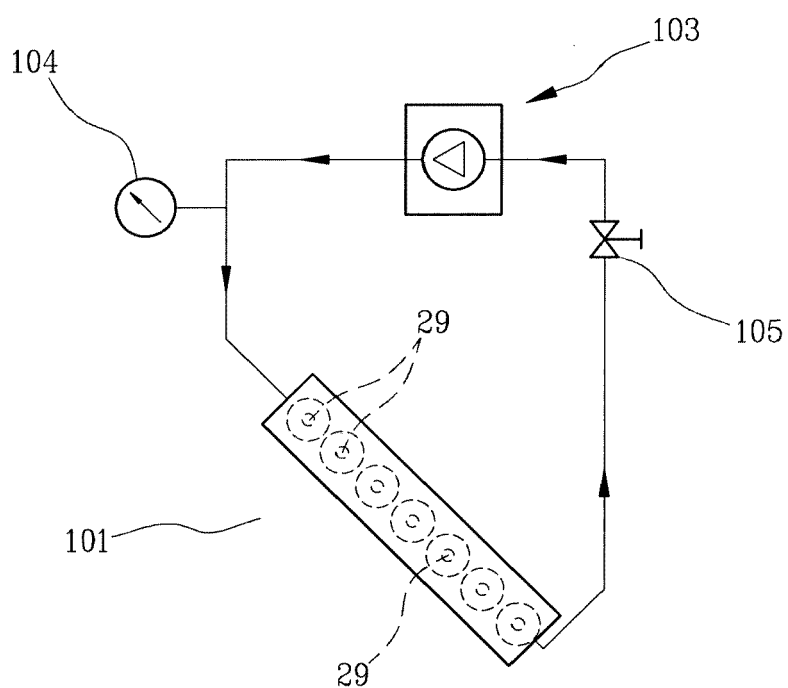
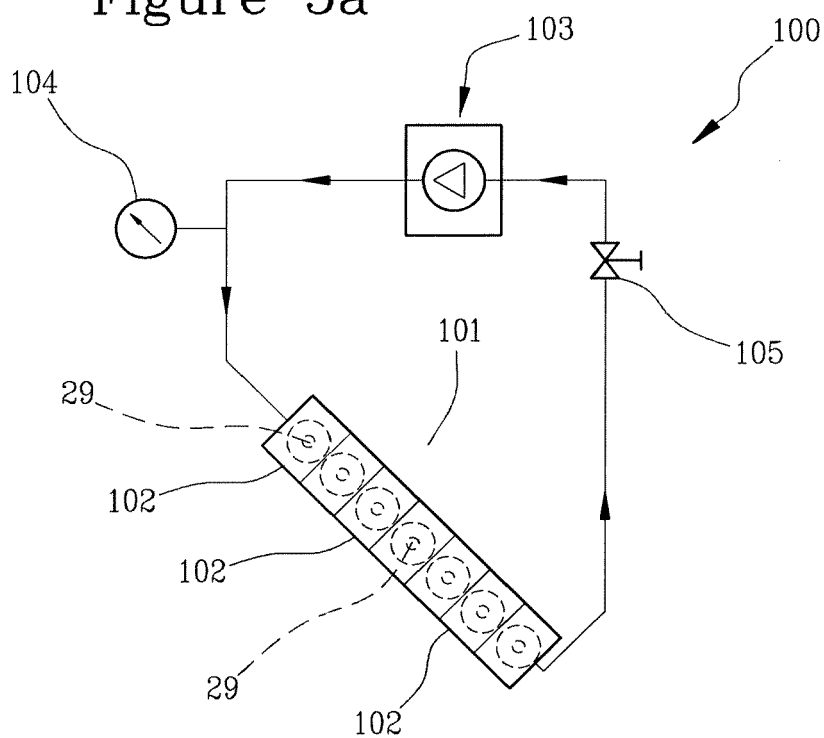


Figure 5b



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 Application Number
 EP 13 42 5119

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Place of search The Hague		Date of completion of the search 6 January 2014	Examiner Bardet, Maude
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