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(54) **ELECTROSTATICALLY ACTUATED DEVICE**

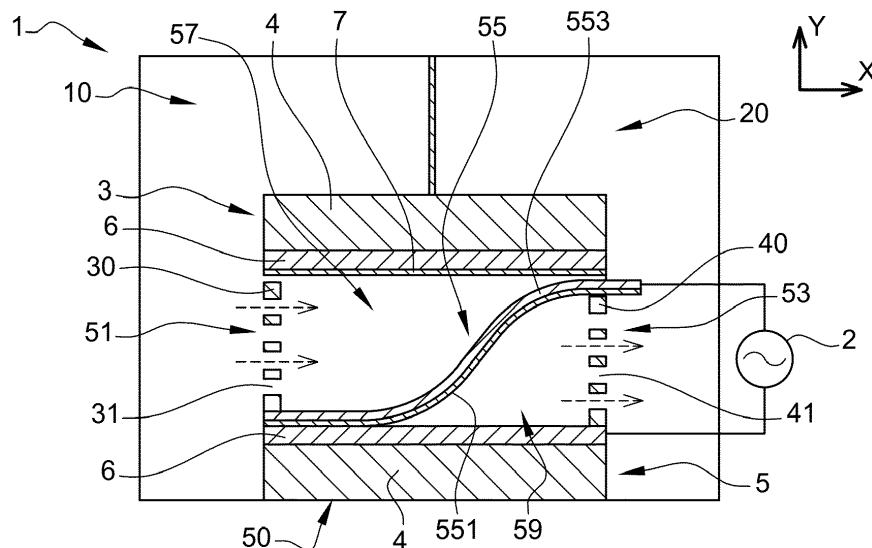
(57) The invention relates to an electrostatically actuated device (1) comprising at least one electrode chamber (50) extending along a direction of extension (X) between a first electrode chamber end (51) comprising at least one first fluid channel (31), and a second electrode chamber end (53) comprising at least one second fluid channel (41).

The at least one electrode chamber (50) comprises at least one lateral electrode (3, 5) extending laterally along the direction of extension (X), and is adapted to

receive a deformable electrode (55) configured to cooperate with the at least one lateral electrode (3, 5) such as to be actuated between at least a first position and a second position, to push reversely a volume of fluid through at least one channel chosen between the at least one first fluid channel (31), and the at least one second fluid channel (41).

The invention also relates to spectacles (S) comprising such electrostatically actuated device (1)

Fig. 1



Description

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates to the field of displacement devices for liquids. More specifically, this invention deals with electrostatics pump and precisely with electrostatics actuated devices using a membrane to displace at least one fluid.

BACKGROUND

[0002] It is known from the state of the art to use devices for displacing an amount of fluid using piezoelectric actuators for instance. The main problem raised by these concepts is that they are usually designed for continuous operations like circulating continuously small fluxes of liquids through a pipe. Therefore they are slow, and exhibit very low power efficiency, sometimes reaching a power efficiency less than 0.1. Consequently, they are not adapted to the need of the reversible pumping of a limited quantity of liquid and using low power consumption.

[0003] A recent solution described for example in EP3507644A1 suggest using a deformable electrode that may be electrostatically actuated between a first position and a second position when cooperating with an actuation electrode. By this way, a limited amount of fluid may be pushed through fluid passages intended through the actuation electrode. Although this solution allows pushing a limited volume of fluid with low power consumption, it involves using a dedicated actuation electrode structure, which can increase the manufacturing process costs. Further, the overall structure of the electrostatically actuated device presents a high complexity since the actuation function and the fluidic path function are bear by the same component: the actuation electrode.

SUMMARY OF THE INVENTION

[0004] The present invention aim at solving the aforementioned problems. To this end, the invention concerns an electrostatically actuated device comprising at least one electrode chamber; said at least one electrode chamber extending along a direction of extension between a first electrode chamber end and a second electrode chamber end, wherein:

- the first electrode chamber end comprises at least one first fluid channel emerging outwardly and configured to allow the passage of a fluid;
- the second electrode chamber end comprises at least one second fluid channel emerging outwardly configured to allow the passage of a fluid;
- the at least one electrode chamber comprises at least one lateral electrode extending laterally along the direction of extension.

[0005] The at least one electrode chamber is adapted to receive a deformable electrode, said deformable electrode being configured to cooperate with the at least one lateral electrode such as to be actuated between at least a first position and a second position.

[0006] The deformable electrode is configured to push reversely a volume of fluid through at least one channel chosen between the at least one first fluid channel, and the at least one second fluid channel when the deformable electrode is actuated between the at least first position and the second position.

[0007] The electrostatically actuated device described above make it possible to push reversely fluids contained in the electrode chamber outwardly by actuation of the deformable electrode. Such electrostatically actuated device may for example be used to control the optical power of fluid lens.

[0008] The dedicated structure of the at least one electrode chamber with at least one lateral electrode extending laterally to the direction of extension allows both to have a better control of fluid movements and to simplify the overall structure of the electrode chamber.

[0009] Indeed dissociating the actuating function of the lateral electrode and the fluidic path function of the first fluid channel and the second fluid channel facilitate the electrostatically actuated device manufacturing and assembly.

[0010] According to an embodiment, the electrostatically actuated device comprises one or more of the following features, taken alone or in combination.

[0011] According to one embodiment, the electrostatically actuated device is configured to push a limited volume only.

[0012] According to one embodiment, the electrostatically actuated device comprises a power supply configured to actuate the deformable electrode and a voltage controller configured to supply an alternative current and/or an alternative voltage from the power supply to the deformable electrode. For example, said alternative current and/or an alternative voltage is applied between the deformable electrode and the lateral electrode.

[0013] According to an embodiment, the deformable electrode is disposed in at least one electrode chamber such as to partition the at least one electrode chamber in a first electrode compartment, and a second electrode compartment.

[0014] It is well understood that the first electrode compartment and the second electrode compartment are distinct.

[0015] According to one embodiment, the first electrode compartment is fluidly isolated from the second electrode compartment. In others words, according to one embodiment, the first electrode compartment does not fluidly communicate to the second electrode compartment.

[0016] The arrangements described above make it possible to simultaneously and reversely push a volume of fluid outside from the first electrode compartment, and

to suck the same volume of fluid in the second electrode compartment when the deformable is actuated between the first position and the second position.

[0017] According to one embodiment, the deformable electrode comprises a deformable dielectric layer and at least one electroconducting portion.

[0018] Thus, this configuration allows having a displacement of the deformable electrode via an electric field.

[0019] According to an embodiment, a dimension of the at least one electrode chamber is smaller than 600 μm .

[0020] The arrangements described above make it possible to design a micrometric electrostatically actuated device, adapted to be integrated in wearable device. For example, the electrostatically actuated device is adapted to be mounted on microfluidic devices for biological applications, tests, diagnosis, medical devices. Such medical devices include contact lenses, intraocular implants but also non-optical medical devices like small electrostatically actuated devices for drug delivery of small electrostatically actuated devices for biological fluids analysis external as well as implanted in a living body.

[0021] Besides, such configuration allows having a stronger pumping pressure on the different fluids.

[0022] According to one embodiment, the dimension of the at least one electrode chamber being less than 600 μm corresponds to the dimensions separating two opposite lateral electrodes.

[0023] According to one embodiment, the electrostatically actuated device may be implemented on all apparatus where a limited amount of fluid needs to be pushed with small power consumption.

[0024] According to one embodiment, the electrostatically actuated device may be used to control the optical power of fluid lens embedded in spectacles.

[0025] According to an embodiment, the at least one lateral electrode comprises an insulating layer configured to electrically insulate at least partially the at least one lateral electrode from the deformable electrode.

[0026] Thus, is possible to avoid direct contact between the deformable electrode and the at least one lateral electrode, to suppress any short-cut issue between said deformable electrode and said lateral electrode.

[0027] According to an embodiment, the at least one electrode chamber comprises two lateral electrodes disposed opposite to each other compared to the deformable electrode.

[0028] According to an embodiment, the at least one lateral electrode comprises a printed circuit board.

[0029] The arrangements described above make it possible to reduce the industrial and manufacturing costs of the at least one lateral electrode.

[0030] According to one embodiment, the printed circuit board comprises a substrate on which a thin metallic layer is deposited to form an electrode or a plurality of conducting paths.

[0031] According to one embodiment, the thin metallic

layer comprises at least one metal chosen between copper, nickel, silver, gold, or equivalent.

[0032] According to one embodiment, the substrate comprises a metallic plate, or an epoxy glass.

[0033] According to one embodiment, the substrate comprises a polymer plate, for example a polyethylene terephthalate (PET) plate, a polytetrafluoroethylene (PTFE) plate, or equivalent.

[0034] According to one embodiment, the lateral electrode is a plate lateral electrode.

[0035] According to one embodiment, the lateral electrode comprises two opposite extremities, each extremity being provided with a conducting pad configured to be electrically connected to the power supply.

[0036] According to an embodiment, the at least one lateral electrode presents a roughness index inferior to 1 μm , and more particularly inferior to 50 nm.

[0037] Using a polished lateral electrode allows both to increase the surface capacitance to improve the actuation efficiency, and to allow broader deformation of the deformable electrode when entering in contact with the lateral electrode. It is particularly suitable with micrometric devices when a slight deformation induces a relative large fluidic displacement.

[0038] According to an embodiment, the electrostatically actuated device comprises:

- at least one first chamber comprising a first primary fluid passage; said first primary fluid passage emerging outwardly;
- at least one second chamber distinct from the at least one first chamber and comprising a second primary fluid passage; said second primary fluid passage emerging outwardly.

[0039] The at least one electrode chamber is disposed between the at least one first chamber and the at least one second chamber, the at least one first fluid channel being configured to allow the passage of a fluid between the at least one electrode chamber and the at least one first chamber, and the at least one second fluid channel is configured to allow the passage of a fluid between the at least one electrode chamber and the at least one second chamber.

[0040] According to one embodiment, the first primary fluid passage is emerging outwardly from the electrostatically actuated device.

[0041] According to one embodiment, the second primary fluid passage is emerging outwardly from the electrostatically actuated device.

[0042] According to one embodiment, the at least one electrode chamber is encapsulated between the first chamber and the second chamber.

[0043] According to an embodiment, the at least one electrode chamber comprises a first partition wall defined adjacent to the first chamber and a second partition wall defined adjacent to the second chamber, said first partition wall comprising the at least one first fluid channel,

and said second partition wall comprising the at least one second fluid channel.

[0044] According to one embodiment, a distance between the first partition wall and the second partition wall is comprised between 5 mm and 10 mm.

[0045] According to one embodiment, the first electrode compartment is delimited at least partially by the first partition wall, the deformable electrode, and the at least one lateral electrode.

[0046] According to one embodiment, the second electrode compartment is delimited at least partially by the second partition wall, the deformable electrode, and the at least one lateral electrode.

[0047] According to an embodiment, at least one partition wall chosen between the first partition wall and the second partition wall is formed by pillars disposed between the two lateral electrodes.

[0048] For example, said pillars may be formed by a polymer material deposited by any suitable manufacturing method including for example lithography, screen-printing, inkjet printing or equivalent.

[0049] According to an embodiment, the first partition wall is disposed opposite to the second partition wall compared to the deformable electrode.

[0050] According to one embodiment, the first partition wall, and the second partition wall define two transversal sides of the electrode chamber, and two opposite lateral electrodes define two lateral side of the electrode chamber.

[0051] According to one embodiment, the electrode chamber present a general shape of a parallelepiped, each of the first partition wall, the second partition wall, and the at least one lateral electrode defining a side of said parallelepiped respectively.

[0052] According to one embodiment, the electrode chamber has a cubic shape.

[0053] According to one embodiment, the electrode chamber has a rectangle parallelepiped shape.

[0054] According to one embodiment, the electrode chamber has a trapezoidal shape.

[0055] It is well understood that the fluidic evacuation or suction from the electrode chamber is realized laterally through the at least one first fluid channel and through the at least one second fluid channel. Thus, the electrostatically actuated device presents reduced fluidic response time.

[0056] According to an embodiment, the electrostatically actuated device comprises a plurality of electrode chambers, each of the first partition wall of each electrode chamber of the plurality of electrode chambers comprises at least one first fluid channel configured to allow the passage of a fluid to a unique first chamber, said first chamber being common to the plurality of electrode chambers, and each of the second partition wall of each electrode chamber of the plurality of electrode chambers comprises at least one second fluid channel configured to allow the passage of a fluid to a unique second chamber, said second chamber being common to the plurality

of electrode chambers.

[0057] According to an embodiment, the electrode chambers of the plurality of electrode chambers are stacked adjacent to each other.

5 **[0058]** According to an embodiment, each electrode chamber is stacked to any other adjacent electrode chamber along one among the at least one lateral electrode.

10 **[0059]** According to an embodiment, each electrode chamber share at least one lateral electrode with any other adjacent electrode chamber.

[0060] The arrangements described above make it possible to propose a compact electrostatically actuated device.

15 **[0061]** According to one embodiment, said shared lateral electrode comprises a plate substrate comprising two opposite plate surface covered respectively by a thin metallic layer. Thus one unique lateral electrode can act as lateral electrode for two adjacent stacked electrode chambers.

20 **[0062]** According to this embodiment, the two opposite thin metallic layers are electrically connected by at least one via provided through the plate substrate of the lateral electrode.

25 **[0063]** According to one embodiment, the two opposite thin metallic layers are electrically isolated from one another.

[0064] According to an embodiment, each deformable electrode comprised in each electrode chamber of the plurality of electrode chambers is actuated individually compared to any other deformable electrode.

30 **[0065]** The arrangements described above make it possible to tune the actuation of the electrostatically actuated device, by actuating more precisely each deformable electrode.

35 **[0066]** According to an embodiment, the plurality of electrode chambers comprises a first electrode chamber delimiting a primary internal volume and a second electrode chamber delimiting a secondary internal volume, said primary internal volume being strictly different from said secondary internal volume.

[0067] In other words, the internal volume of each electrode chamber of the plurality of electrode chambers varies.

45 **[0068]** Advantageously, the electrostatically actuated device comprises electrode chambers with different internal volumes. Thus, it is possible to actuate independently each electrode chamber to push reversely an adapted volume of fluid.

50 **[0069]** According to one embodiment, a distance between the first partition wall and the second partition wall of one electrode chamber varies compared to a distance between the first partition wall and the second partition wall of another electrode chamber.

55 **[0070]** According to one embodiment, a distance between two lateral electrodes of one electrode chamber varies compared to a distance between two lateral electrodes of another electrode chamber.

[0071] According to one embodiment, the first electrode compartment delimits a first volume and the second electrode compartment delimits a second volume; the first volume and the second volume are controlled by a capacitance measurement.

[0072] Thus, this configuration allows the control of the first volume and/or of the second volume by a capacitance measurement more exactly by measuring the frequency of a relaxation oscillator, which depends on the capacitance for example.

[0073] The object of the invention may also be achieved by implementing spectacles comprising an electrostatically actuated device according to one of the embodiments described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0074] The foregoing and other purposes, features, aspects and advantages of the invention will become apparent from the following detailed description of embodiments, given by way of illustration and not limitation with reference to the accompanying drawings, in which the same reference refer to similar elements or to elements having similar functions, and in which:

Figure 1 represents a sectional view of an electrostatically actuated device comprising a unique electrode chamber according to a first embodiment.

Figure 2 represents two perspective views of an electrostatically actuated device showing the first and second primary fluid passages.

Figure 3 represents a perspective view of an electrode chamber comprising pillars.

Figure 4 represents a sectional view of an electrostatically actuated device comprising three electrode chambers according to a second embodiment.

Figure 5 represents a sectional view of an electrostatically actuated device comprising four electrode chambers according to a third embodiment.

Figure 6 represents a perspective view of spectacles comprising two electrostatically actuated devices according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0075] In the figures and in the remainder of the description, the same references represent identical or similar elements. In addition, the various elements are not represented to scale so as to favor the clarity of the figures. Furthermore, the different embodiments and variants are not mutually exclusive and can be combined with one another.

[0076] As illustrated on figures 1 to 6, the invention concerns an electrostatically actuated device 1, which may be used to control the optical power of fluid lens. More generally, the electrostatically actuated device 1 may be implemented on all apparatus where a limited amount of fluid needs to be pushed with small power

consumption. The invention also concerns spectacles S comprising said electrostatically actuated device 1.

[0077] As shown in figure 1, the electrostatically actuated device 1 comprises at least one electrode chamber 50, extending along a direction of extension X between a first electrode chamber end 51 and a second electrode chamber end 53. The first electrode chamber end 51 comprises at least one first fluid channel 31 emerging outwardly and configured to allow the passage of a fluid, for example a first fluid. The second electrode chamber end 53 comprises at least one second fluid channel 41 emerging outwardly configured to allow the passage of a fluid, for example a second fluid.

[0078] The electrostatically actuated device 1 may also comprise at least one first chamber 10, and at least one second chamber 20 distinct from the at least one first chamber 10. the at least one electrode chamber 50 being disposed between the at least one first chamber 10 and the at least one second chamber 20 so that the at least one electrode chamber 50 is encapsulated between the first chamber 10 and the second chamber 20. Consequently, the at least one first fluid channel 31 is configured to allow the passage of the first fluid between the at least one electrode chamber 50 and the at least one first chamber 10, and the at least one second fluid channel 41 is configured to allow the passage of the second fluid between the at least one electrode chamber 50 and the at least one second chamber 20. As illustrated in figure 2, the at least one first chamber 10 may then comprise a first primary fluid passage 12 emerging outwardly from the electrostatically actuated device 1, and said at least one second chamber 20 may comprise a second primary fluid passage 14 emerging outwardly from the electrostatically actuated device 1.

[0079] The at least one electrode chamber 50 also comprises at least one lateral electrode 3, 5 extending laterally along the direction of extension X. Figure 1 illustrate an embodiment where the electrostatically actuated device 1 comprises one first lateral electrode 3, and a second lateral electrode 5. Besides, the electrode chamber 50 may comprises longitudinal walls extending longitudinally to the electrode chamber 50 along the direction of extension X.

[0080] The at least one electrode chamber 50 may also include a first partition wall 30 defined adjacent to the first chamber 10 and a second partition wall 40 defined adjacent to the second chamber 20. According to the embodiment illustrated on figure 1, the first partition wall 30 is disposed at the first electrode chamber end 51, and the second partition wall 40 is disposed at the second electrode chamber end 53. Thus, the first partition wall 30 is disposed opposite to the second partition wall 40 compared to the deformable electrode 55. Consequently, the first partition wall 30 can comprise the at least one first fluid channel 31, and the second partition wall 40 can comprise the at least one second fluid channel 41. According to a first variant, a distance between the first partition wall 30 and the second partition wall 40 is com-

prised between 5 mm and 10 mm.

[0081] As illustrated on figure 3, at least one partition wall chosen between the first partition wall 30 and the second partition wall 40 is formed by pillars disposed between the two lateral electrodes 3, 5. For example, said pillars may be formed by a polymer material deposited by any suitable manufacturing method including for example lithography, screen-printing, inkjet printing or equivalent.

[0082] According to one embodiment, the electrode chamber 50 presents a general shape of a parallelepiped, for example presenting a cubic shape, a rectangle parallelepiped shape, or a trapezoidal shape. Each of the first partition wall 30, the second partition wall 40, the longitudinal walls, and the at least one lateral electrode 3, 5 defining a side of said parallelepiped respectively. The first partition wall 30 and the second partition wall 40 can define two transversal sides of the electrode chamber 50, and two opposite lateral electrodes 3, 5 may define two lateral sides of the electrode chamber 50. In the variant represented on figure 1, the first partition wall 30 and the second partition wall 40 are extending substantially parallel with respect to each other, and substantially perpendicular to the direction of extension X. Besides, the first lateral electrode 3 and the second lateral electrode 5 are extending substantially parallel with respect to each other, and substantially perpendicular to a transversal direction Y defined perpendicular to the direction of extension X. Advantageously, a dimension of the at least one electrode chamber 50 may be smaller than 600 μm . Particularly, the dimension of the at least one electrode chamber being less than 600 μm may correspond to the dimension separating two opposite lateral electrodes 3, 5.

[0083] As illustrated on figure 1, each lateral electrode 3, 5 is a plate lateral electrode 3, 5, and can comprise a printed circuit board. Thus it is possible to reduce the industrial and manufacturing costs of the at least one lateral electrode 3, 5. Said printed circuit board may comprise a substrate 4 on which a thin metallic layer 6 is deposited to form an electrode or a plurality of conducting paths. For example, the substrate 4 comprises a metallic plate, an epoxy glass, or a polymer plate, such as polyethylene terephthalate (PET), polytetrafluoroethylene (PTFE), or equivalent. The thin metallic layer 6 can comprise at least one metal chosen between copper, nickel, silver, gold, or equivalent. Advantageously, the at least one lateral electrode 3, 5 can present a roughness index inferior to 1 μm , and more particularly inferior to 50 nm. In other words, the at least one lateral electrode 3, 5 may present an active surface, directed towards the interior of the electrode chamber 50, said active surface presenting a roughness inferior to 1 μm and more particularly inferior to 50 nm.

[0084] The at least one electrode chamber 50 is further adapted to receive a deformable electrode 55. According to one embodiment, the deformable electrode 55 is disposed in at least one electrode chamber 50 such as to

partition said at least one electrode chamber 50 in a first electrode compartment 57, and a second electrode compartment 59. It is well understood that the first electrode compartment 57 and the second electrode compartment 59 are distinct. Advantageously, the first electrode compartment 57 is fluidly isolated from the second electrode compartment 59. In other words, the first electrode compartment 57 does not fluidly communicate to the second electrode compartment 59. The first electrode compartment 57 is then delimited at least partially by the first partition wall 30, the deformable electrode 55, and the at least one lateral electrode 3, 5. The second electrode compartment 59 is delimited at least partially by the second partition wall 40, the deformable electrode 55, and the at least one lateral electrode 3, 5.

[0085] The deformable electrode 55 is configured to cooperate with the at least one lateral electrode 3, 5 such as to be actuated between at least a first position and a second position. By this way, the deformable electrode 55 is able to push reversely a volume of fluid through at least one channel chosen between the at least one first fluid channel 31, and the at least one second fluid channel 41 when the deformable electrode 55 is actuated between the at least first position and the second position. To perform such actuation, the electrostatically actuated device 1 comprises a power supply 2 configured to actuate the deformable electrode 55 and a voltage controller configured to supply an alternative current and/or an alternative voltage from the power supply 2 to the deformable electrode 55. In the particular embodiment illustrated on figure 1, the electrode chamber 50 comprises two lateral electrodes 3, 5 disposed opposite to each other compared to the deformable electrode 55. For example, each lateral electrode 3, 5 can comprise two opposite extremities being provided respectively with a conducting pad configured to be electrically connected to the power supply 2. The arrangements described above make it possible to simultaneously and reversely push a volume of fluid outside from the first electrode compartment 57, and to suck the same volume of fluid in the second electrode compartment 59 when the deformable is actuated between the first position and the second position. According to one embodiment, the first electrode compartment 57 may delimit a first volume and the second electrode compartment 59 may delimit a second volume. According to this embodiment the first volume and the second volume may be controlled by a capacitance measurement. Thus, this configuration allows the control of the first volume and/or of the second volume by a capacitance measurement more exactly by measuring the frequency of a relaxation oscillator, which depends on the capacitance for example.

[0086] The actuation of the deformable electrode 55 to push a volume of fluid is for example implemented according to the embodiments described in EP3507644A1, which is hereby incorporated by reference to the maximum extent allowable by law. The dotted arrows illustrated in figure 1 illustrate an example of

movement of the first fluid and the second fluid when the deformable electrode 55 is actuated between the first position and the second position. In is indeed possible that said first fluid and said second fluid are push in the opposite direction when the deformable electrode 55 is actuated in the other direction too.

[0087] The configurations described above allows having a stronger pumping pressure on the different fluids. It is well understood that the fluidic evacuation or suction from the electrode chamber 50 is realized laterally through the at least one first fluid channel 31 and through the at least one second fluid channel 41. Thus, the electrostatically actuated device 1 presents reduced fluidic response time.

[0088] Advantageously, the deformable electrode 55 can comprise a deformable dielectric layer 551 and at least one electroconducting portion 553. Thus, this configuration allows having a displacement of the deformable electrode 55 via an electric field.

[0089] As stated before, the lateral electrode 3, 5 may present a roughness inferior to $1\mu\text{m}$ or inferior to 50 nm. Thus, using a polished lateral electrode 3, 5 allows both to increase the surface capacitance to improve the actuation efficiency, and to allow broader deformation of the deformable electrode 55 when entering in contact with the lateral electrode 3, 5. It is particularly suitable with micrometric devices when a slight deformation induces a relative large fluidic displacement.

[0090] Generally, the at least one lateral electrode 3, 5 comprises an insulating layer 7 configured to electrically insulate at least partially the at least one lateral electrode 3, 5 from the deformable electrode 55. Thus, is possible to avoid direct contact between the deformable electrode 55 and the at least one lateral electrode 3, 5, to suppress any short-cut issue between said deformable electrode 55 and said lateral electrode 3, 5.

[0091] The electrostatically actuated device 1 described above make it possible to push reversely fluids contained in the electrode chamber 50 outwardly by actuation of the deformable electrode 55. For example, the electrostatically actuated device 1 may be configured to push a limited volume only. Such electrostatically actuated device 1 may for example be used to control the optical power of fluid lens. The dedicated structure of the at least one electrode chamber 50 with at least one lateral electrode 3, 5 extending laterally to the direction of extension X allows both to have a better control of fluid movements and to simplify the overall structure of the electrode chamber 50. Indeed dissociating the actuating function of the lateral electrode 3, 5 and the fluidic path function of the first fluid channel 31 and the second fluid channel 41 facilitate the electrostatically actuated device 1 manufacturing and assembly.

[0092] The small dimension of the overall device make it possible to design a micrometric electrostatically actuated device 1, adapted to be integrated in wearable device. For example, the electrostatically actuated device 1 is adapted to be mounted on microfluidic devices for

biological applications, tests, diagnosis, medical devices. Such medical devices include contact lenses, intraocular implants but also non-optical medical devices like small electrostatically actuated devices for drug delivery of small electrostatically actuated devices for biological fluids analysis external as well as implanted in a living body.

[0093] According to another embodiment illustrated in figure 4 and 5, the electrostatically actuated device 1 can comprise a plurality of electrode chambers 50. Each of the first partition wall 30 of each electrode chamber 50 of the plurality of electrode chambers 50 comprises at least one first fluid channel 31 configured to allow the passage of a fluid to a unique first chamber 10, said first chamber 10 being common to the plurality of electrode chambers 50. Analogously, each of the second partition wall 40 of each electrode chamber 50 of the plurality of electrode chambers 50 comprises at least one second fluid channel 41 configured to allow the passage of a fluid to a unique second chamber 20, said second chamber 20 being common to the plurality of electrode chambers 50. Advantageously, the electrode chambers 50 of the plurality of electrode chambers 50 are stacked adjacent to each other for example along one among the at least one lateral electrode 3, 5. The arrangements described above make it possible to propose a compact electrostatically actuated device 1.

[0094] On the particular embodiment illustrated on figure 5, each electrode chamber 50 share at least one lateral electrode 3, 5 with any other adjacent electrode chamber 50. Consequently, a first electrode chamber 50a comprises an upper lateral electrode 3a and a lower lateral electrode 5a. A second electrode chamber 50b, adjacent to the first electrode chamber 50a comprises an upper lateral electrode 3b common with the lower lateral electrode 5a. Said shared lateral electrode 3b, 5a comprises a plate substrate 4 comprising two opposite plate surface covered respectively by a thin metallic layer 6. Thus, one unique lateral electrode 3b, 5a can act as lateral electrode 3b, 5a for two adjacent stacked electrode chambers 50a, 50b. A corresponding stacking structure may be implemented between the second electrode chamber 50b and a third electrode chamber 50c by sharing the upper lateral electrode 3c of the third electrode chamber 50c and the lower lateral electrode 5b of the second electrode chamber 50b. Finally, an analogous stacking structure may be implemented between the third electrode chamber 50c and a fourth electrode chamber 50d by sharing the upper lateral electrode 3d of the fourth electrode chamber 50d and the lower lateral electrode 5c of the third electrode chamber 50c. According to one embodiment, the two opposite thin metallic layers 6 of one shared lateral electrode 3, 5 may be electrically connected by at least one via provided through the plate substrate 4 of the lateral electrode 3, 5.

[0095] Advantageously, each deformable electrode 55a-d comprised in each electrode chamber 50 of the plurality of electrode chambers 50 is actuated individually compared to any other deformable electrode 55. The ar-

rangements described above make it possible to tune the actuation of the electrostatically actuated device 1, by actuating more precisely each deformable electrode 55.

[0096] Moreover, when the plurality of electrode chambers 50 comprises a first electrode chamber 50a, and a second electrode chamber 50b, it can be intended that said first electrode chamber 50a delimit a primary internal volume and that the second electrode chamber 50b delimit a secondary internal volume being strictly different from said primary internal volume. In other words, the internal volume of each electrode chamber 50 of the plurality of electrode chambers 50 may vary. Thus, when the electrostatically actuated device 1 comprises electrode chambers 50 with different internal volume, it is possible to actuate independently each electrode chamber 50 to push reversely an adapted volume of fluid. In order to tune the internal volume of each electrode chamber 50, a distance between the first partition wall 30 and the second partition wall 40 of one first electrode chamber 50a may vary compared to a distance between the first partition wall 30 and the second partition wall 40 of another electrode chamber 50, for example the second electrode chamber 50b. Simultaneously or not, a distance between two lateral electrodes 3, 5 of one electrode chamber 50 may vary compared to a distance between two lateral electrodes 3, 5 of another electrode chamber 50, to tune the internal volume of each electrode chamber 50.

Claims

1. Electrostatically actuated device (1) comprising at least one electrode chamber (50); said at least one electrode chamber (50) extending along a direction of extension (X) between a first electrode chamber end (51) and a second electrode chamber end (53), wherein:

- the first electrode chamber end (51) comprises at least one first fluid channel (31) emerging outwardly and configured to allow the passage of a fluid;

- the second electrode chamber end (53) comprises at least one second fluid channel (41) emerging outwardly configured to allow the passage of a fluid;

- the at least one electrode chamber (50) comprises at least one lateral electrode (3, 5) extending laterally along the direction of extension (X);

the at least one electrode chamber (50) being adapted to receive a deformable electrode (55), said deformable electrode (55) being configured to cooperate with the at least one lateral electrode (3, 5) such as to be actuated between at least a first position and a second position;

said deformable electrode (55) being configured to push reversely a volume of fluid through at least one channel chosen between the at least one first fluid channel (31), and the at least one second fluid channel (41) when the deformable electrode (55) is actuated between the at least first position and the second position.

2. Electrostatically actuated device (1) according to claim 1, wherein the deformable electrode (55) is disposed in at least one electrode chamber (50) such as to partition the at least one electrode chamber (50) in a first electrode compartment (57), and a second electrode compartment (59).

3. Electrostatically actuated device (1) according to any of the claims 1 or 2, wherein a dimension of the at least one electrode chamber (50) is smaller than 600 μm .

4. Electrostatically actuated device (1) according to any of the claims 1 to 3, wherein the at least one lateral electrode (3, 5) comprises an insulating layer (7) configured to electrically insulate at least partially the at least one lateral electrode (3, 5) from the deformable electrode (55).

5. Electrostatically actuated device (1) according to any of the claims 1 to 4, wherein the at least one electrode chamber (50) comprises two lateral electrodes (3, 5) disposed opposite to each other compared to the deformable electrode (55).

6. Electrostatically actuated device (1) according to any of the claims 1 to 5, wherein the at least one lateral electrode (3, 5) comprises a printed circuit board.

7. Electrostatically actuated device (1) according to claim 6, wherein the at least one lateral electrode (3, 5) presents a roughness index inferior to $1\mu\text{m}$, and more particularly inferior to 50nm.

8. Electrostatically actuated device (1) according to any of the claims 1 to 7, comprising:

- at least one first chamber (10) comprising a first primary fluid passage (12); said first primary fluid passage (12) emerging outwardly;

- at least one second chamber (20) distinct from the at least one first chamber (10) and comprising a second primary fluid passage (14); said second primary fluid passage (14) emerging outwardly;

the at least one electrode chamber (50) being disposed between the at least one first chamber (10) and the at least one second chamber (20), the at least one first fluid channel (31) being configured to

allow the passage of a fluid between the at least one electrode chamber (50) and the at least one first chamber (10), and the at least one second fluid channel (41) being configured to allow the passage of a fluid between the at least one electrode chamber (50) and the at least one second chamber (20).

9. Electrostatically actuated device (1) according to claim 8, wherein the at least one electrode chamber (50) comprises a first partition wall (30) defined adjacent to the first chamber (10) and a second partition wall (40) defined adjacent to the second chamber (20), said first partition wall (30) comprising the at least one first fluid channel (31), and said second partition wall (40) comprising the at least one second fluid channel (41).
10. Electrostatically actuated device (1) according to claims 5 and 9, wherein at least one partition wall chosen between the first partition wall (30) and the second partition wall (40) is formed by pillars disposed between the two lateral electrodes (3, 5).
11. Electrostatically actuated device (1) according to any of the claims 9 or 10, wherein the first partition wall (30) is disposed opposite to the second partition wall (40) compared to the deformable electrode (55).
12. Electrostatically actuated device (1) according to any of the claims 9 a 11, comprising a plurality of electrode chambers (50), each of the first partition wall (30) of each electrode chamber (50) of the plurality of electrode chambers (50) comprises at least one first fluid channel (31) configured to allow the passage of a fluid to a unique first chamber (10), said first chamber (10) being common to the plurality of electrode chambers (50), and wherein each of the second partition wall (40) of each electrode chamber (50) of the plurality of electrode chambers (50) comprises at least one second fluid channel (41) configured to allow the passage of a fluid to a unique second chamber (20), said second chamber (20) being common to the plurality of electrode chambers (50).
13. Electrostatically actuated device (1) according to claim 12, wherein the electrode chambers (50) of the plurality of electrode chambers (50) are stacked adjacent to each other.
14. Electrostatically actuated device (1) according to claim 13, wherein each electrode chamber (50) is stacked to any other adjacent electrode chamber (50) along one among the at least one lateral electrode (3, 5).
15. Electrostatically actuated device (1) according to any of the claims 12 to 14, wherein each electrode chamber (50) share at least one lateral electrode (3, 5)

with any other adjacent electrode chamber (50).

16. Electrostatically actuated device (1) according to any of the claims 12 to 15, wherein each deformable electrode (55) comprised in each electrode chamber (50) of the plurality of electrode chambers (50) is actuated individually compared to any other deformable electrode (55).
17. Electrostatically actuated device (1) according to 12 to 16, wherein the plurality of electrode chambers (50) comprises a first electrode chamber (50a) delimiting a primary internal volume and a second electrode chamber (50b) delimiting a secondary internal volume, said primary internal volume being strictly different from said secondary internal volume.
18. Spectacles (S) comprising an electrostatically actuated device (1) according to any of the claims 1 to 17.

Fig. 1

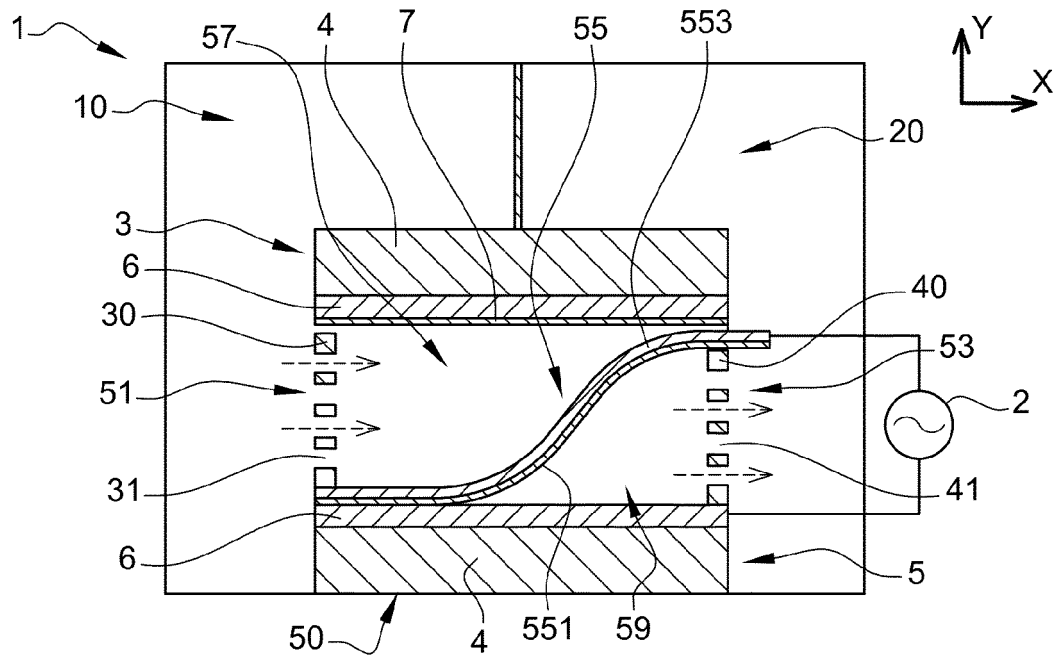


Fig. 2

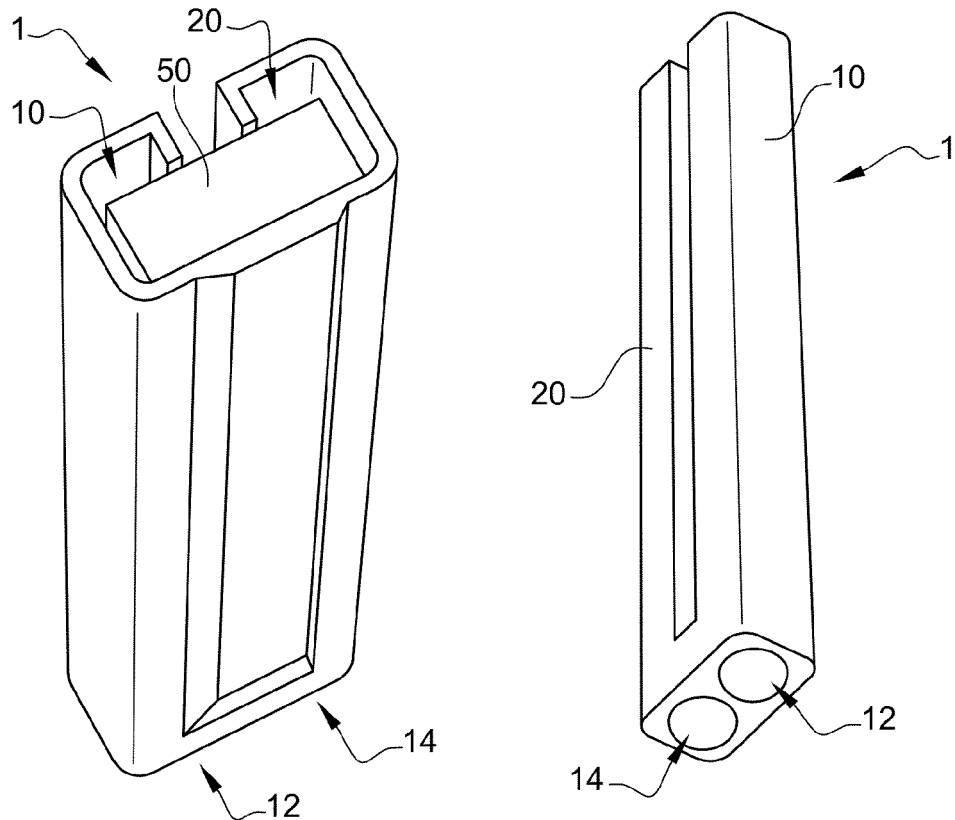


Fig. 3

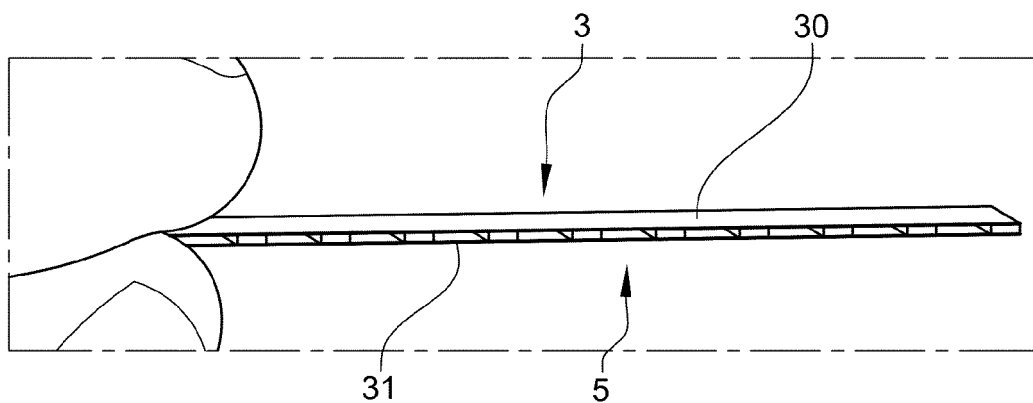


Fig. 4

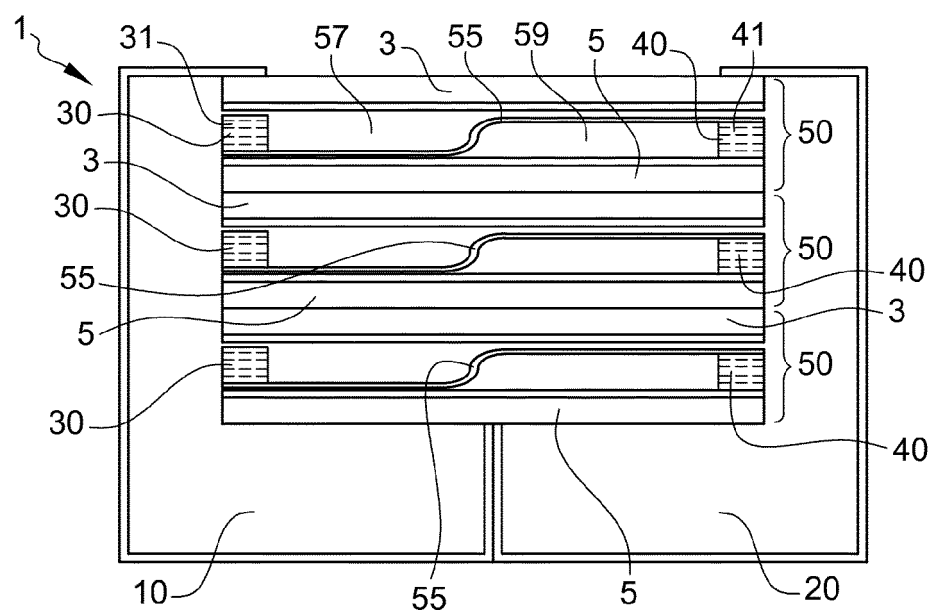


Fig. 5

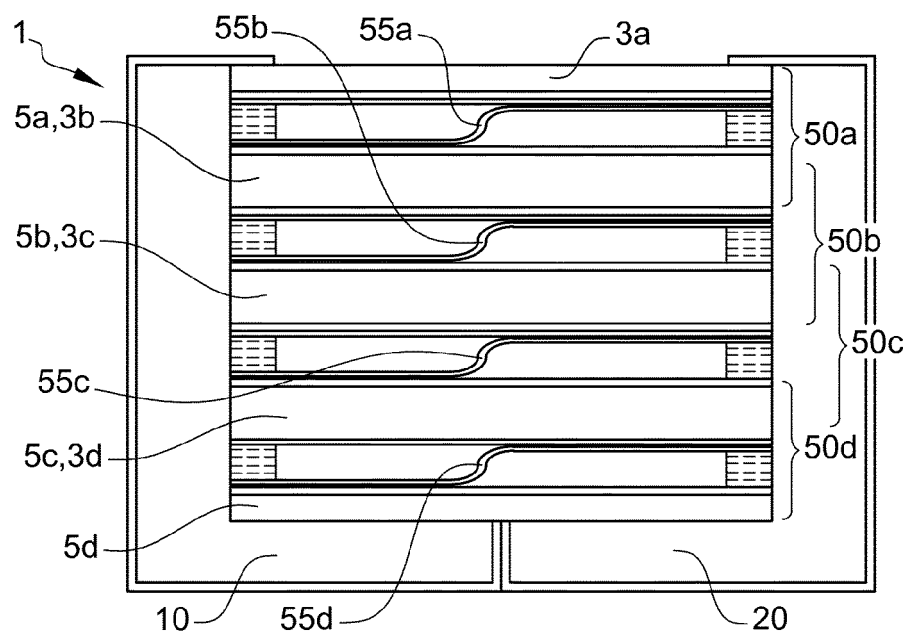
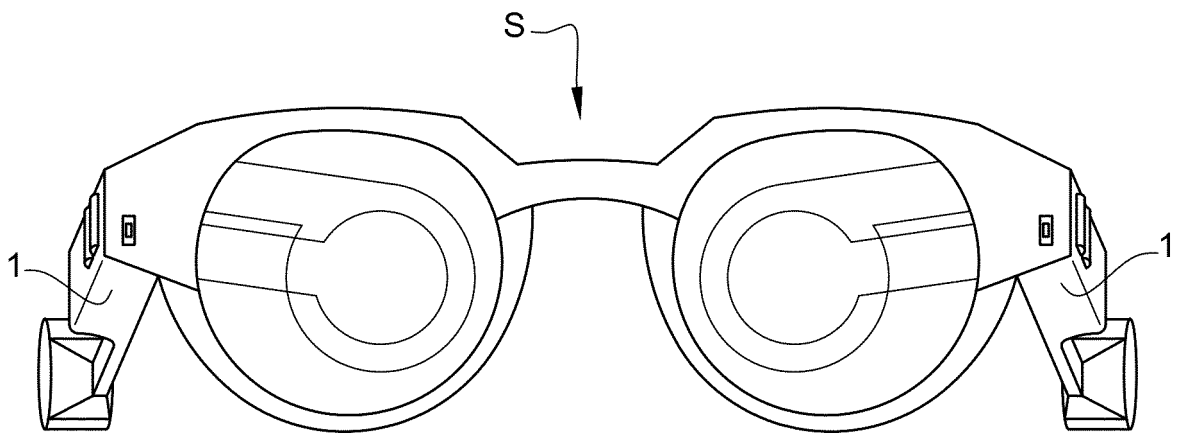


Fig. 6





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