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(54) MICROFLUIDIC VALVE WITH PARTIALLY RESTRAINED ELEMENT

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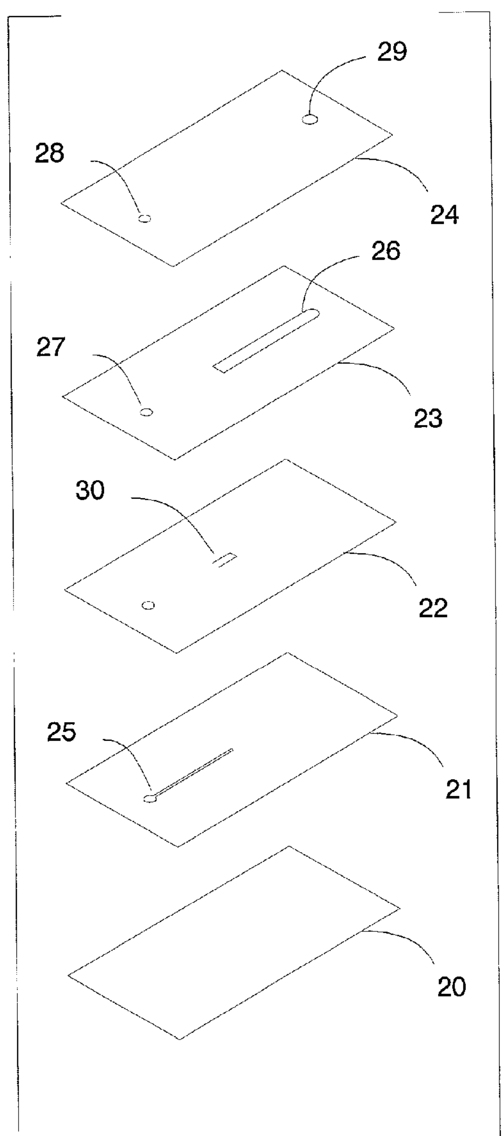
(57) **ABSTRACT**

The invention provides microfluidic devices having valves disposed therein. The valves can be configured as one-way valves. The invention also provides microfluidic pumps using two or more microfluidic valves. The valves can be configured to rest in an open or closed position. The valves also can be single use valves or can be multiple use valves. The valves may be further responsive to actuators, including electromechanical and magnetic actuators.



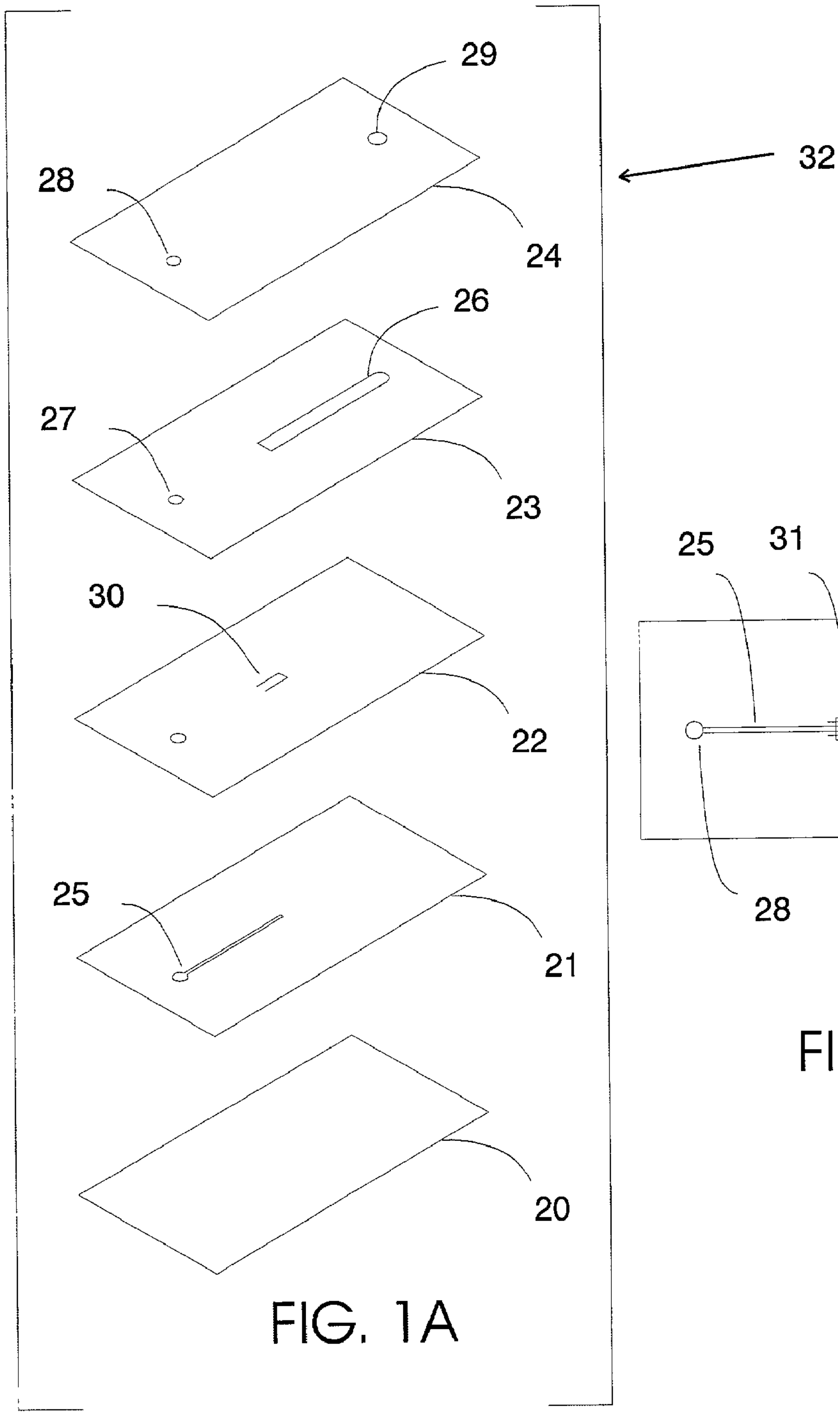


FIG. 1A

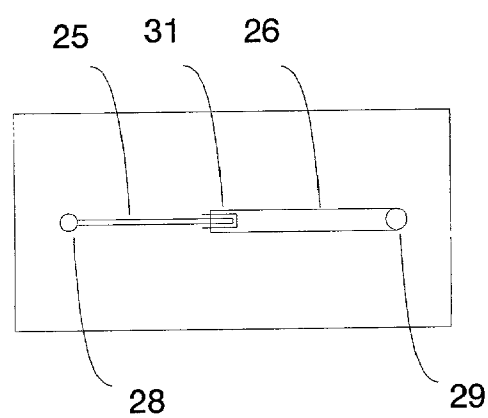


FIG. 1B

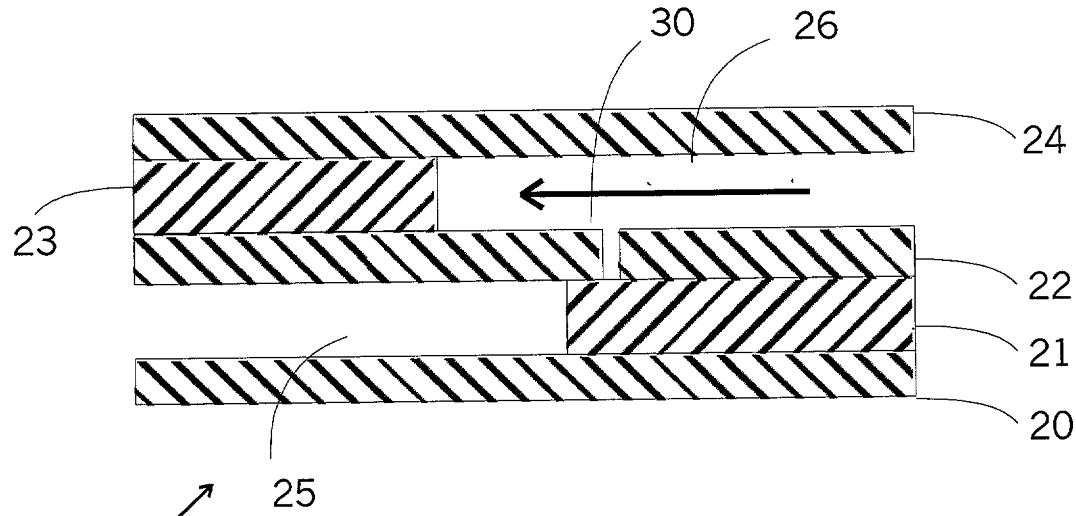


FIG. 1C

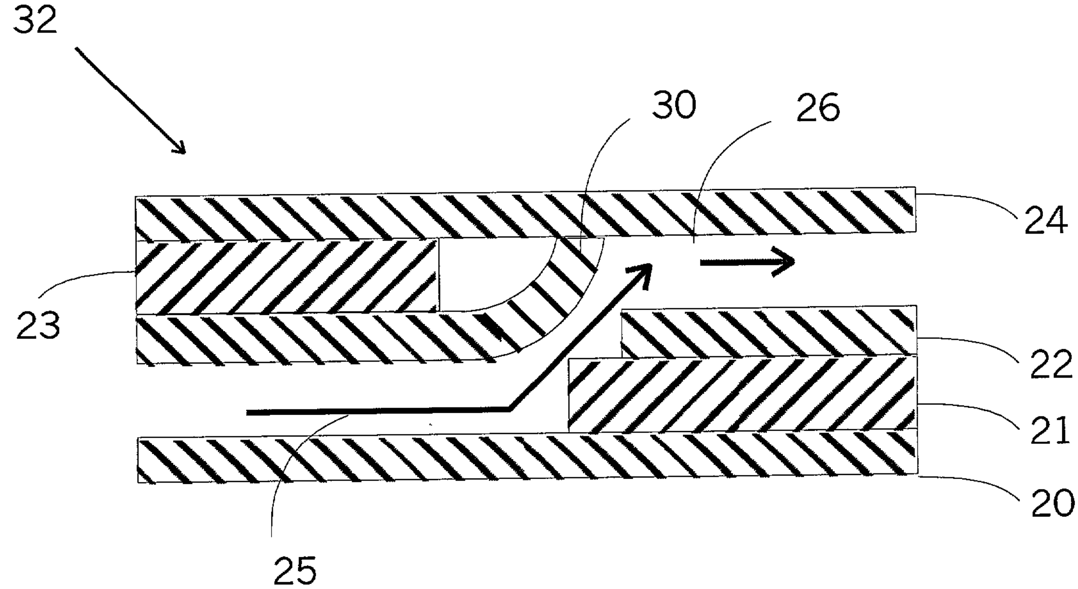


FIG. 1D

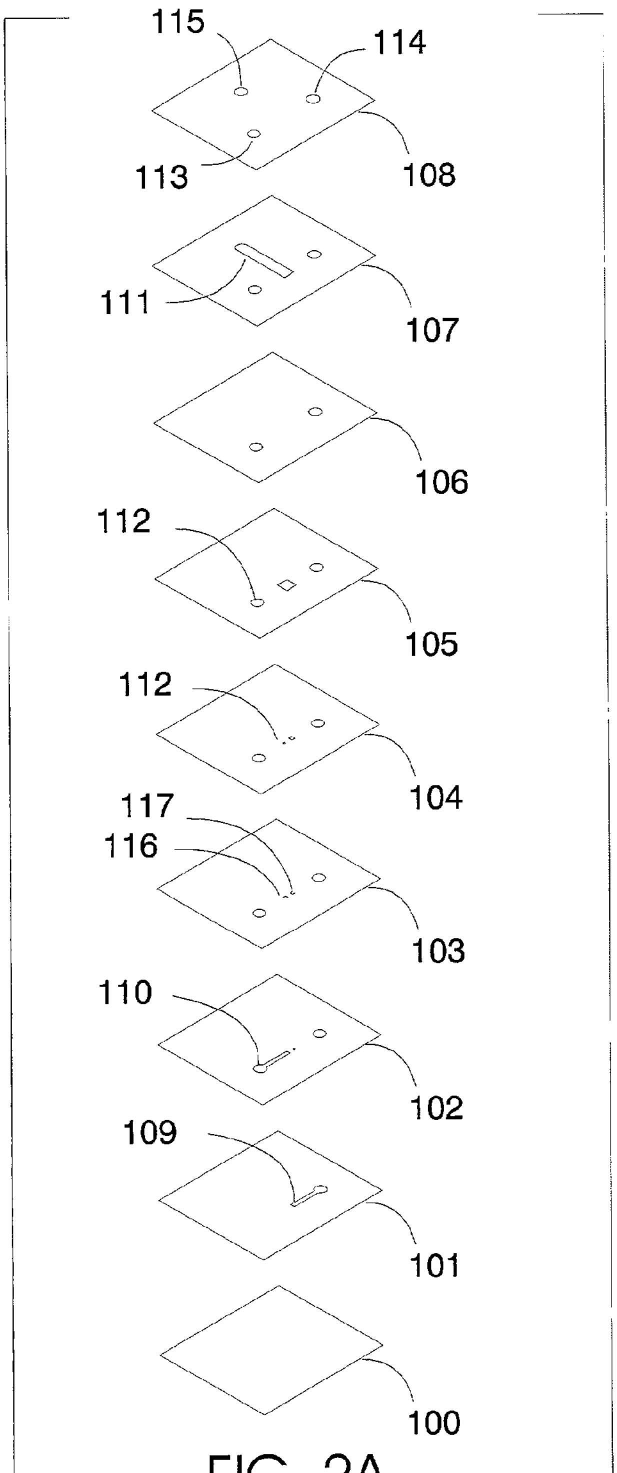

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FIG. 2A

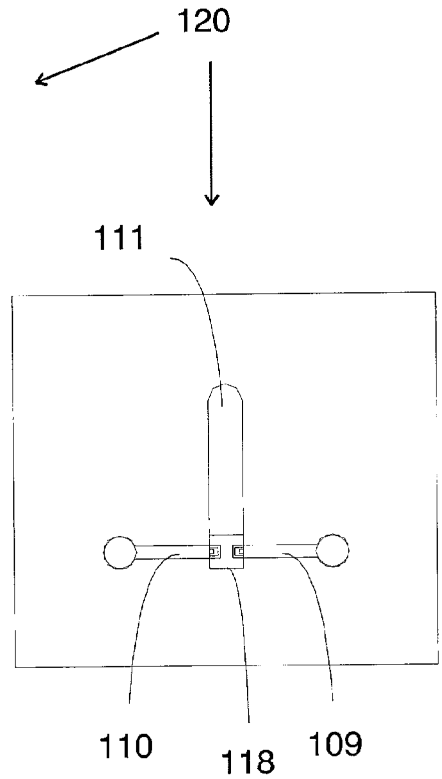
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FIG. 2B

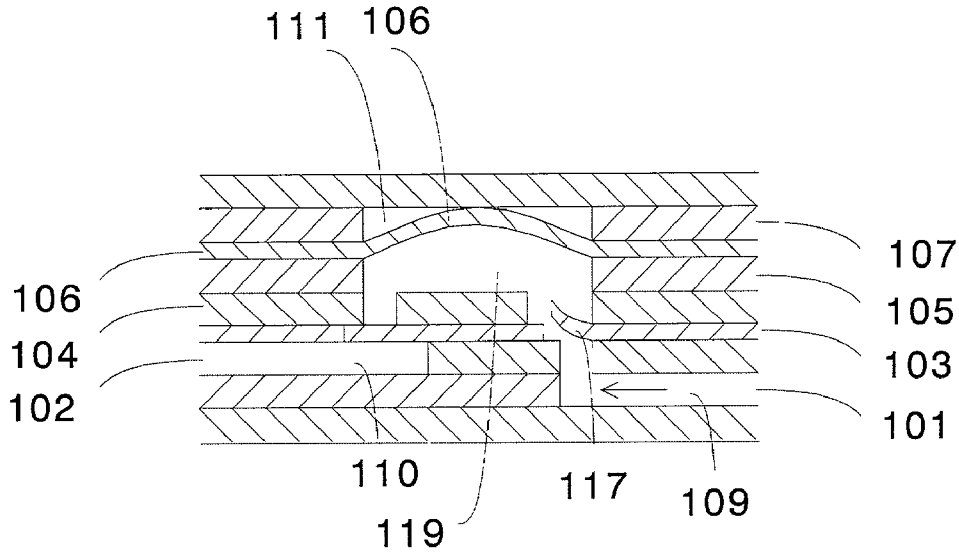
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FIG. 2C

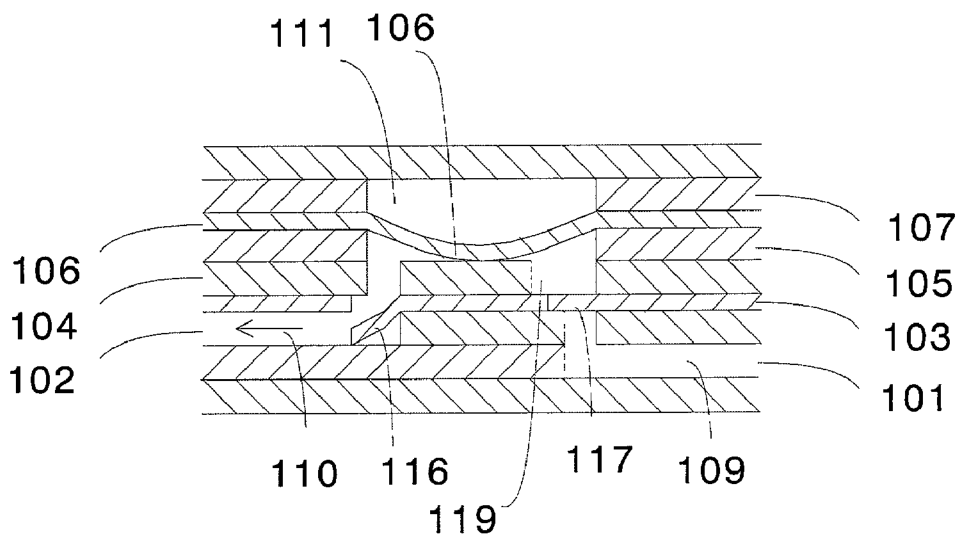
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FIG. 2D

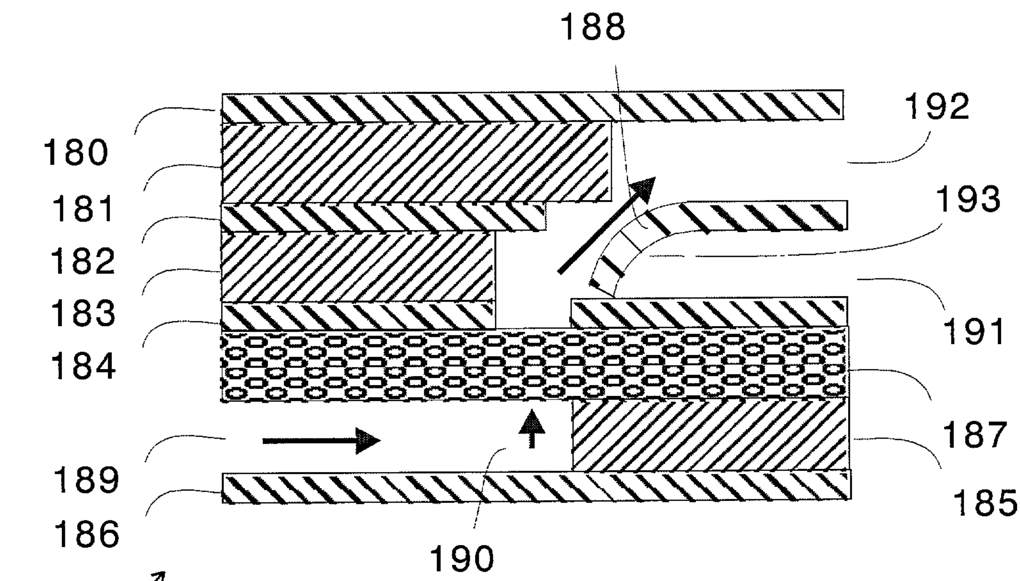
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FIG. 3A

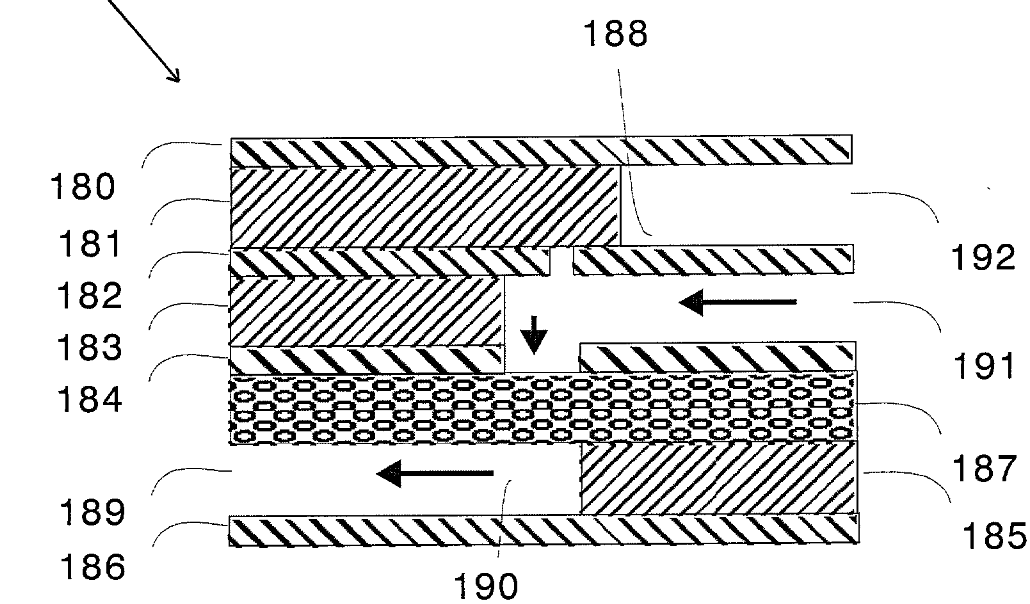
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FIG. 3B

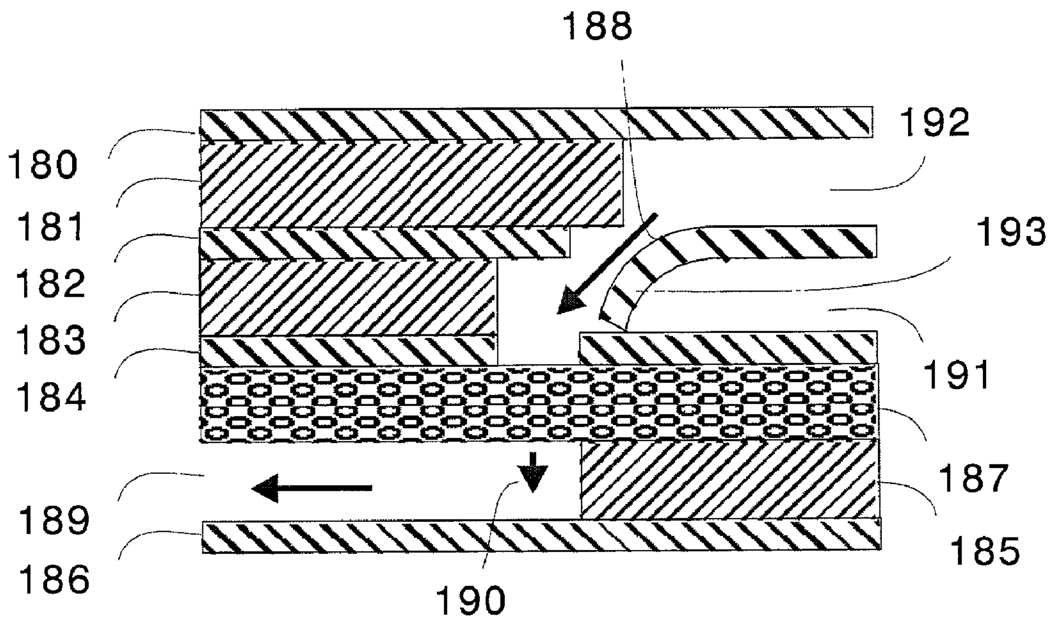
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FIG. 3C

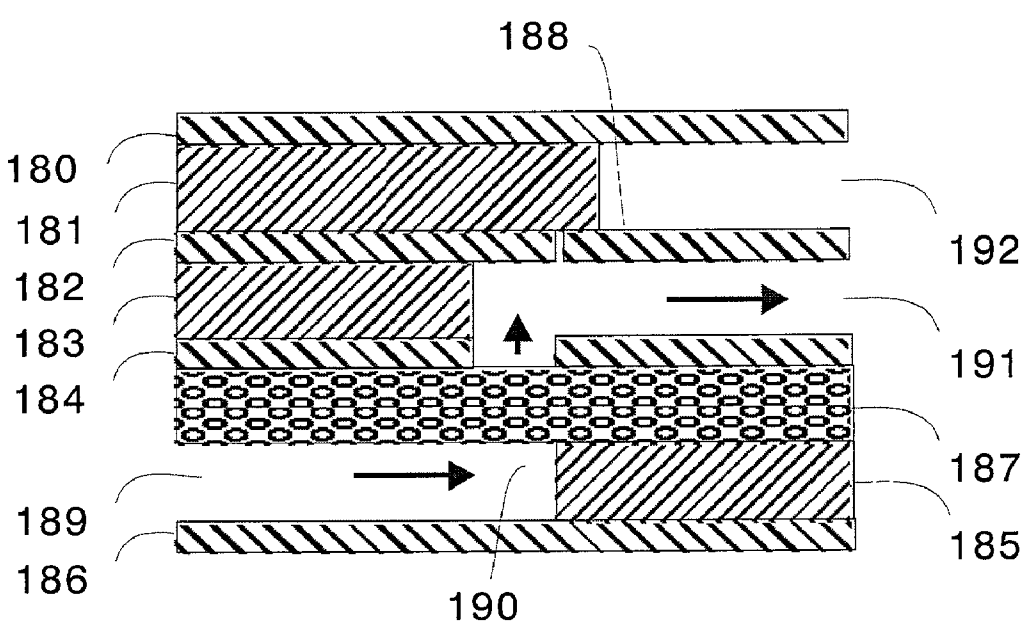
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FIG. 3D

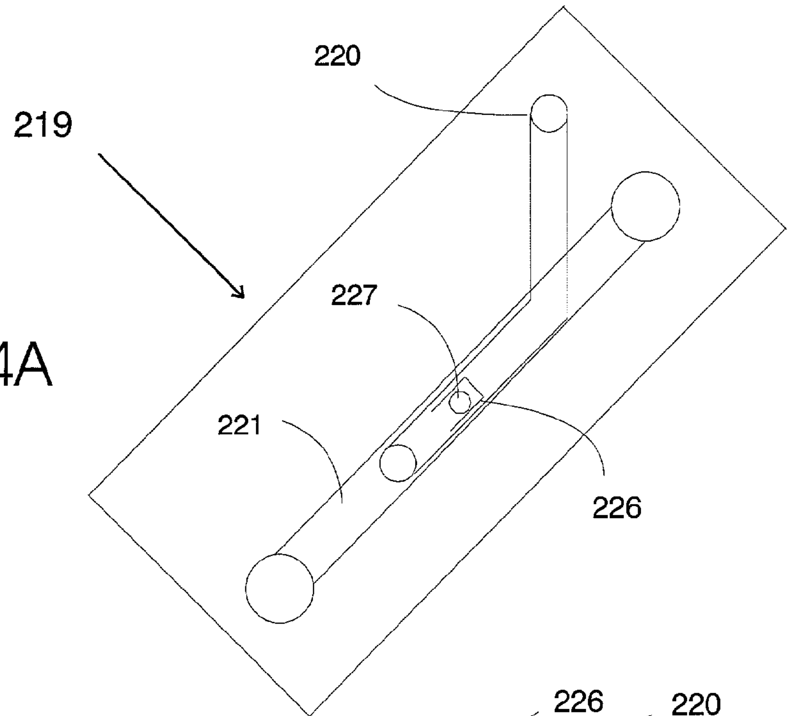

FIG. 4A

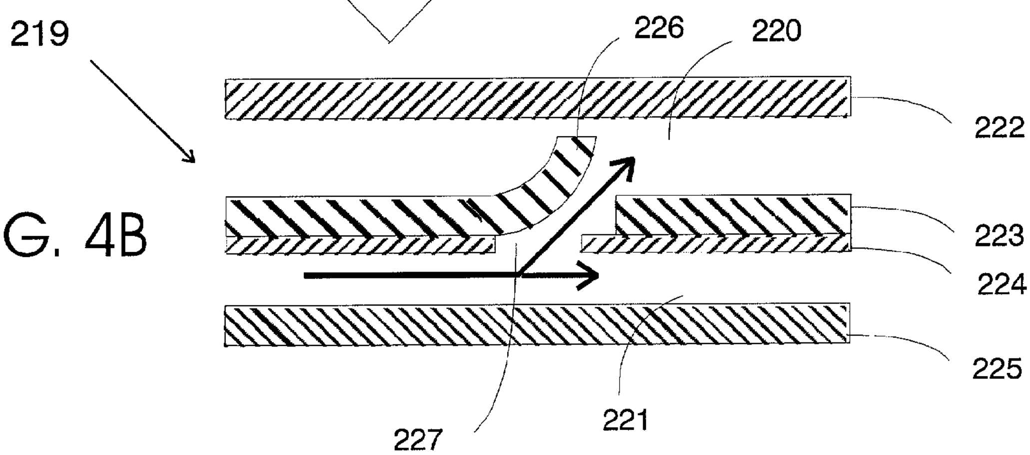

FIG. 4B

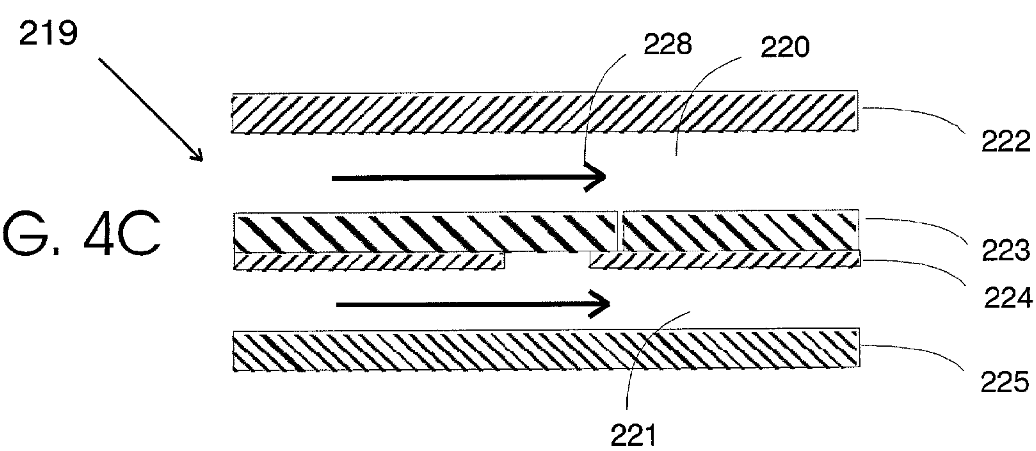

FIG. 4C

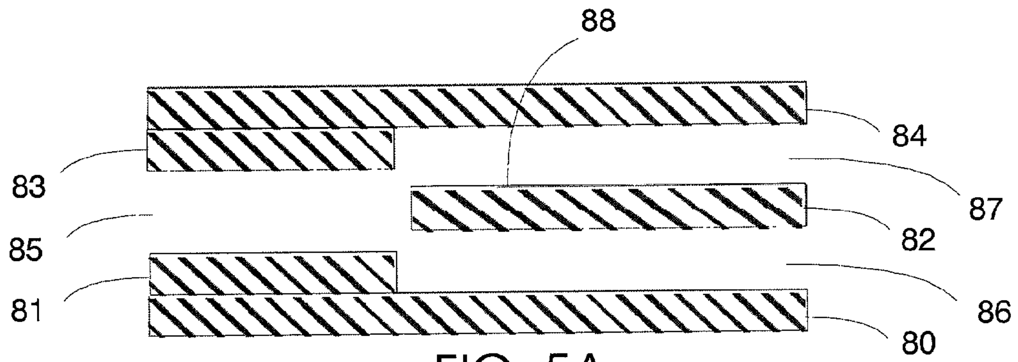

FIG. 5A

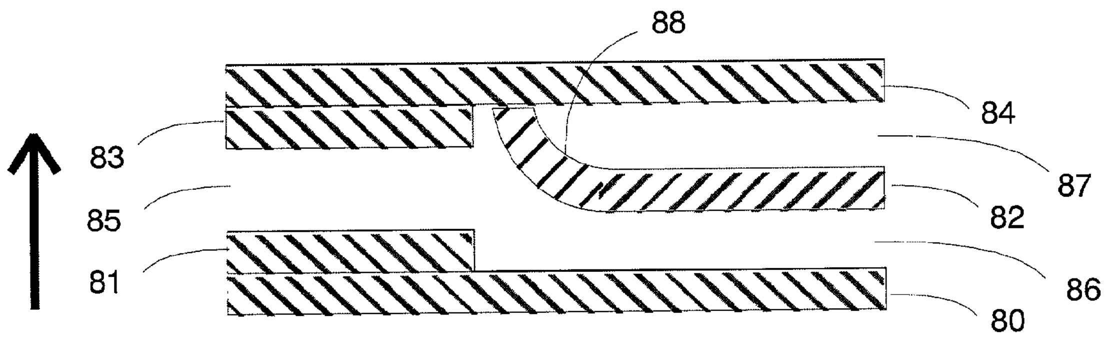

FIG. 5B

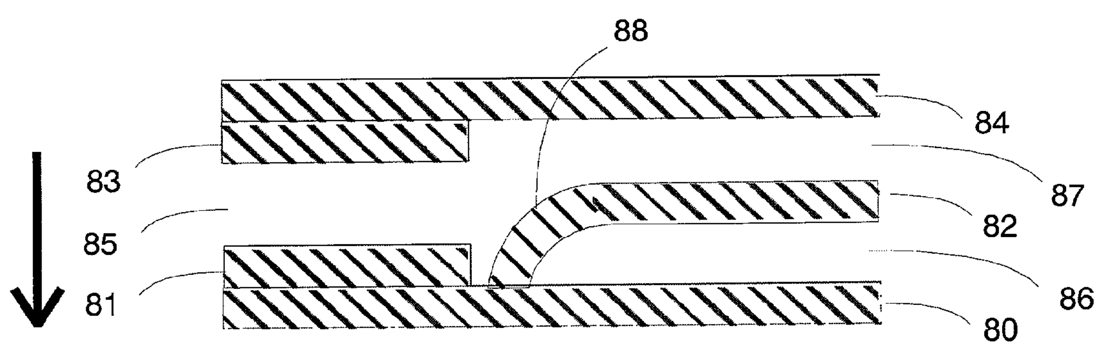

FIG. 5C

MICROFLUIDIC VALVE WITH PARTIALLY RESTRAINED ELEMENT

FIELD OF THE INVENTION

[0001] The present invention relates to microfluidic devices having valves therein. The invention also relates to microfluidic pumps.

BACKGROUND

[0002] Microfluidic devices are becoming more important in a variety of fields, from biochemical analysis to medical diagnostics and to fields as diverse as environmental monitoring to chemical synthesis. There has been a growing interest in the manufacture and use of microfluidic systems for the acquisition of chemical and biological information. In particular, microfluidic systems allow complicated biochemical reactions to be carried out using very small volumes of liquid. These miniaturized systems increase the response time of the reactions, minimize sample volume, and lower reagent cost.

[0003] Traditionally, these microfluidic systems have been constructed in a planar fashion using silicon fabrication techniques. Representative systems are described, for example, in some early work by Manz et al. (Trends in Anal. Chem. (1990) 10(5): 144-149; Advances in Chromatography (1993) 33: 1-66). These publications describe microfluidic devices constructed using photolithography to define channels on silicon or glass substrates and etching techniques to remove material from the substrate to form the channels. A cover plate is bonded to the top of this device to provide closure.

[0004] More recently, a number of methods have been developed that allow microfluidic devices to be constructed from plastic, silicone or other polymeric materials. In one such method, a negative mold is first constructed, and plastic or silicone is then poured into or over the mold. The mold can be constructed using a silicon wafer (see, e.g., Duffy et al., Analytical Chemistry (1998) 70: 4974-4984; McCormick et al., Analytical Chemistry (1997) 69: 2626-2630), or by building a traditional injection molding cavity for plastic devices. Some molding facilities have developed techniques to construct extremely small molds. Components constructed using a LIGA technique have been developed (see, e.g., Schomburg et al., Journal of Micromechanical Microengineering (1994) 4: 186-191). Other approaches combine LIGA and a hotembossing technique. Imprinting methods in polymethylmethacrylate (PMMA) have also been demonstrated (see, Martynova et al., Analytical Chemistry (1997) 69: 4783-4789). However, these techniques do not lend themselves to rapid prototyping and manufacturing flexibility. Additionally, these techniques are limited to planar structures. Moreover, the tool-up costs for both of these techniques are quite high and can be cost-prohibitive.

[0005] Generally, construction of microfluidic devices having integral pumps and valves is problematic using the traditional techniques of microfluidic device construction. Rigid silicon fabrication, for example, does not lend itself to construction of flexible parts. Often devices containing integrated valves and pumps are complex and difficult to manufacture. Such devices also can require several different manufacturing techniques to create the valve or pump structures. In spite of the limitations in the current state of the art, there is a clear need in the field of microfluidic devices for improved valves and pumps.

SUMMARY OF THE INVENTION

[0006] This invention relates to the microfluidic devices that contain valves for controlling fluid flow. In one aspect of the present invention, certain sections of microfluidic channels are partially restrained, that is, not connected at all points. Since certain sections are not completely held in place, the material in this area is flexible and can form a microfluidic flap. These flaps can be used to control the flow of fluid. In certain embodiments, these flaps can be used as one-way flow controllers. In other embodiments, these flaps can be used to pump fluids. In still further embodiments, these flaps can be used to direct fluid among different levels of a three-dimensional device.

[0007] The invention provides a microfluidic valve device having a first microfluidic channel disposed in a first layer. The microfluidic device has a second microfluidic channel in a second layer with at least one dimension smaller than that of the first channel. The device has a (third) flap layer disposed between the first microfluidic channel and the second microfluidic channel, the third layer having a movable flap formed therein. The flap has a closed position sealed against a sealing surface formed by the second layer and can open into the first microfluidic channel. The flap can have at least one dimension, typically width, that is smaller than that of the channel into which it is deflected.

[0008] The flap can be formed from a material that is flexible or substantially rigid. When the flap is substantially rigid, the flap can have a hinge region. The hinge region can be a portion of the material that has a reduced thickness relative to the movable portion of the flap. In another embodiment, the hinge region is constructed from a different material from the movable portion of the flap.

[0009] The layers of the device can be integral in the device or can be assembled from individual stencil layers. The stencil layers can be any suitable material including polymeric materials. The stencil layers can be, for example, adhesive tapes.

[0010] The device can be constructed such that the movable flap can contact one or more surfaces of the first channel, and restrict fluid flow therein. The microfluidic device also can have a sealing layer adjacent to the flap layer with holes or apertures disposed therein to allow fluid communication through the flap region. The sealing layer can be a substantially rigid material. The sealing layer also can contain an aperture disposed adjacent to the movable flap.

[0011] The movable flap can be flexible, substantially rigid, or a combination of flexible and rigid portions. When the movable flap is substantially rigid, it can have a hinge region. A hinge region can be formed from a flexible material. Either the top or bottom or both surfaces of the movable flap can be adhesively coated.

[0012] The invention also provides microfluidic pumps that have two or more microfluidic valves of the invention arranged in fluid communication with a pumping chamber having an adjustable volume. The pumping chamber can be, for example, a cylinder with a movable piston for changing the volume. The pumping chamber also can have a deformable membrane forming one surface of the pumping chamber. The deformable membrane can be deformed to change the volume of the pumping chamber. Deformation can be achieved with a mechanical actuator including, for example, an electromechanical actuator. Electromechanical actuators include, for example, piezoelectric materials. The pumping device also can have a pressurizable chamber that has at least one side formed by the deformable membrane. The pressure in the pressurizable chamber can be adjusted, for example, using a pump. Such a pressure change can cause the membrane to be deformed and thereby operate the pump.

[0013] Definitions

[0014] The term "channel" as used herein is to be interpreted in a broad sense. Thus, it is not intended to be restricted to elongated configurations where the transverse or longitudinal dimension greatly exceeds the diameter or cross-sectional dimension. Rather, such terms are meant to comprise cavities or tunnels of any desired shape or configuration through which liquids may be directed. Such a fluid cavity may, for example, comprise a flow-through cell where fluid is to be continually passed or, alternatively, a chamber for holding a specified, discrete amount of fluid for a specified period of time. "Channels" may be filled or may contain internal structures comprising valves or equivalent components.

[0015] The term "microfluidic" as used herein is to be understood, without any restriction thereto, to refer to structures or devices through which fluid(s) are capable of being passed or directed, wherein one or more of the dimensions is less than 500 microns.

[0016] The term "microfluidic flap" as used herein is to be understood, without any restriction thereto, to refer to a portion of a surface forming a wall of a microfluidic channel that is not connected at all points to other portions of the structure forming the channel. A microfluidic flap can have the property that it may move within said channel when certain physical characteristics of the channel change, such as pressure, temperature, flow rate of fluid, type of fluid, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] **FIG. 1A** shows an exploded view of a microfluidic device having a microfluidic valve disposed therein. **FIG. 1B** shows a top view of the same device assembled. **FIG. 1C** shows a side view of the device during operation. The dark arrow shows the direction of fluid flow. **FIG. 1D** shows the same side view of the device during operation with the flow reversed. Again, dark arrows indicate the direction of fluid flow within the device.

[0018] **FIG. 2A** shows an exploded view of a microfluidic device capable of being used to pump fluid. **FIG. 2B** shows a top view of the device of **FIG. 2A**. **FIGS. 2C and 2D** show cross-sectional views of the same device in operation. **FIG. 2C** shows the device with a negative pressure applied to chamber **111**, while **FIG. 2D** shows the device with a positive pressure applied to chamber **111**.

[0019] **FIGS. 3A and 3B** show cross-sectional views of a microfluidic device having a microfluidic diversion valve therein where the flap portion is usually in the down position. In **FIG. 3**A, the device is show in operation with fluid flowing according to the single arrows through channels **189** and **192**. In **FIG. 3**B, fluid is flowing in the reverse direction through channels **191** and **189** as indicated by the single arrows. In both cases, fluid flows through filter region **190**.

[0020] **FIGS. 3C and 3D** show cross-sectional views of a microfluidic device having a microfluidic diversion valve therein where the microflap portion is usually in the up position. In **FIG. 3**C, the device is show in operation with fluid flowing according to the single arrows through channels **192** and **189**. In **FIG. 3**D, fluid is flowing in the reverse direction through channels **191** and **189** as indicated by the single arrows. In both cases, fluid flows through filter region **190**.

[0021] **FIG. 4A** shows a top view of a microfluidic device having a flap valve therein. **FIG. 4B** shows the same device with the flap deformed towards channel **220** while **FIG. 4C** shows the same device with the flap in the closed position.

[0022] **FIG. 5A** shows a side view of a microfluidic device having a flap valve therein, the device subject to no external forces. **FIG. 5B** shows a side view of the device of **FIG. 5**A, subject to application of an external force that deforms the flap valve upward. **FIG. 5C** shows a side view of the same flap valve, subject to application of an external force that deforms the flap valve downward.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The invention provides microfluidic devices having fluid control valves disposed therein. In one embodiment, the valve is a one-way valve or a check valve. The microfluidic valve includes a first channel formed within a first layer of a microfluidic device and a second channel formed within a second layer of the microfluidic device substantially coplanar with the first channel. A layer disposed between the first and second layers forms a flap structure. The first channel is smaller than the second channel in at least one dimension within the plane of the channels such that a seating surface is formed. A third layer disposed between the first and second layers has a flap that is movable within the device but remains attached to the third layer. In a preferred embodiment, the flap and the third layer are formed from the same material, with material removed from the third layer to form the flap.

[0024] The flap is movable, such that in a closed position it seals with the seating surface. As used herein, the term "seals" refers to contact of a flap against a seating surface. Sealing of a flap includes both the formation of a fluid-tight junction and junction that allow restricted fluid flow through the device. Mobility of the flap can be achieved by any suitable modification of the flap material or dimensions, including, for example, altering the material of the flap, the dimensions of the flap (e.g., thickness), the degree of connection of the flap to the third layer and combinations thereof. For example, the flap can be formed from a substantially rigid material, with a hinge region to allow movement. A hinge region can be formed in a rigid material by reducing its thickness at the desired hinge region. The flap also can be formed from a pliable material. A material is suitably pliable if, at the desired operating pressures of the device, the material will bend or deform. The degree of pliability will depend on the nature of the material used and on the thickness of the material used. A flap can have any shape such that the flap can deform within the device towards the second channel. In certain embodiments, the flap will seal against the first channel within normal operating pressures of the device. In other embodiments, the flap will seal against the second channel within normal operating pressure of the device. In one embodiment, a flap has one side separated from the membrane from which it is formed. In another embodiment, the flap is formed by cutting three sides of a rectangle into the membrane material to form a flap with a substantially rectangular shape.

[0025] The stencil layer or membrane in which the flap resides, the flap layer, can be made of any suitable material. A suitable material can be chosen by one of skill in the art, depending on the type of construction used to make the microfluidic device. For repeated usage, it is preferred that the material chosen has a degree of elasticity allowing it to rebound into the seated position. For example, the material can be a metal foil, paper or polymer or combinations or laminates thereof. When the device is to be constructed from layered stencil layers, and the flap is integral with the flap layer, the flap and flap layer are preferably fabricated from a polymeric material. Suitable polymeric materials include, for example, polytetrafluorethylenes, polystyrenes, polypropylene, polyethylene, polyimides, polyacrylates, rubbers and silicones. In certain embodiments, one or both sides of the flap region may be covered or coated with a material to enhance adhesion to the upper or lower channel surface. The adhesion materials can be permanent or reversible. In a preferred embodiment, adhesive materials are coated onto the surface that is to make up the flap portion prior to the construction of the device.

[0026] Microfluidic coupling devices have stencil layers and substrate layers that define channels therein. Such devices can be constructed from discrete layers of material or can be fabricated as an integral unit. When a coupling device is constructed as an integral unit, layers refer only to positions within a device rather than to individual components. A microfluidic device can be constructed with stencil layers, using techniques described, for example, in co-pending U.S. patent application Ser. No. 09/453,029, incorporated herein by reference in its entirety. When the device is to be constructed by assembling stencil layers with adhesive separating the layers or using self-adhesive tape materials, the material forming the sealing surface and the side of the flap region interacting with the sealing surface are both preferably non-adhesive. Alternatively, the area of the flap interacting with the sealing surface and/or the seating surface can be adhesively coated, and the adhesive strength can be chosen to prevent permanently closing the valve. Any suitable adhesive can be used to assemble a device from stencil layers.

[0027] The material chosen for use as a valve is preferably substantially impermeable to the fluid to be used in the device. A device can, however, use a material that is permeable to a fluid. In one embodiment, the flap layer is formed from a material that is impermeable to the fluid for which the device is designed, but may be permeable to a gaseous fluid, such as air.

[0028] In a preferred embodiment, the flap region may be used to seal a hole or via that goes from one level of the device to another. In certain embodiments, the flap portion may be more effective at blocking fluid flow if it covers a hole or via rather than a channel portion.

[0029] The height of the outlet channel also can be varied to change the operation of the flap. A large flap relative to the height of the outlet channel will allow the flap to seal against the lower surface of the channel into which the flap is deflected. For example, referring to **FIG.** 1D, membrane **22** having flap **30** disposed therein opens into channel **26** in layer **23**. The thickness of layer **23** (the height of channel **26**) and the length of the flap **30** can be varied such that the deflected flap may or may not come in contact with the lower surface of layer **24**.

[0030] Referring to **FIG. 1, a** microfluidic device is constructed from five stencil layers **20-24** that have channels **25**, **26**, vias **27**, and inlet/outlet ports **28**, **29**. Additionally, one section **30** of layer **22** is cut so that the region is still attached to the stencil layer but can move freely. The resulting flap **31** is only partially restrained from moving. The completed device is shown in **FIG.** 1B and the region where the flap **31** is in contact with the upper sealing surface of layer **21** is shown. A cross section of region **31** is blown up in **FIGS. 1C and D**. Two possible uses are shown. In **FIG.** 1C, fluid is injected at the entry port **29**. The fluid passes through channel **26** until it reaches the flap valve region **31**. Here, the flap region **30** is pushed down against the sealing surface of stencil layer **21**. Thus, the flap region **30** prevents fluid flow from channel **26** into channel **25**. In operation, the fluid may never reach the region at flap **30**, since the fluid will compress the air within channel **26** and build up pressure which may prevent the fluid from flowing at all. In operation in the reverse direction, when fluid is injected at port **28**, it passes through the vias **27** and through channel **25**. When the fluid now encounters the flap portion **30**, the flap is free to be displaced upwards since the area above it is open channel **26**. The fluid passes through this region, into channel **26** and can exit through port **29**.

[0031] Also provided is a microfluidic pump having a first inlet channel, a first microfluidic one-way valve, with a first flap opening into a chamber in fluid communication with the first inlet channel, and an outlet channel in fluid communication with the chamber through the second microfluidic check valve. The second one-way valve has a second flap opening into the second channel. The volume of the pumping chamber can be altered. In one embodiment, the pumping chamber is a cylinder with a piston assembly. In another embodiment, the pumping chamber has a deformable membrane forming one side of the chamber. Deformation of the deformable membrane can result in movement of the deformable membrane. The deformable membrane can be moved by mechanical force. For example, the membrane can be deformed using a mechanical actuator. In one embodiment, the mechanical actuator is a piston. In another embodiment, the mechanical actuator is an electromechanical material, for example, a piezoelectric device of a Ti—Ni device. In another embodiment, the material can be a magnetic material and a magnetic field can be fluctuated to force the membrane up and down. In another embodiment, the material can be driven up and down using a camshaft that is asymmetrical. In another embodiment, force to deform the membrane is supplied by having an additional chamber opposite the pumping chamber, the pressure of which can be varied, for example, by a pressure pump or a vacuum pump. In another embodiment, the temperature of the chamber **111** can be cycled up and down to force movement of the membrane.

[0032] Referring to **FIG. 2A, a** microfluidic pumping system was constructed from nine stencil layers **100-108** that had channels **109-111**, through regions **112**, inlet outlet holes **113,114** and a pressure entrance **115** removed. Additionally, two flap regions **116,117** we partially cut in stencil layer **103**. The assembled device is shown in **FIG. 2B**. The cross section of pumping area **118** is shown in **FIGS. 2C and D**. In use, the pumped worked as follows. Fluid was injected at port **114** and filled both channels **109** and **110** and chamber **119**. An external pressure/vacuum source was hooked up to the inlet port **115**. When the external source applied a slight vacuum to channel **111**, the stencil layer **106** flexes up towards the channel **111**. This creates a slight negative pressure in chamber **119** directly below the stencil **106**. In order to adjust for this, flap **117** is lifted up towards the negative pressure and fluid flows into chamber **119**. Flap **116** does not open since it is blocked by the lower surface of stencil layer **104** above. Once the chamber equilibrates (or prior to equilibration), the pressure on the external source at **115** was reversed. Referring to **FIG. 3**D, the positive pressure within channel **111** causes the stencil layer **106** to push down into the chamber, increasing the pressure. In order to adjust to the new pressure, flap **116** opens towards channel **110** and pushes fluid into outlet channel **110**. When the pressure at the inlet **115** oscillates up and down, a net fluid flow from channel **109** to **110** occurs. This pumping mechanism can be used to push fluid throughout additional channels within the microfluidic structure, or to push fluid off board. The pumping speed and amount can be altered in a number of ways. The size of the pressure change at the input **115** as well as the period of the oscillation can have an effect. The geometry and size of the channels themselves can also alter the pumping parameters. For example, the size of the flaps will determine the amount of fluid transferred per stroke. Alternatively, the size of the chamber just below the stencil layer **106** can also be altered to change the parameters. Likewise, the material used to construct deformable membrane **106** will determine the change in volume of pumping chamber **119**, as will the composition of the fluid itself.

[0033] Fluid control valves of the invention also can be used to direct fluid flow among layers of a microfluidic device. These valves can be incorporated into a system in such as way that a particular microfluidic device can perform a variety of functions depending on how the chip is used. Additionally, channels within a particular device can be used more than once for different functions when using these valves.

[0034] Microfluidic devices of the invention also can have filter materials embedded within the channels. A filter is any material that partially blocks or selectively alters fluid flow within a channel. A filter is typically a porous material. The material also can have surface chemical properties that alter its interaction with various fluids to be used in the device.

[0035] Two similar configurations of the present invention that perform in two distinct manners are shown in FIGS. 3A-D. These figures are of the cross-section of a portion of a complete device having valve structures. In this particular embodiment, the devices contain filter material for performing ultra-filtration of biological or chemical molecules. Referring to **FIG. 3A, a** device is shown with an input channel **189** for loading a biological sample. Fluid injected into channel **189** from the left will encounter filter material **187**. When fluid is injected, it goes across the filter area at **190** and into the region above. In this application, the filter is chosen so the biological targets within the sample of choice will become stuck at the lower surface of the filter **187** at region **190**. In certain embodiments, the filter can be chosen so that large nucleic acid targets will be blocked at the entrance of the filter and other non-specific biomass will proceed. The stencil layer **182** in this device is composed of a flexible material so that the flap valve **188** rests on the lower stencil surface **184** in the normal position. Additionally, semi-permanent adhesive material is used on the lower surface of the flap portion **193** and/or the upper surface of the lower stencil **184**. In the normal position, channel **191** is blocked and the fluid is diverted into the upper channel **192**. Once the sample is fully injected and the filter material washed, extraction fluid is injected into channel **191**. Referring to **FIG. 3**B, the pressure from the fluid being injected at **191** pushed the moveable flap **188** up into a closed position against stencil layer **181**. The fluid passes down through the filter and pushes the nucleic acid off the filter and into the solution. The sample then passes down **189** to an exit port or another portion of the device for further analysis.

[0036] Another device configuration is shown in **FIG. 3C**. In this example, the stencil layer **182** is composed of a material such that flap region **188** is normally in the closed position as shown in **FIG. 3D**. In use, the sample is loaded through **192** and passes through the filter region. The nucleic acid material in this example is stuck on the top surface of the filter area **190**. Once the wash buffer has been passed across the filter, elution buffer can be added in the reverse direction (see **FIG. 3D**) and be directed to the exit channel **191**. Other configurations are possible, as are other types of sample materials and filters.

[0037] Another embodiment of the present invention is shown in FIGS. 4A-C. In this embodiment, a separate control channel is used to alter the fluid being pumped. Referring to **FIG. 4A, a** microfluidic device is shown from the top view with a flow channel **221** and control channel **220**. Also shown are a via **227** formed in the sealing layer **224** and a flap region **226** that form the valve adjacent to central layer **223**. Cross sectional views of the valve region are shown in **FIGS. 4B and 4C**. In use, if no pressure is applied to control channel **220**, fluid flows through channel **221**, reaches the valve region and the pressure of the flow opens the flap valve **226** that covers the via **227**. A portion of the fluid then passes into the upper channel **220** as well as the flow channel **221**. In an alternative use, pressure is applied to the control channel **220** during use. If the pressure in control channel **220** is higher than the pressure in flow channel **221**, the flap **226** completely covers the via **227** and all of the fluid flows down channel **221**. The pressure in channel **220** can be adjusted as desired to produce a pseudo flow regulator in **221**. If the flap is partially open, then only a smaller portion of fluid will flow up into **220**. In a similar manner, channel **220** could be used as the flow channel and channel **221** as the control channel. In this embodiment, all of the fluid would remain in channel **220** and the movement of the flap region **226** would act as a flow constrictor.

[0038] A further embodiment of the present invention is shown in FIGS. 5A-C. In this embodiment, the flap **88** is composed in whole or in part of a material with magnetic susceptibility, such as a ferromagnetic, paramagnetic, or diamagnetic material. The device further includes an magnetic actuator (not shown), preferably external to the device, for deforming and therefore controlling the position of the flap **88**. Referring to **FIG. 5A, a** microfluidic device is shown from a side view with a no magnetic field is applied to the device, and the flap **88** is shown from side view with an first channel **85** and second and third channels **86, 87** defined between outer layers **80, 84**. Inner boundary layers **81, 83** assist with directing the flow when the flap **88** is deflected from a substantially linear position aligned with central layer **82**, such as shown in **FIG. 5B**. In **FIG. 5**B, an external magnetic force is applied to the flap **88** in the direction of the dark arrow (upward) using a magnetic actuator (not shown). This upward force causes the flap **88** to deflect, either just a small amount or sufficiently to contact the outer layer **84**. In the situation where fluid is flowing from channel **85** and being split into both channels **86, 87**, a small deflection in the valve may alter the flow characteristics of the liquid in the channels **86, 87**. If sufficient force is applied, the flap **88** may deflect sufficiently to divert all the flow into channel **86**. **FIG. 5C** is substantially the same as **FIG. 5**B, but the direction of the magnetic force, represented by the dark arrow, is reversed (downward). In this manner, a microfluidic device responsive to the application of magnetic force may be constructed to control the flow of liquid.

[**0039**] The particular devices and construction methods illustrated and described herein are provided by way of example only, and are not intended to limit the scope of the invention. The scope of the invention should be restricted only in accordance with the appended claims and their equivalents.

What is claimed is:

1. A microfluidic valve device comprising:

a first microfluidic channel disposed in a first layer, the first microfluidic channel having an upper surface;

a second microfluidic channel in a second layer, wherein the second microfluidic channel has at least one dimension smaller than that of the first channel, the second layer having a sealing surface; and

a flap layer disposed between the first microfluidic channel and the second microfluidic channel, the flap layer having a movable flap formed therein, wherein the flap has a closed position sealed against the sealing surface and can open into the first microfluidic channel.

2. The microfluidic device of claim 1, wherein said layers are integral.

3. The microfluidic device of claim 1, wherein said layers are stencil layers.

4. The microfluidic device of claim 3, wherein said stencil layers are polymeric layers.

5. The microfluidic device of claim 3, wherein said stencil layers are adhesive tapes.

6. The microfluidic device of claim 1, wherein the movable flap can contact a second surface of the first layer, wherein such contact restricts fluid flow within the first channel.

7. The microfluidic device of claim 1, further comprising a fourth layer adjacent to the flap layer.

8. The microfluidic device of claim 7, wherein the fourth layer is substantially rigid.

9. The microfluidic device of claim 7, wherein the fourth layer has an aperture disposed therein, wherein the flap can seal against the fourth layer adjacent to the aperture.

10. The microfluidic device of claim 1, wherein the flap has a width that is narrower than the first channel.

11. The microfluidic device of claim 1, wherein the flap is flexible.

12. The microfluidic device of claim 1, wherein the flap is substantially rigid.

13. The microfluidic device of claim 12, wherein the flap has a hinge region.

14. The microfluidic device of claim 13, wherein the hinge region comprises an area with the flap layer with reduced thickness relative to the movable portion of the flap region.

15. The microfluidic device of claim 13, wherein the hinge region is formed from a flexible material.

16. The microfluidic device of claim 1, wherein the flap has an upper flap surface and a lower flap surface and is adhesively coated on either said upper or said lower flap surface.

17. The microfluidic device of claim 16, wherein the flap is adhesively coated on both the upper flap surface and the lower flap surface.

18. A microfluidic pump comprising:

a first microfluidic valve of claim 1;

a second microfluidic valve of claim 1;

wherein the first and the second microfluidic valves are in fluid communication with a pumping chamber having an adjustable volume.

19. The microfluidic pump of claim 18, wherein the pumping chamber comprises a cylinder and movable piston assembly.

20. The microfluidic pump of claim 18, further comprising a deformable membrane forming one surface of the pumping chamber.

21. The microfluidic pump of claim 20, further comprising an actuator for deforming the deformable membrane.

22. The microfluidic pump of claim 21, wherein the actuator is electromechanical.

23. The microfluidic pump of claim 22, wherein the electromechanical actuator is a piezoelectric or titanium nickel material.

24. The microfluidic pump of claim 20, further comprising a pressurizable chamber having at least one side formed by the deformable membrane.

25. The microfluidic pump of claim 24, further comprising a pressure regulating pump capable of altering pressure within the pressurizable chamber.

26. The microfluidic device of claim 1, wherein the flap layer includes a material with magnetic susceptibility, the device further comprising a magnetic actuator.

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