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(54) FEEDBACK CONTROL FOR MICROFLUIDIC CARTRIDGES

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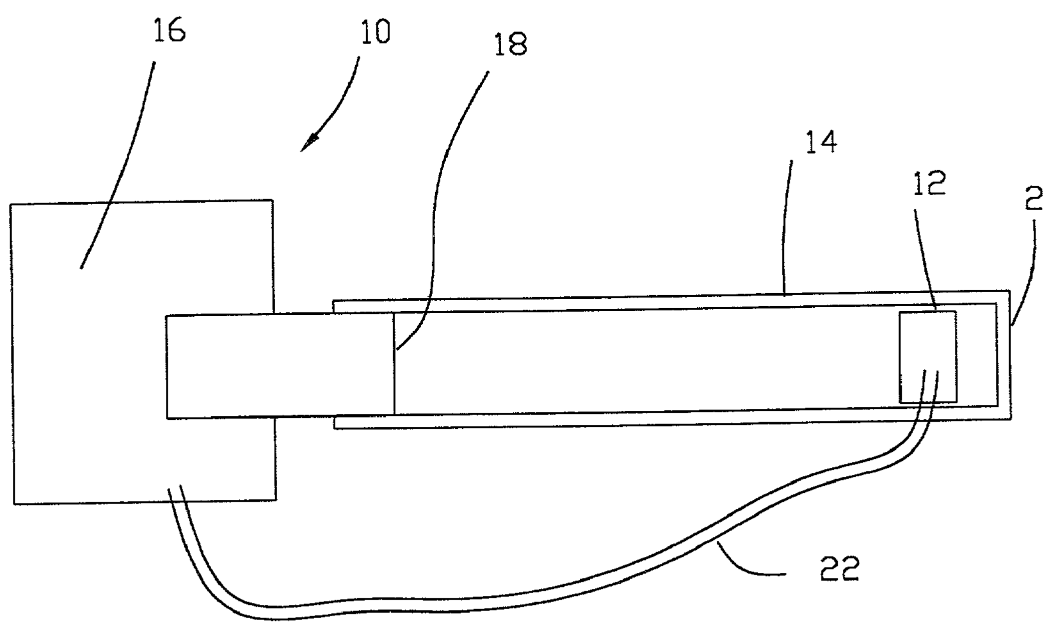
(57) ABSTRACT

A device for sensing fluid movement within a microfluidic channel which uses feedback to control its operation. The device measures electric parameters to interpret fluidic parameters such as flow speed, and the presence or absence of fluid within the channel.



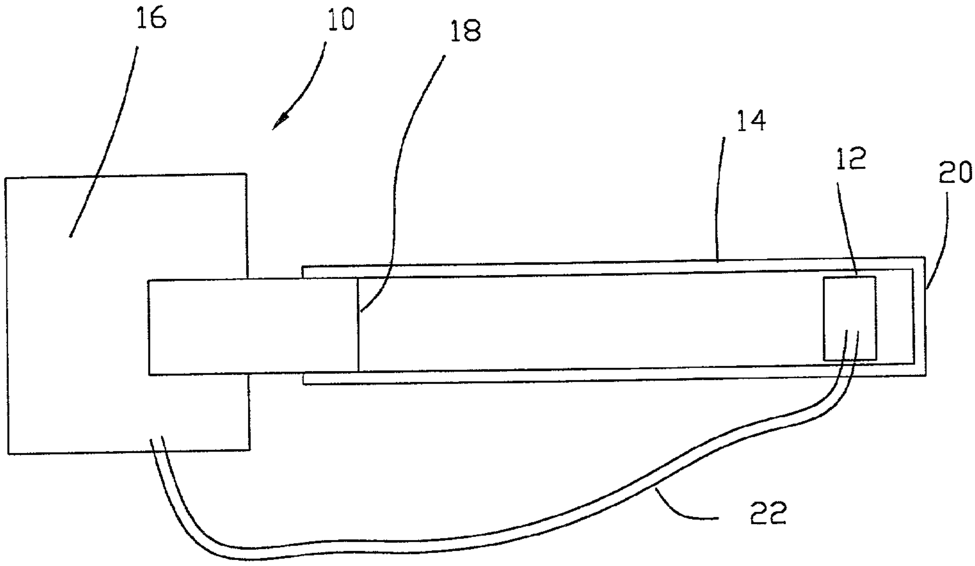


FIG. 1

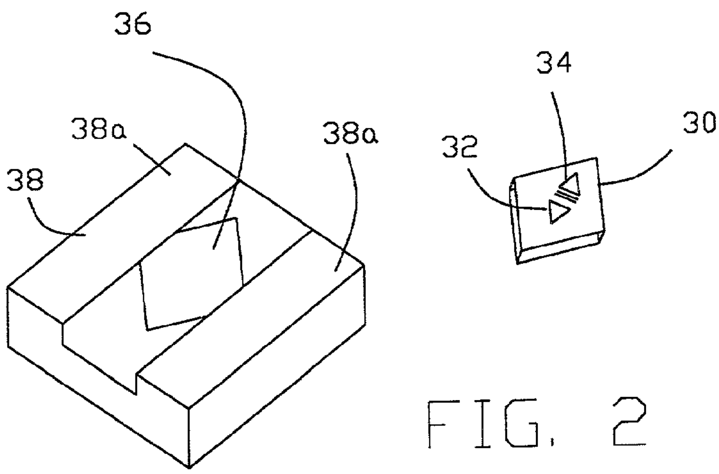


FIG. 2

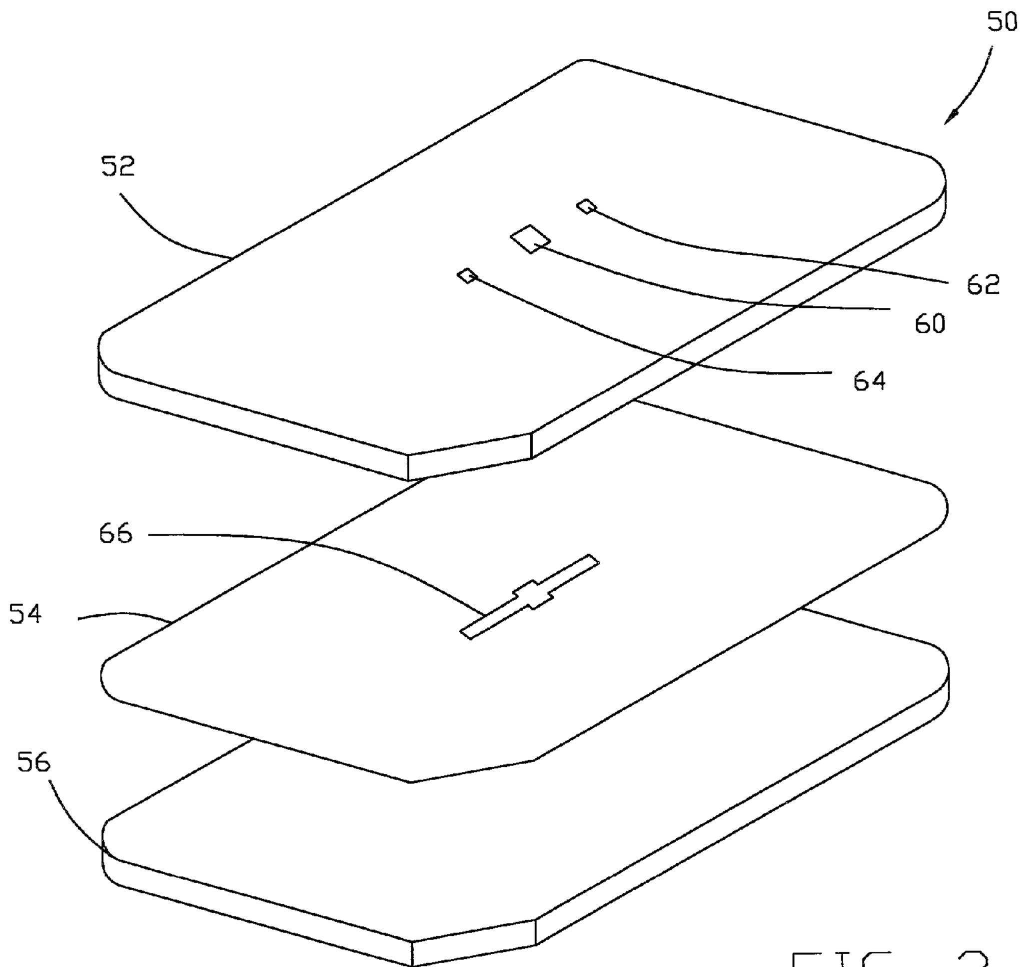


FIG. 3

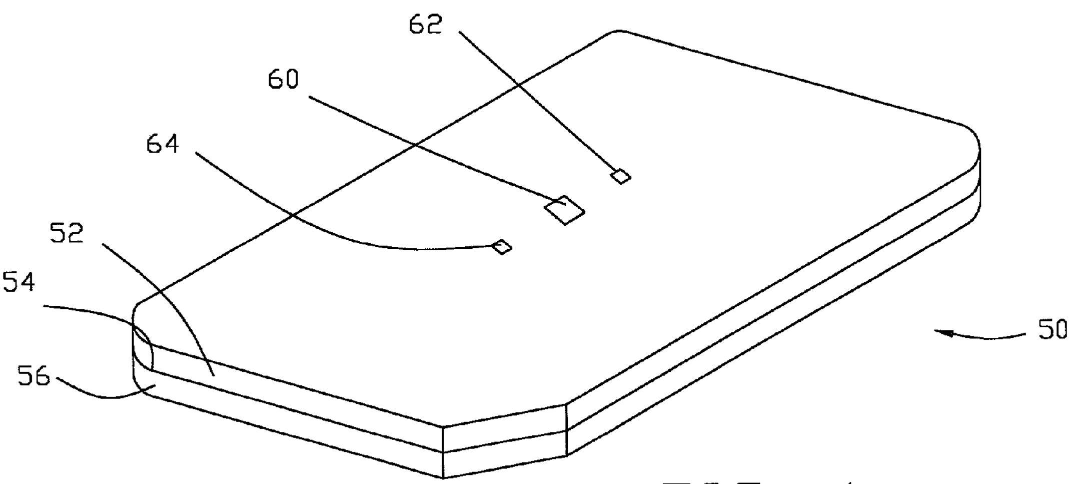


FIG. 4

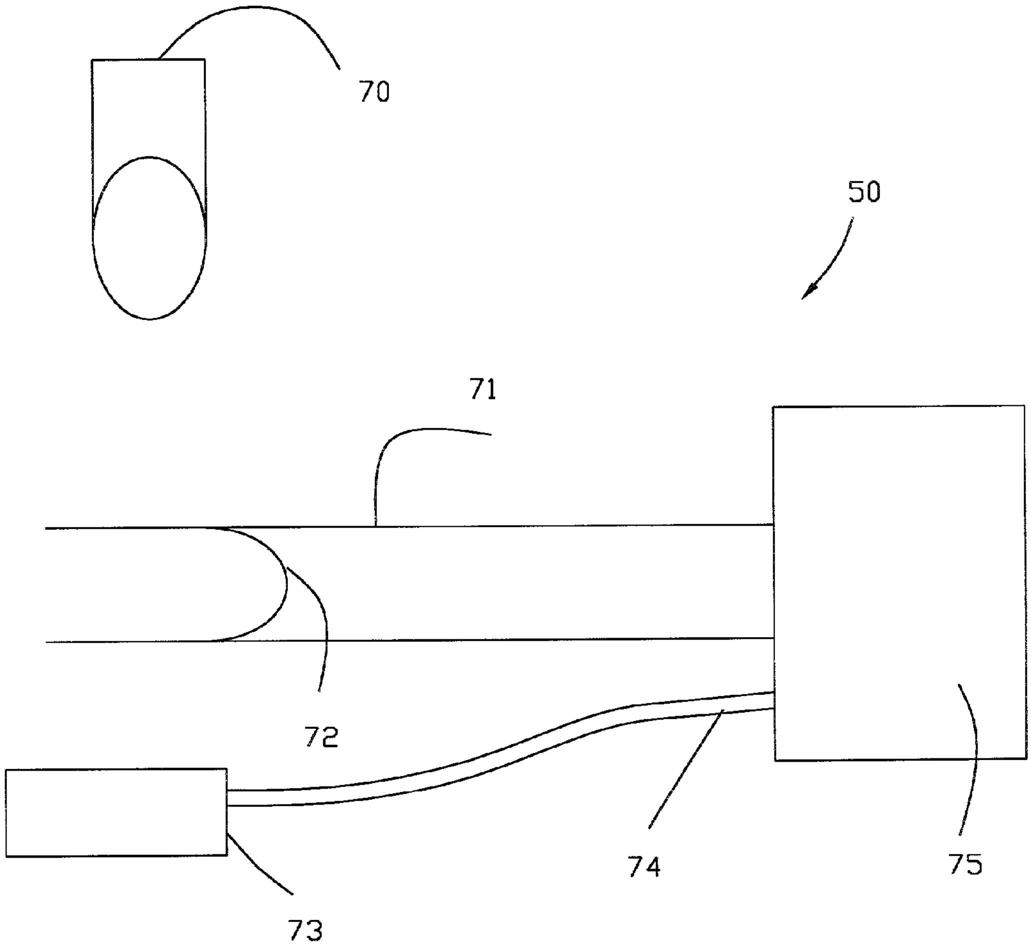


FIG. 5

FEEDBACK CONTROL FOR MICROFLUIDIC CARTRIDGES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent application claims benefit from U.S. Provisional Patent Application Serial No. 60/213,865, filed Jun. 23, 2000, which application is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates generally to microscale devices for performing analytical testing and, in particular, to a microfluidic cartridge which uses embedded electrodes for feedback control in the operation of its device.

[0004] 2. Description of the Prior Art

[0005] Microfluidic devices have recently become popular for performing analytical testing. Using tools developed by the semiconductor industry to miniaturize electronics, it has become possible to fabricate intricate fluid systems which can be inexpensively mass produced. Systems have been developed to perform a variety of analytical techniques for the acquisition of information for the medical field.

[0006] Microfluidic devices may be constructed in a multi-layer laminated structure where each layer has channels and structures fabricated from a laminate material to form microscale voids or channels where fluids flow. A microscale channel is generally defined as a fluid passage which has at least one internal cross-sectional dimension that is less than 500 μm and typically between about 0.1 μm and about 500 μm. The control and pumping of fluids through these channels is affected by either external pressurized fluid forced into the laminate, or by structures located within the laminate.

[0007] The use of electrodes within microfluidic channels for the manipulation of fluids has been practiced extensively in the prior art. U.S. Pat. No. 5,126,022 teaches a device for moving molecules by the application of a plurality of electrical fields by the use of a plurality of electrodes which were placed at regular intervals along a gel-filled channel which produced traveling electrical waves propelling charged particles through the medium within the channel for separation and resolution purposes.

[0008] U.S. Pat. No. 5,989,402 teaches an electrically controlled microfluidic system having an electrical interfere array with a plurality of electrode pins which are oriented for insertion into a plurality of ports. The electrode pins on each electrically coupled to a separate electrical lead, which leads are connected to an electrical control system which concomitantly delivers a voltage to each of the leads.

[0009] U.S. Pat. No. 6,007,690 is directed to a device for performing microchannel electrophoresis in capillaries, in which the main electrophoretic flow path has associated with it at least one pair of electrodes for applying an electric field to the medium present in the flow path, thus providing for precise movement of entities along the flow path.

[0010] U.S. Pat. No. 6,171,850 is directed to a device for performing temperature controlled reactions and analyzes in microfluidic systems. Heat exchangers are fabricated from a material that is both thermally and electrically conductive, so that they can function as both a heat exchanger and an electrode when placed into a fluid filled reservoir.

SUMMARY OF THE INVENTION

[0011] It is therefore an object of the present invention to provide a device which uses feedback from a sensing means to control operation of a microfluidic device.

[0012] It is a further object of the present invention to provide a device which measures electric parameters to determine the presence or absence of fluid in microfluidic channels.

[0013] It is a still further object of the present invention to provide a device which uses electrodes within microfluidic channels to measure flow speed and wetout.

[0014] It is still a further object of the present invention to provide a device which uses optical sensors located in proximity to microfluidic channels to measure wetout.

[0015] These and other objects of the present invention will be more readily apparent in the description and drawings that follow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] **FIG. 1** is a representation of a flow sensor according to the present invention used within a microfluidic channel;

[0017] **FIG. 2** is an enlarged view of the sensor and sensor holder of the flow assembly shown in **FIG. 1**;

[0018] **FIG. 3** is an exploded view of the sensor carrier device shown in **FIG. 1**;

[0019] **FIG. 4** is an assembled view of the device shown in **FIG. 3**; and

[0020] **FIG. 5** is a plan view of an optical sensor assembly according the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] Referring now to **FIG. 1**, there is shown a fluid sensor assembly, generally indicated at **10**, according to the present invention. Assembly **10** uses a fluid sensor **12**, which is located within a microfluidic channel **14** to monitor the flow of fluids within channel **14**. Fluid is provided to channel **14** via a fluid driving and control means **16**. Means **16**, which may contain a separate fluid supply or merely pump fluid from another circuit into channel **14**, is coupled to channel **14** at a channel inlet **18**. The opposite end of channel **14** comprises a channel outlet **20**, which end may be coupled into additional microfluidic circuitry.

[0022] Sensor **12** is electrically coupled to driving and control means **16** by a cable **22**. Cable **22** provides electrical signals from sensor **12** to means **16** relative to fluid flow within channel **14** at the location where sensor **12** is positioned. These signals from sensor **12** may be used by means **16** to measure specific electric parameters, such as conductivity or capacity across channel **14**. In addition, these electric parameters can be used to interpret fluidic parameters, such as flow speed, or the presence or absence of fluid within channel **14**.

[0023] Means **16** is capable of analyzing signals received from sensor **12**, and adapting the flow within channel **14** in response to information received from sensor **12** via cable **22**. This use of feedback signals to control the operation of assembly **10** may be implemented by a computer, programmable controller, or any other device well known to persons familiar with this art.

[0024] Fluid flow within channel **14** may be in the form of a liquid or a gas, and sensor **12** may be located at any point within channel **14**, or may consist of multiple sensors located at different regions of channel **14**. Means **16** may detect a gradient between different regions of channel **14** and react to the differences, such as differences in flow speed or conductivity. As means **16** analyzes the information returned from sensor **12**, it reacts to adjust the operation of fluid driving within channel **14**.

[0025] Sensor **12** may consist of a single electrode, a series of electrodes, an optical sensing device, or even a hot wire anemometer capable of monitoring temperature changes within the fluid flowing within channel **14**. Many sensing devices capable of performing these operations are well known in the art.

[0026] **FIG. 2** illustrates an embodiment of the sensor and sensor holder which may be used in conjunction with the present invention. A sensor **30** is shown having a pair of electrodes **32**, **34** embedded within the body of sensor **30**. Sensor **30** is adapted to be inserted into an opening **36** within a sensor holder **38**. Opening **36** is sized such that sensor **30** slides into said opening from the rear and is prevented from sliding out of the top by extensions ***38a*** of holder **38**.

[0027] **FIG. 3** is an exploded view of a sensor for use in the present invention. Sensor carrier device, generally indicated at **50**, consists of an upper layer **52**, a central layer **54**, and a bottom layer **56**. Upper layer **52** includes a plurality of apertures **60**, **62**, **64**. Aperture **64** allows sensor **30** to monitor conditions within a microfluidic channel in which carrier device **50** is mounted, while apertures **62**, **64** provide access for the cabling to operate fluid sensor assembly **10**. Layer **54** includes a cutout section **66** for accommodating sensor **30** within carrier device **50**, while bottom layer **56** is used to hold sensor **30** in its proper position for operation. The assembled sensor carrier device **50** can be seen in **FIG. 4**.

[0028] **FIG. 5** illustrates the use of an optical sensor to determine the wetout of a microfluidic channel. Light source **70** is positioned in optical proximity to channel **71** such that it illuminates a portion of channel **71**. As channel **71** is filled, meniscus **72** creates an optically detectable signal (e.g., absorption or light scattering), which is picked up by detector **73**. The detector signal is then fed back through leads **74** into fluid driver **75** to control the flow.

[0029] While the present invention has been shown and described in terms of several preferred embodiments thereof, it will be understood that this invention is not limited to these particular embodiments and that many changes and modifications may be made without departing from the true spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A microfluidic device, comprising:

a microfluidic channel having an inlet and an outlet;

means associated with said channel and located between said inlet and said outlet, for sensing fluid flow within said channel, and generating electrical signals corresponding to fluidic properties of the fluid flow;

and means, coupled to said sensing means, for controlling fluid flow through said channel as a result of information obtained from said electrical signals from said sensing means.

2. The device of claim 1, wherein said sensing means comprises an electrode assembly.

3. The device of claim 2, wherein said electrode assembly includes a plurality of electrodes.

4. The device of claim 1, wherein said sensing means is positioned within said microfluidic channel.

5. The device of claim 1, wherein said control means further comprises:

means for analyzing said electrical signals from said sensing means, and

means for pumping a fluid into the inlet of said microfluidic channel in response to commands from said analyzing means.

6. The device of claim 1, wherein said sensing means comprises an optical detector.

7. The device of claim 1, wherein said optical detector is located in close proximity to said microfluidic channel.

8. The device of claim 7, wherein said optical detector comprises a light source located on one side of said channel and a light detector located on the other side of said channel such that the light from said source may be altered by the presence or absence of a liquid in said channel.

9. The device of claim 1, wherein said sensing means is capable of detecting wetout in said channel.

10. The device of claim 1, wherein said sensing means is capable of detecting the presence of a liquid within said channel.

11. The device of claim 1, wherein said sensing means is capable of detecting the presence of a gas within said channel.

12. The device of claim 2, wherein said electrode assembly is located within said channel and is capable of detecting the flow speed of fluids flowing within said channel.

13. The device of claim 5, wherein said pumping means is capable of changing the flow rate of a fluid within said channel in response to a command from said analyzing means.

14. The device of claim 1, wherein said sensing means is capable of detecting a meniscus of a liquid flowing within said microfluidic channel.

15. The device of claim 1, wherein said sensing means comprises a hot wire anemometer.

16. The device of claim 5, wherein said pumping means is capable of stopping a fluid from flowing within said channel in response to a signal from said analyzing means.

17. The device of claim 5, wherein said analyzing means includes a computer link.

18. The device of claim 1, wherein said fluidic properties include conductivity.

19. The device of claim 1, wherein said fluidic properties include capacity.

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