US 20110056834A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2011/0056834 A1
Fan (43) Pub. Date: Mar. 10, 2011

(54) DIELECTROPHORESIS-BASED MICROFLUIDIC SYSTEM

(76) Inventor: **Shih-Kang Fan**, Hsinchu (TW)

(21) Appl. No.: **12/591,693**

(22) Filed: **Nov. 30, 2009**

(30) **Foreign Application Priority Data**

Sep. 4, 2009 (TW) 98129958

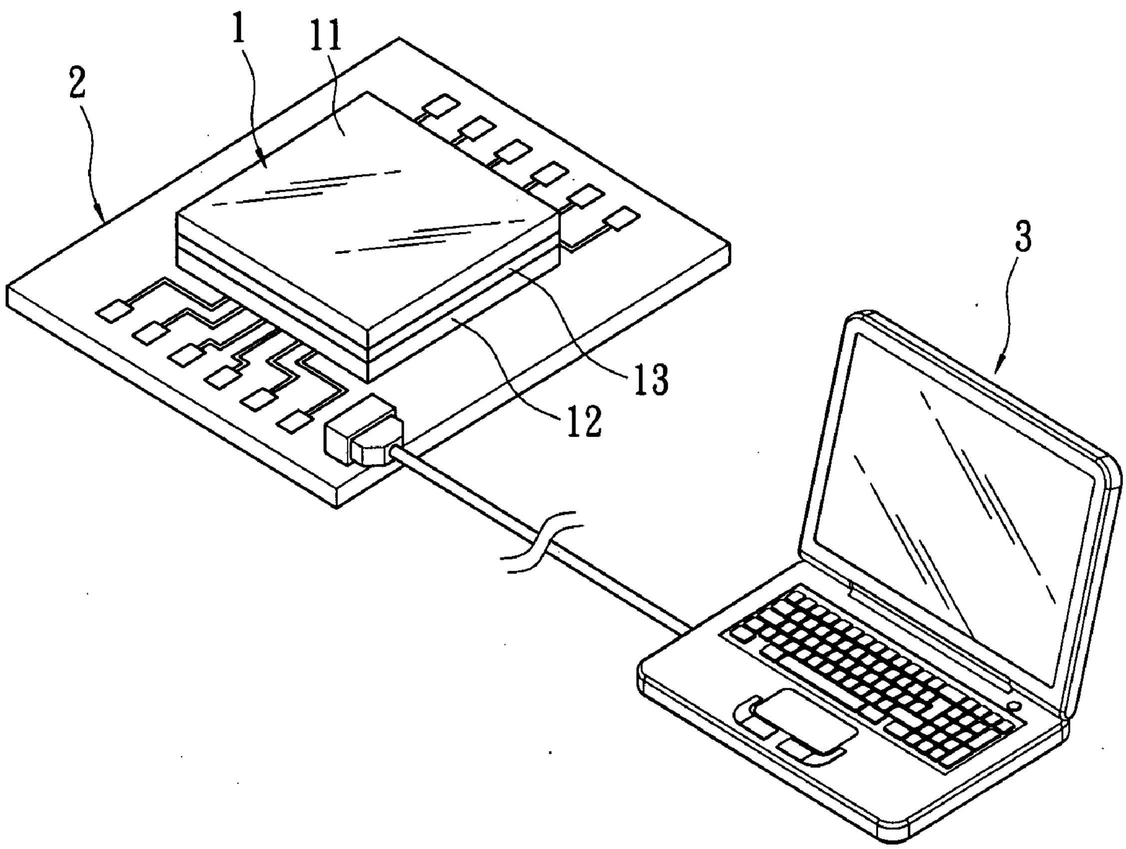
Publication Classification

(51) **Int. Cl.**
B03C 5/02 (2006.01)

(52) **U.S. Cl.** **204/643**

(57) **ABSTRACT**

A dielectrophoresis-based microfluidic system includes a first electrode plate, a second electrode plate and a spacing structure. The first electrode plate comprises a first substrate and an electrode layer disposed on one side surface of the first substrate. The second electrode plate comprises a second substrate and a plurality of electrodes. The electrodes are disposed on one side surface of the second substrate which is opposite to the electrode layer, and arranged in a microchannel pattern. The spacing structure is disposed between the first electrode plate and the second electrode plate so that a space is defined between the first electrode plate and the second electrode plate. Accordingly, users can inject microfluid into the space and apply voltage to different electrodes to drive the microfluid to flow towards different directions.



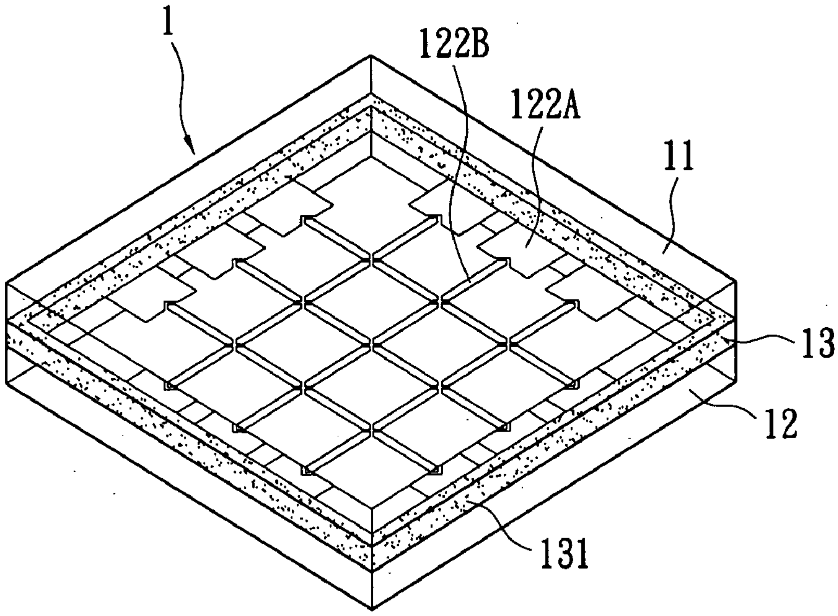


FIG. 1

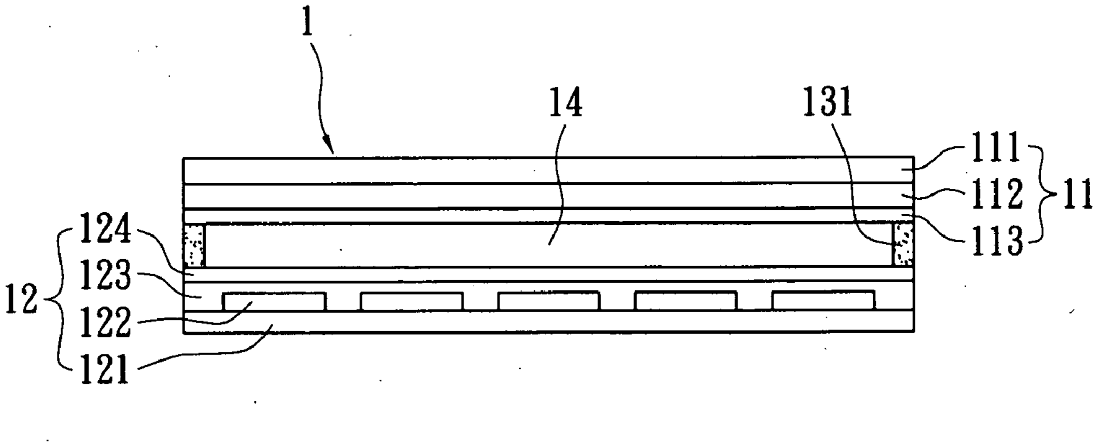


FIG. 2

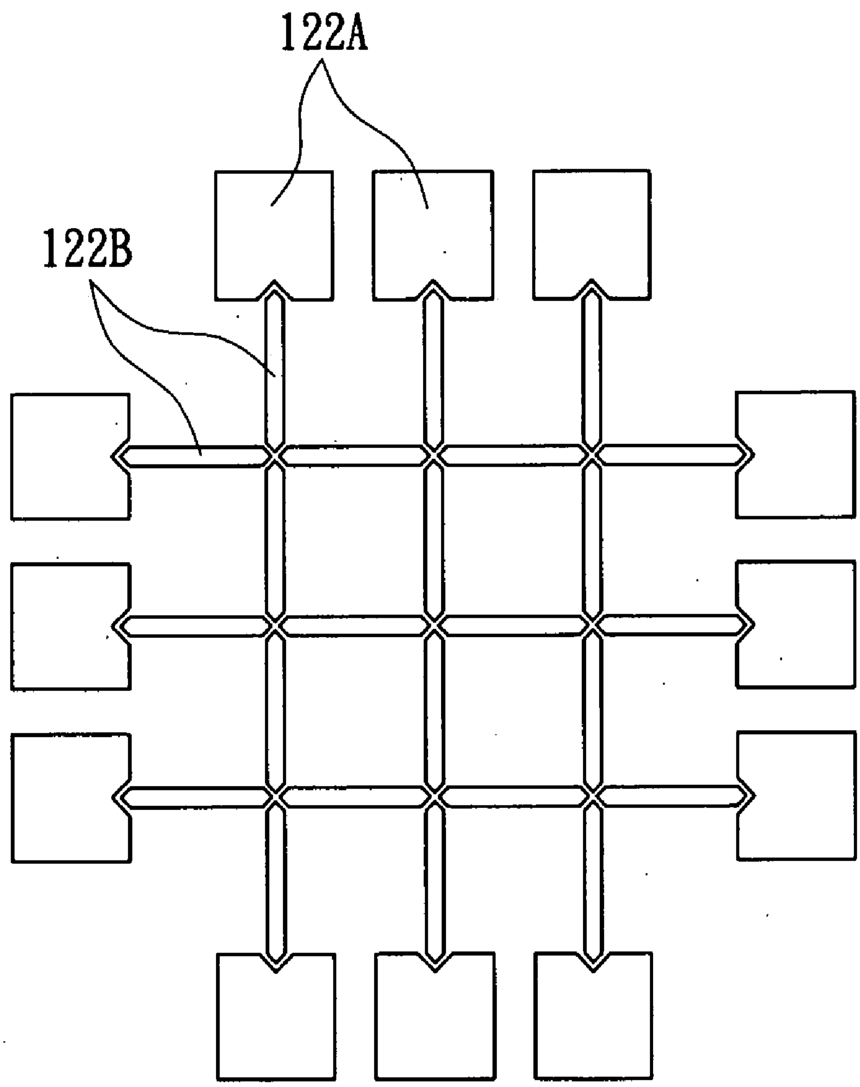


FIG. 3

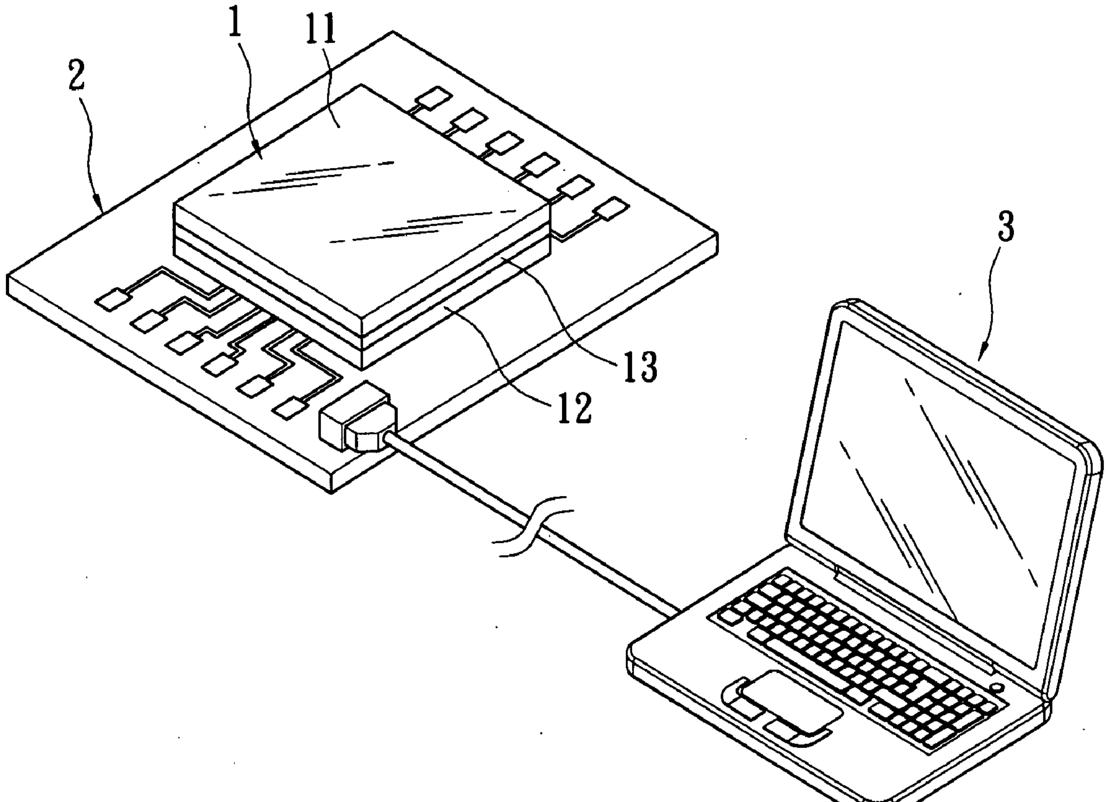


FIG. 4

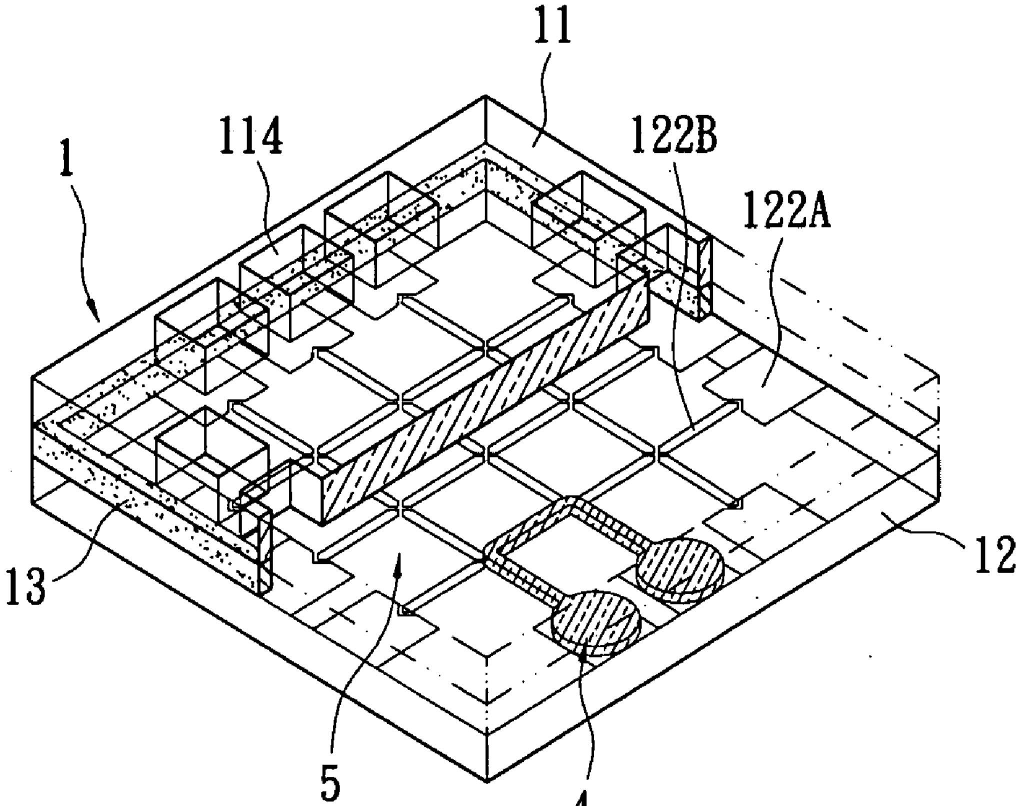


FIG. 5

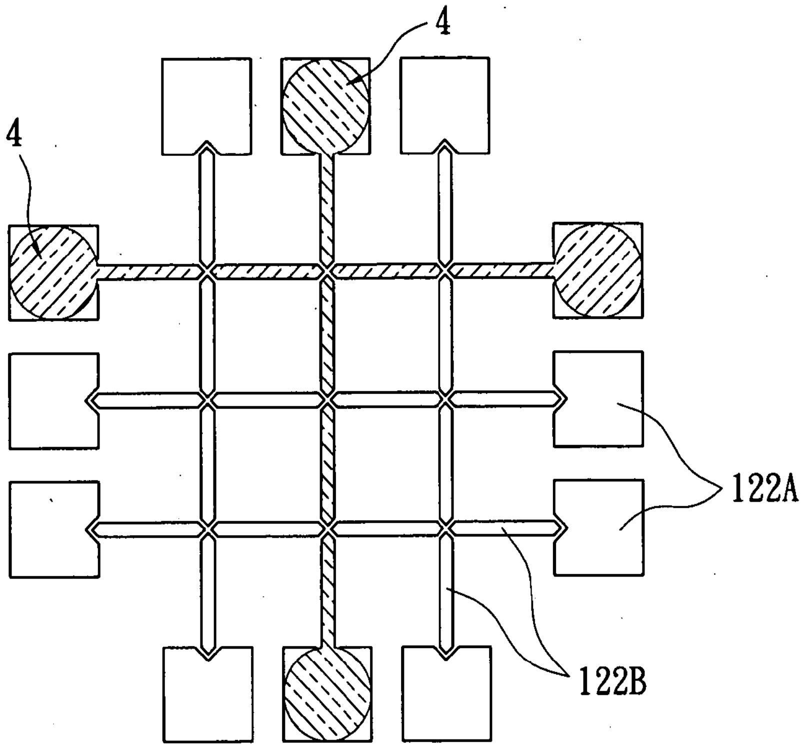


FIG. 6

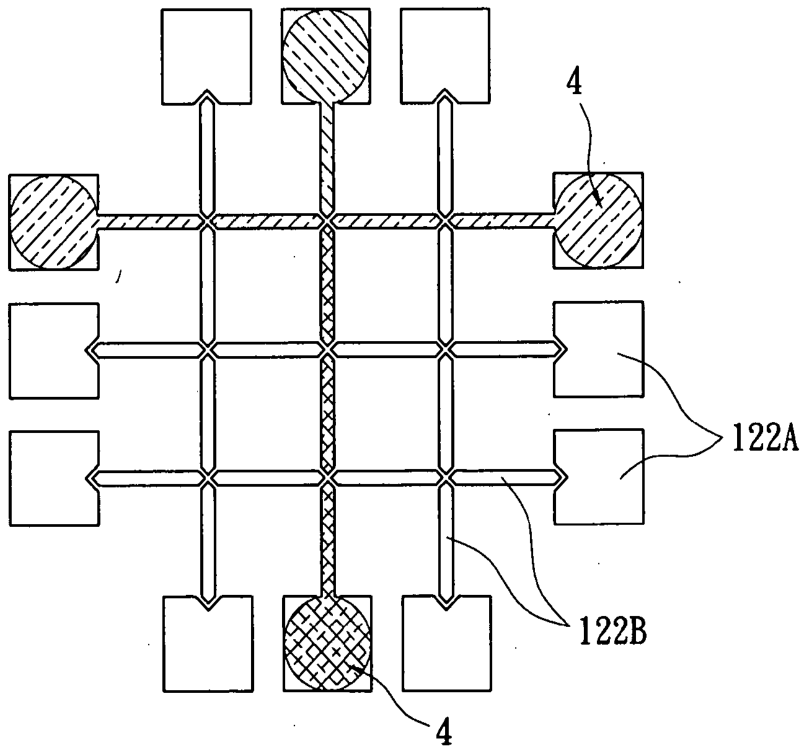


FIG. 7

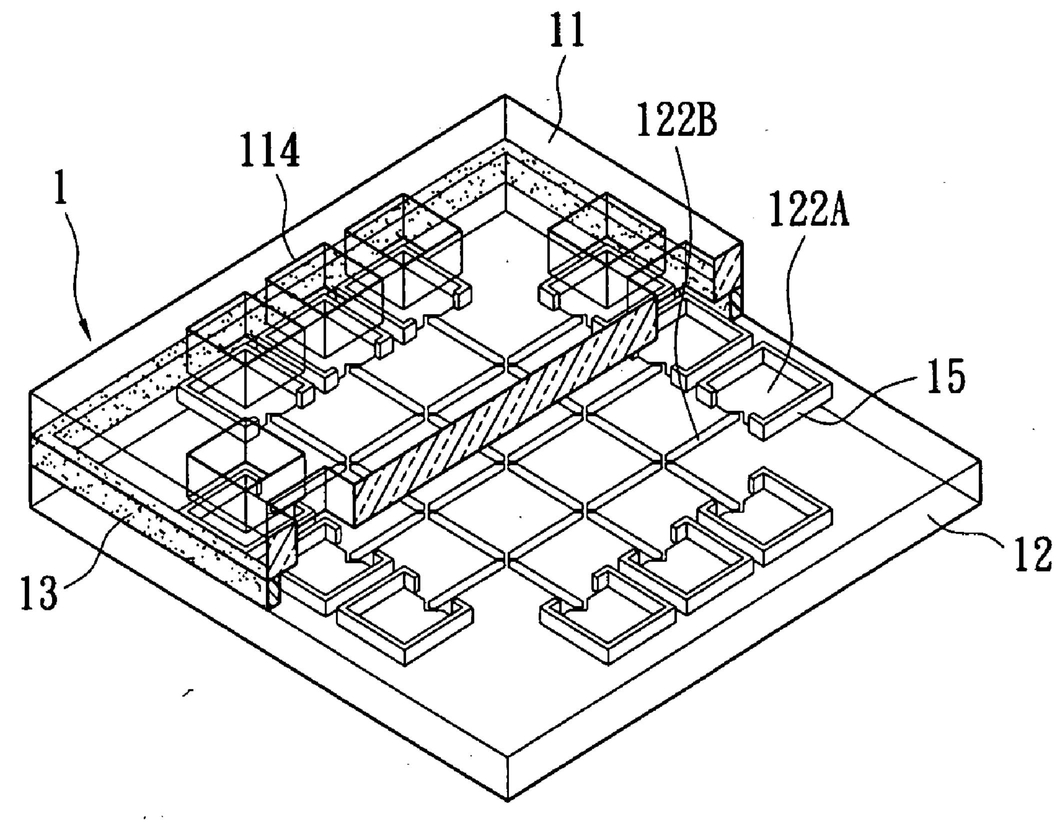


FIG. 8

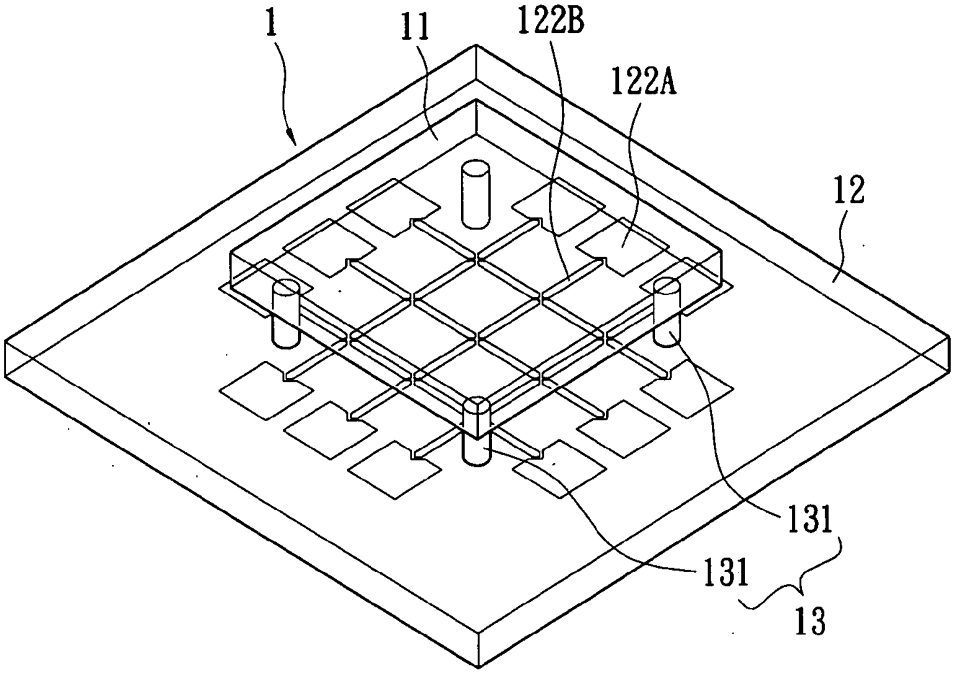


FIG. 9

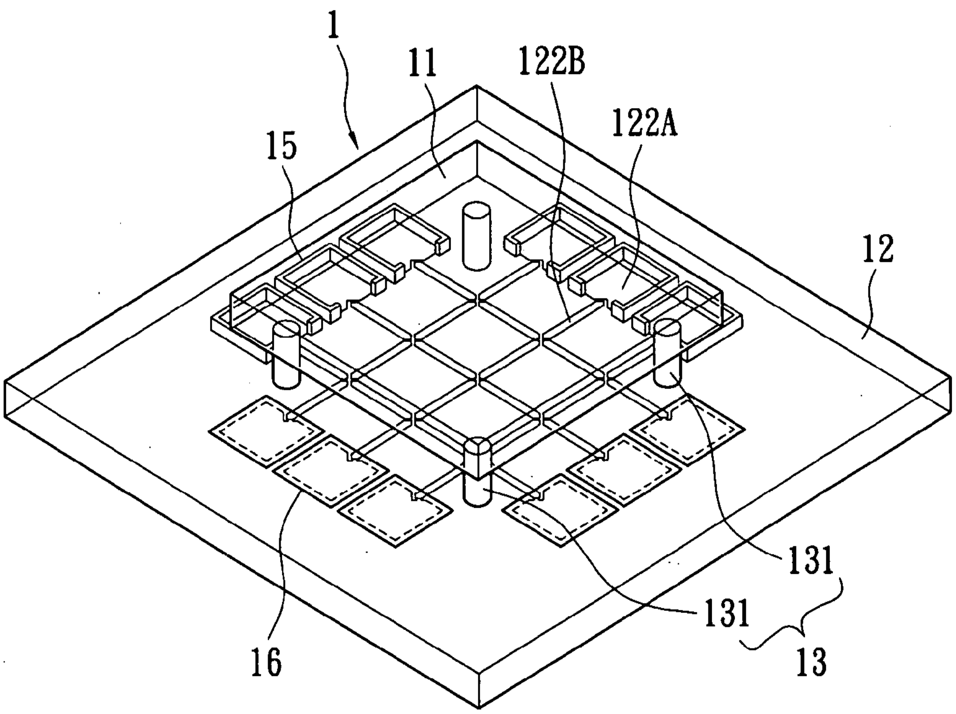


FIG. 10

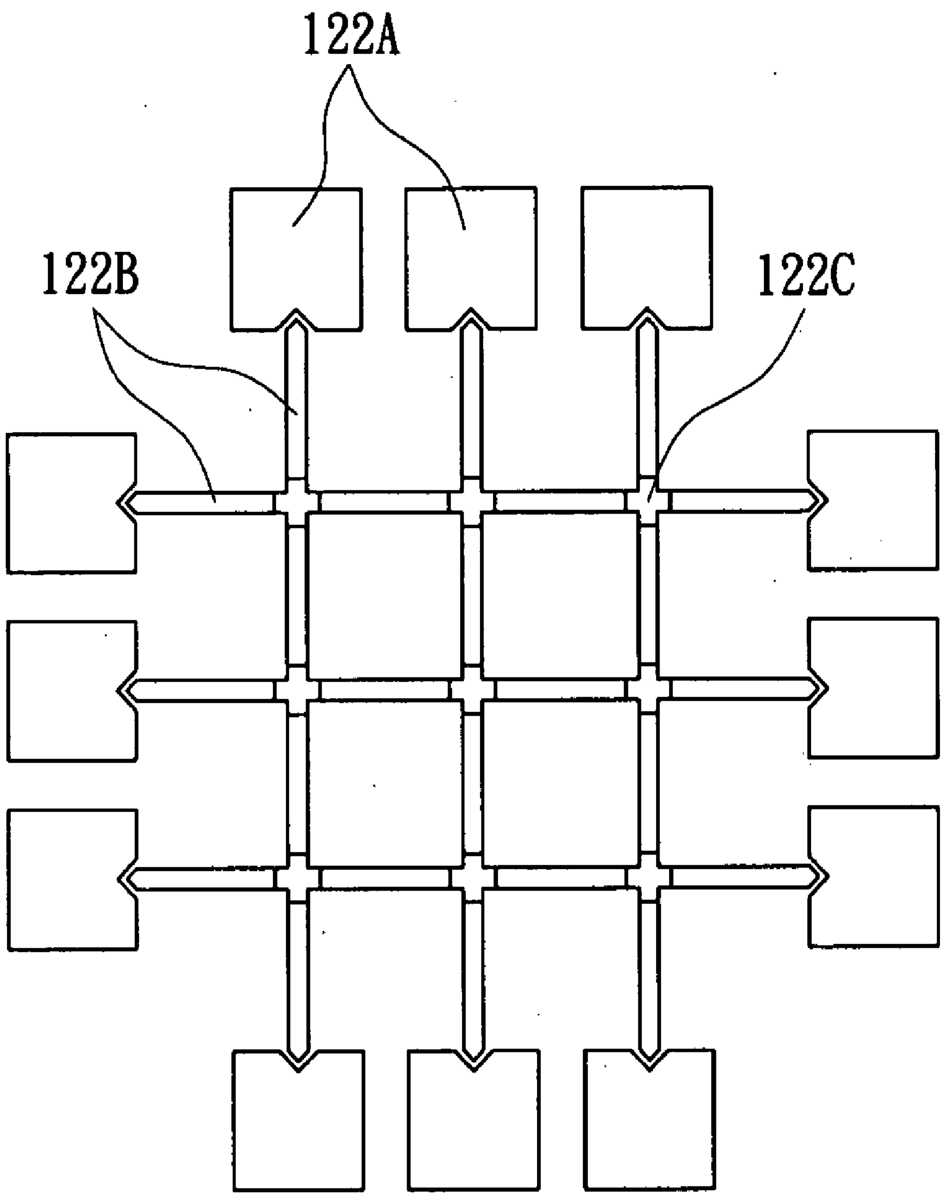


FIG. 11

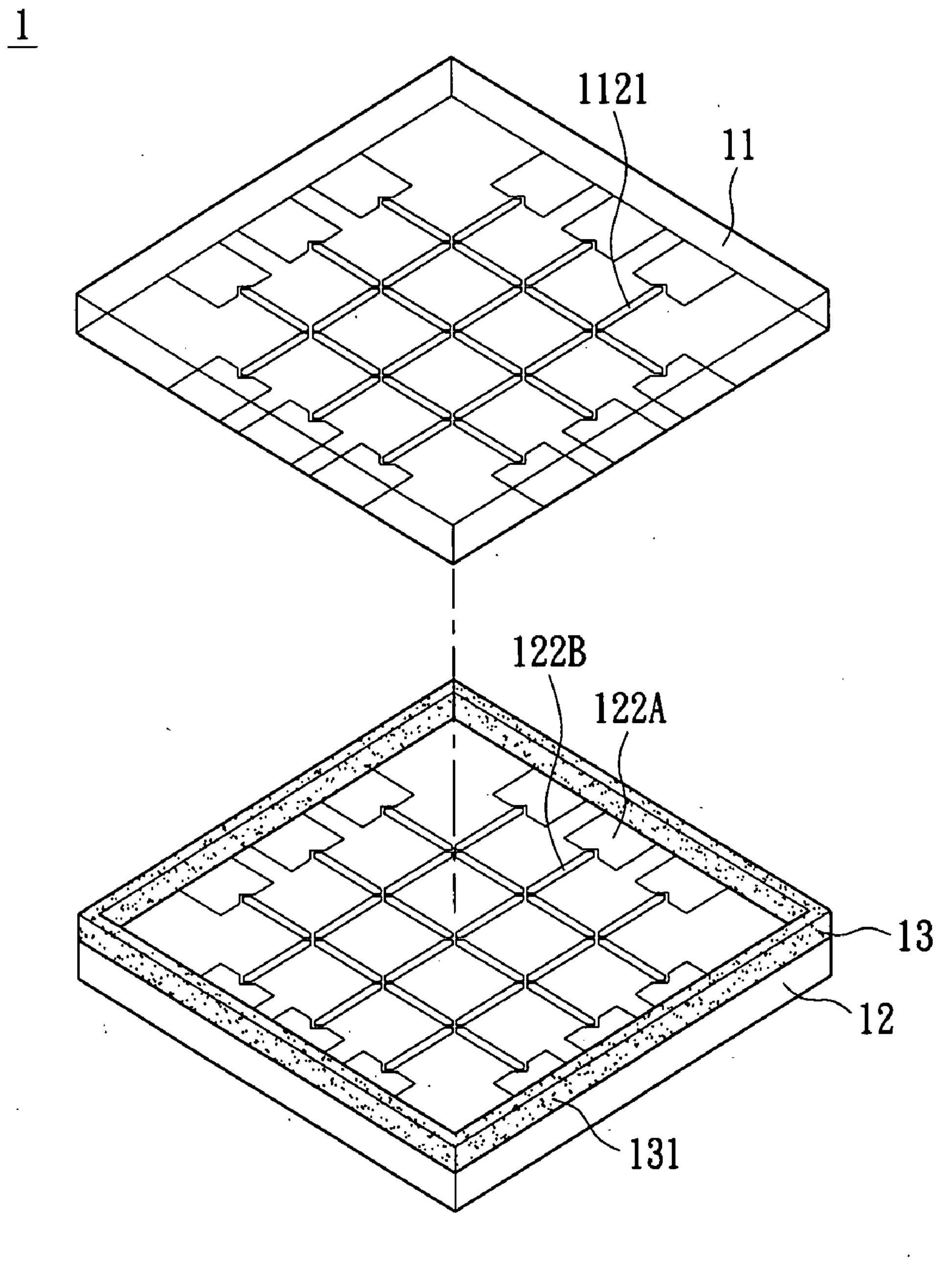


FIG. 12

DIELECTROPHORESIS-BASED MICROFLUIDIC SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a microfluidic system, and more particularly to a dielectrophoresis-based microfluidic system.

[0003] 2. Description of Related Art

[0004] At present, microfluidic systems, or called microfluidic chips, are developed widely. Since microfluidic systems have the advantages of rapid reaction rate, high sensitivity, high reproducibility, low costs, low pollution, and so on, they are widely used in various applications such as biological application, medical application, and photoelectric application and so on.

[0005] A basic structure of a conventional microfluidic system includes a substrate in which one channel or a plurality of channels in micrometer size, or called microchannels, are formed. Fluid may fill in the microchannels and then flow in the microchannels.

[0006] Additionally, some microfluidic systems further include pumps for providing power for fluid so that the fluid can flow in microchannels successfully.

[0007] However, the above-mentioned microfluidic systems have the shortcoming of fixed microfluidic networks. Once a microfluidic system is manufactured, its microfluidic network is fixed and cannot be changed to make fluid flow in different directions. Furthermore, the placement of the pumps increases the overall dimensions of the microfluidic systems, thereby reducing the transportability.

[0008] Hence, the inventors of the present invention believe that the shortcomings described above are able to be improved and finally suggest the present invention which is of a reasonable design and is an effective improvement based on deep research and thought.

SUMMARY OF THE INVENTION

[0009] A main objective of the present invention is to provide a dielectrophoresis-based microfluidic system which has unfixed virtual channels.

[0010] To achieve the above-mentioned objective, a dielectrophoresis-based microfluidic system in accordance with the present invention is provided. The dielectrophoresis-based microfluidic system includes: a first electrode plate which has a first substrate and an electrode layer disposed on one side surface of the first substrate; a second electrode plate which has a second substrate and a plurality of electrodes, wherein the electrodes are disposed on one side surface of the second substrate which is opposite to the electrode layer, and arranged in a microchannel pattern; and a spacing structure which is disposed between the first electrode plate and the second electrode plate so that a space is formed between the first electrode plate and the second electrode plate.

[0011] The dielectrophoresis-based microfluidic system of the present invention has the efficacy as following: the channels of the microfluidic system are virtual channels formed by the plurality of electrodes, thereby avoiding that conventional real channels limit flow directions of pumped fluid. As long as users apply voltage to different electrodes, the pumped fluid can flow to different locations, thereby achieving the intended result of programmable fluid manipulation. Additionally, since the present invention does not require a pump, the overall dimension of the present invention is smaller.

[0012] To further understand features and technical contents of the present invention, please refer to the following detailed description and drawings related the present invention. However, the drawings are only to be used as references and explanations, not to limit the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** is a perspective view of a first embodiment of a dielectrophoresis-based microfluidic system of the present invention;

[0014] FIG. **2** is a planar cross-sectional view of the first embodiment of the dielectrophoresis-based microfluidic system of the present invention;

[0015] FIG. **3** is a schematic view of a microchannel pattern of the first embodiment of the dielectrophoresis-based microfluidic system of the present invention;

[0016] FIG. **4** is a schematic view of the first embodiment of the dielectrophoresis-based microfluidic system of the present invention, connected with a driving circuit board and a controller;

[0017] FIG. **5** is a schematic view of the first embodiment of the dielectrophoresis-based microfluidic system of the present invention, in a used state;

[0018] FIG. **6** is a first schematic view of the first embodiment of the dielectrophoresis-based microfluidic system of the present invention separating DNA sample liquid;

[0019] FIG. **7** is a second schematic view of the first embodiment of the dielectrophoresis-based microfluidic system of the present invention separating DNA sample liquid;

[0020] FIG. **8** is a perspective view of a second embodiment of the dielectrophoresis-based microfluidic system of the present invention;

[0021] FIG. **9** is a perspective view of a third embodiment of the dielectrophoresis-based microfluidic system of the present invention;

[0022] FIG. **10** is a perspective view of a fourth embodiment of the dielectrophoresis-based microfluidic system of the present invention;

[0023] FIG. **11** is a schematic view of a microchannel pattern of a fifth embodiment of the dielectrophoresis-based microfluidic system of the present invention; and

[0024] FIG. **12** is a perspective view of a sixth embodiment of the dielectrophoresis-based microfluidic system of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] The present invention provides a dielectrophoresis-based microfluidic system with unfixed virtual channels for users to manipulate microfluids programmably. The dielectrophoresis-based microfluidic system can be referred as "microfluidic system" for short below.

[0026] Please refer to FIG. **1** and FIG. **2** illustrating a first preferred embodiment of the dielectrophoresis-based microfluidic system **1** according to the present invention, which includes a first electrode plate **11**, a second electrode plate **12** and a spacing structure **13**.

[0027] The following is to demonstrate the features of each of components and then the connection relationship between the components. Each direction (up, down, front, rear, left or right) in the following description is only used to express a relative direction, and doesn't limit the actual used directions of the dielectrophoresis-based microfluidic system **1**.

[0028] The first electrode plate **11** includes a first substrate **111**, an electrode layer **112** and a first hydrophobic layer **113**. The first substrate **111** is a rectangular plate of which a material may be glass, silicon substrate, poly-dimethylsiloxane (PDMS), polyethylene terephthalate (PET), polyethylene naphthalate (PEN) or a flexible polymer material etc.

[0029] The electrode layer **112** is disposed on the bottom surface of the first substrate **111** and covers the whole bottom surface of the first substrate **111**. The material of the electrode layer **112** may be a conductive metal material, a conductive polymer material or a conductive oxide material etc., such as Cr/Cu metal or indium tin oxide (ITO) etc.

[0030] The electrode layer **112** is deposited on the first substrate **111** via E-beam evaporation, physical vapor deposition, sputtering etc.

[0031] The first hydrophobic layer **113** is disposed on the bottom surface of the electrode layer **112** and covers the whole bottom surface of the electrode layer **112**. The material of the first hydrophobic layer **113** may be a hydrophobic material such as Teflon and so on. The effect is that the pumped fluid **4** mentioned below (please refer to FIG. **5**) has a hydrophobic characteristic, or the surface of the first electrode plate **11** is hydrophobic to the pumped fluid **4**, which is convenient for driving the pumped fluid **4**. The first hydrophobic layer **113** is deposited on the electrode layer **112** via physical or/and chemical deposition or spin coating etc.

[0032] Even if the first hydrophobic layer **113** is not disposed on the electrode layer **112**, it will not cause that the pumped fluid **4** cannot be driven. Furthermore, if the pumped fluid **4** has a good hydrophobic characteristic itself, or its surface energy is large, then it is not required to dispose the first hydrophobic layer **113** on the electrode layer **112**. In other words, for the first electrode plate **11**, the first hydrophobic layer **113** is optional.

[0033] The above is the illustration for the first electrode plate **11**, and the following is to describe the second electrode plate **12**.

[0034] The second electrode plate **12** includes a second substrate **121**, a plurality of electrodes **122**, a dielectric layer **123** and a second hydrophobic layer **124**.

[0035] The second substrate **121** is similar to the first substrate **111**, that is, the second substrate **121** is a rectangular plate and the material of the second substrate **121** may be glass, silicon substrate, poly-dimethylsiloxane (PDMS), polyethylene terephthalate (PET), polyethylene naphthalate (PEN) or a flexible polymer material etc.

[0036] The electrodes **122** are disposed on the top surface of the second substrate **121**. The material of the electrodes **122** is similar to that of the conductive layer **121** and may be a conductive metal material, a conductive polymer material or a conductive oxide material etc., such as Cr/Cu metal or Indium tin oxide (ITO) etc. The shape and the arrangement of the electrodes **122** depend on a particular microchannel pattern.

[0037] Please further refer to FIG. **3**, the microchannel pattern includes a plurality of quadrate reservoirs **122**A and a plurality of long-strip-shaped channels **122**B. Each of the reservoirs **122**A and the channels **122**B is one of the electrodes **122**. Each channel **122**B is connected with other three channels **122**B (there are spaces between the channels) to form a cruciform channel, and each reservoir **122**A is connected with several channels **122**B located on more peripheral positions. The functions of the reservoirs **122**A and the channels **122**B will be explained in the following operating instructions of the microfluidic system **1**.

[0038] The manufacturing process for the electrodes **122** is as following: depositing a layer of material on the second substrate **112** via E-beam evaporation, physical vapor deposition, or sputtering etc. and removing unwanted materials via etching and so on to form the plurality of electrodes **122** arranged in the microchannel pattern. The electrodes **122** may also be manufactured via other processes, such as lift-off and so on.

[0039] The dielectric layer **123** is disposed on the electrodes **122** and covers all of the electrodes **122**. The material of the dielectric layer **123** may be various dielectric materials, such as parylene, positive photoresist, negative photoresist, materials with high dielectric constant, or materials with low dielectric constant.

[0040] The second hydrophobic layer **124** is disposed on the top surface of the dielectric layer **123** and covers the whole dielectric layer **123**. The material of the second hydrophobic layer **124** is similar to that of the first hydrophobic layer **113** and may be a hydrophobic material such as Teflon and so on. The effect is that the pumped fluid **4** (please refer to FIG. **5**) has a hydrophobic characteristic, or the second electrode plate **12** is hydrophobic to the pumped fluid **4**, which is convenient for driving the pumped fluid **4**.

[0041] The dielectric layer **123** is formed by depositing the material of the dielectric layer **123** on the second substrate **121** and the electrodes **122**, and the second hydrophobic layer **124** may also be formed by depositing the material of the second hydrophobic layer **124** on the dielectric layer **123**.

[0042] Additionally, for the second electrode plate **12**, the dielectric layer **123** is optional. That is, as long as the dielectric characteristic of the pumped fluid **4** meets the applied requirements, it doesn't need the dielectric layer **123** existing in the second electrode plate **12**. For the second electrode plate **12**, the second hydrophobic layer **124** is optional. As long as the pumped fluid **4** has the hydrophobic characteristic itself, or the surface of the electrode plate **12** is hydrophobic to the pumped fluid **4**, it does not need to dispose the second hydrophobic layer **124** on the dielectric layer **123**.

[0043] The above is the illustration of the second electrode plate **12**, and the following is the illustration for the spacing structure **13**. The spacing structure **13** includes four spacers **131**, each of which may be an insulating spacer. The four spacers **131** are arranged in a continuous frame structure.

[0044] The above is the explanation of each of components of the microfluidic system **1**, and then the connection relationship between the components is to be explained. The first electrode plate **11** and the second electrode plate **12** are arranged in parallel. The electrode layer **112** is opposite to the electrodes **122**. The spacers **131** of the spacing structure **13** are disposed between the first electrode plate **11** and the second electrode plate **12**, so that a space **14** is defined between the first electrode plate **11** and the second electrode plate **12**.

[0045] Please refer to FIG. **4**, the microfluidic system **1** is further mounted on a driving circuit board **2** and electrically connected with the driving circuit board **2** by wires or connectors, so that the driving circuit board **2** provides voltage to the electrode layer **112** and the electrodes **122** of the microfluidic system **1**.

[0046] A controller **3** (for example, a desktop computer, a notebook computer, a personal digital assistant or a mobile phone etc.) is connected with the driving circuit board **2** with or without wires. Users can set various control programs in the controller **3**, so that the controller **3** can send a control signal to the driving circuit board **2** according to the control programs and the driving circuit board **2** can supply voltage for different electrodes **122** according to the control signal.

[0047] Please refer to FIG. **5**, during using the microfluidic system **1**, at first, injecting one kind of pumped fluid **4** into the microfluidic system **1**, that is, placing the pumped fluid **4** in the space **14** on one or a plurality of electrodes **122** (reservoirs **122**A). Then, injecting one kind of surrounding fluid **5** into the space **14** to surround the pumped fluid **4**. The pumped fluid **4** and the surrounding fluid **5** is injected into the space **14** through an opening **114** of the first electrode plate **11**, and the opening **114** is located over the reservoirs **122**A.

[0048] It is noted that the dielectric constant of the pumped fluid **4** must be greater than that of the surrounding fluid **5** so that the pumped fluid **4** can flow basing on the dielectrophoresis phenomenon. So the pumped fluid **4** may be water and the surrounding fluid **5** may be air or silicone oil; or alternatively, the pumped fluid **4** may be silicone oil and the surrounding fluid **5** may be air. The above-mentioned pumped fluid **4** and surrounding fluid **5** are only examples and are not merely limited thereto.

[0049] After the pumped fluid **4** and the surrounding fluid **5** is injected into the microfluidic system **1**, the driving circuit board **2** applies voltage to the electrode layer **112** and one of the electrodes **122**, so that the electric field between the electrode layer **112** and the electrodes **122** changes. The pumped fluid **4** and the surrounding fluid **5** is polarized in varying degrees, so that the pressure difference exists between the pumped fluid **4** and the surrounding fluid **5**, and then the pumped fluid **4** flows in the low-pressure direction. The phenomenon is called a dielectrophoresis phenomenon and the pressure difference between the pumped fluid **4** and the surrounding fluid **5** may be called a dielectrophoresis force.

[0050] Accordingly, as long as the driving circuit board **2** applies voltage to different electrodes **122**, the pumped fluid **4** will flow towards the electrode **122** to which the voltage is applied; that is, without a pump, the pumped fluid **4** can be controlled to flow towards different directions.

[0051] In other words, the configuration of the channels of the microfluidic system **1** is unfixed and changeable with applying voltages to different electrodes **122**. Users write control programs to control the driving circuit board **2** to apply voltage to different electrodes **122**, thereby controlling the pumped fluid **4** to flow towards different electrodes **122**. Accordingly, the programmable microfluid control can be achieved.

[0052] Please refer to FIG. **6**, the above-mentioned microfluidic system **1** may be used to separate DNA. Inject DNA sample liquid (the pumped fluid) **4** into the left uppermost and the right uppermost reservoirs **122**A, and then inject buffer liquid (the pumped fluid) **4** into the upper middle and the lower middle reservoirs **122**A.

[0053] Subsequently, applying voltages to four longitudinal channels **1228** between the upper middle reservoir **122**A and the lower middle reservoir **122**A, so that the buffer liquid **4** flows into the four longitudinal channels **122**B. That is, the four longitudinal channels **122**B are filled with the buffer liquid **4**. Further, applying voltages to four transversal channels **122**B between the left uppermost reservoir **122**A and the right uppermost reservoir **122**A, so that the DNA sample liquid **4** flows into the four transversal channels **122**B. That is, the four transversal channels **122**B are filled with the DNA sample liquid **4**. The DNA sample liquid **4** and the buffer liquid **4** flows crosswise.

[0054] Please refer to FIG. **7**, finally, applying voltages to four longitudinal channels **122**B between the upper middle reservoir **122**A and the lower middle reservoir **122**A, so that the crossed DNA sample liquid **4** flows towards the lower middle reservoir **122**A basing on the electrophoresis force and electroosmosis, and separates in the channels **122**B basing on the mass-to-charge ratio.

[0055] The above is the first embodiment of the microfluidic system **1** of the present invention. Please refer to FIG. **8** illustrating a second embodiment of the microfluidic system **1** of the present invention. The difference between the second embodiment and the first embodiment is that the microfluidic system **1** of the second embodiment further includes a plurality of fence structures **15** disposed on the top surface of the second electrode plate **12** and respectively surrounding each reservoir **122**A.

[0056] When the pumped fluid **4** is injected into the reservoirs **122**A, the fence structures **15** can help the pumped fluid **4** keep in the reservoirs **122**A and ensure that the amount of the pumped fluid **4** in each reservoir **122**A is equal.

[0057] Please refer to FIG. **9**, illustrating a third embodiment of the microfluidic system **1** of the present invention. The difference between the third embodiment and the first embodiment is that the area of the first electrode plate **11** of the microfluidic system **1** of the third embodiment is larger than that of the second electrode plate **12**, the spacing structure **13** includes four individual spacers **131** respectively located at four corners of the first electrode plate **11** and the second electrode plate **12**, and the reservoirs **122**A are located on the periphery of the first electrode plate **11**.

[0058] During using the microfluidic system **1**, the pumped fluid **4** is dripped in the reservoirs **122**A of the second electrode plate **12**, and voltage is applied to different electrodes **122** so that the pumped fluid **4** flows between the first electrode plate **11** and the second electrode plate **12** under the effect of dielectrophoresis.

[0059] Please refer to FIG. **10**, illustrating a fourth embodiment of the microfluidic system **1** of the present invention. The difference between the fourth embodiment and the third embodiment is that the microfluidic system **1** of the fourth embodiment further includes a plurality of fence structures **15** and a plurality of hydrophilic layers **16** which are respectively prepared on the top surface of the first electrode plate **11** and located over the partial reservoirs **122**A.

[0060] During using the microfluidic system **1**, the pumped fluid **4** is dropped in the fence structures **15** or on the hydrophilic layers **16**. The pumped fluid **4** is kept in the fence structures **15** or on the hydrophilic surface **16**, and doesn't flow between the first electrode plate **11** and the second electrode plate **12** until the electrodes **122** are electrified.

[0061] Furthermore, the fence structures **15** and the hydrophilic layers **16** can be applied in the third embodiment of the microfluidic system **1**, independently, and are not limited in any specific combinations by applying them. In the microfluidic system **1** of the second embodiment, all or partial of the fence structures **15** may be replaced by the hydrophilic layers **16** In other words, the microfluidic system **1** may selectively have one kind of or all kinds of the opening **114**, the fence structures **15** and the hydrophilic layers **16**.

[0062] Please refer to FIG. **11**, illustrating a fifth embodiment of the microfluidic system **1** of the present invention.

The difference between the fifth embodiment and the abovementioned embodiments is that the microfluidic pattern formed by the electrodes **122** further includes a plurality of joints **122**C of which each is connected with at least two channels **122**B. The joints **122**C may also be applied voltage to so as to help the pumped fluid **4** change its flow direction.

[0063] Please refer to FIG. **12**, illustrating a sixth embodiment of the microfluidic system **1** of the present invention. The difference between the sixth embodiment and the abovementioned embodiments is that the electrode layer **112** of the first electrode plate **11** does not cover the whole bottom surface of the first substrate **111**, and comprises a plurality of the electrodes **1121**. The electrodes **1121** are arranged in another microchannel pattern, which may be the same to the microchannel pattern of the electrodes **122**.

[0064] Using the microfluidic system **1** of the sixth embodiment is similar to using the microfluidic system **1** of other embodiments. Voltage is applied to the designated electrode **122** and the corresponding electrode **1121**, and then the pump fluid **4** will flow towards the designated electrodes.

[0065] Consequently, the dielectrophoresis-based microfluidic system of the present invention has the characteristics as follows: the channels of the microfluidic system are virtual channels formed by a plurality of electrodes, thereby avoiding that conventional real channels limit the flow directions of the pumped fluid. As long as users apply voltages to different electrodes, the pumped fluid can flow in different directions, thereby achieving the intended result of the programmable fluid manipulation. Additionally, since the present invention does not require a pump, the present invention has smaller size and can be manufactured in a semiconductor fabrication process.

[0066] What are disclosed above are only the specifications and the drawings of the preferred embodiments of the present invention and it is therefore not intended that the present invention be limited to the particular embodiments disclosed. It will be understood by those skilled in the art that various equivalent changes may be made depending on the specifications and the drawings of the present invention without departing from the scope of the present invention.

What is claimed is:

1. A dielectrophoresis-based microfluidic system, comprising:

a first electrode plate, comprising a first substrate and an electrode layer disposed on one side surface of the first substrate;

a second electrode plate, comprising a second substrate and a plurality of electrodes, the electrodes disposed on one side surface of the second substrate which is opposite to the electrode layer, and arranged in a microchannel pattern; and

a spacing structure, disposed between the first electrode plate and the second electrode plate so that a space is defined between the first electrode plate and the second electrode plate.

2. The dielectrophoresis-based microfluidic system as claimed in claim **1**, wherein the microchannel pattern includes a plurality of reservoirs and a plurality of channels, in which the reservoirs are respectively connected with one or more than one of the plurality of channels, and each of the channels is in fluid communication with at least one another of the plurality of channels.

3. The dielectrophoresis-based microfluidic system as claimed in claim **2**, wherein the microchannel pattern further includes a plurality of joints of which each is connected with at least two channels of the plurality of channels.

4. The dielectrophoresis-based microfluidic system as claimed in claim **1**, wherein the spacing structure has a plurality of spacers.

5. The dielectrophoresis-based microfluidic system as claimed in claim **1**, wherein the first electrode plate further has a hydrophobic layer disposed on the electrode layer.

6. The dielectrophoresis-based microfluidic system as claimed in claim **1**, wherein the second electrode plate further has a dielectric layer disposed on the electrodes.

7. The dielectrophoresis-based microfluidic system as claimed in claim **6**, wherein the second electrode plate further has a hydrophobic layer disposed on the dielectric layer.

8. The dielectrophoresis-based microfluidic system as claimed in claim **1**, wherein the first electrode plate further has a plurality of openings.

9. The dielectrophoresis-based microfluidic system as claimed in claim **1**, further comprising a plurality of fence structures disposed on a top surface of the second electrode plate.

10. The dielectrophoresis-based microfluidic system as claimed in claim **1**, further comprising a plurality of hydrophilic layers prepared on a top surface of the second electrode plate.

11. The dielectrophoresis-based microfluidic system as claimed in claim **1**, further comprising a pumped fluid located in the space over one or more than one electrodes of the plurality of electrodes.

12. The dielectrophoresis-based microfluidic system as claimed in claim **11**, further comprising a surrounding fluid located in the space and surrounding the pumped fluid.

13. The dielectrophoresis-based microfluidic system as claimed in (claim **12**, wherein dielectric constant of the pumped fluid is greater than that of the surrounding fluid.

14. The dielectrophoresis-based microfluidic system as claimed in claim **1**, wherein the first electrode layer comprises a plurality of electrodes arranged in another microchannel pattern.

* * * * *