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(54) DIELECTROPHORETIC CONCENTRATION OF PARTICLES UNDER ELECTROKINETIC FLOW

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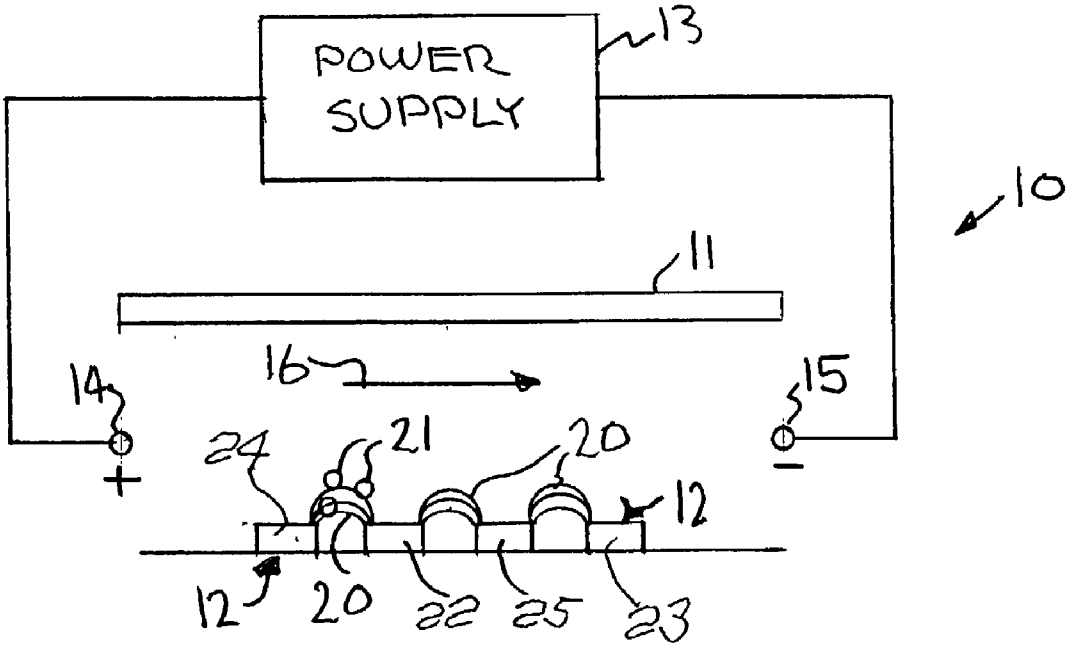
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(57) **ABSTRACT**

The use of dielectrophoresis to collect particles under the conditions of electrokinetically-driven flow. Dielectrophortic concentration of particles under electrokinetic flow is accomplished by interdigitated electrodes patterned on an inner surface of a microfluid channel, a DC voltage is applied across the ends to the channel, and an AC voltage is applied across the electrodes, and particles swept down the channel electrokinetically are trapped within the field established by the electrodes. The particles can be released when the voltage to the electrodes is released.



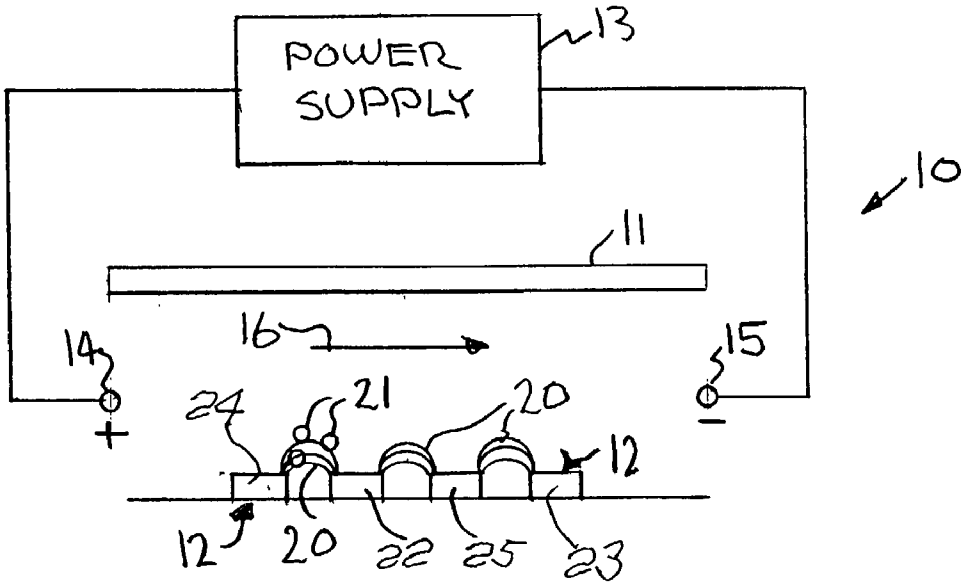

POWER SUPPLY
13
10
11
16
14
15
+
−
24
21
20
12
12
20
22
25
23

FIG. 1

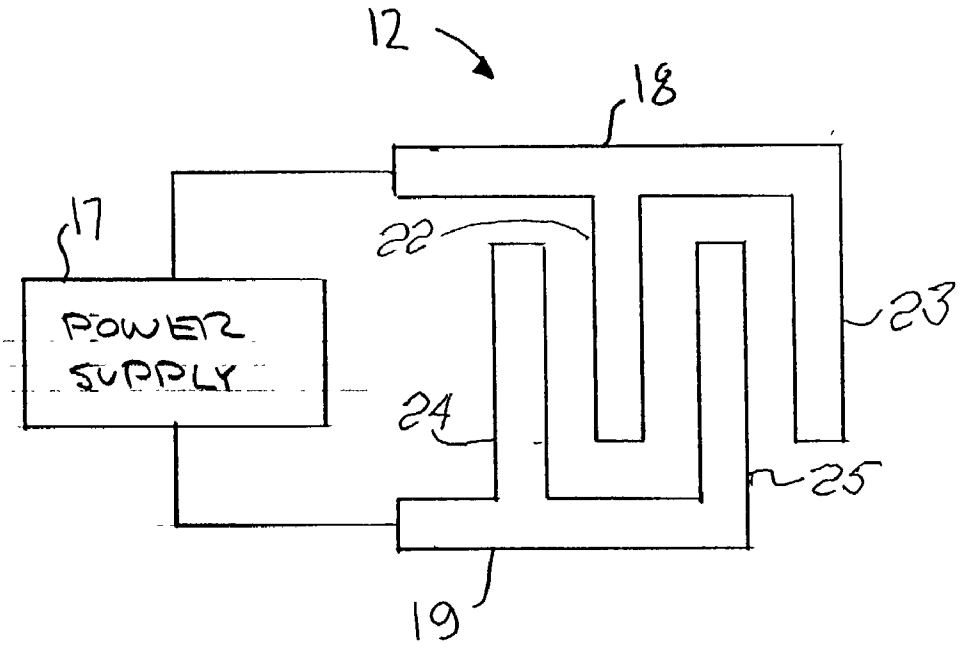

12
18
17
22
23
POWER SUPPLY
24
25
19

FIG. 2

DIELECTROPHORETIC CONCENTRATION OF PARTICLES UNDER ELECTROKINETIC FLOW

[0001] The United States Government has rights in this invention pursuant to Contract No. W-7405-ENG-48 between the United States Department of Energy and the University of California for the operation of Lawrence Livermore National Laboratory.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to the concentration of particles in microfluidic devices, particularly to the use of dielectrophoresis to collect or concentrate the particles, and more particularly to the use of dielectrophoresis to collect particles under the conditions of electrokinetically-driven flow.

[0003] Microfluidic devices are most useful when operating with small sample volumes. Small sample volumes result in increased reaction times and reduced reagent use which means significantly reduced costs for the multitude of tests that one desires to conduct on any given sample. Dielectrophoretic concentration of the samples is a useful method for achieving these goals. Dielectrohporesis is attractive on the microfluidic scale because the forces become significant and useful at dimensions of less than 1 mm. Electrokinetic/electroosmotic flow is also useful in these devices because it obviates the need for micropumps and microvalves.

[0004] The present invention involves the combination of dielectrophoresis (DEP) and electrokinetic/electroosmotic flow. Such combination would not normally be an obvious choice since one might think that the two electric fields and their associated double charge layers may interfere with each other. Also, dielectrophoresis collection works best in the slow boundary-layer flow normally associated with pressure-driven flow. However, by the present invention, it has been found that particles can still collect even in the more uniform flow field associated with electroosmotic flow. The 5-10 mm double charge layer associated with establishing electroosmotic flow does not interfere, or be interfered with, by the DEP field in a significant way.

SUMMARY OF THE INVENTION

[0005] It is an object of the present invention to collect particles in a microfluidic channel using dielectrophoresis.

[0006] A further object of the invention is to provide for dielectriphoretic concentration of particles under electrokinetic flow.

[0007] Another object of the invention is to use delectrophoresis to collect particles under the conditions of electrokinetically-driven flow.

[0008] Another object of the invention is to use a combination of dielectrophoresis and electrokinetic/electroosmotic flow for the collection of particles in a microfluidic device.

[0009] Another object of the invention is to provide a microfluidic device capable on dielectrophoretic concentration of particles under electrokinetic flow.

[0010] Other objects and advantages of the present inventions will become apparent from the following description and accompanying drawing. Basically the present invention involves a method and apparatus for collecting or concentrating particles in a microfluidic channel using dielectrophoresis under conditions of electrokinetically-driven flow. This is accomplished by interdigitated electrodes patterned on the inner surface of a microfluidic channel, preferable formed of glass, applying a DC voltage across the ends of the channel to initiate an electrokinetic/electroosmotic flow field, and applying an AC voltage across the interdigitated electrodes to set up a non-uniform electric field capable of trapping particles using the dielectrophortic force. The trapped particles are released upon removal of the voltage to the electrodes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying drawings, which are incorporated into and form a part of the disclosure, illustrate an embodiment of the invention and, together with the description, serve to explain the principles of the invention.

[0012] **FIG. 1** is a schematic illustration of a microfluidic eletrokinetic flow channel with interdigitated electrodes located along the length of the channel.

[0013] **FIG. 2** is a greatly enlarged top view of the interdigitated electrodes of **FIG. 1** and AC power source therefor.

DETAILED DESCRIPTION OF THE INVENTION

[0014] The present invention is directed to dielectrophoretic concentration of particles under electrokinetic flow. The present invention involves a method and apparatus for collecting particles in a microfluidic channel using the combination of dielectrophoresis and electrokinetic/electroosmotic flow. Electrokinetically-driven flow is an important technique for moving fluids and sample around a microfluidic biochemical assay chip, and the combination with the advantages of dielectrophoretic manipulation in this regime significantly advances this field of technology.

[0015] **FIGS. 1 and 2** schematically illustrate an embodiment of an apparatus for carrying out the present invention, with **FIG. 2** being a top view of a pair of interdigitated electrodes of **FIG. 1**. Interdigitated electrodes are patterned on the inner surface of a microfluidic channel but can be suspended within the fluid. Glass is the preferred material for the microfluidic channel because it promotes electroosmotic flow, particularly if preconditioned with sodium hydroxide. However, other materials, such as certain types of plastics may be utilized. A direct current (DC) voltage is applied across the ends of the channel to initiate the electrokinetic/electroosmotic flow field. An alternating current (AC) voltage is applied across the interdigitated electrodes to set up a non-uniform electric field capable of trapping particles using the dielectrophoretic force. Particles are swept down the channel electrokinetically and are trapped within the field established by the interdigitated electrodes. The trapped particles can be released when the voltage to the interdigitated electrodes is released. Thus, this approach enables concentration of the sample prior to testing, since dielectrophoresis effects the motion on polarizable particles within a non-uniform electric field. Positive dielectrophoresis can be used to concentrate particles in areas of high electric field gradients, and can be used to eliminate the use

of centrifuging to concentrate biological samples. Negative dielectrophoresis can be used to discriminate between various types of biological particles.

[0016] Referring now to the drawings, a microfluidic device generally indicated at **10** includes at least one microfluidic channel **11**, having a pair of spaced sets of interdigitaled electrodes generally indicated at **12** patterned on the inner surface of the channel **11**, which, for example, may be formed of bonded glass plates with the channel **11** formed therein as known in the art. A DC voltage supply **13** having a positive electrode **14** and a negative electrode **15** located at opposite ends of channel **11** produces a voltage across the ends of the channel **11** to initiate an electrokinetic/electroosmotic flow field indicated by arrow **16**. An AC power supply **17** provides a voltage which is applied across the electrode plates **18** and **19** of interdigitated electrodes **12**, as shown in **FIG. 2**, which set up a non-uniform electric field **20** capable of trapping particles **21** using the dielectriphoretic force. Each of electrode plates **18** and **19** include projecting legs **22-23** and **24-25**, with leg **22** located intermediate legs **24** and **25** and with leg **25** been located intermediate legs **22** and **23**.

[0017] It has thus been shown that the present invention provides for dielectrophoretic concentration of particles under electrokinetic flow, by using at least one set of interdigitated electrodes patterned on the inner surface of a microfluidic channel. Particles swept down the channel electrokinetically are trapped within the field established by the interdigitated electrodes. Thus, the apparatus can be used to concentrate the sample prior to testing due to the combined use of dielectrophoresis and electrokinetic/electroosmotic flow. While only one microfluidic channel has be shown, the present invention can be applied to microfluidic devices having a number of channels.

[0018] While a particular embodiment has been illustrated and described to exemplify and teach the principles of the invention, such is not intended to be limiting. Modifications and changes may become apparent to those skilled in the art, and it is intended that the invention be limited only by the scope of the appended claims.

The invention claimed is:

1. An apparatus for dielectrophoretic concentration of particles under electrokenelic flow, comprising:

at least one microfluidic channel,

means for producing a DC voltage across ends of said microfluidic channel

at least one pair of interdigitated electrodes located on a surface of said microfluidic channel, and

means for producing an AC voltage across the interdigitated electrodes.

2. The apparatus of claim 1, additionally including a plurality of pairs of interdigitated electrodes along a length of said microfluidic channel

3. In a microfluidic device using electrokinetic/electroosmotic flow to sweep particles down a microfluidic channel, improvement comprising:

interdigitated electrodes patterned on an inner surface of a microfluidic channel, and means for applying an AC voltage across the interdigitated electrodes to set up a non-uniform electric field capable of trapping particles using a dielectrophoretic force as the particles are swept down the microfluidic channel electrokinetically.

4. The improvement of claim 3, additionally including a plurality of spaced pairs of interdigitated electrode located along a length of said microfluidic channel.

5. The improvement of claim 3, wherein said patterned interdigitated electrodes each comprising a first section with spaced second and third sections extending transversely from said first section, said first section of each electrode being positioned substantially parallel, with a third section of one of the electrode being located intermediate the spaced second and third sections of the other electrode.

6. A method for concentrating particles under electrokinetic flow, comprising:

forming at least one pair of interdigitated electrodes on a fluidic microchannel through which particles are swept electrokinetically, and

applying an AC voltage across the interdigitated electrodes to establish a non-uniform electric field capable of trapping particles using the dielectrophoretic force.

7. The method of claim 6, additionally including applying a DC voltage across ends of the fluidic microchannel to initiate an electrokinetic/electroosmotic flow field.

8. The method of claim 6, additionally including forming a plurality of space pairs of interdigitated electrodes along a length of the fluidic microchannel.

9. The method of claim 8, additionally including controlling the voltage applied to each pair of interdigitated electrodes

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