and methods according to the present disclosure can manipulate single or multiple biological cells, particles or other objects of interest in a large quantity with easy, precise, and rapid control. Furthermore, semiconductor-based IC/microfluidic hybrid systems and methods according to various embodiments of the present disclosure offer significant flexibility over conventional microfluidic systems. In particular, somewhat more complex conventional microfluidic systems control biological samples in a fixed channel network using predetermined valve controls; hence, different operations require different specific microfluidic systems. In contrast, semiconductor-based/microfluidic hybrid systems and methods according to various embodiments of the present disclosure are capable of performing various and sophisticated cell/particle manipulation operations without necessarily requiring a complex microfluidic system structure.

[0030] For example, in one embodiment, a programmable hybrid system according to the present disclosure may be implemented using a relatively simple microfluidic system having only a single chamber (a "bathtub") integrated with a semiconductor-based system that provides programmable and independently controllable electromagnetic fields. In this implementation, cells may be moved through the chamber along virtually any path under computer control of the electromagnetic fields. In this manner, the topology of a "virtual micro-scale plumbing system" for samples of interest may be flexibly changed for a wide variety of operations based on the programmability afforded by computer control. This provides an extremely powerful tool for precision cell/object manipulation in both relatively simple and more sophisticated operations.

[0031] In sum, one embodiment according to the present disclosure is directed to an apparatus, comprising a plurality of CMOS fabricated field-generating components, a microfluidic system configured to contain a fluid in proximity to the plurality of CMOS fabricated field-generating components, and at least one controller configured to control the plurality of CMOS fabricated field-generating components to generate at least one electric or magnetic field having a sufficient strength to interact with at least one sample suspended in the fluid.

[0032] Another embodiment according to the present disclosure is directed to a method, comprising an act of generating at least one electric of magnetic field from a plurality of CMOS fabricated field-generating components, the at least one electric or magnetic field having a sufficient strength to interact with at least one sample suspended in a fluid contained in a microfluidic system in proximity to the plurality of CMOS fabricated field-generating components.

[0033] The following references are incorporated herein by reference:

[0034] U.S. Non-provisional application Ser. No. 10/894,674, filed Jul. 19, 2004, entitled "Methods and Apparatus Based on Coplanar Striplines;"

[0035] U.S. Non-provisional application Ser. No.10/894,717, filed Jul. 19, 2004, entitled "Methods and Apparatus Based on Coplanar Striplines;" and

[0036] PCT Application No. PCT/US02/36280, filed Nov. 5, 2002, entitled "System and Method for Capturing and Positioning Particles," International Publication No. WO 03/039753 A1.

[0037] It should be appreciated that all combinations of the foregoing concepts and additional concepts discussed in greater detail below are contemplated as being part of the inventive subject matter disclosed herein. In particular, all combinations of claimed subject matter appearing at the end of this disclosure are contemplated as being part of the inventive subject matter disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] **FIG. 1** is a block diagram showing an overview of various components of a semiconductor-based/microfluidic hybrid system according to one embodiment of the present disclosure;

[0039] **FIG. 2** illustrates an exemplary physical arrangement of components for the hybrid system shown in **FIG. 1**, according to one embodiment of the present disclosure;

[0040] FIGS. **3**(*a*)-(*d*) illustrate a microelectromagnet wire matrix which provides one example of magnetic field-generating components that may be included in the hybrid system shown in **FIGS. 1 and 2**, according to one embodiment of the present disclosure;

[0041] **FIG. 4** is a schematic illustration of a "ring trap" which also may serve as a magnetic field-generating component in the hybrid system shown in **FIGS. 1 and 2**, according to one embodiment of the present disclosure;

[0042] FIGS. **5**(*a*) and (*b*) illustrate a micropost array which provides one example of electric field-generating components that may be included in the hybrid system shown in **FIGS. 1 and 2**, according to one embodiment of the present disclosure;

[0043] **FIG. 6**(*a*) is a conceptual perspective illustration of a microcoil array that may be employed as field-generating components in the hybrid system shown in **FIGS. 1 and 2**, according to one embodiment of the present disclosure;

[0044] **FIG. 6**(*b*) shows a conceptual illustration of a top (overhead) view of a portion of the array shown in **FIG. 6**(*a*), looking down to the array through a portion of a microfluidic channel that contains a liquid in which are suspended exemplary samples comprising a magnetic bead attached to a cell, according to one embodiment of the present disclosure;

[0045] FIGS. **7**(*a*) and **7**(*b*) show perspective and exploded views, respectively, of a multiple-layer microcoil that may be employed in the arrays of **FIG. 6**(*a*) and (*b*), according to one embodiment of the present disclosure;

[0046] **FIG. 8** conceptually illustrates a vertical layer structure of a portion of a CMOS IC chip showing the multiple-layer microcoil structure of FIGS. **7**(*a*) and **7**(*b*) in relation to other features and layers of the chip, according to one embodiment of the present disclosure;

[0047] **FIG. 9** illustrates an exemplary magnetic field profile above a multi-layer microcoil similar to those illustrated in **FIGS. 7 and 8** when a current flows through the microcoil, according to one embodiment of the present disclosure;

[0048] **FIG. 10** conceptually illustrates two neighboring microcoils of the array shown in **FIG. 6**(*a*) and (*b*), in which an essentially equal current flows through the microcoils to