generate two essentially equal magnetic field peaks, according to one embodiment of the present disclosure;

[0049] FIGS. **11** (*a*)-(*e*) show five exemplary scenarios for the neighboring microcoils of **FIG. 10**, with varying current magnitudes and directions in the respective coils and the resulting magnetic fields generated, according to one embodiment of the present disclosure;

[0050] **FIG. 12** is a graph illustrating the current magnitude and direction in each of the coils for each of the five exemplary scenarios illustrated in FIGS. **11**(*a*)-(*e*);

[0051] **FIG. 13** shows a microcoil array similar to that shown in **FIG. 6**(*a*) and various field control components associated with the array, according to one embodiment of the present disclosure;

[0052] **FIG. 14** shows various interconnections of components in a first quadrant of the array of **FIG. 13**, according to one embodiment of the present disclosure;

[0053] **FIG. 15** illustrates the contents of a microcoil switching unit included in a microcoil cell of the first quadrant shown in **FIG. 14**, according to one embodiment of the present disclosure;

[0054] **FIG. 16** illustrates details of a current source, according to one embodiment of the present disclosure, that provides current to the first quadrant shown in **FIG. 14**;

[0055] **FIG. 17** illustrates an arrangement of RF/detection components that forms a "frequency locked loop," according to one embodiment of the present disclosure, for facilitating sample detection;

[0056] **FIG. 18** illustrates further details of a phase detector in the frequency locked loop shown in **FIG. 17**, according to one embodiment of the present disclosure;

[0057] **FIG. 19** illustrates further details of a phase comparator of the phase detector shown in **FIG. 18**, according to one embodiment of the present disclosure;

[0058] **FIG. 20** illustrates an alternative arrangement of RF/detection components for facilitating sample detection, according to another embodiment of the present disclosure;

[0059] **FIG. 21** illustrates an arrangement of temperature regulation components according to one embodiment of the present disclosure;

[0060] **FIGS. 22-26** illustrate various process steps involved in fabricating a polyimide-based microfluidic system as part of a hybrid system according to one embodiment of the present disclosure;

[0061] **FIGS. 27-32** illustrate various process steps involved in fabricating a microfluidic system based on patterning of ultraviolet curable epoxy, according to one embodiment of the present disclosure;

[0062] **FIGS. 33-38** illustrate various process steps involved in fabricating a microfluidic system based on soft lithography techniques, according to one embodiment of the present disclosure;

[0063] FIGS. **39**(*a*)-(*d*) illustrate exemplary implementations of cell detection via RF sensing techniques as discussed above in connection with **FIGS. 17-20**, according to various embodiments of the present disclosure;

[0064] **FIG. 40** illustrate a cell sorting apparatus based on the hybrid system of **FIGS. 1 and 2**, according to one embodiment of the present disclosure; and

[0065] **FIGS. 41-43** illustrate a tissue assembly method using the hybrid system of **FIGS. 1 and 2**, according to one embodiment of the present disclosure.

DETAILED DESCRIPTION

[0066] Following below are more detailed descriptions of various concepts related to, and embodiments of, methods and apparatus according to the present disclosure for one or more of manipulation, detection, imaging, characterization, sorting and assembly of biological or other materials. It should be appreciated that various aspects of the subject matter introduced above and discussed in greater detail below may be implemented in any of numerous ways, as the subject matter is not limited to any particular manner of implementation. Examples of specific implementations and applications are provided primarily for illustrative purposes.

[0067] I. System Overview

[0068] One embodiment of the present disclosure is directed to a semiconductor-based/ microfluidic hybrid system that combines the power of microelectronics with the biocompatibility of a microfluidic system. In some examples below, the microelectronics portion of the hybrid system is implemented in CMOS technology for purposes of illustration. It should be appreciated, however, that the disclosure is not intended to be limiting in this respect, as other semiconductor-based technologies may be utilized to implement various aspects of the microelectronics portion of the systems discussed herein.

[0069] **FIG. 1** is a block diagram showing a general overview of various components of a semiconductor-based/ microfluidic hybrid system **100**, and **FIG. 2** illustrates an exemplary physical arrangement of components for such a system, according to one embodiment of the present disclosure. As illustrated in **FIGS. 1 and 2**, the hybrid system **100** comprises a microfluidic system **300** for holding liquids containing objects of interest (hereafter "samples"). The hybrid system also includes a number of other components, including electric and/or magnetic field-generating components **200**, field control components **400**, and temperature regulation components **500**. In general, these other components may be employed to facilitate manipulation (e.g., trapping and/or moving), detection, imaging and/or identification of samples via electric and/or magnetic fields, including biological samples requiring regulation of environmental conditions (e.g., temperature).

[0070] In one aspect of this embodiment, as shown in **FIG. 2**, some or all of these other components of the hybrid system **100** may be implemented as one or more integrated circuit (IC) chips **102** using various semiconductor fabrication techniques. For example, **FIG. 2** illustrates that various field-generating components **200**, field control components **400**, and temperature components **500** may be fabricated on a semiconductor substrate **104**, pursuant to any of a variety of semiconductor fabrication techniques, to form an IC chip **102**. As mentioned above and discussed in greater detail below, one exemplary implementation of such an IC chip may be fabricated using standard CMOS protocols. The IC chip **102** further may be mounted on a package substrate