[0115] Based on the foregoing general dimensions, a microcoil inductance on the order of approximately 1 nano Henry (1 nH) or higher may be achieved. By generally decreasing various dimensions relating to the metal conductors, the number of coil turns may be increased, resulting in inductances as high as 60 to 100 nano Henries (60-100 nH). It should be appreciated, however, that as the width of metal conductors becomes smaller, the parasitic resistance of the coil generally increases and the maximum allowable current through the coil generally decreases, which ultimately limits the strength of the magnetic field that may be generated; hence, there may be practical trade-offs between coil size and field strength.

[0116] More generally, it should be appreciated that the vertical layer structure shown in **FIG. 8** is not limited to the above-indicated dimensions, or to three metal layers; based on present CMOS fabrication technology, up to approximately seven metal layers would be possible. Thus, again, the three layer microcoil structure is presented as merely one example of a number of possible microcoil configurations according to the present disclosure.

[0117] As shown in the vertical layer structure of **FIG. 8**, above the insulating material **112** a passivation layer **116** is deposited, which may comprise, for example, silicon nitride or polyimide. Finally, to ensure biocompatibility, a polydimethylsiloxane (PDMS) layer **118** is deposited above the passivation layer **116** and serves as the interface with the microfluidic system **300**. In various implementations, a distance **120** between the upper metal layer/portion **212**A of the microcoil and the interface between the PDMS layer **118** and the microfluidic system **300** may be on the order of approximately 3-4 μm.

[0118] Based on the general structure of a CMOS microcoil as outlined above, significant local magnetic fields may be generated above each microcoil of the array **200**B to manipulate samples. To provide an illustrative range of values for magnetic field strength and sample trapping force, a two-layer microcoil structure having an overall diameter of approximately 20 μm and 4 coil turns per layer is considered. The exemplary microcoil includes an aluminum conductor having an average conductor cross-section of 1×1 μm^2, wherein the line width is 1 μm, the gap between adjacent conductor turns of a given layer is 1 μm, and the distance between the two layers is 1 μm. The maximum current density for an aluminum conductor is approximately 200 mA/μm^2; hence, the exemplary microcoil under consideration is capable of supporting approximately 200 mA of maximum current flowing through it. **FIG. 9** illustrates the magnetic field profile in an x-y plane located at approximately 1 μm above such a microcoil, near the floor of the microfluidic system in which a sample would be located. As observed in **FIG. 9**, based on a maximum current of 200 mA flowing through the microcoil, a significant magnetic field peak on the order of approximately 300 Gauss is generated.

[0119] If a sample of interest includes a cell coupled to a conventionally available magnetic bead (e.g., Dynabead) having a diameter of approximately 4-5 μm and a magnetic susceptibility χ of approximately 0.25, the force F exerted on the sample by the peak magnetic field of approximately 300 Gauss shown in **FIG. 9**, according to Eq. (1) above, is on the order of approximately 1 nano Newton (nN). This force is more than sufficient for effective manipulation of such bead-bound samples. Stated differently, the maximum fluidic velocity that a trapped sample can withstand based on such a force F is on the order of 1 centimeter/second. Additionally, the magnetic potential energy generated by the microcoil with 200 mA of current is on the order of 3×10^6 times larger than the thermal energy for such a bead-bound sample at a biologically compatible temperature of 37 degrees C (T=310 K), demonstrating a strong trap capability of the microcoil.

[0120] While the foregoing example is based on an exemplary maximum current through the microcoil, it should be appreciated that significantly lower currents (e.g., on the order of approximately 20 mA) nonetheless provide sufficient peak magnetic fields and resulting forces (e.g., on the order of approximately 10 pico Newtons) for the effective manipulation of a variety of magnetic samples. Generally, the magnitude of magnetic force generated by the microcoil increases with current through the microcoil. In some instances, as current is increased toward a maximum current, a high current density in a microcoil over a prolonged period may result in electromigration, a phenomenon in which a large current in a narrow conductor gradually results in metal void failures. Electromigration generally is more pronounced at higher temperatures, though. Hence, in the hybrid systems described herein (in which operating temperatures typically would be below 50 degrees C., and in some cases regulated for biocompatibility at 37 degrees C.), current densities that generate magnetic forces sufficient for effective sample manipulation generally would not cause significant electromigration.

[0121] Moreover, while the foregoing example demonstrates that microcoils similar to those shown in **FIGS. 7 and 8** can provide appreciable magnetic forces for sample manipulation, some particular applications may require magnetic forces even greater than those illustrated above. Accordingly, in another embodiment, Permalloy, a conventionally known nickel alloy containing about **20**% Iron and **80**% Nickel, which can be easily magnetized and demagnetized depending on the current surrounding it to enhance magnetic force, may be employed in the microcoil design. In particular, in one exemplary fabrication process, Permalloy may be appropriately deposited (e.g., electroplated) in the multi-layer microcoil structure (i.e., with submicron scale resolution) using photolithography or e-beam lithography techniques.

[0122] According to yet another embodiment, "vertical" microcoils may be fabricated and used in manipulation and imaging of magnetized samples, similarly to the multi-layer microcoils described above. Presently available CMOS technologies support primarily planar metal layers, and hence the microcoils discussed above are essentially "planar" in that they are disposed along a plane parallel to the x-y axes indicated in the various figures, and generate magnetic fields perpendicular to the surface of the IC chip **102** (i.e., essentially along the z axis). However, in another embodiment, by employing micromachining and/or other three-dimensional assembly processes as post-fabrication steps, it is possible to tilt the planar microcoil away from the substrate surface (after removal of oxide), yielding a vertical microcoil. Such a vertical microcoil produces a magnetic field parallel to the surface of the IC chip **102** (i.e., essentially in a plane parallel to the x-y axes). By employing both vertical and planar microcoils in one implementation