iron-containing materials with a biocompatible material. As mentioned above, when the magnetic regions are islands, a portion of the island may be magnetic while the remainder of the island is made of a nonmagnetic material.

[0117] C. Fabrication

[0118] In certain embodiments of the invention the chip comprises a regular two-dimensional array of magnetic material regions formed on a non-magnetic substrate. The magnetic regions may be formed using any of a variety of processes. In particular, the fabrication process may employ photolithographic techniques that are well known in the field of integrated circuit technology (See, e.g., Campbell, S., *The Science and Engineering of Microelectronic Fabrication,* Oxford University Press, New York: 1996). The process may be additive or subtractive in nature. One example of a subtractive process is depicted in **FIG. 10**. As shown in the figure (step 1) a layer of magnetic material such as cobalt, referred to as a magnetic film, may be deposited on a substrate. The layer may be of any appropriate thickness, e.g., between 0.1 and 0.5 μm, between 0.5 and 1.0 μm, between 1.0 and 2.0 μm, between 2.0 and 3.0 μm, between 3.0 and 5.0 μm, etc. A typical width is between 0.7 and 1.0 μm. Thinner layers may also be used, in particular for applications involving nanometer scale magnetic particles. In general, the thickness of the layer may be selected according to the size of the magnetic particles to be trapped and the geometry selected for the magnetic regions and gaps, as described above.

[0119] Any suitable deposition process including sputtering (e.g., argon sputter etching using a UHV DC magnetron sputtering system) or evaporation can be used. A layer of photoresist (PR) is then applied onto the layer of magnetic material as shown in Step 2 of **FIG. 10**. The photoresist is then patterned according to conventional methods (e.g., exposed to e-beam or optical lithography and developed as shown in Step 3) to generate a mask. Then the magnetic material is etched (e.g., using argon sputter etching using an ion-milling etcher) through the regions exposed by the developed photoresist as shown in Step 4. Ion beam etch or plasma etch processes allow the formation of magnetic regions with substantially vertical side walls, as is desirable in certain embodiments of the invention. The photoresist is then stripped, leaving the magnetic islands projecting above the substrate (Step 5). Finally, the magnetic islands are magnetized along a chosen axis at a field sufficient to ensure saturation. For example, a field of several thousand Gauss is sufficient to saturate cobalt. **FIG. 11** shows an AFM image of a portion of a magnetic chip fabricated according to the foregoing process. The scale is in tens of microns, showing the gap sites to be approximately 30 μm apart in both x and y dimensions. The elongated, rectangular-shaped magnetic islands projecting above the substrate surface are clearly visible.

[0120] In an example of an additive process, a layer of photoresist is deposited on a substrate and exposed to form a pattern of apertures. A magnetic material is deposited within the apertures (e.g., by vapor deposition) and the photoresist is then removed to leave islands of magnetic material on the substrate.

[0121] As will be evident to one of ordinary skill in the art, a number of variations on the above processes may be used. In general, selection of appropriate processes may depend upon the exact chip configuration selected (e.g., whether the magnetic regions are islands or are flush with the substrate or present in wells). Although semiconductor manufacturing technologies such as those described above are convenient, welldeveloped, and readily scalable, other types of processes may also be employed.

[0122] D. Trapping Energy and Localized Magnetic Fields

[0123] As discussed above, the magnetic chip concept involves the use of magnetic regions to produce localized magnetic fields of appropriate strength and shape to reversibly immobilize (trap) magnetic particles. The force on the magnetic particle is determined by the gradient of the magnetic field times the magnetization of the particle. Thus a localized magnetic field has a gradient sufficient to generate a localized force on a magnetic particle that results in trapping. The localized magnetic field results in a force in the direction in which the gradient is greatest. This force tends to pull a magnetic particle in such a direction. Trapping efficiency may be enhanced if the localized magnetic field falls off rapidly outside the volume where the magnetic particle is to be trapped. In certain embodiments of the invention the localized magnetic field decreases to less than half, less than 25%, less than 10%, less than 5%, less than 2%, or less than 1% of its maximum value within a distance equal to the maximum dimension of either the volume between two adjacent magnetic regions (in those embodiments of the invention where the localized magnetic fields extend between opposite poles of adjacent magnetic regions) or the volume of a single magnetic region (in those embodiments of the invention where the localized magnetic fields extend between opposite poles of individual magnetic regions. In certain embodiments of the invention the force on a magnetic particle decreases to less than half, less than 25%, less than 10%, less than 5%, less than 2%, or less than 1% of its maximum value within a distance equal to the maximum dimension of either the volume between two adjacent magnetic regions (in those embodiments of the invention where the localized magnetic fields extend between opposite poles of adjacent magnetic regions) or the volume of a single magnetic region (in those embodiments of the invention where the localized magnetic fields extend between opposite poles of individual magnetic regions. In certain embodiments of the invention the fringing fields have negligible effect on the arraying behavior of magnetic particles.

[0124] The strength of trapping of the magnetic particles is determined by the magnetic field profile at the attachment locations (e.g., at the gap between magnetic islands in the embodiment described above) and may be expressed in terms of the trapping energy. The trapping energy may be thought of as the amount of energy that would be required to remove a magnetic particle once it has been trapped. Thus the trapping energy influences both the strength with which a particle is immobilized and the conditions required to remove it.

[0125] Writing the magnetization in terms of the volumetric magnetic susceptibility and integrating the force results in an expression for the binding energy. The components of the localized magnetic field H may be calculated as described above. As mentioned previously, H_y integrates to approximately zero over the gap region. H_z may be approximated as zero provided the magnetic regions generating the