magnitude and polarity or individually turned "ON" and "OFF" by applying the appropriate current-induced magnetic fields to each individual spin-valve array or each individual spin-valve element.

[0064] In the "OFF" state, the spins in the free layer of each spin-valve element are aligned antiparallel to the spins in the pinned layer. The fields from each layer cancel one another effectively leaving the trap non-magnetic in nature. In this case, particles would not be attracted to the trap and would be free to seek out the closest region with a high magnetic field gradient. In the "ON" state, the free layer in the trap is aligned with the pinned layer, thereby producing a magnetic field gradient that is strongest at the ends of the trap. In this state, the particles are trapped in the local magnetic field gradient of each spin-valve element. When using current induced magnetic fields, each individual spin-valve arrays or individual spin-valve elements can be turned "ON" and "OFF". The proper sequence of "ON/OFF" events produces sorting of magnetic particles by the stationary array of spin-valve elements in any portion of its respective spin-valve array as illustrated in **FIG. 7** where the magnetic particles **21** are depicted as being attached to spin-valve elements **22** that are in their "ON" state. In addition, magnetic particles can be moved between adjacent spin valve elements with an appropriate pulse sequence. Finally, a movable tip with a spin-valve element on the end can also be used to sort the particles as discussed in more detail below.

[0065] Since there is a minimum magnetic field necessary to flip between states, a second magnetic field can be applied to systems of the present invention that include multilayered spin-valve elements. For example, in the "ON" state, a second magnetic field of sufficient strength to rotate the particle, but of insufficient strength to change the ferromagnetic character of the spin-valve arrays or relevant traps, can be applied to provide torsional/rotational manipulation to samples (e.g. biological specimens, chemical compounds, etc.) that can be attached to the trapped magnetic particles.

[0066] **FIGS. 8A-8C** depict various geometries for the application of a rotational magnetic field to a biopolymer (DNA) **25** that is held by opposite ends **26** by separated spin-valve traps **1**. The rotation of the magnetic field can be about the X, Y or Z axes. Since the direction of rotation (i.e., clockwise or counterclockwise) is the same for all particles, rotation about the Y and X axes **(FIGS. 8B and 8A)** will not allow for the application of torque to biological molecules **25**. For rotation about the X-axis, the entire molecule **25** will rotate about a fixed point as indicated in **FIG. 8A**. For rotation about the Y-axis, it is possible for the molecule **25** to flip to alleviate the any applied torsional force as indicated in **FIG. 8B**. For rotation about the Z-axis, torsional force can be applied to the molecule **25** as depicted in **FIG. 8C**. For this geometry, it is noted that the attachment points of the molecule **25** to the magnetic particle point must both point away from the membrane surface. This can be accomplished by providing steric hinderance in the form of small grooves in the membrane.

[0067] According to experiments conducted during the course of the present invention, a rotational field of approximately 12 Oe with a 0.003 T/cm magnetic field gradient was determined to be sufficient to rotate particles about spin-valve elements in an array of a spin-valve element. The small magnitude of the rotational field had a negligible effect on the trap magnetization state since the minimum field required to flip the state of the spin-valve was 15 Oe. **FIGS. 9A-9I** depict a sequence of a magnetic particle confined by the field gradient produced by a spin-valve element during rotation of the magnets about the platform. To visually demonstrate the rotation of the magnetic particles, a strand of particles **28** was used instead of individual particles in **FIGS. 9A-9I**. The length of the strands was four particles, the first of which is trapped in the field gradient to the right of the spin-valve element. As the magnetic field was rotated, the line of particles followed the field. For angles of 135° to 270°, the length of the strand of magnetic particles appears shorter. This is due to the fact that the trapped particle remains in its initial location and the strand of particles overlap the spin-valve element and are obscured by it.

[0068] The experiments which were conducted to provide the results depicted in **FIGS. 8 and 9** above demonstrate that bistable spin-valve elements, in the absence of applied magnetic fields, are capable of confining magnetic particles that are separated from the traps by a membrane and that with the application of a rotating magnetic field gradient, it is possible to rotate magnetic particles while they are confined to a specific location. This ability to rotate confined particles can be used to apply torsional forces to arrays of DNA molecules and other biological specimens, chemical compounds, etc. This ability allows for high-throughput and low power consumption measurement and control of biological and chemical processes on a single molecule level.

[0069] According to another aspect of the present invention, which will now be discussed, the microfluidic magnetic trap platform is used with an applied magnetic force microscope (MFM) cantilever. The MFM cantilever tip serves as a magnetorobotic arm that provides a translatable local magnetic field gradient to capture and move magnetic particles with nanometer precision. The MFM electronics can be programmed to sort an initially random distribution of particles by moving them within an array of magnetic trapping elements. The system permits a particle sorting rate of approximately 5500 particles/minute. Release of the particles from the MFM tip is made possible by the membrane that separates the arm and magnetic trap elements from the particle solution. This platform has potential applications for magnetic based sorting, manipulation and probing of biological molecules in a constant displacement or a constant force mode.

[0070] In initial experiments using a commercially available cobalt coated MFM tip with a radius of 90 nm, a height of 15 μm, and width at the top of the tip of 10 μm it was discovered that the particles were not strongly attracted to the tip field gradients and did not translate with the tip. This was attributed to the fact that the tip slope was sufficiently large to allow for a diminished interaction between the magnetic material on the sidewall of the tip and the particles. To increase the area of interaction between the tip and the particle, the tip was sanded by scanning it rapidly on a hard surface such as vicinal yttria stabilized cubic zirconia. Scanning electron microscopy images show a sanded tip had a 0.8 μm wide sanded plateau. With this geometry, the magnetic material that produces the field gradient to capture the particles consists of a ring having a 60 nm width and a radius of approximately 400 nm.