

aspects of the present invention. The invention may be better understood by reference to one or more of these figures in combination with the detailed description of specific embodiments presented herein.

[0015] FIG. 1A shows a schematic of a DNA detector comprised of a DNA probe (binding molecule) and a spin valve or magnetic tunnel junction (MTJ) detector, in accordance with one aspect of the present invention.

[0016] FIG. 1B shows a magnetic nanoparticle tag attached to a DNA fragment to be detected (target molecule).

[0017] FIG. 1C shows the configuration of the DNA detector and the magnetic nanoparticle tag after the target DNA and binding DNA are hybridized.

[0018] FIG. 2A shows a spin valve detector with a magnetic tag above it, illustrating the pinned layer magnetization along the y-direction. The free layer magnetization has an easy-axis along x and hard-axis along y.

[0019] FIG. 2B shows two modes of interrogation method of spin valve detector, the AC tickling field H_t is either parallel (in-plane mode) or normal to (vertical mode) the spin valve plane (x-y plane). H_b is the DC bias field.

[0020] FIG. 2C shows spin valve resistance change ΔR due to a single Co nanoparticle as a function of the phase of the tickling field H_t in the vertical detection mode.

[0021] FIG. 3A illustrates a magnified view of a 16-nm Fe_3O_4 nanoparticle monolayer on a 0.3- μm spin valve (SV) sensor.

[0022] FIG. 3B illustrates a graph of the voltage signals of a 0.3- μm spin valve (SV) sensor with a Fe_3O_4 nanoparticle monolayer and a sensor without nanoparticles; the line is the modeling result.

[0023] FIG. 4 shows the magnetoresistance (MR) and ΔR values for a spin valve sensor submerged in a blocking solution. As shown, the spin valve maintains its MR ratio and ΔR after 24 hours of exposure to the blocking solution.

[0024] FIG. 5 shows a schematic representation of a synthetic antiferromagnetically coupled magnetic nanoparticle with an under layer (Underlayer) and a gold cap, Au. The layers with arrows are ferromagnetic layers which are antiferromagnetically coupled in the remanence state. The number of the ferromagnetic layers can vary from about 2 to about 6 depending upon the application. The gold cap is for bio-conjugation, while the under layer is for proper film growth as well as biochemistry applications.

[0025] FIG. 6 illustrates an additive fabrication method of synthetic ferromagnetic nanoparticles.

[0026] FIG. 7A shows microfluidic channels directly integrated on a long detector, with the DNA probes attached specifically to the detector surface. As shown in the figure, the detector is made slightly larger than 20 μm , the width of the microfluidic channel, while the long detector is suitable for relatively large quantities of DNA samples.

[0027] FIG. 7B shows microfluidic channels directly integrated on a short detector, with the DNA probes attached specifically to the detector surface. The detector is made shorter than the width of the microfluidic channel, so as to be more suitable for use with relatively small quantities of DNA samples.

DEFINITIONS

[0028] The following definitions are provided in order to aid those skilled in the art in understanding the detailed description of the present invention.

[0029] "Binding molecule", as used herein, refer to antibodies, strands of polynucleic acids (DNA or RNA), and molecular receptors capable of selectively binding to or 'recognizing' potential target molecules such as polynucleic acids, enzymes, proteins, peptides, antibodies, lipids, polymers, metal ions, and low molecular weight organic and inorganic species such as toxins, drugs (both prescription and illicit), explosives, and biohazards.

[0030] "Target molecule", or "target species", as used herein, refers to the molecule, molecular species, or organism whose presence, absence, or concentration the assay in question actually determines. Target molecules included for use with the present invention include but are not limited to viruses, bacteria, other biological organisms such as fungi, antibodies, proteins, peptides, polynucleic acids, lipids, polymers, pharmaceutical compounds, organic compounds, biohazardous compounds, explosive compounds, and toxins, among others.

[0031] "Detector", as used herein, refers to any number of magnetic detection systems including spin valve detectors (also referred to as spin valve film detectors), magnetic tunnel junction (MTJ) detectors, and MagArray™ detectors, as well as MagArray™ variants of both spin valve detectors and MTJ detectors.

DETAILED DESCRIPTION OF THE INVENTION

[0032] A detection system can typically involve an array of spin valves or MTJ detectors, oligonucleotide probes complementary to a target of interest attached to individual detectors in the array as shown in FIG. 1A, a macrofluidic or microfluidic sample delivery system, and magnetic nanoparticles bound with target DNA fragments as shown in FIG. 1B. Tagged DNA fragments are delivered by fluidic channels to the detector array for selective hybridization as shown in FIG. 1C. Non-hybridized DNA fragments are washed away, or are removed by a magnetic field gradient. The detector array is interrogated with a combination of DC bias field and AC tickling field, as shown in FIGS. 2A and 2B. The applied fields cause the magnetic nanoparticle tags to display net magnetic moments, which in turn can be picked up by the spin valve or MTJ detectors. In the in-plane detection mode, the detector signal has the same frequency as the AC tickling field H_t . In contrast, in the vertical mode, the detector signal is a second harmonic of the AC tickling field as shown in FIG. 2C. In either case, lock-in detection can be employed even if the signal to noise ratio is small. The presence of a magnetic nanoparticle tag, signaling the presence of a target DNA fragment, can thus be detected. The detector voltage signal is proportional to the number of magnetic nanoparticles, and therefore the number of target DNA fragments.

[0033] Generally, a DNA fragment can be tagged with a magnetic nanoparticle. The tagged fragment can be selectively bound to a substrate using a complementary nucleotide above a spin valve. The spin valve is then used to detect the magnetic nanoparticle.