Microbeads detection using spin-valve structures; a micromagnetic approach

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I. Introduction

A micromagnetic simulation for the detection of magnetic microbeads by spin-valve sensors is presented. Detection of magnetic fields generated by these magnetic particles encapsulated in plastic, carbon or ceramic spheres which are coated with chemical or biological species such as DNA or antibodies that selectively bind to the target analyte can be made using magnetoresistive (GMR) or Planar Hall effect sensors made from spin-valve structures. This detection concept is suitable to biomolecular recognition, and in particular to single molecule detection.

II. Results and Discussion

The bonding of the magnetic beads to the sites – spin-valve sensors - via the molecules to be detected has been described in many studies [1, 2]. The microbeads are made up of nm sized iron oxide particles that have little or no magnetization in the absence of an applied field. The magnetic beads polarized by a dc or ac magnetic field contribute to a nonuniform dipole field, which can affect the magnetization state of spin-valve sensor, leading to a detectable resistance change. Because both systems, microbeads and spin-valve sensors, are made-up from magnetic materials, there is a magnetostatic interaction between them. Basically two detection schemes can be used: (i) the external magnetic field is applied parallel to the GMR sensor surface and (ii) the magnetic field is applied perpendicular on the GMR sensor. It is to mention that spin-valve devices are sensitive only for in plane magnetic fields. In both cases a differential measurement setup has to be considered. Each bead is assumed to be a sphere with a diameter of about 0.2 μm and the thickness of the immobilization and protection layer (Si_3N_4) between the bead and the GMR sensor is 0.2 μm. The saturation magnetization of the magnetic micro-bead is assumed to be 400 emu/cm^3 [2, 3]. The GMR sensor is a multilayer structure FeMn/$Ni_{80}Fe_{20}$(10 nm)/Cu(4 nm)/$Ni_{80}Fe_{20}$(10 nm).

To simulate the magnetic behaviour and the GMR response of the sensor, we take a square region of 1x1 μm^2 on which are placed magnetic microbeads.

In what follows we shall discuss only the case when the magnetic field is applied perpendicular to the sensor surface. The microbeads will produce horizontal components of the stray field which can change the magnetic state of the sensor and hence can generate a GMR effect.

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However, for a large number of particles, located over the centre of the sensor, the horizontal components of the stray fields will cancel each other and the GMR response will be very weak as we can see in Fig. 1; Δy=0 denotes the fact that the magnetic beads are located over the centre of the sensor. If the ensemble of particles is moved from the centre toward the margin of the sensor, following the y direction, the horizontal components of the stray fields generated by the beads will not cancel entirely and the net field applied in the film plane increases, Fig. 1.

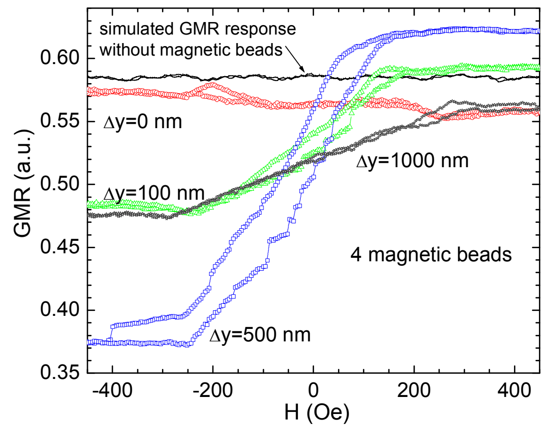

Fig. 1. Micromagnetic simulation of the GMR effect, for three selected positions of the magnetic beads, when the field is applied perpendicular to the film surface. Four microbeads are placed above the free layer at a distance of 200 nm from his surface. They are equally spaced between them. In our simulations the distance between the nearest beads is 200 nm.

There will be a position for which the maximum GMR response is achieved. For the optimum position (Δy=500 nm, in this case) the dependence of the output signal (the amplitude of differential signal due to GMR effect) in function of the number of magnetic beads is quite linear and shows the possibility to detect a single particle.

III. Conclusions

We performed micromagnetic simulations regarding the response of the GMR sensor covered with magnetic beads used for biomedical applications. These results are useful in the designing process of the detection system used in lab-on-chip devices.

References

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