Design and Fabrication of a GMR sensor based microsystem for concentrating and detecting magnetic particles

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A novel giant magnetoresistance (GMR) sensor based microsystem is proposed to concentrate and detect magnetic micro/nano particles. Magnetic particles which can be manipulated by external magnetic field gradients have many advantages such as a large specific surface for binding biomolecules, biocompatibility, and stability due to being independent of reagent chemistry or photo-bleaching [1, 2].

The novelty of the presented system lies in the unique method of guiding magnetic particles towards the fabricated GMR sensor for biosensing. The magnetic microsystem has n-number of planar square-shaped conducting coils. The number of coils depends on the area from which magnetic particles need to be attracted, trapped and guided to the GMR sensing area. The basic design of the system is shown in Fig. 1 (a). Conducting wires in the micro meter range are able to generate large magnetic flux gradients due to its small width and high aspect ratio [3, 4]. In the presence of magnetic particles the large magnetic flux gradients generate forces on the particles. These forces are used to attract, trap and guide the magnetic particles to the target destination. The square loops are designed in such a way that a current can be applied to them independently. The magnetic forces produced by these currents must be higher than two other dominant forces acting against manipulation of beads by electromagnets, the drag (due to fluid motion) and gravitational forces. Current can be applied sequentially starting from the outermost square loop, to direct magnetic beads to go from the farthest to the innermost square loop or the other way around. The speed of movement can be manipulated by switching current to the rings at different times.

The GMR sensor utilized is a spin valve type with magnetoresistance ratio of 8 %. Four spin valve GMR elements are formed of thin films on the surface of the substrate below the conducting square loop structures with four connection/bonding pads, lead conductors for electrically connecting the spin valve GMR elements to the connection/bonding pads and a protection film for covering the spin valve GMR elements and lead conductors, except parts of the connection/bonding pads. The spin valve GMR sensors, connection/bonding pads and lead conductors are formed on a wafer by a wafer process utilizing thin film photolithography techniques. The GMR sensors are patterned into the shape shown in Fig. 1 by photolithography and ion beam etching (IBE). The GMR structure consists of an antiferromagnetic layer that is used to fix or pin the magnetization of the pinned ferromagnetic layer, a non-magnetic space layer and a free layer of ferromagnetic material where the magnetization is free to move in response to an applied magnetic flux density. The active spin valve GMR elements detect the induced magnetic field in the magnetic particles tangent to the sensor surface. The spin valve GMR sensing elements are connected in a half-Wheatstone bridge circuit fashion, i.e. with two active elements as shown in Fig. 1 (b), for optimum noise suppression.

A full set of experiments will be performed with magnetic particles of various sizes to verify the feasibility of the proposed system. The research performed is an approach towards miniaturization and automation of analytical applications. The combination of magnetic particle concentration and detection has the potential to result in highly integrated bio-assay systems which can be used from sample treatment to read-out effectively.


Figure 1. (a) Design of GMR sensor based microsystem to concentrate and detect magnetic particles, and (b) Half-bridge Wheatstone configuration of the SV GMR sensors.