Real-time Detection of Magnetic Beads using Highly Sensitive Spin-valve Devices for a Chip-cytometer

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1. Introduction

The development of a chip-cytometer based on the detection of magnetic beads using spintronic devices has recently attracted great interests since they are capable of realizing both cell-separation and cell-counting on a chip at the same time. In order to implement a chip-cytometer, the real-time detection of magnetic beads moving in a microfluidic channel is one of the key issues. The sensing elements for the detection of the moving magnetic beads are to have characteristics such as high sensitivity, good signal to noise ratio (*S*/*N*) and low detection limit. Spin-valve devices offer sufficiently these characteristics compared with the other spintronic devices such as anisotropic magnetoresistance(AMR) devices, Halle ffect devices and magnetic tunnelling junction(MTJ)devices. However, to date, no one has attempted yet to apply a spin-valve device as a sensing element for a chip-cytometer. In the present work, we report on the real-time detection of moving magnetic beads using highly sensitive spin-valve devices integrated in a microfluidic channel for the application of a chip-cytometer.

2. Experiment

Spin valves were deposited on a thermally oxidized Si(100) substrate in a dc/rf magnetron sputtering system with a base pressure of 4×10^{-8} Torr. The generic structure of a spin-valve was $Co_{84}Fe_{16}(20)/NOL/Ni_{81}Fe_{19}(25)/Co_{84}Fe_{16}(10)/Cu(17)/Co_{84}Fe_{16}(20)/Ir_{22}Mn_{78}(75)/Ta(50)$(Å). In this work, nano-oxide layers (NOLs) were employed to enhance the sensitivity and to enlarge the range of a magnetic field resolved by a spin-valve sensor. The spin-valve sensor was observed to exhibit about 10 % magnetoresistance(MR). A combination of photo lithography and a lift-off process has been utilized to fabricate a spin-valve devices (w = 6 μm, l = 30 μm). The patterned spin-valve devices were measured to be ~5 % MR.

In order to transport magnetic beads toward the active sensing areas of the spin-valve devices, a poly-dimethylsiloxane (PDMS) microfluidic channel was fabricated using soft-lithography. The channel size used in our experimental had a height of 30 μm and a width of 30 μm. The length of channel is about 12 mm from center of inlet to center of outlet. Both surfaces of microfluidic channel and spin-valve devices were activated by O_2 plasma after fabrication of microfluidic channel in order to integrate the spin-valve devices into the microfluidic channel.

3. Result & Discussion

Prior to the real time detection, the motion of magnetic beads in the fluidic channel was simulated by computer simulations (incompressible Navier-Stokes module in COMSOL 3.2b. COMSOL Inc.) in order to stabilize the real-time signal voltage. It was found that the velocity of the magnetic beads in a microfluidic channel at a flow rate of 0.01 l/min was 0.5 μm/s.

In order to generate a magnetic dipole field of magnetic beads, a DC magnetic field of 34 Oe was applied to the longitudinal direction of the spin-valve structure. The real time detection of a single-bead was observed by the direct measurement of a magnetic dipole filed from a moving magnetic bead using a spin-valve sensor. It was found that the real-time signal voltage of 0.3 μV dropped when a magnetic bead approached the active area of the spin-valve sensor. The signal voltage output recovered the initial voltage as the magnetic bead completely passed over the active area. This signal voltage drop is attributed to a fringe field of the magnetic bead, which partially cancels the applied field in the free layer of the spin-valve structure.

4. Summary

Our results demonstrate the possibility of implementing a chip-cytometer for biological applications using high-sensitive spin-valve devices integrated with a microfluidic channel. Further studies will be extended to the real-time detection of animal cells coated with magnetic beads for the biological applications.

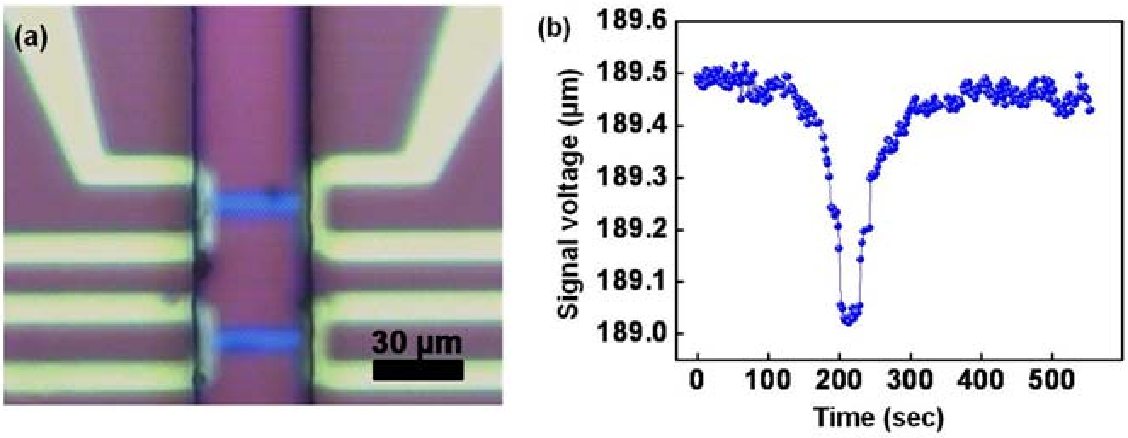

그림 1. (a) The optical microscope image of spin-valve devices integrated with a microfluidic channel (b) the real-time signals voltage of spin-valve devices