QC16

The thermal stability of exchange-coupled trilayers with thickness asymmetry

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As the magnetic cell approaches to the nanoscale region, the thermal stability issue is of great concern. Trilayer synthetic antiferromagnets have been used for advanced magnetic device applications such as magnetic random access memory (MRAM). Worledge predicted the thermal stability of trilayer synthetic antiferromagnets by using simple assumptions [1, 2]. Magnetostatic coupling of the two layers was considered. However, in the absence of thickness asymmetry, no or minimal shape anisotropy effect was predicted from the model due to the simplifying assumption that the self-demagnetizing field is equal to the dipole field [3]. In case that the assumption is relaxed slightly, for example, the dipole field is 90% of the demagnetizing field, the energy barrier to spin-flop is doubled to 80 kT in an ellipsoidal cell wth an aspect ratio of 2 (212 nm x 106 nm) [4]. In this work, the relaxation of the assumption is applied to magnetic cells with thickness asymmetry.

The trilayer synthetic antiferromagnets consisted of two ferromagnets and a nonmagnetic spacer. The cell was assumed to be an ellipsoid with a long axis of 212 nm and a short axis of 106 nm, corresponding to an aspect ratio of 2. The exchange coupling between two layers was -0.05 erg/cm2, the induced anisotropy was 25 Oe, the saturation magnetization was 1500 emu/cc, and the total thickness was 5 nm. Unlike the Worledge model, we assumed that the cell was not perfectly single domain state and the parameter d was used to reflect this assumption.. $d = 1$ for a single domain state. Also we assumed that the dipole field was always smaller than the demagnetizing field and the parameter p was used to quantify the dipole field with respect to the demagnetizing field. So, we have the following relation, $p < d$. The total energy including the parameters, d and p, was derived in an analytical form and the thermal stability was predicted by locating the energy barrier between two minimum states (stable or metastable)..

At zero applied field, the thermal stability is higher at a larger d value for a fixed d-p difference. The d dependence of the thermal stability is greater at a larger thickness asymmetry. When the thickness asymmetry parameter (z), defined by the ratio of the large to small thickness,is 1.6, the energy barrier (or the magnetic energy) is about 120 kT at $d = 0.9$, but it is reduced to 90 kT at $d = 0.3$.. As the thickness asymmetry increases, the energy barrier increases and its dependence on the applied fieldbecomes similar to that observed in a single layer structure.

REFERENCES

[1] D. C. Worledge, Appl. Phys. Lett. **84**, 2847 (2004).
[2] D. C. Worledge, Appl. Phys. Lett. **84**, 4559 (2004).
[3] J. K. Han, K. H. Shin, and S. H. Lim, J. Magn. Magn. Mater. (In the Press).
[4] J. K. Han, K. H. Shin, and S. H. Lim, J. Appl. Phys. (In the Press).

QD01

Highly Sensitive Spin-Valve Sensors Integrated with a Microfluidic Channel for a Chip-cytometer

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The development of a chip-cytometer detecting magnetic beads using a spin-valve sensor has recently attracted great interest since it is capable of realizing both cell-separation and counting on a chip. In order to realize a chip-cytometer, the real-time detection of magnetic beads in microfluidic channel is essentially required for cell-counting [1]. For this reason, sensors with high sensitivity and large signal to noise ratio, i.e. giant magnetoresistance (GMR) spin-valve sensors, are prerequisite to detect moving magnetic beads.. In this work, we report on the real-time detection of moving magnetic beads using a highly sensitive spin-valve sensor integrated witha microfluidic channel.

The 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 photolithography and a lift-off process has been utilized to fabricate a spin-valve sensors (w = 4 μm, l = 20 μm). A polydimethylsiloxane (PDMS) microfluidic channel with a height of 25 μm and a width of 30 μm was fabricated in order to transport superparamagnetic beads with d = 2.8 μm (Dynal bead 280). Fig. 1 shows the optical microscope image of the fabricated spin-valve sensor arrayintegrated with microfluidic channel. 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.

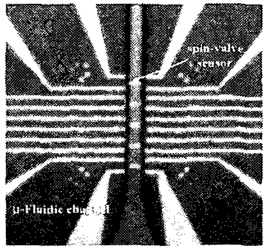

Fig.1. Optical microscope image of the fabricated spin-valve sensors integrated with microfluidic channel.

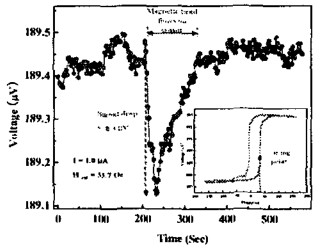

Fig.2. Real-time voltage data demonstrating single-bead detection.

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. Fig. 2 shows the real-time voltage output of the spin-vlave sensor for single bead detection. It was found that the real-time signal voltage of 0.3 μV sharply 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 freelayer of the spin-valve structure. We extend our study to the real-time detection of animal cells coated with magnetic beads for the biological application. Our results demonstrate the possibility of implementing a chip-cytometer for biological applications using high-sensitive spin-valve sensor integrated with a microfluidic device.

REFERENCES

[1] W. Shen et al, Appl. Phys. Leet. 86, 253901 (2005) [2] H. A. ferreira et al, J. Appl. Phys., 93, 7281 (2003)