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Magnetoresistance and domain wall motion in horseshoe shape $Ni_{80}Fe_{20}$ wires

J. L. Tsai[1], Y. D. Yao[2], S. F. Lee[2], D. C. Chen[2], T. Y. Chen[2], K. W. Cheng[2]
[1]Department of Materials Engineering, National Chung Hsing University, Taichung, Taiwan, R. O. C.
[2]Institute of Physics, Academia Sinica, Taipei, Taiwan, R. O. C.

Berger predicted that the spin polarized current exerts an exchange torque on magnetization and induces the domain wall motion. Current-induced domain wall motion has been proved in continuous film, nanowire, and ring structure with or without notch. Domain wall displacement has also been measured before and after current pulse. In this article, we study current induced domain wall motion in single layer ferromagnetic horseshoe shape structure. In this structure, the parallel and anti-parallel arrangement of the magnetization of the two bars are expected to be stable at different field. Domain walls or vortex are expected to show at the semicircle area without inserting any notch in the pattern. We supply a simple pattern to explore the current driven on domain wall motion.

The horseshoe shape patterned $Ni_{80}Fe_{20}$ wires were fabricated by conventional lift-off process. The e-beam lithography was used to write a pattern in the two layered resist with an undercut structure. The Ti/Au leads for four point measurement and $Ni_{80}Fe_{20}$ wires were deposited by dc magnetron sputtering with a base pressure of 5×10^{-7} torr. All sample presented here were 40nm thick, 0.5 μm wide and the gaps were 1 μm. The dimension of Ti/Au lead is 500nm with the thickness of 6nm/40nm by using similar lift-off process. The magnetoresistance (MR) was measured at 77K by four-channel dc measurement system under the maximum applied field of 4000 Oe. The magnetic domain structure was observed by magnetic force microscopy (MFM) with Digital Instrument (DI-3100) system under the real time scanning field between -1000 Oe to 1000 Oe.

We have observed two magnetic states in U-shape pattern. One is the vortex type domain wall at the center of semicircular arc area of the horseshoe shape pattern and the other is the continuous magnetic state without domain wall in between. In general, the current density of the order of $\sim10^{7}$A/cm^{2} is needed to drive a magnetic domain wall. However, it can be reduced extensively if the current is applied just below its coercive force. We have shown experimentally that the critical current reduces dramatically as the bias field is just below its switching field. In this study, the minimum current density for domain wall motion is 7×10^{6}A/cm^{2}. Therefore, the horseshoe shape pattern supplied a good way to study the current induced domain wall motion effect.