ST01

Spin transfer torque efficiency in magnetic domain wall motion

Jae-Chul Lee[1,2]*, Kab-Jin Kim[1], Gi-Hong Gim[1], Kyung-Ho Shin[2], Sug-Bong Choe[1]
[1]Department of Physics, Seoul National University, Seoul 151-747, Republic of Korea
[2]Spin Device Research Center, Korea Institute of Science & Technology, Seoul 136-791, Republic of Korea

1. Introduction

The realization of the STT-devices has been impeded due to the difficulty in finding proper materials with high spin-transfer-torque (STT) efficiency for small critical current density. Recently, based on the predictions of high STT efficiency in nanowires with perpendicular magnetic anisotropy (PMA) owing to their narrow DW with large magnetization gradient, several experimental works have been devoted to estimate the STT efficiency of several PMA materials such as Pt/Co/AlOx, $[Co/Pt]_N$, and Co/Ni. It has been done mostly by measuring the DW 'oscillation' or 'depinning' at geometrical constriction, rather than the DW 'propagation' along nanowires. In this paper, we accomplish the DW propagation in MgO/Co/Pt nanowires driven by both the current and magnetic field. By analyzing the linear and quadratic contribution of the current on the DW propagation speed, we determine the STT efficiencies caused by either the adiabatic andnonadiabatic STTs.

2. Experiments

The DW propagation experiment is carried out as follows. We first saturate the nanowire by applying a sufficiently large magnetic field pulse to the direction from the sample to the substrate. then, a current pulse through the vertical current line is injected to generate a local Oersted field, which consequently reverses the magnetization adjacent to the current line and thus, creates a DW at the boundary between the reversed and unreversed magnetization. Once a DW is created, the DW is pushed to the other side of the nanowire by applying electric current through the nanowire, under a bias magnetic field in the direction from the substrate to the sample. The DW arrival time at a position 7 μm away from the initial DW position is measured by use of a scanning magneto-optical Kerr effect (MOKE) microscope. The bias magnetic field is kept less than 20 mT, which is sufficiently smaller than the coercive field, to avoid the domain nucleation due to the field.

3. results and discussion

The effect of electric current was converted into an effective magnetic field by using the relation, $\Delta H=\varepsilon J+\eta J^2$, where the linear term is ascribed to the non-adiabatic STT and the quadratic term is known to be caused by the adiabatic STT. Figure 1(a) shows overlapped DW speed with respect to the total effective magnetic field ($H+\Delta H$), which obeys the thermally activated creep law $v^*=v_0\exp[-\alpha\{H+\Delta H(J)\}^{-1/4}]$ with the characteristic speed v0 and a scaling constant α. Here, v^* is the speed, normalized for a constant temperature T_0 in order to remove the Joule heating effect. The effect of current can be converted into an effective field, as plotted in Figure 1(b). The plot clearly shows that the effective field follows the relation, $\Delta H=\varepsilon J+\eta J^2$. From the best fitting, we find the STT efficiency ε is $(0.9\pm0.03)\times10^{-14}$ Tm^2/A and η = $(1.2\pm0.2)\times10^{-26}$ Tm^4/A^2, respectively. Based on the effective magnetic field analysis, we found that the effect of current is composed of linear and quadratic contributions, of which values are quantitatively determined. We propose a new methode to examine STT efficiency and the present result can provide useful reference for STT efficiency of DW motion in MgO based ferromagnetic nanowires.

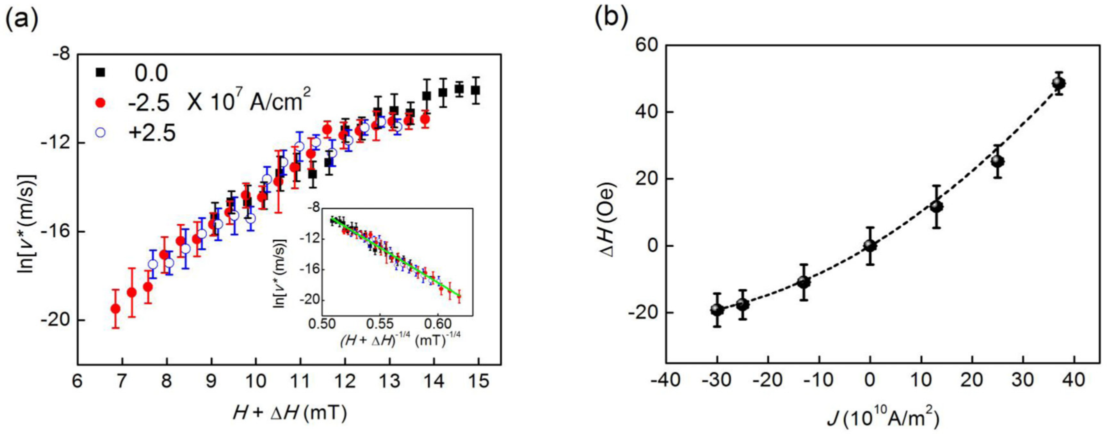

Figure 1. (a) Overlapped DW speed with respect to the total effective magnetic field ($H+\Delta H$). (inset) creep plot of DW speed. Green line is the best fit withln $v^{*}=\ln v_0-\alpha\{H+\Delta H(J)\}^{-1/4}$. (b) Effective field ΔH as a function of the current density J. The error bars are the maximum in accuracy of ΔH and J measurements. The dotted line shows the best fit with $\Delta H=\varepsilon J+\eta J^2$.