Atomistic simulation of heat assisted linear reversal mode in nano-dots with perpendicular anisotropy

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1. Introduction

As a way to achieve ultra-high recording density in a hard disk or MRAM, so-called HAMR (Heat assisted magnetic recording), is promising to reduce or eliminate the energy barrier for magnetization reversal by laser irradiation heating or Joule heating. In particular, the magnetization process in the vicinity of the Curie temperature exhibits a liner reversal mode, in which the averaged magnetization is changing. In the present study, nano-dots with practical perpendicular anisotropy are focused, and atomic level spin dynamics in the linear reversal mode was numerically investigated with atomistic simulations. Dependence of switching properties on thermal pulse intensity and duration were also systematically studied.

2. Numerical model

The ferromagnetic nano-dot was numerically modeled by a cubic magnetic moment lattice ($9\times9\times9$, $\mu = 3.2\mu_B$) with nearest neighbor exchange coupling ($J_{ij} = 3.5\times10^{-15}$ erg/link) and single ion anisotropy ($K = 3.5\times10^{-15}$ erg), where the $L1_0$ FePt was assumed as a material system. The dot size is expected to be 3.4 nm assuming the lattice constant of 0.38 nm for FePt. The anisotropy energy of the dot is evaluated as 2.6×10^{-12} erg (= 62 k_BT, @T=300 K). Atomistic simulations were performed by discretizing the Langevin-LLG equation, based on 3-dimensional Heisenberg Hamiltonian, in time increments of 10^{-16} s. Thermal disturbance effect was introduced as a heat equivalent random Langevin fields model. Currie temperature evaluated from simulated Arrott plot was 750 K.

3. Results of discussion

As for a preliminary simulation, time transient of the averaged magnetization change caused by a rectangular heat pulse (magnitude ΔT= 500 K) application is simulated as shown in Fig. 1, which exhibits exponential demagnetization process with relaxation time of 2 ps and tail-less fast ordering time of 2 ps. Heat assisted magnetization reversal process with Gauss thermal pulse with various pulse width T_w are compared in Fig. 2. The fast magnetization reversal time of several 10ths ps can be associated with the linear reversal mode accompanied with significant averaged magnetization reduction. Heat assisted reversal probability were studied for various heat pules amplitude ΔT and width T_w, as shown in Fig. 3(a) and 3(b). It shows the thermal pulse width dependence of the magnetization reversal probability when performing the magnetization reversal in Fig. 3.(b). The results reveal that superior heat assisted effect is performed at T_w longer than the relaxation time of 40 ps, and the elevated temperature should be higher than the Currie temperature T_c. Fig. 4 compares the magnetization reversal field for with and without the heat assist.

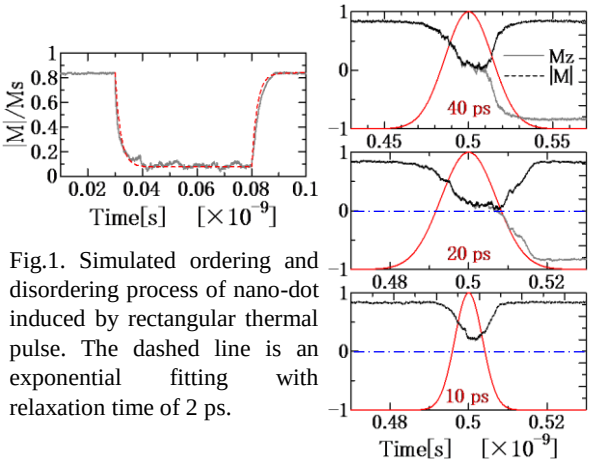

Fig.1. Simulated ordering and disordering process of nano-dot induced by rectangular thermal pulse. The dashed line is an exponential fitting with relaxation time of 2 ps.

Fig.2. Magnetization dynamics for a 10 kOe downward external field and Guess thermal pulse with ΔT=500K at an ambient temperature of 300K.

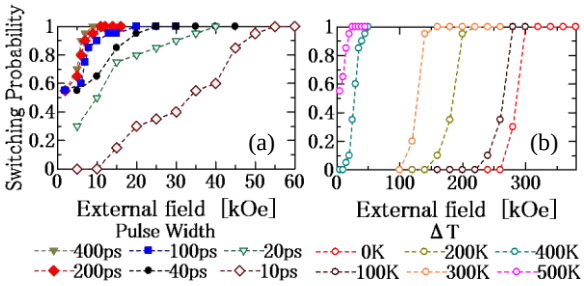

Fig.3. Magnetization reversal probability for various thermal pulse width T_w (a), and magnitude ΔT (b).

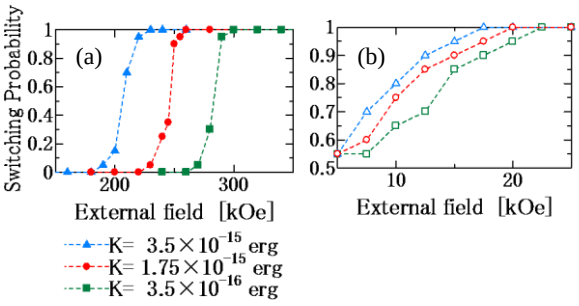

Fig.4. Dependence of magnetization reversal field on single ion anisotropy for with and without the heat assist: (a) T_w = 40ps, ΔT= 0 K, (b) T= 40ps, ΔT = 500 K.

Though the drastic reduction of the reversal field can be achieved with the optimized thermal pulse, the reversal field still depends on the single ion anisotropy even if the averaged magnetization and the resultant energy barrier is disappeared.

Reference

1) R. F. L. Evans, *et al*. *Appl. Phys. Lett.* **105**, 192405(2014)
2) M. O. A. Ellis, *et al*. *Appl. Phys. Lett.* **106**, 162407(2015)