Time resolved magneto-optical Kerr effect and spin transfer torque switching of GdFeCo / TbFe exchange coupled bilayers

T. Kato[1], T. Higashide[1], B. Dai[2], D. Oshima[3], S. Iwata[3]
[1]Department of Electrical Engineering and Computer Science, Nagoya University, Nagoya 464-8603, Japan
[2]Center for Comosite Materials and Structures, Harbin Institute of Technology, Harbin 150080, P.R.China
[3]Institute of Materials and Systems for Sustainability, Nagoya University, Nagoya 464-8603, Japan

Spin transfer torque (STT) switching is considered as a promising technology to realize Gbit class magnetic random access memories (MRAMs). However, there still remains a challenge to develop high-density MRAMs with densities of several Gbit and beyond, since it has a conflicting requirement, i.e., a reduction of critical current density J_c to switch the memory cell while keeping a sufficient thermal stability of the cell. One of the solutions for this challenge is so-called thermally assisted MRAM in which the memory layer is heated during the writing[1)]. We have studied amorphous TbFe[2), 3)] and GdFeCo[4), 5)] as a memory layer of the thermally assisted MRAM cell. In this paper, we discuss the STT switching of GdFeCo single layers and GdFeCo / TbFe exchange coupled bilayers. Moreover, Gilbert damping constant α of GdFeCo / TbFe bilayers is discussed to compare the product of Gilbert damping and perpendicular anisotropy with the switching current density J_c.

GdFeCo (10 – x nm) / TbFe (x nm) exchange coupled bilayers were deposited on thermally oxidized Si substrates by RF magnetron sputtering, where the TbFe thickness x was varied from 0 to 5 nm. Time resolved magneto-opcical Kerr effect (TRMOKE) measurements were carried out to estimate Gilbert damping α and anisotropy field H_k of the bilayer. For STT switching, giant magneto-resistance (GMR) films with GdFeCo / TbFe memory layers were sputtered, and the GMR films were microfabricated into the size of 120 × 180 nm^2.

Figure 1 (a) shows TbFe thickness dependence of Gilbert damping constant α of the bilayer. The damping constant α of the GdFeCo / TbFe was relatively low 0.051 for $x = 0$, and it significantly increased to 0.23 for $x = 1$. TbFe thickness dependence of the anisotropy field H_k estimated from the TRMOKE measurements was shown as closed circles in Fig. 1 (b). The H_k gradually increased with increasing TbFe. The H_k estimated from TRMOKE agreed well with the H_k estimated from hysteresis loops which is shown as open circles in Fig. 1 (b). We compares the product $\alpha \times M_sH_k$ of the as-deposited GdFeCo / TbFe bilayers with the J_c of CIMS as shown in Fig. 1 (c), since the J_c is known to be proportional to the product, $\alpha \times M_sH_k$, in a single memory layer. The J_c of the GdFeCo (9 nm) / TbFe (1 nm) was confirmed to increase by 1.6 times compared to that of the GdFeCo (10 nm), while the product $\alpha \times M_sH_k$ was confirmed to increase by a factor of 10. This suggests that an empirical relation, $J_c \propto \alpha \times M_sH_k$, does not hold in the exchange coupled bilayer system.

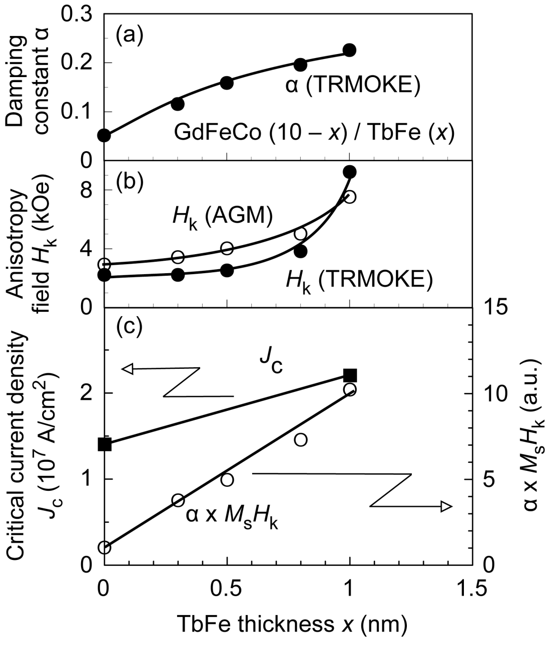

Fig. 1 (a) TbFe thickness dependence of the damping constant α of the GdFeCo / TbFe bilayer. (b) TbFe layer thickness dependence of the anisotropy field H_k estimated from TRMOKE and hysteresis loops, (c) TbFe thickness dependence of the critical current density J_c of the GMR nano-pillars with GdFeCo / TbFe bilayers and the product $\alpha \times M_sH_k$ of the bilayers.

Reference

1) I. L. Prejbeanu *et al.*, J. Phys. D: Appl. Phys., **46**, 074002 (2013).
2) L. You *et al.*, Jpn. J. Appl. Phys., **47**, 146 (2008).
3) L. You *et al.*, J. Magn. Magn. Mater., **321**, 1015 (2009).
4) B. Dai *et al.*, IEEE Trans. Magn., **48**, 3223 (2012).
5) B. Dai *et al.*, IEEE Trans. Magn., **49**, 4359 (2013).