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 \(\alpha\) 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-optical Kerr effect (TRMOKE) measurements were carried out to estimate Gilbert damping \(\alpha\) 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 \(\times\) 180 nm\(^2\). Figure 1 (a) shows TbFe thickness dependence of Gilbert damping constant \(\alpha\) of the bilayer. The damping constant \(\alpha\) 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 \(\alpha \times M_H H_k\) 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, \(\alpha \times M_H H_k\), 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 \(\alpha \times M_H H_k\) was confirmed to increase by a factor of 10. This suggests that an empirical relation, \(J_c \propto \alpha \times M_H H_k\), does not hold in the exchange coupled bilayer system.

Reference

Fig. 1 (a) TbFe thickness dependence of the damping constant \(\alpha\) 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 \(\alpha \times M_H H_k\) of the bilayers.