Asteroid Curve of Synthetic Ferrimagnet

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1. Introduction

A synthetic ferrimagnet (SyF), composed of two magnetic layers sandwiching a very thin non-magnetic spacer, has attracted much attention as a free layer in magnetic random access memory (MRAM). As a memory device, stability of stored information in SyF should be secured primarily. Since the stability is largely influenced by external magnetic fields, accurate information of stability over external magnetic field required. And for a toggle-mode MRAM [1], it is also important to know how magnetization reacts under external magnetic field with various field angles. For a single magnetic layer, where total energy can be described only by Zeeman and anisotropy energy terms, stability over external magnetic field is simply interpreted by asteroid curve as shown in Fig. 1. In asteroid curve, the switching field where stability is lost is drawn in a single curve. However total energy of SyF is much more complicated than single magnetic layer, and it is quiet obvious that SyF will not follow asteroid curve of single magnetic layer. Worledge reported critical switching curve of SyF based on analytical total energy equation [2]. But assumptions in this analytical equation make the results far from real situation. Recently, analytical/numerical combined method for calculation of totally energy of SyF in real situation was introduced [3]. In this study, switching field curve of SyF in real situation based on analytical/numerical combined method was investigated.

2. Computational method

Elliptical SyF with lateral dimension of 160 nm x 80 nm is considered. Thicknesses of magnetic layers are 1.8 and 2.2 nm. Thickness of spacer is 0.6 nm. The magnetic parameters used were: M_s = 1034 emu/cc; K_u = 5170 erg/cm^3, J_{ex} = -0.17 erg/cm^2. Total energy of SyF can be calculated from Eq. (1) [3]. And from this total energy equation, critical fields and energy barrier at given external magnetic field were numerically calculated. Critical field is defined as the field where stability is lost. In other words, it is the field where reversible process ends.

$$\begin{aligned} E(\theta_1,\theta_2) = &-M_s\left[H_{a,x}(V_1\cos\theta_1+V_2\cos\theta_2)+H_{a,y}(V_1\sin\theta_1+V_2\sin\theta_2)\right] \\ &+\frac{1}{2}M_s\left[H_{dem,x-1}V_1\cos^2\theta_1+H_{dem,x-2}V_2\cos^2\theta_2+H_{dem,y-1}V_1\sin^2\theta_1+H_{dem,y-2}V_2\sin^2\theta_2\right] \\ &+\frac{1}{2}M_s\left[(V_1H_{dip,x-2}+V_2H_{dip,x-1})\cos\theta_1\cos\theta_2+(V_1H_{dip,y-2}+V_2H_{dip,y-1})\sin\theta_1\sin\theta_2\right] \\ &-\frac{1}{2}M_sH_i(V_1\cos^2\theta_1+V_2\cos^2\theta_2)-AJ\cos(\theta_1-\theta_2) \end{aligned} \tag{1}$$

3. Results and discussion

Fig. 2 shows asteroid curve of synthetic ferrimagnet. It seems rather complicated than that of single magnetic layer as can be seen in Fig. 1. However it can be interpreted in same manner. Open rectangles are critical field at each given angles of external magnetic field. In filled region, energy barrier is expressed as a contour. And in this region, reversible process occurs continuously just as in the asteroid curve of single magnetic layer. Stability is maintained how the field sequence is schemed, unless it does not cross the critical fields. Finally, validity of asteroid curve of exchange-coupled trilayer was confirmed by micromagnetic simulation.

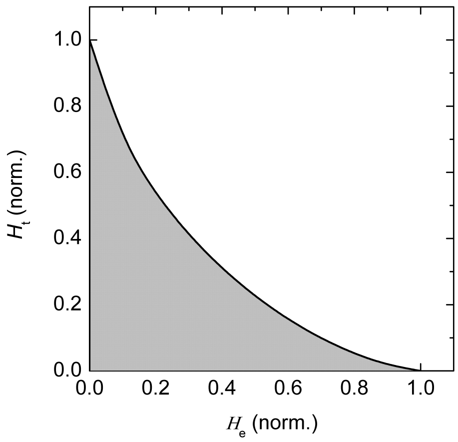

Fig. 1. Asteroid curve of single magnetic layer.

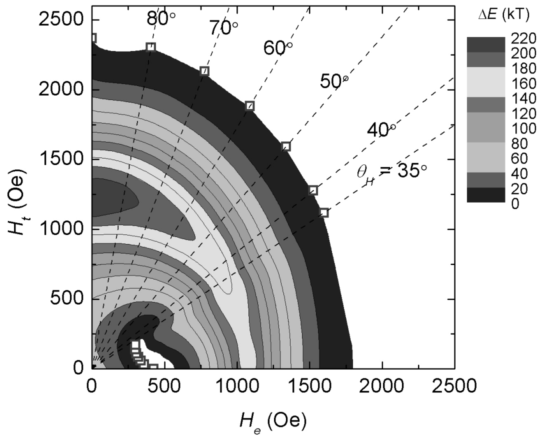

Fig. 2. Asteroid curve of synthetic ferrimagnet.

4. References

[1] L. Savatchenko, B. N. Engel, N. D. Rizzo, M. F. Deherrera, and J. A. Janesky, U.S. Patent No. 6,545,906 (2003).

[2] D. C. Worledge, Appl. Phys. Lett. 84, 4559 (2004).

[3] J. K. Han, J. H. NamKoong, and S. H. Lim, J. Physics D 41, 232005 (2008).