G-5

Dynamic magnetization switching behavior in interacting nanostructured thin film

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The physics of magnetization reversal dynamics in nanostructured magnetic materials has been a subject of intense investigation not only for its fundamental interest but also due to applications in many area of advanced technology, including magnetic random access memory and sensor applications. The influence of the exchange coupling interaction on the dynamic magnetization reversal in nanostructured magnetic film was investigated by micromagnetic simulation based on Landau-Lifschitz-Gilbert equation [1-3].

The elliptical magnetic thin film, having lateral dimensions of 200×100 nm^2 was considered. The film was divided in the plane using a mesh size of 2.5×2.5 nm^2. Each mesh is a single domain, and has same saturation magnetization (M_s) of 820 emu/cc. The thickness of the film is 2 nm. The damping parameter is $\alpha = 0.003$ and the cubic crystal anisotropy constant (K_u) is 1000 erg/cm^3. The strength of exchange interaction (H_{ex}) between the magnetic cells was changed by varying exchange coupling constant (A_{ex}) which was changed widely from 0.05×10^{-6} to 2.0×10^{-6} erg/cm. The exchange length L_{ex} is in the range of 1.0 ~ 6.8 nm. Subpicosecond time steps were used to simulate dynamics of the magnetization reversal at zero temperature.

Figure 1(a) shows the time evolution of the normalized magnetization M_x (easy-axis) at various external magnetic fields for weakly coupled magnetic cells of $A_{ex} = 0.05 \times 10^{-6}$ erg/cm. The field h is the normalized external magnetic field H_{ext} with respect to the coercivity H_c of 80 Oe. The dynamic switching process shows a quite different behavior with the external field strength. For the relatively small external fields of h = 1.0 and 1.05, the value of the normalized M_x gradually decrease to t_p = 1.9 and 1.7 ns, respectively, and then switches to the negative value quickly. Finally, it was saturated to the external field direction. For the external field of h = 1.2 and 1.4, the magnetization initially reverses more quickly, however, the reversal is incomplete. At t_p = 4 ns after the magnetization reversed, the average value of the normalized M_x is almost -1.0 at the fields of h = 1.0 and 1.05, however the value at higher fields of h = 1.2 and 1.4 is only about -0.45. This incomplete switching is due to the vortex formation during the reversal process. Fig. 1(b) shows the time evolution of the normalized magnetization component of M_x for the strongly coupled magnetic cells of $A_{ex} = 1.3 \times 10^{-6}$ erg/cm. The dynamic magnetization reversal for the strongly coupled cells shows a quite different behavior from that of weakly coupled cells in Fig. 1(a). For the case of h = 1.04, there is very small change in the value of M_x for the short time of $t_p < 3.5$ ns. And then, M_x is switched from positive to negative direction at t_p = 3.5 ns abruptly. After then, M_x oscillates around the effective field direction to dissipate the excessive energy. This oscillation corresponds to an excitation of nonlinear spin wave mode. As the external field was increased, the magnetization was reversed more quickly.

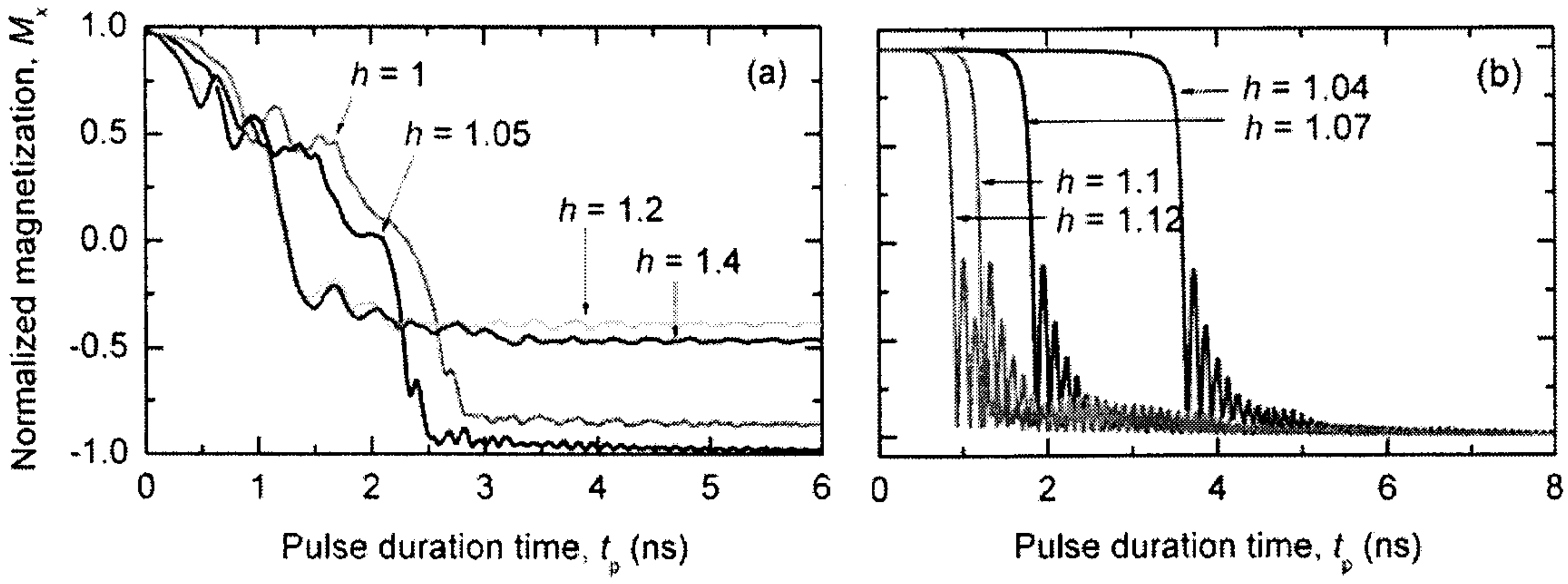

Figure 1. Time evolution of the normalized magnetization M_x (easy-axis) at various external magnetic fields for weakly coupled magnetic cells of A_{ex} = 0.05 × 10^{-6} erg/cm (a) and for strongly coupled magnetic cells of A_{ex} = 1.3 × 10^{-6} erg/cm (b). The field *h* is the normalized external field with respect to the coercivity.

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