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Effects of external field and thickness asymmetry on dynamic magnetization switching of exchange-coupled trilayer

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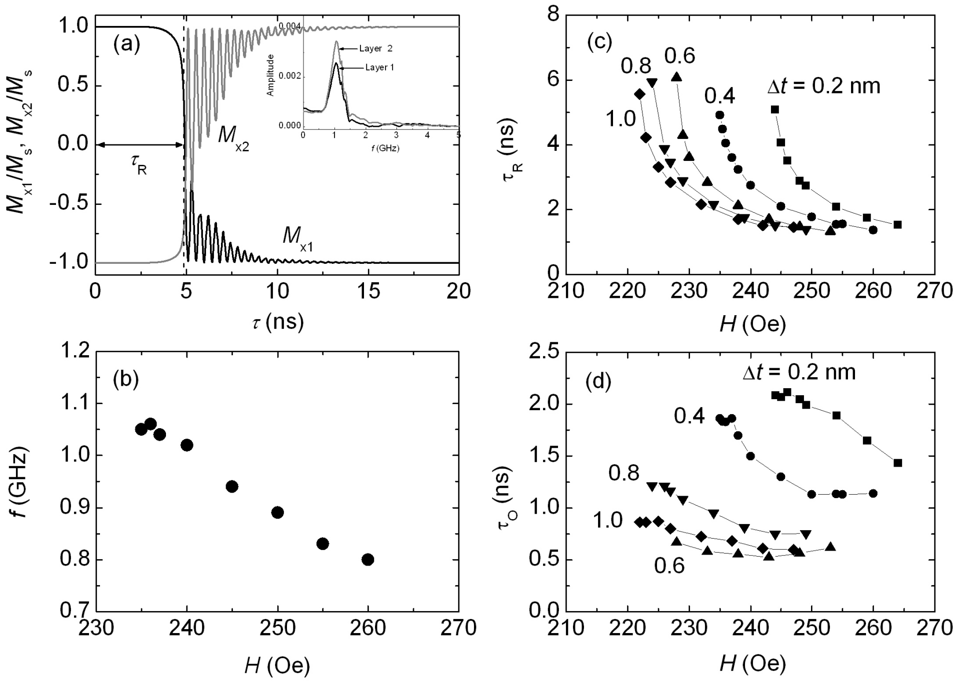
Exchange-coupled trilayers, which are composed of two ferromagnetic layers separated by a thin non-magnetic spacer, have received considerable attention in recent years because of their potential advantages in ultra high density magnetic random access (MRAM) applications [1-3]. Notable advantages include an enhanced thermal stability when the exchange-coupled trilayers use as a free layer structure due to increased magnetic volume over a single magnetic free layer [3], and an reduced critical current density for current induced magnetization switching (CIMS) due to a reduction of the *effective* magnetization [3]. In this work, the dynamic magnetization switching behavior of exchange-coupled trilayers was investigated by micromagnetic simulation. A particular emphasis was places on the effects of the external field and the thickness asymmetry of the two ferromagnetic layers on the dynamic switching process.

Micromagnetic simulation was performed using a commercial program code of MicroMagus (Sura Instruments, Germany) based on the Landau-Lifschtz equation. The exchange-coupled trilayer is composed of two ferromagnetic layers separated by a very thin non-magnetic spacer. An elliptical magnetic thin film with lateral dimensions of 200 nm × 100 nm was considered. The total thickness of the two magnetic layers ($t_1 + t_2$) was fixed at 4 nm, however, the thickness of each magnetic layer was varied. The thickness of the spacer was fixed at 0.6 nm. The magnetic parameters used were; a saturation magnetization (M_s) of 820 emu/cc, an exchange constant (A_{ex}) of 1.0×10^{-6} erg/cm, an induced anisotropy constant (K_u) of 4100 erg/cm^3, an interlayer exchange constant (J_{ex}) of -0.05 erg/cm^2, and a damping constant (α) of 0.003. Subpicosecond time steps were used to simulate dynamics of the magnetization reversal.

Figures (a) and (b) show the results for the dynamic magnetization switching behavior for a sample with a thickness asymmetry, Δt = 0.4 nm (t_1 = 2.2 nm and t_2 = 1.8 nm). Fig. (a) shows the time evolution of the normalized magnetization components in the length (x) direction, M_{x1} (for thick layer) and M_{x2} (for thin layer). The magnetizations of the two ferromagnetic layers are initially in the antiparallel state M_1 and M_2 point to the $+x$ and $-x$ directions, respectively. Two different characteristic times can be defined: the coherent rotation time τ_R and the oscillation time τ_O. The magnetization M_x initially does not react to the external field at $\tau \leq 5$ ns, after which, both M_{x1} and M_{x2} start to switching abruptly. Following this magnetization reversal, both magnetizations oscillate with exactly same frequency as shown in insert for a long period time. The oscillation frequency is quite small (1.05 GHz at the switching field of 235 Oe) and decreases as the external field increases as shown in Fig. (b). Figs. (c) and (d) show two characteristic times of τ_R and τ_O as a function of the external field at several values of Δt. As expected, both times of τ_R and τ_O decrease as the external field increases indicating the fast switching at high external field. The switching time was also decreased as the thickness asymmetry was increased.



The Korea Science and Engineering Foundation (KOSEF) supported this work through the National Research Laboratory program, which is funded by the Korean Ministry of Science and Technology (Project No. M10600000198-06J0000-19810).

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