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Spin-Polarized Current Switching of Co/Cu/Py Elongated Pac-Man Spin-Valve

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For the application of magnetic random access memory (MRAM) inter-element interactions due to stray magnetic fields should be minimized to achieve high aerial density and reliability [1, 2]. We previously reported that array of elongated Pac-man (EPM) $Ni_{80}Fe_{20}$ (Py) elements reveals closed magnetization configuration and results in negligible interaction between the elements during magnetic field switching [3-5]. In this study, we have performed micromagnetic simulations on EPM spin-valve (Co/Cu/Py) nanopillar structure, shown in Fig. 1(a), as a function of pico-second ranged pulse-width to investigate pulse-width dependence of spin-polarized switching current. Figure 1(b) shows an example of parallel to anti-parallel (P-AP) switching for a 300 ps pulse-width. The first snap-shot in red color corresponds to the Py free layer just before the pulse is applied. As shown in the image at 278 ps the switching occurs coherently without undergoing quasi-stable vortex state. We note that in order to prevent vortex nucleation the aspect ratio of the EPM needs to be optimized as suggested by our previous results [3]. While the snap-shot taken at 2 ns shows the completely switched Py free layer, the Co fixed layer remains unswitched. It is found that the spin-polarized switching current for both P-AP and AP-P gradually decreases with increasing the switching pulse-width as shown in Figure 1(c). In the case of AP-P switching, a vortex nucleated during switching and needs to be annihilated in order to completely switch the Py free layer. The need for the energy to annihilate the vortex resulted in the smaller AP-P current density for longer pulse as compared to P-AP. In conclusion, we have successfully switched EMP spin-valve by spin-polarized current. This result implies that Pac-man shape is a good candidate shape for spin-valve of STT-RAM device.

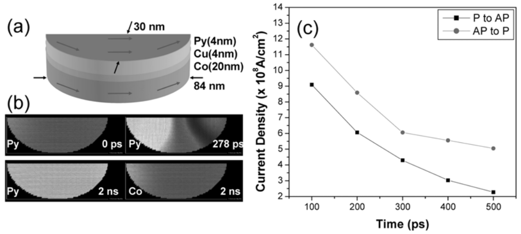

Fig. 1. (a) Schematic of Co/Cu/Py EPM spin-valve, (b) snap-shots of the nonequilibrium states of Py magnetization during P-AP switching for 300 ps pulse, and (c) spin-polarized switching current as a function of pulse duration.

This research was supported in part by AFRL under contract F29601041206.

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Exchange Coupling in FePt/Os/FePt Trilayers

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Effects of the Os layer on the magnetic properties of FePt(10nm)/Os(xnm, x = 0~2.7)/FePt(10nm) were investigated. The magnetic layer of FePt in the as-deposited Ta/FePt/Os/FePt/Ta thin films exhibited very strong (111) orientation in all the cases. As the thickness of Os spacer layer between 0.1 and 0.3 nm, it appeares an antiferromagnetic exchange coupling (AFC) behavior in the hysteresis loop as shown in Fig. 1(a). The exchange coupling transforms to ferromagnetic when the thickness of Os spacer layer was thicker than 0.4 nm. The second maximum of AFC is found as Os thickness = 0.7 nm. Although the J value for FePt/Os/FePt thin films is 0.22 erg/cm^2, which is relatively small than that of Co/Ru system, the GMR effects could be observed. The oscillatory behavior of GMR value is sketched in Fig. 1(b). In general, the AFC in multilayer system shows the first maximum of AFC peak occurring at spacer thickness between 0.8 and 1.1 nm for most spacer materials. In our investigation, this is the first time that a clear AFC behavior observed in FePt/Os/FePt system with Os spacer thickness at 0.2nm. Except for the longitudinal MR, we also measure the perpendicular MR (PMR). We do not observe explicit PMR effect for the films with the thickness of Os layer ranged from 0.1 ~ 0.3 nm. A negative PMR is observed in the film with Os thickness= 0.4 nm. Because the FePt layers do not possess a perpendicular magnetic anisotropy, it indicates a perpendicular AFC in the FePt/Os(0.4nm)/FePt system. For the rest of the films, a positive PMR is observed.

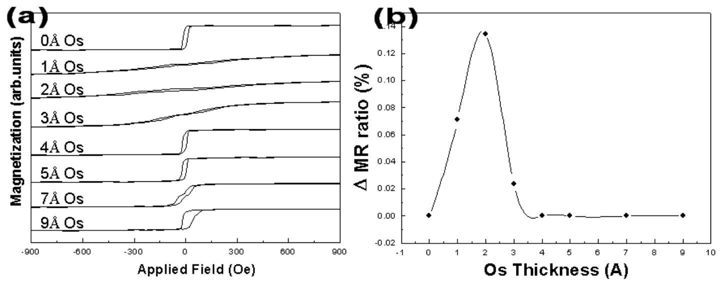

Fig. 1. (a) The M–H loops of FePt/Os/FePt thin films with various Os spacer thickness. (b) Relationship between ΔMR ratio and Os thickness.