Micromagnetic Modeling of Penta-Layer Magnetic Tunnel Junctions with a Composite Soft Layer

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Memory cells based on electric charge storage, such as flash memory, are rapidly approaching the physical limits of scalability. The spin transfer torque random access memory (STTRAM) is one of the promising candidates for future universal memory. The reduction of the current density required for switching and the increase of the switching speed are among the most important challenges in this area. Measurements performed in [1] showed a decrease in the critical current density for the penta-layer magnetic tunnel junction (MTJ) compared with the tri-layer MTJ. In this work we investigate the dynamics of the switching process in a MTJ composed of five layers (where the magnetizations of the two layers are fixed) with a composite soft magnetic layer and compared it with the MTJ from [1] with a monolithic soft layer. The spin torque enhancement in penta-layer structures with a monolithic soft layer was recently investigated in [2]. In contrast to [2] we performed extensive micromagnetic modeling of the penta-layer structures by employing the Slonczewski model [3, 4] for the spin torque. The use of this model is justified in structures with a free ferromagnetic layer thickness of a few nanometers. Based on this model we optimized the penta-layer MTJ from [1] by investigating the influence of the thicknesses of the fixed layers on the magnetostatic exchange magnetic field in the plane of the free magnetic layer. The fastest and the most symmetric switching is achieved, when the second fixed layer thickness is around 9nm. The reason for this result is that the in-plane component of the magnetostatic exchange field is best compensated for this thickness. We also investigated the properties of the MTJ with a composite soft layer, which consists of two half-ellipses separated by a dielectric material. Fig.1 shows the evolution of the magnetization of the free ferromagnetic layer during switching from the anti-parallel (AP) to the parallel (P) state for penta-layer MTJs with a monolithic or a composite soft layer. While the current density is the same, the switching time is reduced by approximately a factor of two for the penta-layer MTJ with the composite soft layer. The snapshots of the magnetizations highlighting the differences in switching are shown in Fig. 2.

This work is supported by the European Research Council through the grant #247056 MOSILSPIN.

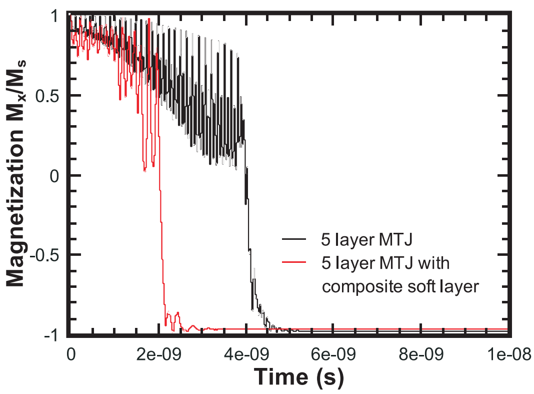

Fig. 1: *Evolution of the averaged magnetization of the free ferromagnetic layer during switching AP→P in a penta-layer structure with a monolithic and with a composite soft layer.*

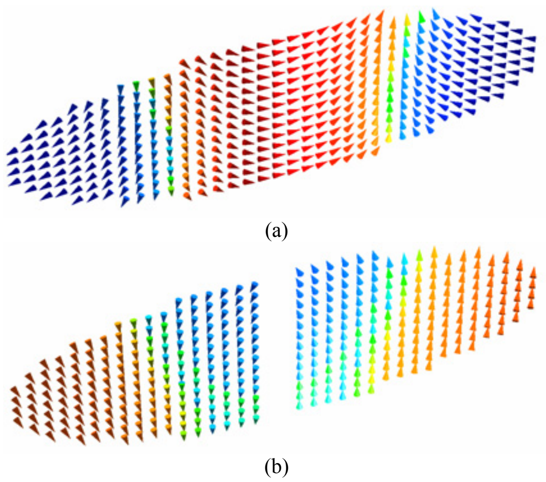

Fig. 2: *Snapshots of the magnetization of the free magnetic layer in a penta-layer MTJ: (a) with a monolithic soft layer; (b) with a composite soft layer.*

References

[1] G. D. Fuchs et al., Appl. Phys. Lett., 86 (2005), 152509.
[2] N.N. Mojumdar et al., J. Appl. Phys., 108 (2010), 104306.
[3] J. Slonczewski, J. Magn. Magn. Mater., 159 (1996), L1-L7.
[4] J. Slonczewski, Phys. Rev. B, 71 (2005), 024411.