Micromagnetic simulations of magnetization reversal by spin-polarized current in nanopillars with perpendicular anisotropy

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I. Introduction

A recent experimental work of Mangin et al. [1] demonstrated that devices exhibiting perpendicular magnetic anisotropy (PMA) showed high thermal stability and reduced critical current.

Here, we numerically demonstrate a strategy to reduce critical current (or switching times) of CoNi/Cu/CoNi-CoPt elliptical nanoscale spin valves. We compare our simulations results to experimental data of current-driven magnetization reversal.

The system studied is a nanopillar spin valve having both ferromagnetic layers with perpendicular anisotropy sufficient to maintain the magnetization in the *z*-direction without applied field. The nanopillar of elliptical shape (100 nm x 50 nm) consists of 4.5 nm CoPt-CoNi pinned layer (PL) (it is a composite Co/Pt and Co/Ni multilayer) and of 2.8 nm CoNi free layer (FL) separated by a 4 nm Cu spacer. The nonmagnetic Pt layers are essential for inducing large perpendicular anisotropy (for FL K_u=3.3x10^5 J/m^3). The simulations have been performed by solving the Landau-Lifshitz-Gilbert-Slonczewski (LLGS) equation [2]-[3].

The magnetic parameters set used in the computations is obtained by fitting static magnetoresistance measurements [1] (See Fig.1).

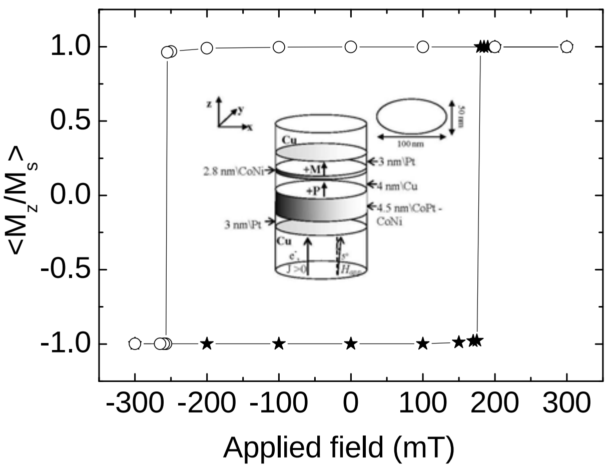

Fig. 1. Normalized *z*-component of the magnetization versus H_{app} for H_{app} perpendicular to the film plane. Inset: Schematic drawing of the ferromagnet multilayer.

II. Results

In general, structures with perpendicular anisotropy are characterized by smaller critical currents and longer times for switching processes with respect to the in-plane anisotropy devices. The reference layer is essentially in the +z direction and the initial magnetization of the FL is set in parallel alignment to the reference layer configuration. A perpendicular external field of 46 mT is applied, this value compensates the contribution due to the effect of the magnetostatic coupling with the PL. We checked that the critical current to switch the FL magnetization from +*z* to -*z* configuration (P→AP) within about 5 ns (typical times for these switching processes) was 8.5x10^7 A/cm^2 (in agreement with experimental data by Mangin et al. [1]). On the other hand, when applying a field of the same amplitude of the magnetostatic coupling, but oscillating at some GHz frequencies, a reduction of the switching times is achieved. By applying to the system the same DC current and an oscillating field with frequency from 9.5 to 10.5 GHz, the switching time decreases (Fig. 2). More numerical details and results together to physical explanation of these processes will be described in the full paper.

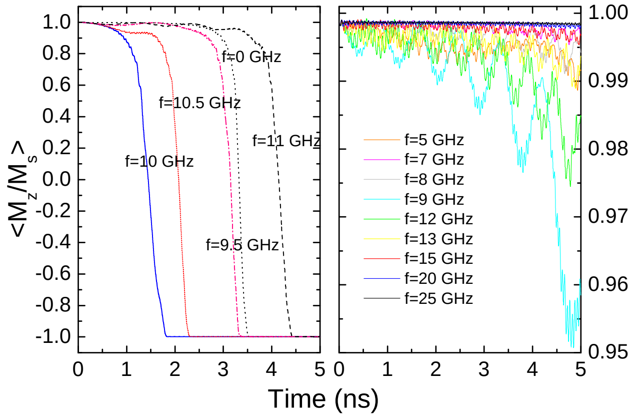

Fig. 2. (Color online) Dynamics of the *z*-component of the magnetization when a DC bias of 3.5 mA and a perpendicular field of 46 mT in amplitude (varying its frequency from 0 to 25 GHz) are applied.

III. References

[1] S. Mangin, D. Ravelosona, J. Katine, M. Carey, B. Terris, E. Fullerton, *Nat. Mater.* **5**, 210 (2006).
[2] J. Slonczewski, *J. Magn. Magn. Mater.* **159**, L1 (1996); *J. Magn. Magn. Mat.* **195**, L261 (1999).
[3] L. Torres, et al., *J. Magn. Mag. Mat.*, **286,** 381, (2005). M. Carpentieri *et al*, *J. Appl. Phys.* **97**, 10C713, (2005).

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