Thermal activated depinning under field and current in wires with perpendicular anisotropy

F. Garcia-Sanchez, L.D. Buda-Prejbeanu, H. Szambolics, A.P. Mihai, J.P. Attané, L. Vila, A. Marty, J.Ch. Toussaint

The perspective of new applications based on domain wall [1] has renewed the interest in domain wall dynamics. The control through spin polarized current, predicted theoretically by Berger [2], is the most appealing phenomenon because it allows to reduce the size of the device. However, there are several issues to address before its implementation in real devices. First, the effect is observed only for large current densities. This situation can be improved by using materials with strong perpendicular magnetic anisotropy, for which a better efficiency is expected [3] and have narrow domain walls and larger velocities [4]. Secondly, in real samples the wall dynamics for intermediate currents present random behavior. The domain wall is pinned in the defects that are disposed randomly along the sample. Additionally, the depinning of the domain wall from the defect is a thermally activated process and, therefore, stochastic by nature. Thus, it is interesting to identify one of such defects and study the depinning from a particular defect. For this purpose, FePt thin films [5] present themselves as ideal systems. This material has very large anisotropy and the films have well defined bidimensional defects. These defects are originated from crystalline dislocations that occupy the whole thickness of the layer and whose position can be determined from topographical investigation.

Our aim in this work is the simulation of thermal activated depinning of the domain wall from a single defect by means of current and field. For this study the thermal fluctuations and the spin torque effects were implemented in the micromagnetic solver. We have used a model that adds two spin torque terms to the Landau-Lifshitz-Gilbert equation: the adiabatic and non-adiabatic terms [6], [7]. The simulated sample has a size of $80 \times 50 \times 5nm^3$ and includes a defect in the center of size $5 \times 10 \times 5nm^3$ (see Inset Fig.1). The material parameters are $K_u = 5 \times 10^6 J/m^3$, $A = 6.9 \times 10^{-12} J/m$, $J_s = 1.03 \times 10^6 A/m$ and $\alpha = 0.1$. For this material the domain wall is very narrow, obtaining a width of $\Delta = \sqrt{A/K_u} = 1.17nm$. We model the defect as a region with anisotropy constant $K_{def} = K_u/2$ and without modifying the remaining parameters. A magnetic field below the depinning field ($\mu_0 H_{dep} = 0.225T$) is applied in the Z direction and the sample temperature is $T = 400K$. The initial configuration contains a domain wall along the X direction, which is pinned at the defect.

F. Garcia-Sanchez, L.D. Buda-Prejbeanu and H. Szambolics are with Spintec, CEA/CNRS, CEA/Grenoble, France. E-mail: liliana.buda@cea.fr

A.P. Mihai, J.P. Attané, L. Vila and A. Marty are with DRFMC/SP2M, CEA/Grenoble, France.

J.Ch. Toussaint is with INP Grenoble, France.

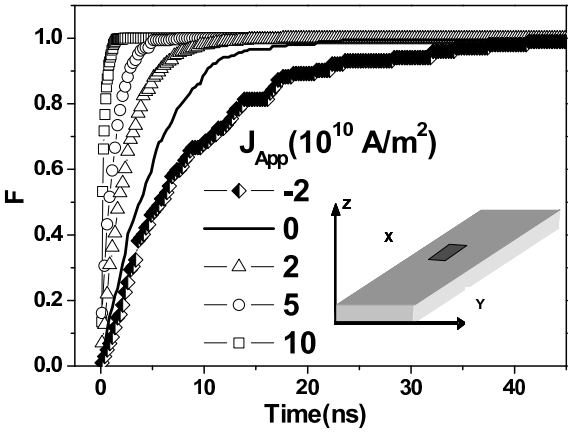

Fig. 1. Cumulative probability of depinning as a function of time for $T = 400K$, $\mu_0 H_{App} = 0.155T$, β=1 and different applied current values. Inset: schematic diagram of the system geometry.

The thermal activated process can be described in the large barrier approximation by the Arrhenius-Néel law and the cumulative probability has the form $F(t) = 1 - \exp(-\frac{t}{\tau})$ where τ is the Arrhenius-Néel relaxation time. Fig.1 shows the cumulative probability for different current densities for $\mu_0 H_{App} = 0.155T$ and β=1. The simulations confirm the exponential law in accordance with recent experiments [8]. An appreciable effect on the average depinning time is observed even for low current densities as well as an asymmetric behavior of probability with respect to the current polarity. Since the origin of the non-adiabatic term can be assigned to the mistracking of the electrons with respect to the local magnetization direction, non-adiabatic term is expected to have larger values in perpendicular anisotropy materials. For this reason we have varied β from 0 to 1. In the adiabatic case, β=0, we have found that, differently from the case of β=1, the current effect is only appreciable for large densities. Finally, in the dynamical regime the non-adiabatic term is equivalent to an applied field [6]. This equivalence introduces an experimental procedure to measure the value of β. We have investigated the validity of this equivalence in the thermal activated regime.

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