*Poster*

# HEAT GENERATION IN TUNNEL JUNCTIONS FOR CURRENT-WRITTEN PINNED LAYER SWITCHING


<u>*A.M. Pereira*</u>[1,a]*, J. Ventura, J. M. Teixeira*[1]*, J. P. Araujo*[1]*, F. Carpinteiro*[1]*,*
*J. B.Sousa*[1]*; b, Y. Liu*[2]*, Z. Zhang*[2] *and P. P. Freitas*[2]
[1]*IFIMUP, Rua do Campo Alegre, 687, 4169-007, Por*to, Portugal
[2]INESC-MN, Rua Alves Redol, 9-1, 1000-029 Lisbon, Portugal
*ampereira@fc.up.pt*


Tunnel junctions (TJ) consisting of two ferromagnetic (FM) layers separated by an insulator (I) [1] show enormous potential for a multiplicity of applications such as read head [2], strain [3], current, position and speed [4] sensors or even to detect magnetically tagged biological specimens [5].

However, probably the most sought after application is high performance, low cost, non-volatile magnetic random access memories (MRAMs) [6]. In a tunnel junction, the magnetization of one of the FM layers (pinned layer) is fixed by an underlying antiferromagnetic (AFM) layer. The magnetization of the other FM layer (free layer) reverses almost freely when a small magnetic field is applied. Due to spin dependent tunneling one obtains two distinct resistance (R) states (the 0 and 1 bits of a magnetic memory) corresponding to pinned and free layer magnetizations parallel (low R) or antiparallel (high R). Consequently, the standard way to switch between R-states in MRAMs is to use magnetic fields generated by current lines. However, the undesirable switching of half selected bits is still a concern for actual MRAM submicron devices. Furthermore, as the size of a memory cell decreases, the magnetic field needed to induce switching greatly increases. To overcome such limitations, a thermally-induced pinned layer switching mechanism was proposed [7, 8]. In fact, when a sufficiently high electrical current flows through the insulating barrier, local temperatures inside the tunnel junction can increase above the blocking temperature of the AFM layer ($T_B \sim 500$ K). One is then able to switch the magnetization of the pinned layer with a small magnetic field H and, upon cooling (under H), a new exchange-bias pinning direction is impressed.

Switching of the magnetic state of the TJ (from parallel to antiparallel or vice-versa) is thenpossible. Here we demonstrate the current-driven pinned layer switching effect in thin magnetic tunnel junctions (MnIr/CoFe/AlOx/CoFe/NiFe) with $T_B = 520$ K [9] using a current density j = 0.75x106 A/cm$^2$. However, numerical results on heat generation in tunnel junctions show that heating is small when such current densities are applied. In fact, only much larger current densities (~15x106 A/cm$^2$) lead to heating above the blocking temperature of the AFM layer. One concludes that the experimental observation of thermally driven pinned layer reversal is due to localized heating in nanoconstrictions that concentrate most of the electrical current leading to high local current densities. Thus, to enhance device performance, the insulating barrier of the tunnel junction should have nanometric inhomogeneities where the local barrier thickness is smaller than average. Such hot-spots lead to a confinement of the electrical current and to an increase of local current densities.

Furthermore, one shows that both heating and cooling (above and below $T_B$ respectively) occur over very small time scales (≤ ns), making current-written pinned layer switching a competitive mechanism for technological implementation.

**References:**


[1] J. S. Moodera, L. R. Kinder, T. M. Wong and R. Meservey, Phys. Rev. Lett. 74, 3273 (1995).

[2] D. Song, J. Nowak, R. Larson, P. Kolbo and R.Chellew, IEEE Trans. Magn. 36, 2545 (2000).

[3] M. Lohndorf, T. Duenas, M. Tewes, E. Quandt, M. Ruhrig and J. Wecker, Appl. Phys. Lett. 81, 313 (2002).
[4] P. P. Freitas, F. Silva, N. J. Oliveira, L. V. Melo, L. Costa and N. Almeida, Sensors and Actuators A 81, 2 (2000).
[5] H. A. Ferreira, D. L. Graham, P. P. Freitas and J. M. S. Cabral, J. Appl. Phys. 93, 7281 (2003).
[6] B. N. Engel, N. D. Rizzo, J. Janesky, J. M. Slaughter, R. Dave, M. DeHerrera, M. Durlam and S.Tehrani, €IEEE Trans. Nanotechnol. 1, 32 (2002).
[7] J. Zhang and P. P. Freitas, Appl. Phys. Lett. 84, 945 (2004).
[8] I. L. Prejbeanu, W. Kula, K. Ounadjela, R. C. Sousa, O. Redon, B. Dieny and J. P. Nozieres, IEEE Trans. Magn. 40, 2625 (2004).