

SPINTRONIC DEVICES FOR MEMORY AND LOGIC APPLICATIONS.

B. Dieny, R. Sousa, G. Prenat

SPINTEC, UMR CEA/CNRS/UJF, Grenoble, France

Giant magnetoresistance [1] found its first application in magnetoresistive spin-valve heads for hard-disk drives [2]. Low field magnetic sensors for position encoders were also developed based on this technology [3] as well as MRAM using pseudo spin-valves [4].

Later on, the observation of large magnetoresistance at room temperature in magnetic tunnel junctions (MTJ) [5,6] opened new prospects of applications. Thanks to the current-perpendicular-to-plane geometry, new MRAM architecture could be conceived allowing reaching much higher density than in earlier spin-valve MRAM designs [7]. The first generations of MRAM design were based on field induced switching with its improved version named “toggle switching”[8]. Freescale launched a first 4Mbit MRAM product based on this technology in 2006.

The discovery of the possibility to manipulate the magnetization of magnetic nanostructure by a spin-polarized current constituted another major breakthrough in the development of spinelectronics. Berger already observed in 1982 that electrical currents could have a direct influence on the propagation of domain walls[9]. However, it is the prediction [10,11] and observation [12] of the possibility to switch the magnetic configuration of spin-valves or MTJ which triggered a considerable interest of the scientific community for these so-called spin-transfer effects. This effect provides a new way to write information in magnetic nanostructures and especially MRAM. The advantages of using spin-transfer writing in MRAM are a better scalability of MRAM design, lower power consumption and better write selectivity [13,14]. In addition, thermal assisted write schemes combined with either field or spin-transfer writing were proposed, offering the ultimate scalability in MRAM design [15]. Intense R&D efforts are in progress in large companies as well as startups to bring these advanced MRAM designs to production. Besides memory applications, the

combination of CMOS components with embedded MTJ in above-IC technology allows conceiving all sorts of innovative hybrid logic devices such as reprogrammable logic gates in which MTJs are used as variable resistance influencing the switching threshold of the CMOS circuits. Innovative architecture of complex electronic devices can also be conceived in which logic and memory are much more intimately intertwined than with CMOS only components. In an historical perspective, the talk will review these present and future developments.

SPINTEC's activity on this topic was partly funded through ANR PNANO CILOMAG and European RTN SPINSWITCH.

References

1. Baibich, M., Broto, J.M., Fert, A., Nguyen Van Dau, F., Petroff, F., Etienne, P., Creuzet, G., Friederich, A. and Chazelas, J., *Phys.Rev.Lett.*, 61 (1988) 2472.
2. Dieny, B., Szeles, V.S., Parkin, S.S.P., Gurney, B.A., Whilhoit, D.R., Mauri, D.. "Giant magnetoresistance in soft ferromagnetic multilayers" *Phys. Rev.B.(Condensed-Matter)* 43 (1991)1297-300.
3. H.Van den Berg et al, "GMR angle detector with an artificial antiferromagnetic subsystem (AAF)", *Journal of Magnetism and Magnetic Materials*, 165 (1), p.524-528, Jan 1997
4. Pohm, A.V., Beech, R.S., Bade, P.A., Chen, E.Y., and Daughton, J.M., "Analysis of 0.1 to 0.3 micron wide, ultra dense GMR memory elements", *IEEE Trans.Magn.*, MAG-30, 4650 (1994).
5. Moodera, J.S., Kinder, L.R., Wong, T.M. and Meservey, R.. "Large magnetoresistance at room temperature in ferromagnetic thin film tunnel junctions", *Phys.Rev.Lett* 74, (1995) 3273-6.
6. Miyazaki, T., Tezuka, N., "Giant magnetic tunneling effect in Fe/Al₂O₃/Fe junction", *Journ.Magn.Magn.Mater.*139 (1995), L231.
7. Tehrani, S., Slaughter, J.M., Chen, E., Durlam, M., Shi, J., DeHerren, M., "Progress and outlook for MRAM technology", *IEEE.Trans.Magn.*, 35, 2814, (1999).
8. Savtchenko, Leonid et al, "Method of writing to a scalable magnetoresistance random access memory element", patent US20030128603
9. S. Jen and L. Berger, "Dragging of stripe domains by a temperature gradient in Metglas 2826 MB (invited)", *J. Appl. Phys.* 53, 2298 (1982).
10. Slonczewski, J., "Currents and torques in metallic magnetic multilayers", *J. Magn.Magn.Mater.*159, L1 (1996).

11. Berger, L., "Emission of spin waves by a magnetic multilayer traversed by a current", Phys.Rev.B 54, 9353 (1996).
12. Katine, J.A., Albert, F.J ., Buhrman, R.A., Myers, E.B., and Ralph, D.C., "Current-Driven Magnetization Reversal and Spin-Wave Excitations in Co /Cu /Co Pillars ", Phys.Rev.Lett.84, 3149 (2000).
13. Slonczewski, J, "Electronic device using magnetic components", patent US 5,695,864 (1997).
14. O.Redon et al, "Magnetic spin polarisation and magnetisation rotation device with memory and writing process, using such a device", patent US6532164 (Nov.2001)
15. B.Dieny et al, "Magnetic device with magnetic tunnel junction, memory array and read/write methods using same", US 6950335(Nov2002).