Eur. Phys. J. B **59**, 413–414 (2007)
DOI: 10.1140/epjb/e2007-00304-3

THE EUROPEAN
PHYSICAL JOURNAL B

Editorial

Topical Issue on New Trends in Spin Transfer Physics

E. Fullerton[1,a], A. Mougin[2], D. Ravelosona[3], and S. Mangin[4]

[1] Center for Magnetic Recording Research, University of California, CA92093-0401 San Diego, USA
[2] Laboratoire de Physique des Solides, Université Paris-Sud, Bâtiment 510, 91405 Orsay Cedex, France
[3] Institut d'Électronique Fondamentale, Université Paris-Sud, 91405 Orsay, France
[4] Laboratoire de Physique des Matériaux, Université Henri Poincaré-Nancy, 54506 Nancy, France

Magnetic materials and devices have played a major role in science and technology for the last half century. Hard disk drives dominate information storage and magnetic random access memory (MRAM) is emerging in the memory market. Present magnetic devices are complex metal hetero-structures that combine many layers and state-of-the-art lithography. The basic functionality results from spin-dependent scattering of polarized currents by magnetic layers separated by a non-magnetic spacer layer. The phenomenon is known as giant magneto-resistance (GMR) for metal interlayers or tunneling magneto-resistance (TMR) for insulating spacer layers. The application of GMR in devices has sparked research in the broader field of spintronics, which relies on manipulating the spin rather than the charge of the electron via spin injection, manipulation and detection. Its discovers were awarded the Nobel Prize in physics in 2007 (P. Grunberg and A. Fert).

While in most magnetic applications the orientations of the magnetic elements within devices are controlled by external magnetic fields, it has recently been appreciated that the relative orientations of nano-magnets can be controlled directly by the injection of spin polarized currents; this is known as a spin transfer effect. The basic phenomena of spin transfer occur for current flowing through two magnetic elements separated by a thin nonmagnetic spacer layer. The current becomes spin polarized by transmission through or upon reflection from the first magnetic layer (the reference layer) and mostly maintains this polarization as it passes through the non-magnetic spacer and enters and interacts with the second ferromagnetic layer (the free layer). This interaction leads to a change of resistance depending on the relative orientation of the magnetic layers giving rise to GMR. The GMR is proportional to the transfer of angular momentum from the polarized current to the free layer magnetization that can be described as an effective torque. This spin torque can oppose the intrinsic damping of the magnetic layer exciting spin waves and, for sufficient current strengths, reverses the direction of the magnetization.

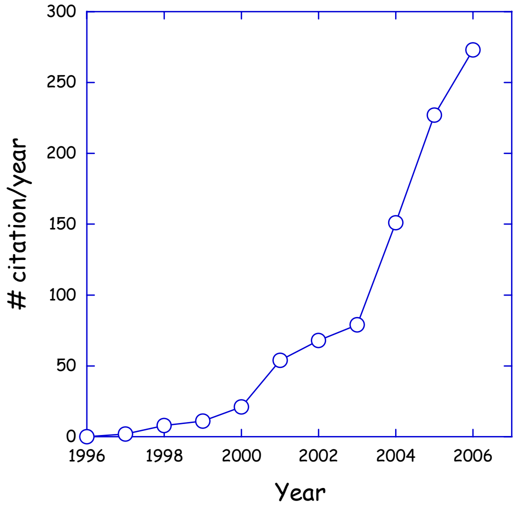

Fig. 1. Number of citations per year for the Sloncewski and Berger papers published in 1996.

The theoretical predictions by Slonczewski [1] and Berger [2] in 1996 and early experimental verification [3–5] of spin transfer torques, provoked tremendous excitement, the level and growth of which can be seen by plotting the number of citations for the Slonczewski and Berger papers each year over the last ten years (Fig. 1). Although the initial impact of the papers was modest, there has been explosive growth in this field over the last four years. The excitement reflected in Figure 1 is driven by a number of factors. First, spin transfer effects provide a probe of the interactions between spins and magnetism and strengthen our fundamental understanding of magnetic materials. Not only do these effects arise from spin interactions at interfaces but they also occur from current flowing through non-uniformities of the magnetization (such are domain walls). These effects are well described by additional terms in the traditional Landau-Lifshitz-Gilbert equations. Thus spin

---

[a] *Guest Editors:* E. Fullerton, A. Mougin, D. Ravelosona and S. Mangin

transfer links the physical phenomena of magnetic excitations, damping, reversal and micro-magnetic configurations with spin transport. A second driver for the growth of the study of spin-transfer effects is that experimental fabrication techniques have only recently been developed that allow devices to be readily made at a nanometer scale. Indeed, the thicknesses of layers involved in the device stack need to be comparable to the characteristic lengths of spin transport, such as the spin diffusion length and the electron mean free path. Moreover, the devices need to be lateratelly nano-structured at the sub-100 nm dimensions that can sustain high current densities. In larger structures, the fields generated by the currents can have as large an effect as the spin transfer phenomena. It is only in the smaller structures that spin transfer effects dominate. It is this convergence of theoretical understanding with experimental capabilities that drives the research presented here. Finally, spin transfer has significant potential for novel applications for spin-based devices. Spin transfer effects provide a local means of manipulating magnetization rather than relying on the long-range effects mediated by a remote current via its Oersted field. Potential applications include spin-transfer written MRAM, high frequency non-linear oscillators, three dimensional solid state memories and magnetic logic operations. Conversely, the fact that spin transfer and GMR are intimately linked from an applications point of view can have significant detrimental implications in some GMR-based devices, such as hard disk drive read heads. In both cases a detailed understanding of the phenomena is needed.

The following nine papers in this issue highlight much of the current theoretical and experimental understanding of spin transfer effects. Included are theoretical discussions of analytical, numerical and quantum calculations of the spin transfer phenomena and experimental papers on the spin dynamics and transport phenomena in metallic, semiconductor and metal-oxide tunneling and hybrid systems. These papers show the progress that has occurred over the last ten years and indicate the direction for future research in this exciting field.

References

1. J.C. Slonczewski, J. Magn. Magn. Mater. **159**, L1 (1996)
2. L. Berger, Phys. Rev. B **54**, 9353 (1996)
3. M. Tsoi, A.G.M. Jansen, J. Bass, W.C. Chiang, M. Seck, V. Tsoi, P. Wyder, Phys. Rev. Lett. **80**, 4281 (1998)
4. J.Z. Sun, J. Magn. Magn. Mater. **202**, 157 (1999)
5. J.A. Katine, F.J. Albert, R.A. Buhrman, E.B. Myers, D.C. Ralph, Phys. Rev. Lett. **84**, 3149 (2000)