CURRENT-INDUCED MAGNETIZATION DYNAMICS

M. D. Stiles

Center for Nanoscale Science and Technology, National Institute of Standards and Technology, Gaithersburg, MD, USA

Collaborators: Tingyong Chen, Hongki Min, Keith Gilmore, Ion Garate, Christian Heiliger, Mark Hoefer, Yi Ji, Jiang Xiao, Jack Bass, C.-L. Chien, Michael J. Donahue, Allan H. MacDonald, Jacques Miltat, Daniel C. Ralph, Wayne M. Saslow, Thomas J. Silva, and Andrew Zangwill

The interaction between electric current and the magnetization of ferromagnets plays an important role in most aspects of our modern lives. Applications range from large generators that convert motion into electricity, through transformers that change the voltage of our current supply, to motors that convert electricity into motion. These interactions are mediated by the magnetic field. The new field of spintronics is based on a direct interaction between electricity and magnetism. Here, the electric current becomes spin polarized with the electron moments aligned with the magnetization, in other words, there is a magnetic current, usually referred to as a spin current. The polarization of the current can affect the resistance of a device depending on the orientation of the magnetization in different parts of the device. This dependence leads to effects like giant magnetoresistance (GMR) and tunneling magnetoresistance (TMR), which find application in magnetic field sensors and memory elements. This talk focuses on the additional interaction in which this spin current changes the magnetization in other parts of a device.

When the spin current flows into regions of a device in which the magnetization is not collinear, it exerts a torque on the magnetization which is referred to as a spin-transfer torque. Spin transfer torques are most frequently studied in magnetic multilayers and magnetic nanowires. In a typical magnetic multilayer, two ferromagnetic layers are separated from each other by an ultrathin, non-magnetic layer. The magnetization of one layer is usually kept fixed and is used to polarize the current that flows from it to the other layer. In the other layer, referred to as a free layer, the moments of the current carrying electrons and the moments of the magnetization precess around each other and for high enough currents this mutual precession can induce switching of the magnetization. Switching memory elements by spin-transfer torque is under development to allow scaling of magnetic random access memory (MRAM).

The magnetization in magnetic nanowires tends to break up into domains with the magnetization pointing in opposite directions along the wire. When current flows through the domain walls, the magnetization exerts a torque on the electron moments tending to keep the moments aligned with the magnetization. The reaction torque back on the magnetization causes the magnetization to move. For a domain wall, the reaction torque translates the domain wall. The ability to move domain walls is the basis for potential future memory devices.

For relevant publications see:

http://cnst.nist.gov/epg/Projects/Theory/theory_transfer.html and

http://cnst.nist.gov/epg/Projects/Theory/theory_cidwm.html