# Current-Induced Reorientation of Magnetic Moments

Current –driven reorientation of spins was theoretically predicted in 1966 by Slonczewski /1/. Katine et al. /2/ has shown experimentally that magnetization switching can be induced by spin-polarized current. It was for the first time demonstrated that the reorientation of spins in devices containing multilayers of magnetic-nonmagnetic layers does not require the application of an external magnetic filed. The reorientation of spins can be achieved just by electrical current passing through the magnetic layer. The interest on the behaviour of magnetization switching induced by polarized current is motivated by the search for new magnetoelectronic applications as well as the fundamental understanding of the transport mechanism in these structures. Spin-transfer switching demonstrated in multilayers consisting of metal and nonmagnetic layers is very promising for advanced magnetic random access memory (MRAM) applications because spin transfer switching exhibits tuneable resistance values and a high tunnel magnetoresistance output. In general, there are two kinds of multilayer in which the electrical current causes a spin momentum transfer switching:

(1) magnetic metallic multilayers containing alternating nm-scale thick layers of magnetic and nonmagnetic layers
(2) Magnetic tunnel junctions consisting of magnetic-Insulator –magnetic layers.

Until now, the observation of spin transfer switching is mainly based on macroscopic methods such as resistivity measurements. A detailed insight into the local magnetic properties can be achieved by Mössbauer spectroscopy measurements.

The aim of the measurements is to understand the behaviour of the magnetic moment as a function of current. For this reason, we are planning to measure the magnetic hyperfine field distribution and the orientation of hyperfine field as a function of applied electrical current in the following systems:

1- Magnetic tunnel junctions systems consisting of multilayers :

a) Fe (100)/MgO/Fe(100)
b) FeCoB(amorphous)/MgO/FeCoB(amorphous)

Unprecented values of magnetoresistance (MR) are now observed in junctions both of Fe/MgO/Fe and FeCoB/MgO/FeCoB. The large MR is due to selection rule prohibiting the transition of the minority - spin Δ-5 wave function of Fe at transverse momentum K=0 to the slowly decaying Δ-1 wave function within MgO barrier.

In Fe/MgO/Fe with antiparalel alignment of the moment in two Fe layers only the minority channel has the slowly decaying Δ -5 state which exert a torque onto the local magnetization .

2- Magnetic metallic multilayers containing alternating nm-scale thick layers of magnetic and nonmagnetic layers CoFe/Cu/Co

For the observation of spin momentum transfer switching, FeCo/Cu/Co Multilayers were prepared in a geometry suggest by Slonczewiski. Using electron-beam lithography and reactive etching we produced first a hole with the opening of about 4 nm in the substrate. The hole was filled with a thick film of copper. On the opposite side of the substrate a Fe-57Co( 5 nm) layer, Cu(4nm) and Co (100nm) layer were evaporated. In this geometry, it is possible to apply currents with high density perpendicular to the plane direction.

# Why Mössbauer measurements ?

The purpose of measurements with nuclear resonant scattering is the determination of the magnetic hyperfine distributions and the direction of hyperfine fields as a function of hyperfine fields.

The effective hyperfine field B can be expressed as the sum of two terms

$$B = B_{cp} + B_{ce}$$

The core polarization field Bcp represent a contribution due to the exchange interaction between the local electrons and core electrons. The conduction electron polarization term Bce is ascribed to the polarization of conduction electrons by the parent ion and the nearest neighbour Spins. According to the extended Gilbert equation the spin torque is caused by the polarization of conduction electrons which is directly proportional to the magnetic hyperfine field. Because of the changes in the density of conduction electron polarization a relation between Bce , the direction of spins and current should occur.
The second advantage of nuclear resonant scattering is the exact determination of magnetization direction and current in the plane of the film.

## Why nuclear resonant scattering ?

According to the theory / 1/ for the observation of spin momentum transfer switching a large current has to be applied in the direction perpendicular to the plane. Achieving switching current density from 10E05 A/cm$^2$ to 10E07 A/cm$^2$ is the most challenging issue for the application of the spin transfer switching to high density. Therefore the observation of the spin-transfer-effect requires a low dimension of sample. Because of the low dimensions ( 0.5 x 0.5 mm $^2$ ) of the sample and the limited thickness of Fe-57 (about 5 nm) the nuclear resonant scattering with circularly polarized synchrotron radiation is the only suitable method for the microscopic investigation of magnetic the switching phenomena. For the observation of spin momentum transfer switching, Fe/Cu/Co Multilayers were prepared in a geometry suggest by Slonczewiski. Using electron-beam lithography and reactive etching we produced first a hole with the opening of about 4 nm in the substrate. The hole was filled with a thick film of copper. On the opposite side of the substrate a Fe-57 ( 5 nm) layer, Cu(4nm) and Co (100nm) layer were evaporated. In this geometry, it is possible to apply currents with high density perpendicular to the plane direction.

/1/ J.C. Slonczewski, J. Mag. Mag. Mat. 159(1966) P.L1.

/2/ J.A. Katine, F.J. Albert, R.A. Buhrman, E.B. Myers and D.C. Ralph: Phys. Rev. Let. 84(200)3149.