Magnetoresistance and spin-transfer in magnetic tunnel junctions

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We have developed a theory of the tunnel magnetoresistance (TMR) and current induced switching in magnetic tunnel junctions (TMJ) of the form F1/O/F2/NM. F1 is a thick ferromagnetic pinned layer, O a tunnel barrier or paramagnetic metal (in ballistic regime), F2 a thin ferromagnetic layer in contact with a non-magnetic layer. This theory is based on s-d model i.e. considers free s-electrons interacting with localised d-electrons through s-d exchange Jsd [1]. To investigate the dynamic and kinetic properties of the system, the Keldysh approach for nonequilibrium processes was used. This allows us to go beyond the mean field approximation up to the third order on Jsd. In the mean-field approximation, the spin-polarized current and spin-torque are oscillatory functions of the coordinate perpendicular to the plane of the layer with two periods: a short and a long, inversely proportional to kFup+kFdown and kFup-kFdown respectively, where kFup(down) are the Fermi wave-vectors of up(down) spin s-electrons. As a consequence, the average spin-torque and magnetoresistance have resonances for some values of the free layer thickness. The stability of the magnetic configuration under applied voltage was investigated through the calculation of the changes of magnons dispersion law caused by the spin-polarised current The scenario of switching can be described as follows: If initially the magnetisation of the ferromagnetic layers are misaligned, the distribution of magnetisation inside of each layer becomes unstable resulting in the formation of a steady damped spin density wave which relaxes towards uniform magnetization far enough from the tunnel barrier. For increasing applied voltage, the spin-polarized current of s-electrons increases the amplitude of this damped spin density wave and simultaneously s-electrons emit nonequilibrium magnons. That process changes the effective spin-diffusion length thereby changing the value of magnetoresistance. Finally when voltage and current reach some critical value the magnetisation switch to parallel or antiparallel orientation.

References

[1] S.Zhang, P.M.Levy, A.Fert, Phys.Rev.Lett.88, 236 601 (2002).