AB01

Perpendicular-current Spin-polarized Transport: Magnetoresistance & Current-induced Magnetization Switching

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Giant magnetoresistance (MR) in magnetic multilayers, consisting of alternating ferromagnetic and non-magnetic (F/N) layers, is now a major field of study in metallic magnetic materials for fundamental physics reasons and important sensor applications, especially read heads in computer hard drives. Present applications mostly use Current-In-Plane (CIP) MR; but for future applications, the Current-Perpendicular-to-Plane (CPP) geometry has potential because the MR is often larger and the CPP geometry has certain fabrication advantages. While giant MR is a change in resistance, it can also be described as a change in CPP current flow through the multilayer (for fixed voltage) due an alteration of the magnetic order – the change in the magnetizations of the closest F-layers from parallel(usually low resistance) to anti-parallel (usually high resistance) as the magnetic field is swept. There is now great theoretical and experimental interest in the inverse phenomenon to CPP-MR, where an applied high-density ($\sim 10^7$ A/cm^2) spin-polarized CPP current causes the magnetization of a given F-layer to switch. Such current-induced magnetization switching (CIMS) has important potential applications for magnetic random access memories and microwave oscillators.

The CPP-MR usually gives more direct access than the CIP-MR to the fundamental parameters of spin-polarized transport in multilayers, such as the F/N interface resistances, the bulk resistivities of the F-and N-layers, the asymmetry of the conduction electron scattering at the F/N interfaces and in the bulk of F-layers, and the length scales for electron spin-memory loss due to spin-flip scattering. After a brief review of the CPP-MR and CIMS phenomena, I will discuss the important CPP-transport parameters that we have quantified for a wide variety of F and N metals. I will then describe examples of applying this knowledge of the CPP parameters to CIMS in F/N/F trilayer structures – including a CIMS experiment in which the scattering in the N layer is increased (without introducing significant spin-flip scattering) so that the electron transport in the N layer spans the range from 'ballistic' to 'diffusive'.

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AB02

Microscopic Theory of Current-Driven Domain Wall Dynamics

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Motion of a planar domain wall in nanoscale ferromagnets under electric current is studied theoretically based on rigid wall description. The torque and force due to current is calculated diagrammatically using Keldish Green function. The coupled equation of motion of wall coordinates, wall position, X, and polarization, phi, is solved under current classically. In the adiabatic case (i.e., thick wall), domain wall is driven by spin transfer torque, and threshold current for wall motion is determined by an intrinsic pinning arising from hard-axis anisotropy energy of local spin. Non adiabatic correction such as electron reflection results in a force on domain wall. The same force term arises from relaxation of electron spin too, as has recently been discussed. The force term corresponds to a new torque (called beta-term) in Landau-Lifshitz equation, and acts on the wall differently from spin transfer torque. It modifies significantly the terminal velocity of the wall even when it is small, and the intrinsic pinning is smeared out in most cases. Threshold current is thus determined by extrinsic pinning if beta is non-zero. Quantitative prediction of the force (parameter beta) is essential in determining the threshold current. Some recent studies indicate beta is equal to Gilbert damping parameter, alpha, in which case the wall dynamics becomes anomalous. Since the estimate of a force due tospin relaxation is very delicate, we carried out the estimate based on a fully microscopic approach, and our conclusion is that beta is generally different from alpha. Thermal activated motion below threshold is discussed. Results are compared with recent experiments. The case of current-driven vortex is briefly discussed.

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