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Nonequilibrium intrinsic spin torque in a single nanomagnet[1]

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The spin transfer torque usually observed in metallic and tunneling spin-valves, as well as magnetic domain walls, comes from the transfer of the transverse spin-current of conduction electrons to the magnetization [1]. Therefore, it requires both a non collinear configuration of the magnetic structure (or inhomogeneous magnetic texture in the case of domain walls) and magneto-resistive effects. However, a number of magnetic systems show magneto-resistive effects in a single magnetic layer, such as anisotropic magnetoresistance (AMR) [2]. In the presence of spin-orbit interaction (SOI) the electron scattering depends on the magnetization direction. Recent theoretical studies suggest that in such systems, a transverse component of the spin density builds up, due to the spin-dependent scattering introduced by the spin-orbit coupling. Consequently, a transverse spin density arises from intrinsic properties of the band structure without the need of non-collinear magnetization texture. In the case of a single ferromagnet with spin-orbit interaction, the exchange interaction between the accumulated spin and the magnetization gives rise a spin torque on the magnetization. We show that this torque can be used to control the magnetization direction injecting current densities as low as 10ˆ5-10ˆ6 A/cmˆ2, comparable or lower than the spin transfer effect. We first study the general case of a single ferromagnetic layer with spin-orbit interaction and then focus on the cases of effective Hamiltonians, such as Rashba and Dresselhaus SOI, as well as Luttinger hole systems. We discuss the relation between the spin torque and the spatial inversion symmetry of various forms of spin-orbit couplings and compare this spin torque with the conventional spin transfer torque. We finally discuss several magnetic systems for possible experimental realization. This work was done in collaboration with Shufeng Zhang. [1]] J.C. Slonczewski, J. Magn. Magn. Mater. 159, L1 (1996); L. Berger, Phys. Rev. B 54, 9353 (1996). [2] T.R. McGuire and R.I. Potter, IEEE Trans. Mag. 11, 1018 (1975).

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