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Transport and spin transfer torques in Fe/MgO/Fe tunnel barriers.

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The prediction of very high tunneling magnetoresistance (TMR) ratios in crystalline Fe/MgO/Fe [1,2] tunnel junctions has been verified by a number of experiments [3,4]. The high TMR can be understood in terms of the electronic structure of the system. In MgO the Δ_1 states at the Brillouin zone center decay the most slowly and dominate the tunnelling current. For coherent interfaces, which are achievable due to the small lattice mismatch between Fe and MgO, these Δ_1 states at the Brillouin zone center are half-metallic in the Fe layers. The dominance of the Δ_1 states and their half-metallicity cause the high tunnelling magnetoresistance measured in Fe/MgO/Fe tunnel junctions [5]. For the spin transfer torque, we calculate the linear response for small currents and voltages. Our calculations show that the half metallicity of the Fe Δ_1 states leads to a strong localization of the spin transfer torque to the interface. As a result, the linear current dependence of the torque in the plane of the two magnetizations is independent of the free layer thickness for more than three monolayers of Fe. For perfect samples we also find a linear current dependence of the out-of-plane component. However, this linear piece oscillates rapidly with thickness and averages to zero in the presence of structural imperfections like thickness fluctuation, in agreement with experiment [6]. In this talk I discuss the bias dependence of the TMR and spin transfer torque effects mentioned above and the influence on them of the following factors: the interface structure Fe/MgO, the barrier thickness, and the structure of the leads [7]. This work has been supported in part by the NIST-CNST/UMD-NanoCenter Cooperative Agreement. [1] W. Butler, X.-G. Zhang, T. Schulthess, J. MacLaren, Phys. Rev. B 63 (2001) 054416. [2] J. Mathon, A. Umerski, Phys. Rev. B 63 (2001) 220403. [3] S. Yuasa, T. Nagahama, A. Fukushima, Y. Suzuki, K. Ando, Nature Materials 3 (2004) 868. [4] S.S.P. Parkin, C. Kaiser, A. Panchula, P.M. Rice, B. Hughes, M. Samant, S.-H. Yang Nature Materials 3 (2004) 862. [5] C. Heiliger, P. Zahn, I. Mertig, Materials Today 9 (2006) 46. [6] J. C. Sankey, P. M. Braganca, A. G. F. Garcia, I. N. Krivorotov, R. A. Buhrman, and D. C. Ralph, Phys. Rev. Lett. 96 (2006) 227601. [7] C. Heiliger, M.Gradhand, P. Zahn, I. Mertig, Phys. Rev. Lett. 99 (2007) 066804.