MAR15-2014-001034

Abstract for an Invited Paper
for the MAR15 Meeting of
the American Physical Society

New interpretation for recent spin injection experiments[1]

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We elucidate the large discrepancy between known spin relaxation theory and the findings of recent spin injection experiments that make use of a single ferromagnetic-insulator-nonmagnetic junction for both injection and detection of spin-polarized currents. This local setup scheme gained popularity since 2009 when Dash et al. claimed to achieve room temperature spin injection in silicon [1], followed by avalanche of similar experiments in silicon and other materials that resort to this measurement technique. We show that those enhanced signals and their dependence on temperature are set by impurities embedded in the tunnel barrier with large on-site Coulomb repulsion compared with the voltage bias [2]. Depending on the electron occupation of the resonance level, the magnetoresistance effect is established by the interplay between the Zeeman energy and the impurity coupling to the ferromagnetic material. Considering molecular fields due to hyperfine and exchange interactions, we capture the shape and sign dependence of the signal on magnetic field orientation. The findings are used to explain both conventional spin injection [1], and cases where the bias voltage is distributed across the junction while the net charge current is zero (the so-called local Seebeck spin tunneling [3]). Finally, we extend the theory to impurity-rich tunnel junctions, showing that a similar magnetoresistance effect can persist in completely nonmagnetic junctions [4]. The extension beyond electrical spin injection from ferromagnetic electrodes paves the way for a new class of 1D nanometer-size memory cells which represents the ultimate scaling of memories (leaving no room in the bottom).

[1] S. P. Dash et al., Nature 462, 491 (2009).
[2] Y. Song and H. Dery, Phys. Rev. Lett. 113, 047205 (2014).
[3] J.-C. Le Breton et al., Nature 475, 82 (2011).
[4] O. Txoperena et al., Phys. Rev. Lett. 113, 146601 (2014).

[1]This work is supported by NSF and DTRA Contracts No. ECCS-1231570 and No. HDTRA1-13-1-0013, respectively.