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3-terminal Hanle measuements in metals: spin accumulation or novel magnetoresistance effect?

FELIX CASANOVA, CIC nanoGUNE, 20018 San Sebastian (Basque Country, Spain)

A simple device to study spin injection and transport in semiconductors uses a 3-terminal (3T) geometry, in which spin accumulation is induced and probed by a single magnetic tunnel contact, through the Hanle effect [1]. Since this geometry does not require submicron-sized fabrication, 3T-measurements have become very popular [1-3]. However, many of the reported results disagree with the standard theory of spin injection and have put these measurements into question [4-6]. Our recent works shine some light to this controversy. First, we fabricated ferromagnetic-insulator-nonmagnetic (FIN) 3T devices with metallic electrodes to avoid the complications brought by the Fermi-level pinning when using a semiconductor, and demonstrate that measured Hanle- and inverted Hanle-like features are not compatible with spin injection in these metals [5]. Subsequently, we detect this effect in nonmagnetic-insulator-nonmagnetic (NIN) tunnel junctions for the first time and we demonstrate experimentally beyond any doubt that the measured Hanle-like signals are due to impurities in the oxide layer [7]. We support these results with a theory for impurity-assisted tunneling which takes into account spin interactions and Coulomb correlations. We show that this is actually a novel magnetoresistance effect, which is general to any impurity-assisted tunneling process regardless of the oxide thickness or materials used. The presented work will thus be used as a benchmark to spin injection experiments to any nonmagnetic material, and specially will redirect research of semiconductor spintronics, with all the implications in such a technologically relevant area. [1] S. P. Dash et al., Nature 462, 491 (2009); [2] C. H. Li et al., Nature Commun. 2, 245 (2011); [3] A. Jain et al., Phys. Rev. Lett. 109, 106603 (2012); [4] Y. Aoki et al., Phys. Rev. B 86, 081201(R) (2012); [5] O. Txoperena et al., Appl. Phys. Lett. 102, 192406 (2013); [6] H. N. Tinkey al., Appl. Phys. Lett. 104, 232410 (2014); [7] O. Txoperena et al., Phys. Rev. Lett. 113, 146601 (2014).