MAR16-2015-001746

Abstract for an Invited Paper
for the MAR16 Meeting of
the American Physical Society

Spin-Orbit Coupling in Hybrid Semiconductor Structures: From Majorana Fermions to Topological Insulators

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Hybrid semiconductor structures with strong spin-orbit coupling are responsible for many fascinating phenomena. Topological states in systems of reduced dimensionality, in particular, offer many intriguing possibilities, both for fundamental research as well as for potential applications. In this talk, we describe the importance of the interplay of spin-orbit coupling (SOC) and the sample geometry in realizing exotic Majorana fermions (MFs) in quantum dots and rings and discuss several schemes to detect MFs [1]. An effective SOC from the magnetic textures provided by magnetic tunnel junctions could enable a versatile control of MFs and their adiabatic exchange [2]. We show that in 2D topological insulators (TIs), such as inverted HgTe/CdTe QWs, helical quantum spin Hall (QSH) states persist even at finite magnetic fields below a critical magnetic field above which only quantum Hall (QH) states can be found [3]. We propose magneto-optical absorption measurements to probe the magnetic-field induced transition between the QSH and QH regimes. This measurement scheme is robust against perturbations such as additional SOC due to bulk or structure-inversion asymmetry [4]. Finally, tunnel junctions based on the surfaces of 3D TIs are presented. These junctions can exhibit giant tunneling anomalous Hall (TAH) currents and negative differential TAH conductance, which makes them an attractive and versatile system for spintronic applications [5].
[1] B. Scharf and I. Zutic, PRB **91**, 144505 (2015). [2] G. L. Fatin et al., arXiv:1510.08182. [3] B. Scharf et al., PRB **86**, 075418 (2012). [4] B. Scharf, et al., PRB **91**, 235433 (2015). [5] B. Scharf et al, preprint.