Extended Abstracts of the 2005 International Conference on Solid State Devices and Materials, Kobe, 2005, pp.432

G-6-1 (Invited)

Spin Hall effect in a two dimensional spin-orbit coupled semiconductor system

Joerg Wunderlich[1], Bernd Kaestner[1, 2], K. Nomura[3], Jairo Sinova[4], Allan H. MacDonald[3] and Tomas Jungwirth[5, 6]

[1]Hitachi Cambridge Laboratory, Cambridge CB3 0HE, United Kingdom
[2]National Physical Laboratory, Teddington T11 0LW, United Kingdom
[3]Department of Physics, University of Texas at Austin, Austin TX 78712-1081, USA
[4]Department of Physics, Texas A&M University, College Station, TX 77843-4242, USA
[5]Institute of Physics ASCR, Cukrovarnick´a 10, 162 53 Praha 6, Czech Republic
[6]University of Nottingham, Nottingham NG7 2RD, United Kingdom

Abstract

Electrically induced ordering and manipulation of electron spins in semiconductors employing the coupling between the electron spin to its momentum have a number of practical advantages over the previously established techniques using circularly polarized light sources, external magnetic fields and spin injection from a ferromagnet. Electrical control can be achieved and applied locally and the devices may consume little energy. The spin Hall effect utilizes spin-orbit coupling to induce edge spin accumulation in a response to longitudinal electric field, and is observed in regimes where impurity scattering dominates or where the magnitude of the transverse spin current approaches the intrinsic, disorder independent value. We study spin accumulation near the edge of a weakly disordered two-dimensional hole gas (2DHG) where the latter regime should prevail. In our experiment, the 2DHG is bordered by two quasi-lateral p-n junction light emitting diodes used as detectors for the spin polarization at the channel edges. When an electric field is applied across the 2DHG channel, a non zero out-of-plane component of the spin is optically detected whose sign depends on the sign of the field and is opposite for the two edges, consistent with theory predictions. We demonstrate that the two oppositely polarized edges can be separated over large distances with no signs of weakening of the effect. The leading spin-orbit coupling term in the studied system has a cubic dependence on the momentum. Microscopic calculations reveal the dominant mechanism that leads to spin polarization of the edge. We argue that in this system the magnitude of the polarization can be large and that it increases with the strength of the spin-orbit coupling while, simultaneously, becoming more focused at the sample edge. Comparison between theoretical predictions and experiments in our GaAs/AlGaAs two-dimensional hole systems confirm that p-type semiconductor heterojunctions are promising candidates for realizing this optimal, intrinsic spin Hall effect phenomenology.