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Theory of Spin Hall Effect in GaAs

HANS-ANDREAS ENGEL, Harvard University

In the spin Hall effect, an electric current in a system with spin-orbit coupling induces a transverse spin current which leads to non-equilibrium spin accumulation near sample boundaries. Generating and manipulating non-equilibrium spin magnetization by electric fields is one of the most desirable goals of semiconductor spintronics, because electric fields have potentialities for accessing individual spins at nanometer scales. In this talk, I review the different spin-orbit coupling mechanisms in direct gap semiconductors and the implications of these mechanisms for the spin Hall effect. In particular, we recently developed a theory that accounts for spin-orbit coupling at charged impurities. This coupling leads to *extrinsic* spin currents that contain skew scattering and side jump contribution [1]. Applying our theory to bulk n-GaAs, without any free parameters, we find spin currents that are in reasonable agreement with recent experiments by Kato et al. [2]. Also, such contributions are important for p-doped GaAs. Furthermore, we analyzed the effect of *intrinsic* spin-orbit coupling in the presence of anisotropic impurity scattering, and found that, somewhat surprisingly, an electrical field can lead to a bulk magnetization component *perpendicular* to both the spin-orbit field and an external magnetic field. These works have been done in collaboration with B.I. Halperin, E.I. Rashba, and A.A. Burkov.

[1] H.-A. Engel, B.I. Halperin, and E.I. Rashba, Phys. Rev.Lett. **95**, 166605 (2005).
[2] Y.K. Kato, R.C. Myers, A.C. Gossard, and D.D. Awschalom, Science **306**, 1910 (2004).