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**Spin-orbit coupling in graphene: from single layers to graphite<sup>1</sup>**

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The spin-orbit interaction in graphene is full of contrasts. First, this relativistic interaction destroys the ideal relativistic “touching cones” electronic dispersion at the K points. A finite, albeit small, gap appears, giving a finite mass to the electrons. Then, while the spin-orbit splitting in the carbon atom is about 10 meV, the electronic states at the K points have a gap of only about 24 micro eV. Finally, it turns out that this quintessential sp material has its spin-orbit coupling derived almost exclusively from d orbitals. In this talk I will give first-principles [1] and tight-binding [2] perspectives on the spin-orbit coupling in graphene in the presence of a transverse electric field. The field, which would normally come from the substrate or the gates, breaks the space inversion symmetry and gives the extrinsic (Bychkov-Rashba) splitting of the states. It also brings interesting band-structure topologies, from gapped at low electric fields (the topological insulator phase), through a mixture of genuine touching Dirac cones and parabolic bands (the intrinsic and extrinsic spin-orbit strengths equal), to gapples, dominated by the extrinsic effects [1]. The intrinsic coupling is dominated by d orbitals, while the extrinsic by the field induced hybridization of the s and p orbitals. It turns out that similar physics holds for bilayer and trilayer graphene, ultimately also in graphite. I will also discuss the problem of the spin relaxation in graphene. The main issue is that conventional theories predict microseconds for the spin relaxation time, while experiments seem to consistently yield 100 ps. One possibility [3] is that that spin relaxation in graphene is due to adatoms that pull out the carbon-like spin-orbit coupling of the p electrons and lead to the larger spin relaxation of the Dyakonov-Perel type.

[1] M. Gmitra et al., Phys. Rev. B 80, 235431 (2009);

[2] S. Konschuh et al., Phys. Rev. B (in press);

[3] C. Ertler et al., Phys. Rev. B(R) 80, 041405 (2009).

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