Spin-orbit coupling and spin mixing in graphene systems

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The fundamental spin-orbit coupling (SOC) and spin mixing in graphene systems is discussed. Using the k.p theory we revisit the intrinsic spin-orbit coupling in graphene and show that spin mixing due to the intrinsic spin-orbit coupling is possible, even in the presence of mirror symmetry of the lattice. Nevertheless, spin mixing does not enable the Elliott-Yafet [1] spin relaxation mechanism, unless the mirror symmetry of graphene is broken. In experiments however, graphene is not perfectly flat and is often encapsulated in hexagonal boron nitride layers. Rippling and additional layers can modify the crystal potential of graphene and enhance SOC and spin relaxation. By means of first principles methods based on the density functional theory we study how such effects modify spin mixing in single and bilayer graphene.
We also study the intrinsic SOC in other two-dimensional elemental materials. We find, that the strength of SOC increases linearly with Z^2. We also find, that away from spin hot-spots the spin mixing parameter b^2 also follows a scaling law, $b^2 \sim Z^4$, as one can expect from the perturbation theory.

[1]R. J. Elliott Phys. Rev. 96 , 266–279 (1954)