MAR11-2010-001222

Abstract for an Invited Paper
for the MAR11 Meeting of
the American Physical Society

Orbitally controlled Kondo effect in graphene[1]

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Graphene differs from usual metals or semiconductors in being a truly two-dimensional material with the charge carriers resembling massless Dirac fermions and the chemical potential being highly tunable by gate voltages. Recently, scanning tunneling spectroscopy experiments opened the exciting possibility to address the interaction of graphene with magnetic adatoms and to investigate the Kondo effect in a material that is simple, of immediate technological importance and offers unprecedented high tunability. Here, we develop a realistic description of the interaction of magnetic adatoms with graphene and explain the role of orbital symmetries: General symmetry arguments show that the Kondo effect in graphene is controlled not only by the spin but also by the orbital degree of freedom and spin-orbit coupling. For the example of Co adatoms, commonly used in experiments, we identify possible scenarios for the Kondo effect based on ab initio calculations. For a Co atom absorbed on top of a carbon atom, the Kondo effect is quenched by spin-orbit coupling below an energy scale of 15K. For Co with spin S=1/2 located in the center of a hexagon, a crossover from SU(4) Kondo physics at higher energies to an SU(2) Kondo effect on the scale of the Co spin-orbit coupling strength is encountered. The interplay of the orbital adatom physics and the peculiar band structure of graphene is directly accessible in Fourier transform tunneling spectroscopy or in the gate-voltage dependence of the Kondo temperature which is predicted to display a very strong, characteristic particle-hole asymmetry. The particular high symmetry situation provided by adatoms on graphene can pave the way for a deeper understanding of Kondo screening in general nanomagnetic structures.

[1]Support from SFB 668 and SPP 1459 are acknowledged.