Spin States in Graphene Quantum Dots

J. Güttinger[1], C. Stampfer[1,2], F. Libisch[3], T. Frey[1], J. Burgdörfer[3], T. Ihn[1] and K. Ensslin[1]

[1]*Solid State Physics, ETH Zurich, 8093 Zurich, Switzerland*
[2]*JARA-FIT and II. Institute of Physics, RWTH Aachen, 52074 Aachen, Germany*
[3]*Institute for Theoretical Physics, Vienna University of Technology, 1040 Vienna, Austria*

We measure the g-factor of spin states in graphene quantum dots and investigate the spin filling sequence of orbital states.
Quantum dots made from graphene are considered as an ideal host for spin qubits due to small hyperfine coupling and spin-orbit interactions. These two mechanisms limit spin coherence times in GaAs-based quantum dot systems, where the preparation, manipulation, and read-out of single spins have been achieved [1,2].

In previous experiments with graphene electrical tunability and excited states in both, single and double dot systems have been demonstrated [3-7]. Recently, the crossover from electrons to holes in graphene quantum dots has been investigated by analyzing the movement of Coulomb blockade peaks as a function of perpendicular magnetic field [8]. In bulk graphene systems the g-factor has been measured via the Zeeman splitting of conductance fluctuations in graphene [9]. So far, no experiments on the properties of single spins in graphene quantum dots have been reported.

Here we analyze the evolution of Coulomb blockade peaks and excited states of graphene quantum dots in a magnetic field parallel to the graphene sheet. In-situ rotation of the sample allows us to compare the parallel and perpendicular field dependence of the Coulomb peaks. The extracted splitting from peaks with similar orbital dependencies is in agreement with a Zeeman-spin-splitting expected for a g-factor of two. From the evolution of neighboring Coulomb peaks a spin filling sequence is extracted and compared with an energy spectrum based on single-particle confinement and interaction effects. The identification of spin states is a crucial step towards spin qubits in graphene quantum dots and opens the door for more involved spin experiments.

[1] J. M. Elzerman et al., Nature **430**, 431 (2004)
[2] J. R. Petta et al., Science **309**, 2180 (2005)
[3] C. Stampfer et al., Nano Lett. **8**, 2378 (2008)
[4] L. A. Ponomarenko et al., Science, **320**, 356 (2008)
[5] S. Schnez et al., Appl. Phys. Lett., **94**, 012107 (2009)
[6] F. Molitor et al., Appl. Phys. Lett., **94**, 222107 (2009)
[7] X. Liu et al., arXiv:0912.2229v1 (2009)
[8] J. Güttinger et al., Phys. Rev. Lett., **103**, 046810 (2009)
[9] M. B. Lundeberg, and J. A. Folk, Nature Physics **5**, 894 (2009)