Quantum Devices in Graphene

T. Ihn[1,2], A.O. Denisov[1], H. Duprez[1], J. Gerber[1], L. Ostertag[1], C. Tong[1], R. Garreis[1], L. Gächter[1], M. Ruckriegel[1], C. Adam[1], M. Masseroni[1], M. Niese[1], W.W. Huang[1], J. Richter[1], C. Galante Agero[1], A. Kurzmann[1], M. Eich[1], K. Watanabe[3], T. Taniguchi[3], K. Ensslin[1,2]

[1]*Solid State Physics Laboratory, ETH Zurich, 8093 Zurich, Switzerland*
[2]*Quantum Center, ETH Zurich, 8093 Zurich, Switzerland*
[3]*National Institute for Material Science, 1-1 Namiki, Tsukuba 305-0044, Japan*

ihn@phys.ethz.ch

Quantum dots defined by electrostatic gating of bilayer graphene have recently shown most properties needed for implementing high-quality qubits. At the same time, these systems show several graphene-specific phenomena that are not found in other materials. First and foremost, the conduction and valence band structure of bilayer graphene is gate-tuneable. This allows us to turn it insulating in some spatial regions, while forming quantum dots in others. Using tunneling spectroscopy in the Coulomb blockade regime, we have identified the one- and two-particle ground and excited states. Remarkably, the two-electron ground state turns out to be a spin-triplet valley-singlet state because of the valley degree-of-freedom and Coulomb exchange interaction. The valley character of states can be probed through the valley-Zeeman effect, which is due to the Berry curvature of bands. The resulting valley g-factor turns out to be gate-tuneable. The superb device quality allows us to quantify the Kane-Mele-type spin-orbit splitting in graphene to be 73 μeV. In double quantum dots, we have observed Pauli spin- and valley-blockade [1]. The system lends itself to define spin-, valley-, and so-called Kramers (spin-valley) qubits. Charge detection has been implemented in state-of-the-art devices [2]. We measured relaxation times in single- and double quantum dots between various states [3,4]. We find spin-relaxation times up to 400 ms at zero and low magnetic fields [5]. Our measured valley relaxation times have reached 700 ms [4]. Most excitingly, the relaxation times between the states of a Kramers qubit reach values of more than 30 s [5] demonstrating the superb decoupling of these states from their environment. Stronger than intrinsic spin-orbit interaction can be proximity-induced in bilayer graphene devices when WSe_2 or MoS_2 layers are placed next to bilayer graphene in the material stack. Such structures lend themselves for future experiments, in which bilayer graphene quantum dot states are coherently manipulated by gate voltages in real time. In recent experiments, we have already shown how bilayer graphene double quantum dots can be dipole-coupled to photons in a superconducting resonator.

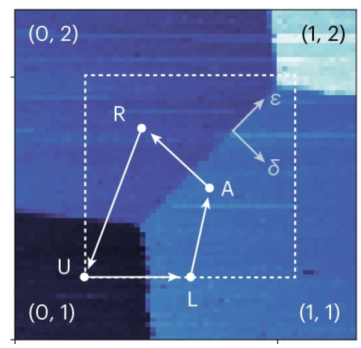

Fig.1. Double dot charge stability diagram and pulsing scheme for T1 measurements.

References

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