Spin and Valley Physics in Graphene Quantum Dots

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In bilayer graphene quantum dots, apart from spins up and down, the additional valley degree of freedom K- and K+ gives rise to an unconventional single-dot two-carrier ground state: spin-triplet valley singlet, altering the canonical even-odd double dot Pauli spin blockade picture [1]. This ground state can be switched to a spin-singlet valley-triplet by a perpendicular magnetic field, allowing us to switch between valley-blockade at low, and spin-blockade at higher magnetic field, for the two-carrier Pauli blockade (1,1) to (0,2) [2]. We demonstrate single-shot read-out with spin- and valley- Pauli blockade in gate-defined bilayer graphene double quantum dots, and thereby the measurement of spin and valley characteristic relaxation times T_1 between spin- or valley-triplet and singlet states [3]. Different valley states can be distinguished from each other with a fidelity of over 99%. The relaxation time between valley triplets and singlets exceeds 500 ms and is more than one order of magnitude longer than for spin states. This valley lifetime is comparable with the state-of-the-art spin- singlet-triplet T_1 measured in Si/SiGe and Si/SiO_2 and an order of magnitude longer than their T_1 reported at such low magnetic field [4,5]. Our results pave the way for future demonstration of coherent valley-qubit oscillations, and thereby the development of qubits based on a material that is only two atomic layers thick. Combining our results with the electrical tunability of the valley g-factor [6], new schemes of electrical qubit control become accessible.

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