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Electrical control of a long-lived spin qubit in a Si/SiGe quantum dot

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Electron spins in Si/SiGe quantum dots are one of the most promising candidates for a quantum bit for their potential to scale up and their long dephasing time. We realized coherent control of single electron spin in a single quantum dot (QD) defined in a Si/SiGe 2D electron gas. Spin rotations are achieved by applying microwave excitation to one of the gates, which oscillates the electron wave function back and forth in the gradient field produced by cobalt micromagnets fabricated near the dot. The electron spin is read out in single-shot mode via spin-to-charge conversion and a QD charge sensor. In earlier work [1], both the fidelity of single-spin rotations and the spin echo decay time were limited by a small splitting of the lowest two valleys. By changing the direction and magnitude of the external magnetic field as well as the gate voltages that define the dot potential, we were able to increase the valley splitting and also the difference in Zeeman splittings associated with these two valleys. This has resulted in considerable improvements in the gate fidelity and spin echo decay times. Thanks to the long intrinsic dephasing time T2* = 900 ns and Rabi frequency of 1.4 MHz, we now obtain an average single qubit gate fidelity of an electron spin in a Si/SiGe quantum dot of 99 percent, measured via randomized benchmarking. The dephasing time is extended to 70 us for the Hahn echo and up to 400 us with CPMG80. From the dynamical decoupling data, we extract the noise spectral density in the range of 30 kHz-3 MHz. We will discuss the mechanism that induces this noise and is responsible for decoherence. In parallel, we also realized electron spin resonance and coherent single-spin control by second harmonic generation, which means we can drive an electron spin at half the Larmor frequency. Finally, we observe not only single-spin transitions but also transitions whereby both the spin and the valley state are flipped. Altogether, these measurements have significantly increased our understanding and raised the prospects of spin qubits in Si/SiGe quantum dots.

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[1] E. Kawakami, P. Scarlino et al. Nature Nanotechnology 9, 666-670 (2014)