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Single-atom spin qubits in silicon[1]

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Spin qubits in silicon are excellent candidates for scalable quantum information processing (QIP) due to their long coherence times and the enormous investment in silicon MOS technology. Here I discuss qubits based upon single phosphorus (P) dopant atoms in Si [1]. Projective readout of such qubits had proved challenging until single-shot measurement of a single donor electron spin was demonstrated [2] using a silicon single electron transistor (Si-SET) and the process of spin-to-charge conversion. The measurement gave readout fidelities $> 90\%$ and spin lifetimes $T_{1e} > 6$ s [2], opening the path to demonstration of electron and nuclear spin qubits in silicon. Integrating an on-chip microwave transmission line enabled single-electron spin resonance (ESR) of the P donor electron. We used this to demonstrate Rabi oscillations of the electron spin qubit, while a Hahn echo sequence revealed electron spin coherence times $T_{2e} > 0.2$ ms [3]. This time is expected to become much longer in isotopically enriched ^{28}Si devices. We also achieved single-shot readout of the ^{31}P nuclear spin (with fidelity $> 99.6\%$) by monitoring the two hyperfine-split ESR lines of the P donor system. By applying (local) NMR pulses we demonstrated coherent control of the nuclear spin qubit, giving a coherence time $T_{2n} > 60$ ms.

[1] B.E. Kane, *Nature* **393**, 133 (1998).
[2] A. Morello et al., *Nature* **467**, 687 (2010).
[3] J.J. Pla et al., *Nature* **489**, 541 (2012).

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