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One- and two-qubit logic using silicon-MOS quantum dots[1]

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Spin qubits in silicon are excellent candidates for scalable quantum information processing [1] due to their long coherence times and the enormous investment in silicon CMOS technology. While our Australian effort in Si QC has largely focused on spin qubits based upon phosphorus dopant atoms implanted in Si [2,3], we are also exploring spin qubits based on single electrons confined in SiMOS quantum dots [4]. Such qubits can have long spin lifetimes T1 = 2 s, while electric field tuning of the conduction-band valley splitting removes problems due to spin-valley mixing [5]. In isotopically enriched Si-28 these SiMOS qubits have a control fidelity of 99.6% [6], consistent with that required for fault-tolerant QC. By gate-voltage tuning the electron g*-factor, the ESR operation frequency can be Stark shifted by >10 MHz [6], allowing individual addressability of many qubits. Most recently we have coupled two SiMOS qubits to realize a CNOT gate [7] using exchange-based controlled phase (CZ) operations. The speed of the two-qubit CZ-operations is controlled electrically via the detuning energy and over 100 two-qubit gates can be performed within a coherence time of 8 μs. [1] D.D. Awschalom et al., "Quantum Spintronics", Science 339, 1174 (2013). [2] J.J. Pla et al., "A single-atom electron spin qubit in silicon", Nature 489, 541 (2012). [3] J.T. Muhonen et al., "Storing quantum information for 30 seconds in a nanoelectronic device", Nature Nanotechnology 9, 986 (2014). [4] S.J. Angus et al., "Gate-defined quantum dots in intrinsic silicon", Nano Lett. 7, 2051 (2007). [5] C.H. Yang et al., "Spin-valley lifetimes in a silicon quantum dot with tunable valley splitting", Nature Comm. 4, 2069 (2013). [6] M. Veldhorst et al., "An addressable quantum dot qubit with fault-tolerant control fidelity", Nature Nanotechnology 9, 981 (2014). [7] M. Veldhorst et al., "A two-qubit logic gate in silicon", Nature 526, 410 (2015).

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