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From Mobility to Fidelity: Demonstrating High-Quality Hole-Spin Qubits in a Natural Silicon Foundry Platform

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The global effort to develop a quantum computer is driving the search for scalable methods to manufacture quantum chips and qubits. One promising pathway is to adapt the mature and highly-scalable silicon manufacturing processes that underpin modern electronics. However, the demands on quantum devices are markedly different from those placed on conventional transistors. Quantum chips must operate at temperatures below −270℃ and require precise control at the level of a single charge. As a result of these new demands, realising mass-produced silicon quantum chips will require new materials and methods to be integrated into foundry processes. This integration must be accompanied by ongoing evaluation to ensure that new approaches maintain the existing quality and reproducibility of established semiconductor manufacturing.

In this work, we present an experimental characterisation of qubits fabricated using a foundry-compatible natural silicon platform. First, we assess device quality at the wafer scale by examining interface quality and charge trap density. Using transport measurements we observe a peak electron mobility of 40,000 cm^2/Vs and the highest reported hole mobility for a silicon MOSFET of 2,000 cm^2/Vs. Building on this, we investigate the suitability of these materials for spin qubit devices. Here we investigate the coherence and relaxation times of hole spins. Hole spins exhibit strong spin-orbit coupling, making them highly sensitive to disorder and allowing them to act as detailed quantum probes of material imperfections. Finally, we investigate the operation of single- and two-qubit gates of hole-spin qubits, achieving fidelities up to 99.8% and a two-qubit gate quality factor of 240, indicating a physical fidelity limit near 99.7%. These results highlight the maturity of silicon hole-spin platforms and their potential for integration into future quantum CMOS technologies. This comprehensive suite of measurements provides a snapshot of the current state of the art in foundry-based quantum chips.

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