editorial

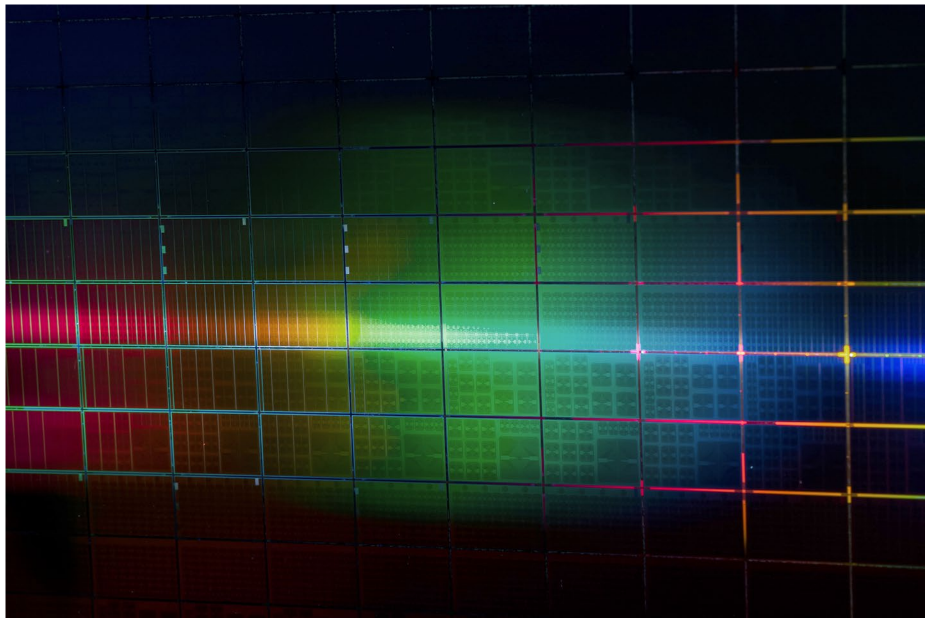
The case for silicon again

Quantum computers based on silicon could exploit the manufacturing techniques used to create conventional computer chips — providing a potential route to scaled-up quantum processors.

In a conventional digital computer, information is encoded in discrete bits that have the value of either 0 or 1. In a quantum computer, information is encoded in qubits (quantum bits) that can exist as a superposition of both 0 and 1. A variety of physical systems — from superconducting circuits to ions held in traps — can be used to build these qubits. But arguably, the platform with the greatest potential to deliver scaled-up quantum computing is the one that delivered scaled-up conventional computing: silicon.

Silicon qubits can be created using electron or hole spins confined in quantum dot structures, or with the nuclear spins of individual dopant atoms. A potential silicon-based quantum computing system can also be broken down into three distinct layers: a quantum processing unit (which uses an array of qubits), a quantum–classical interface and a classical processing layer. As Fernando Gonzalez-Zalba and colleagues explored in a Review Article back in the December issue of *Nature Electronics*[1], all of these different layers can, in principle, be manufactured using the complementary metal–oxide–semiconductor (CMOS) technology that currently lies at the heart of the electronics industry.

For now, demonstrations with silicon qubits are restricted to small-scale devices, but are impressive nonetheless. Earlier this year, for example, reports on two-qubit gates with fidelities in excess of 99% — and above the theoretical threshold required for fault-tolerant quantum computing — were published[2–4], which was closely followed by a report on the control of a six-qubit system[5]. A fully scaled-up quantum computer will require millions of integrated qubits, and thus establishing the potential of such systems to be industrially manufactured is a key step — and one explored in this issue of *Nature Electronics*.



Photograph of a 300-mm wafer containing arrays of silicon quantum dot devices that can function as spin qubits. Credit: Tim Herman/Intel

In the first of two Articles on the topic, Dominik Zumbühl, Andreas Kuhlmann and colleagues at the University of Basel and IBM Research in Zürich report the creation of hole spin qubits in fin field-effect transistor (FinFET) structures similar to those used in advanced integrated circuits. (See also the accompanying News & Views article on the work from Romain Maurand and Xavier Jehl at CEA-Grenoble.) The FinFET devices are fabricated using standard CMOS techniques (including self-aligned gates and chemically selective plasma etches), and can operate at temperatures above 4 K. These relatively high temperatures could allow the quantum hardware and the classical control electronics to be integrated on the same chip — an important requirement for the scaling-up of such systems.

In the second Article, Lieven Vandersypen, James Clarke and colleagues report the fabrication of spin qubits in a 300-mm semiconductor manufacturing facility using all-optical lithography and fully industrial processing. The approach delivers high yields and the team — a collaboration between researchers at Delft University of Technology and researchers at Intel — provide a powerful demonstration of how such silicon qubits can be created with advanced semiconductor manufacturing methods. ❐

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References
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