Silicon FinFETs hosting hole spin qubits at temperatures over 4 Kelvin

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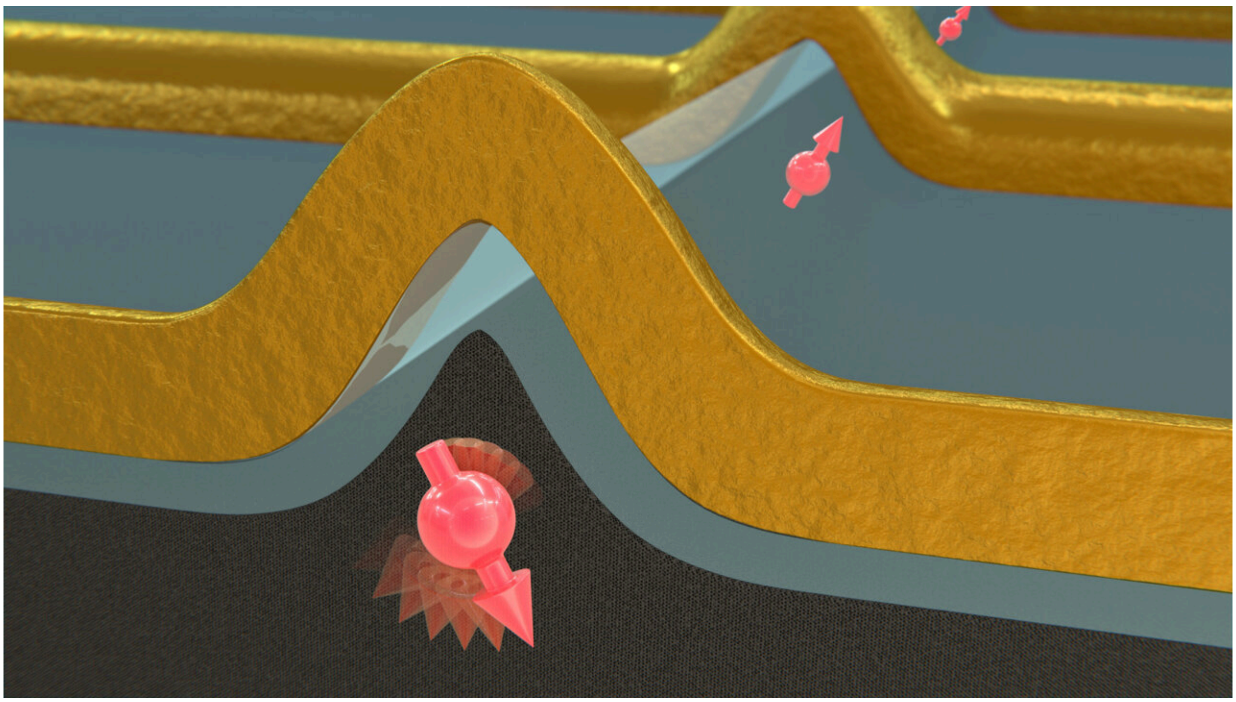

Credit: Camenzind et al.

The idea of creating a spin-based quantum computer using quantum dots was first introduced by Daniel Loss and David Di Vincenzo in 1998. Since then, countless engineers and physicists worldwide have been trying to realize their vision using existing and newly developed hardware components.

So far, silicon has proved to be among the most promising materials for creating spin-based quantum computers, as most complementary metal oxide semiconductors (CMOSs) in use today are made of silicon. Moreover, silicon can be designed to be free of nuclear spins, which are known to degrade the coherence of spin qubits in quantum computers.

Researchers at University of Basel and IBM Research-Zurich have recently explored the possibility of hosting spin qubits in silicon-based FinFETs, a class of transistors first introduced by researchers at University of California- Berkeley. Their results, published in *Nature Electronics*, were very promising, as they suggest that FinFETs could help to improve the scalability of quantum technologies.

"Billions of FinFETs are used in today's computer chips," Andreas Kuhlmann and Dominik Zumbühl, two of the researchers who carried out the study, told TechXplore. "Achieving scalability (i.e., going from a few tens of qubits to many millions) remains the greatest challenge for quantum computing. So, we thought: why not build a quantum computer with a platform that has successfully mastered this challenge? Furthermore, FinFETs are also excellent hosts for (hole) spin qubits and a very handy property of hole spin qubits is their spin-orbit interaction."

The spin-orbit interaction is an important property of hole spin qubits that can be very advantageous, as it allows researchers to manipulate spin states by applying an oscillating electrical signal to them. Physics theory predicts that holes in silicon FinFETs will have an unusually large spin-orbit interaction that can be electrically modulated.

In their experiments, Kuhlmann, Zumbühl and their colleagues tested this prediction using a standard FinFET device to host small, fast and coherent spin qubits that are resistant to high temperatures. Ultimately, they found that the silicon FinFET could host the spin qubits operating at temperatures above 4 Kelvin.

"Our devices work in a similar way to a classical transistor, where the gate electrode controls the current flow from source to drain," Kuhlmann and Zumbühl explained. "Here, we use the gates to trap single hole spins. Once the spins are localized (inside what we call a quantum dot), microwave signals can be applied to manipulate the spin state. The smaller these quantum dots are the more robust they are against temperature."

The FinFET realized by the researchers resemble those that are currently being manufactured worldwide. This means that they could be easy to integrate with existing components and to scale up (i.e., increasing the number of qubits inside them).

Other existing quantum computing platforms, such as those hosting superconducting qubits, typically need to operate at millikelvin (mK) temperatures. The qubits hosted in the platform developed by the researchers, on the other hand, can be operated at temperatures above 4K.

"A cryostat operating at 4K is technically much less demanding than one operating at mK temperatures," Kuhlmann and Zumbühl said. "Furthermore, at 4K the available cooling power is orders of magnitudes larger than at mK temperatures. This means that in future we could integrate the classical control electronics (required for qubit control) on-chip with the qubits. This is important when scaling up the qubit count, since the number of control lines going from room temperature to mK inside a fridge is limited, and the more qubits the more control lines are needed."

In the future, the recent study carried out by Kuhlmann, Zumbühl and their colleagues could help to accelerate the development of quantum computing technology and improve its scalability. In the meantime, the researchers plan to optimize the performance of the qubits inside their device further.

"We want to make the qubits more coherent and at the same time reduce the gate times," Kuhlmann and Zumbühl said. "In addition, we would like to scale up the number of qubits inside our transistor."

More information: Leon C. Camenzind et al, A hole spin qubit in a fin field-effect transistor above 4 kelvin, *Nature Electronics* (2022). DOI: 10.1038/s41928-022-00722-0