Microelectronics and Microsystems
Quantum Computing

Silicon Quantum Bits

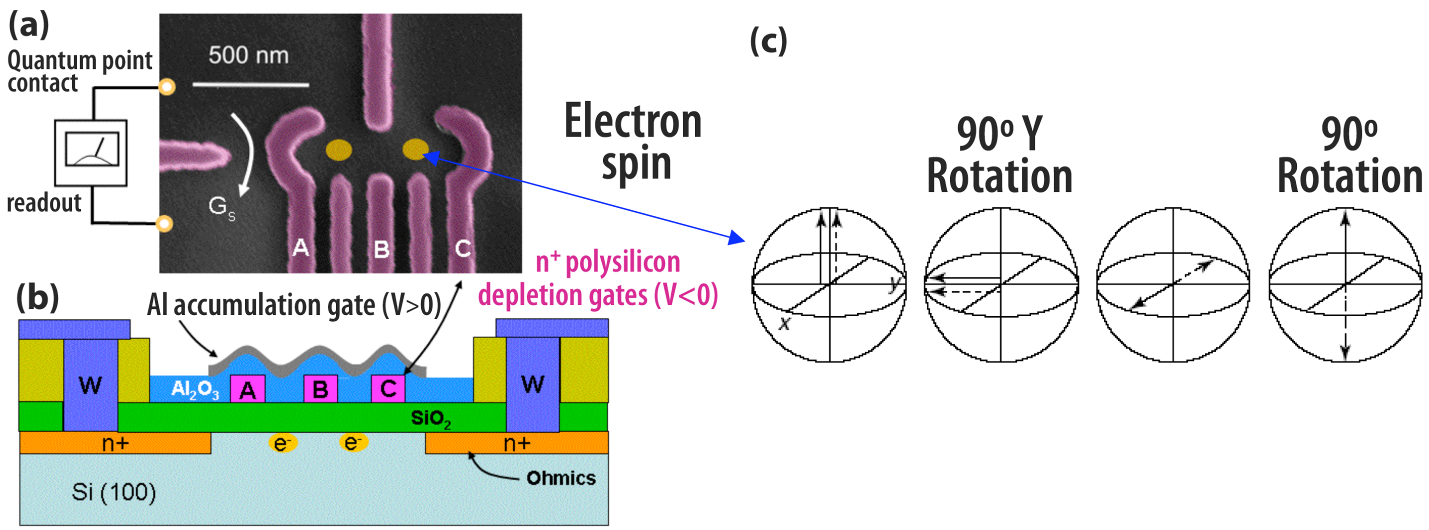

Figure 1: (a) scanning electron microscope image of Sandia's dual quantum dot structure fabricated in silicon (the dots suggest the approximate location of the electron position); (b) schematic cross section of the quantum dot structure showing the position of the single electron locations; and (c) schematic representation of spin manipulation using rotation and precession of two different spins.

Qubit information to be stored in silicon quantum dots

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The Quantum Information Science and Technology (QIST) Grand Challenge is a three-year research effort aimed at producing the world's first silicon-spin-based quantum bit (qubit). Qubits are the basic information storage elements of quantum computers, which perform quantum information processing and offer the opportunity to efficiently solve problems that are numerically challenging for classical computers. Quantum computers, therefore, may someday augment conventional classical computers by employing some of the unusual properties of quantum systems to speed up computation.

A critical challenge in building a quantum information processing system is the need to couple and manipulate tiny qubits in the form of a quantum circuit that produces a useful function. Sandia researchers are focused on the basic questions related to the feasibility of manufacturing a simple qubit and simple quantum circuits – a task that includes demonstrating a silicon qubit, integrating the qubit with classical CMOS (Complementary Metal Oxide Semiconductor) technology, and designing quantum error correction circuits that are tuned to the physical qubit's unique properties. Sandia's approach (Figure 1) is to physically encode quantum information in the spin state of an electron that is confined in a silicon quantum dot. Although gallium arsenide quantum dots have been demonstrated, quantum dots made from silicon are expected to have longer decoherence times and improved integration with silicon-based classical circuitry. A significant challenge, therefore, is to engineer the Si qubit and the surrounding electronics, and have them all operating at ~ 0.1K (0.1 degrees above absolute zero).

Sandia National Laboratories

LDRD Laboratory Directed Research & Development

In the first year of this project, Sandia researchers have fabricated silicon nanoelectronic devices with the goal of isolating, measuring and manipulating single electrons (see Figure 1). Similar structures will be integrated with standard microelectronics circuits that are necessary for future quantum circuitry. The Sandia qubit uses gate features as small as 50 nanometers to apply electrical signals that move and trap individual electrons - functions that will be required in the quantum bits of future quantum circuits. Early measurements show dramatic changes in electrical properties (resonances due to single-electron transistor action) that arise from the addition or removal of a single electron from a quantum dot measuring less than 100 nanometer. This is a critical step towards achieving the goal of measuring and manipulating the quantum spin information encoded in single electrons.

Sandia National Laboratories

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