Quantum computing using single spins

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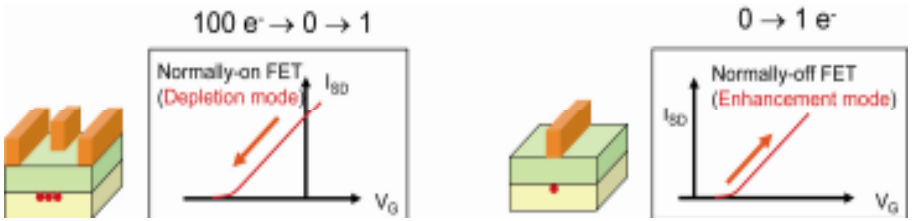
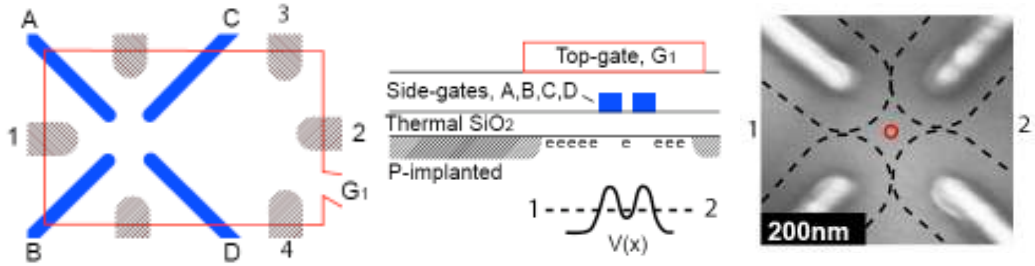
- Solid state implementations of qubits offer the advantage of being scalable.
- An electron spin in a quantum dot under magnetic field is a promising candidate for a qubit, and quantum dots lined up laterally provide the opportunity for scaling up to large numbers of qubits.

- Our single electron quantum dot is built in the silicon MOSFET (Metal-oxide-semiconductor field-effect transistor) system, which has inherent advantages over the other semiconductor systems owing to its material properties, including the large g-factor, abrupt confinement potential, large orbital quantization energy, negligible spin-orbit interaction, and most importantly, very long spin lifetimes.

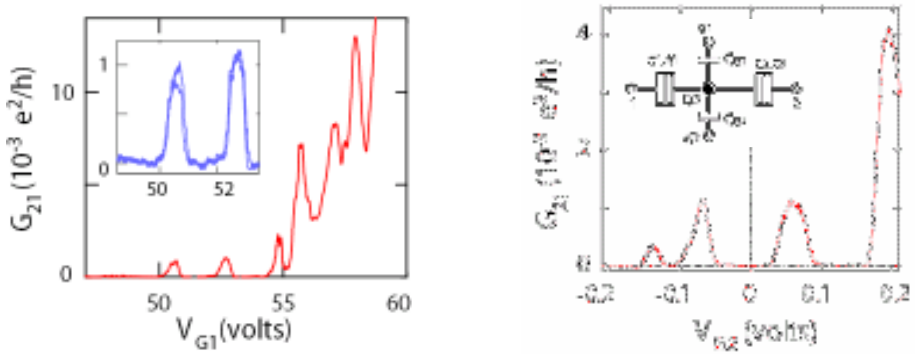
Properties	InAs	GaAs	Silicon
Effective mass, m*	0.023	0.067	0.2/0.9
g-factor	-15	-0.44	2
Quantization energy	20meV	2meV	18meV
Single electron transistor?	Yes	Yes	Yes
Observed one e⁻ yet?	Yes	Yes	Work in progress

- We use "enhancement-mode" SET, not the "depletion-mode" used in all other single electron transistors

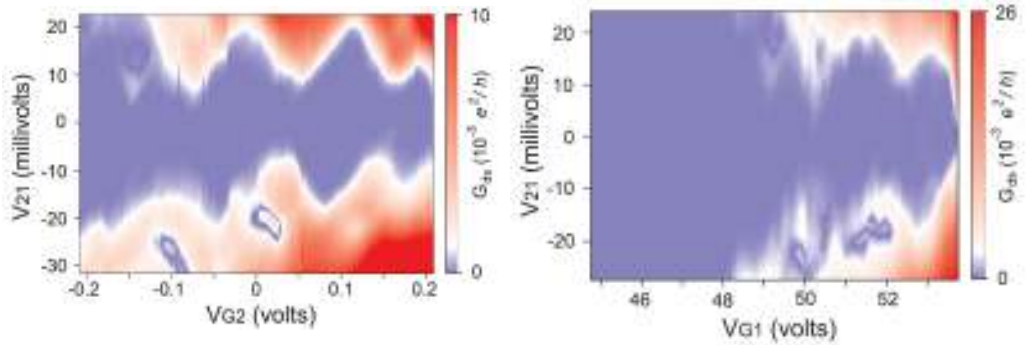




Schematics show the top view (left) and the cross sectional view (middle) of our silicon single-electron transistor structure. (Right) Scanning electron micrograph of 70nm wide side-gates defined by electron-beam lithography, taken before the top-gate is defined. The gap between neighboring side-gates is ~160nm. The dashed lines illustrate the depletion region under the single-electron transistor operating condition. The circle, 20nm in diameter, depicts the location of the quantum dot.



(Left) Transfer characteristics versus the top-gate voltage, at V_A=V_B=V_C=V_D=0V and V_{21}=8mV. The inset shows the up and down traces. (Right) Transfer characteristics controlled by the side-gate voltage, at V_{G1}=54.25V and V_{21}=8mV.



(Left) The stability chart taken with V_{G1}=54.25V, and the side-gates were swept between –32mV to +22mV. (Right) The stability chart taken with all side-gated shorted to zero, and V_{G1} is swept between 44.75V and 53.75V.