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Transport Measurements in Silicon Quantum Dots with Counted Antimony Implants

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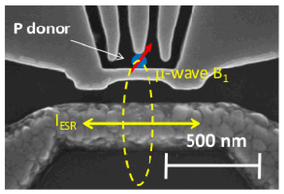
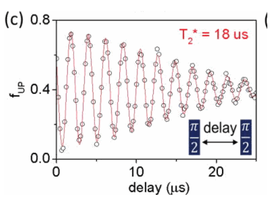
Motivation

- Donor spins in silicon are promising qubits.
- For universal quantum logic one needs - single qubit rotations and two qubit operations.
- Single qubit control has been demonstrated on ^{31}P donors in ^{28}Si (see below).
- Two qubit operations require deterministic control over donor number and location.

Single electron spin resonance device

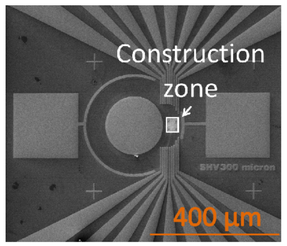




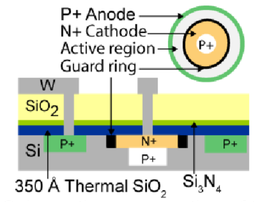
LA Tracy *et al.*, APL **108**, 063101 (2016)

Integrated device fabrication

Si MOS ion detector and nanostructure region

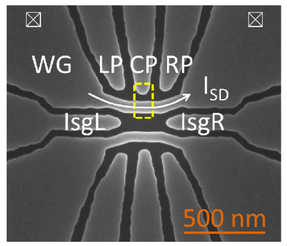


SEM image. Detector is the circular structure.

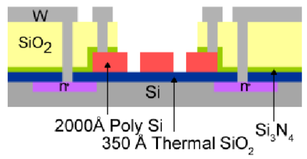


Schematic cross section of the diode detector.

Quantum dot and donor implant device



SET is formed from poly-silicon gates. Implant is targeted for yellow box.

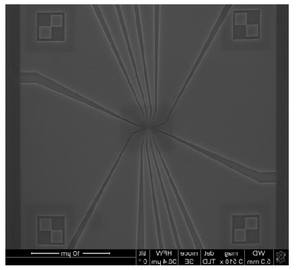


Schematic cross section gates for defining the SET.

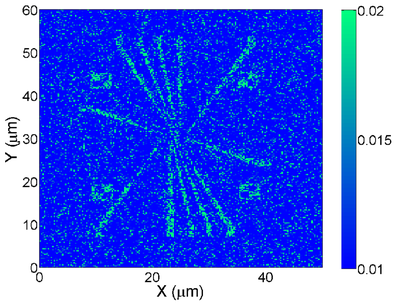
Integrating detector with single-electron transistor allows counted implants.

Single ion detection

Si MOS nanostructure



Ion detection map

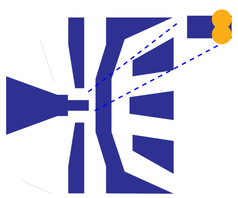


A scanning electron micrograph of the device (left) and an ion beam induced charge map (right generated using an average of 1 ion per pulse 120 keV Sb++ focused ion beam. Ions are observed where the device has only SiO_2 and no other overlayers.

This shows the detector is sensitive to a single ion.

Conclusions and outlook

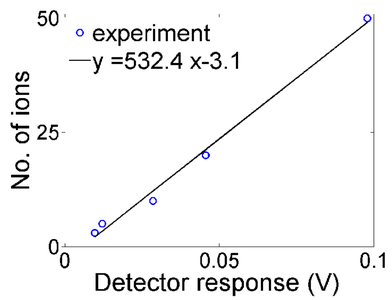
- Diode detectors with single ion detection sensitivity have been integrated next to functional single electron transistors.
- The technique we have developed using a focused ion beam and counted single ion implants can control both the number and location of the donors.
- This control is necessary for future donor based spin qubits.



Multi-qubit devices will require several donors located in precise positions. At the left, we show a diagram of a potential device with two donors separated by a gate that controls the exchange coupling.

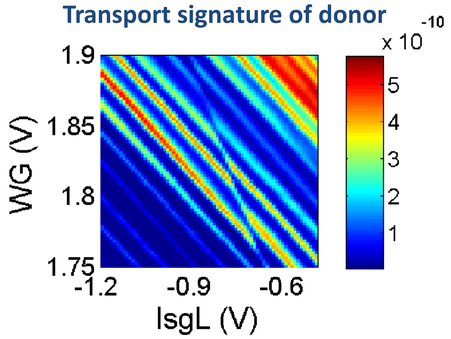
Counted implant, transport and offsets

Ion detector calibration



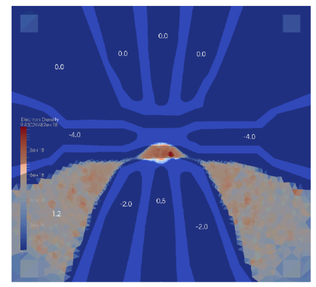
For a given ion species, detector and device structure, the detector response is proportional to the number of ions incident.

Transport signature of donor



Transport measurements at 2K in a device with counted Sb implants show regular Coulomb blockade and offsets.

QCAD device modeling



Measured capacitances agree with semi-classical simulations showing that a quantum dot can be formed in the structure.

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