SAND2016-4269PE

Transport in quantum systems using integrated nanoelectronics

U.S. DEPARTMENT OF ENERGY
Office of Science
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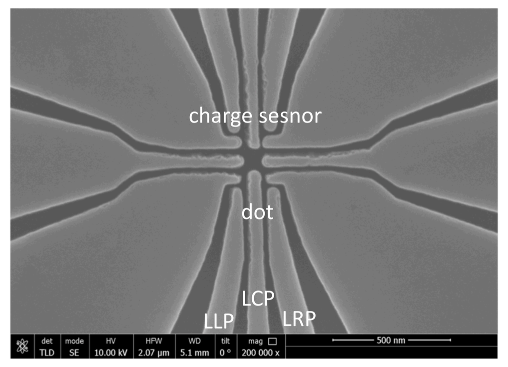
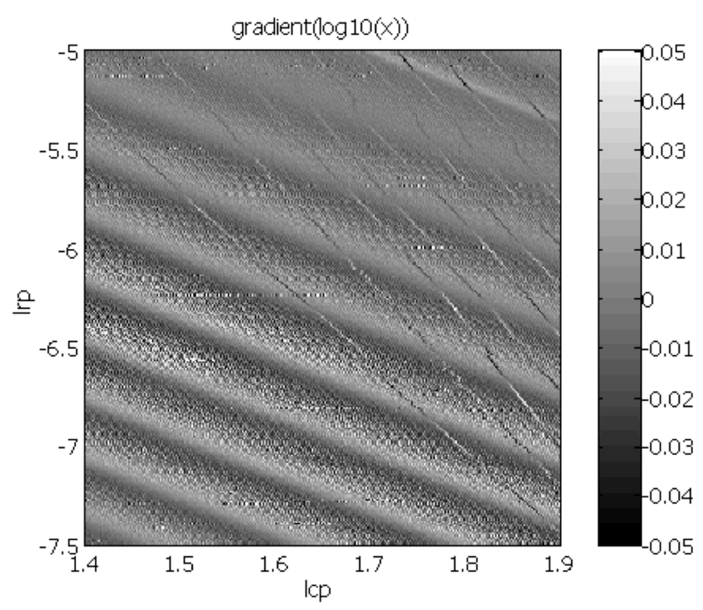
Single electron dots in Si MOS

User project U2015A0092
Luhman, Oxten Bureau, Pioro Ladrarie

Si MOS devices with nanostructures formed using poly-silicon gates provide a good platform for single spin studies.



Top view SEM of quantum dot (bottom) and charge sensor (top).



Charge sensing at 30 mK. Large oscillations are background Coulomb blockade in the chage sensor. Sharp lines are single electron changes in the dot.

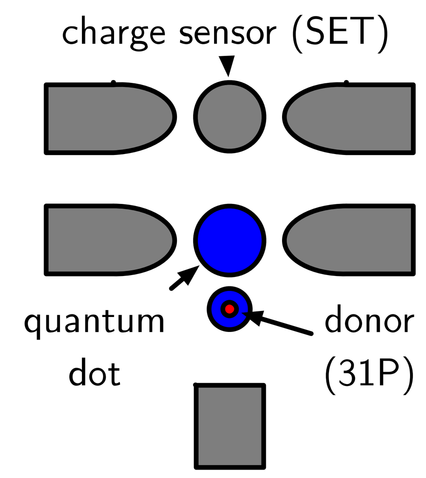
The quantum dot design allows good control of both the dot electron occupation and the tunnel barriers to the leads. Charge sensing demonstrates single electron occupation can be achieved.

Low electron number quantum dots are important for many Si qubit experiments.

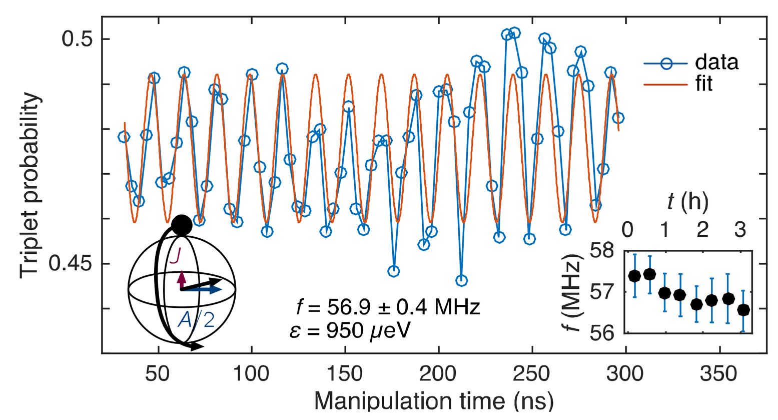
Coherent oscillations in donor / dot system

User project RA2015A0017
Carroll, Harvey-Collard, Pioro Ladrarie

A donor – dot system is a special double quantum dot with a built-in magnetic field gradient defined by ½ of the hyperfine coupling of the electron on the donor (A~117 MHz for P).



Singlet-triplet rotations driven by a single 31P nucleus



Triplet probably for donor-dot at 20 mK. Roations are caused by the hyperfine coupling.

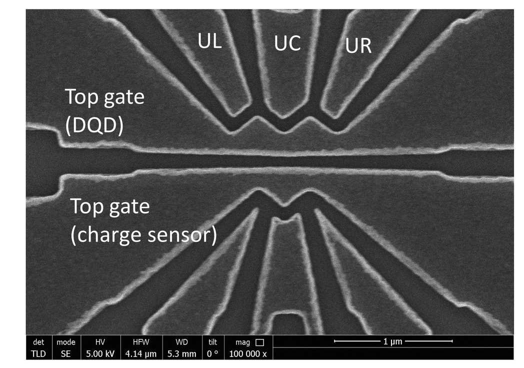
The donor – dot system is operated as a single-triplet DQD. Initialization as a singlet (4,0), and then transfer to (3,1) for a manipulation time leads to singlet-triplet rotations. Readout uses Pauli blockade.

The 57 MHz coherent oscillations are consistent with a P donor.

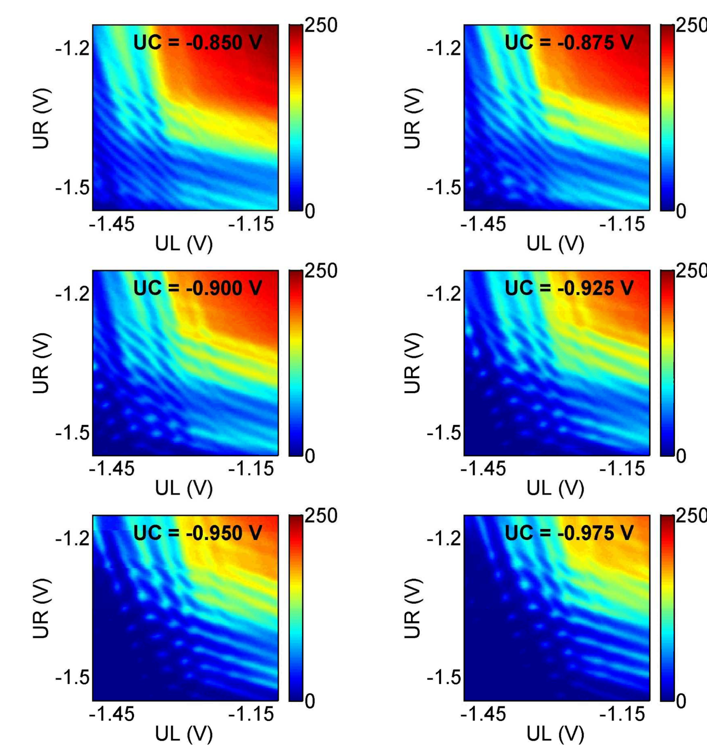
Double quantum dots in SiGe

User project C2015A0055
Tzu-Ming Lu

Enhancement mode SiGe nanostructures can be used to create quantum dots in a material with a low disorder interface and few nuclear spins.



SEM of metal gates on an undoped SiGe heterostructure.



Transport through the SiGe double quantum dot at 0.3 K.

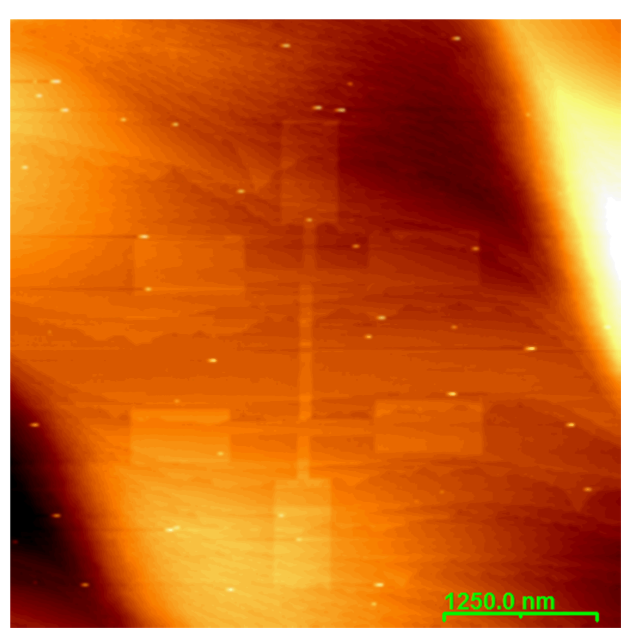
Positive bias on the top gate forms a quantum dot structure. UL and UR change the relative occupations of the dot or double dot, and the transport forms a typical honeycomb. UC controls the amount of coupling in the DQD.

SiGe dots are a good approach for low disorder nanostructures.

STM atomic precision devices

User project C2014A0070
Misra, Ward, Carr and Bussmann

(Right) Example of STM defined hydrogen lithography pattering. This Hall bar has a 100 nm width, but other patterns with 1 nm scale features have been demonstrated.



Magnetic field characterization of these devices confirms the ultra-high density of 2 x 10^{14} cm^{-2} and a mobility of 50 cm^2 / Vs

Integration of nanoelectronics components to access quantum properties

- Single spin physics can be studied using semiconductor quantum dot structures with integrated charge sensors. We have demonstrated one-electron opccupation and single shot spin measurements.
- Different materials are needed for different quantum transport devices. Si MOS is a good material for low background nuclear spins. SiGe and GaAs are good for low disorder nanostructures.
- Using special lithography techniques, we can approach the limit of top down lithography.
- The techniques used here can be extended to other nanoelectronic systems for characterization of spin properties, low temperature ground states and energy level spectroscopy.

This work was performed, in part, at the Center for Integrated Nanotechnologies, a U.S. DOE Office of Basic Energy Sciences user facility. The work was supported by Sandia National Laboratories Directed Research and Development Program. Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed-Martin Company, for the U. S. Department of Energy's National Nuclear Security Administration under Contract No. DE-AC04-94AL85000.

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