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Short 50 Word Abstract

Fabricating arrays of precisely placed dopants in silicon is a promising platform for the analog quantum simulation of solid-state physics. We use RF reflectometry to directly probe charge and spin states in a 3×3 STM-patterned dopant array. We measure individual electron occupation across the array and observe Pauli spin blockade.

Fabrication and Measurement of Atom-scale Quantum Dot Arrays for Analog Quantum Simulation

Lattices of dopants in silicon are a promising platform for the analog quantum simulation of many body physics in silicon, exceeding the capabilities of classical computation methods for even modest sized arrays. We use STM lithography to precisely fabricate arrays of individual atoms on a patterned silicon substrate, see Figure 1. These atomic structures are then encapsulated in epitaxial silicon, patterned with contacts and gates in a cleanroom, and then measured at low temperature in a dilution refrigerator. Recently we demonstrated the analog quantum simulation of an extended Hubbard model using 3x3 arrays of dopant atoms by measuring transport through arrays from the weakly coupled regime to atom arrays separated by just a few nanometers.

Probing electron charge and spin configurations directly in an artificial lattice goes well beyond conventional transport measurements and is essential for validating analog quantum simulations by benchmarking detailed physical system behavior with classical Hubbard model calculations. Here, we demonstrate the use of radiofrequency (RF) reflectometry to directly probe charge and spin states in a 3×3 STM-patterned silicon dopant array, Figure 2. Site-resolved charge addition lines are identified, enabling unambiguous assignment of electron occupation across the lattice. Interdot charge transition signals allow quantitative extraction of nearest-neighbor tunnel couplings, providing direct experimental access to Hubbard parameters. Finally, we observe Pauli spin blockade between neighboring sites and measure singlet–triplet relaxation times. These results demonstrate STM patterned arrays of precisely placed dopant atoms as a platform for solid-state analog quantum simulation and RF reflectometry as a powerful characterization technique for probing charge and spin configurations in dopant arrays.

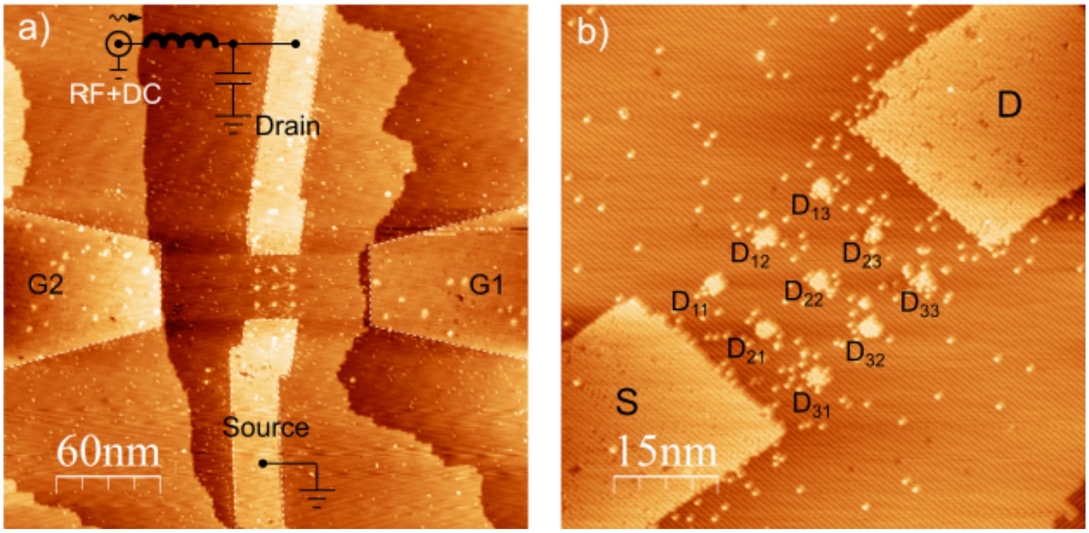

Figure 1. a) STM image of the weakly coupled 3x3 array device. b) Zoomed in image at the central dot region. The dots are name by row and column from D11 to D33 with an average lattice constant of 10.7 nm. The edge dots are directly tunnel coupled to the source and drain lead with similar tunneling gaps.

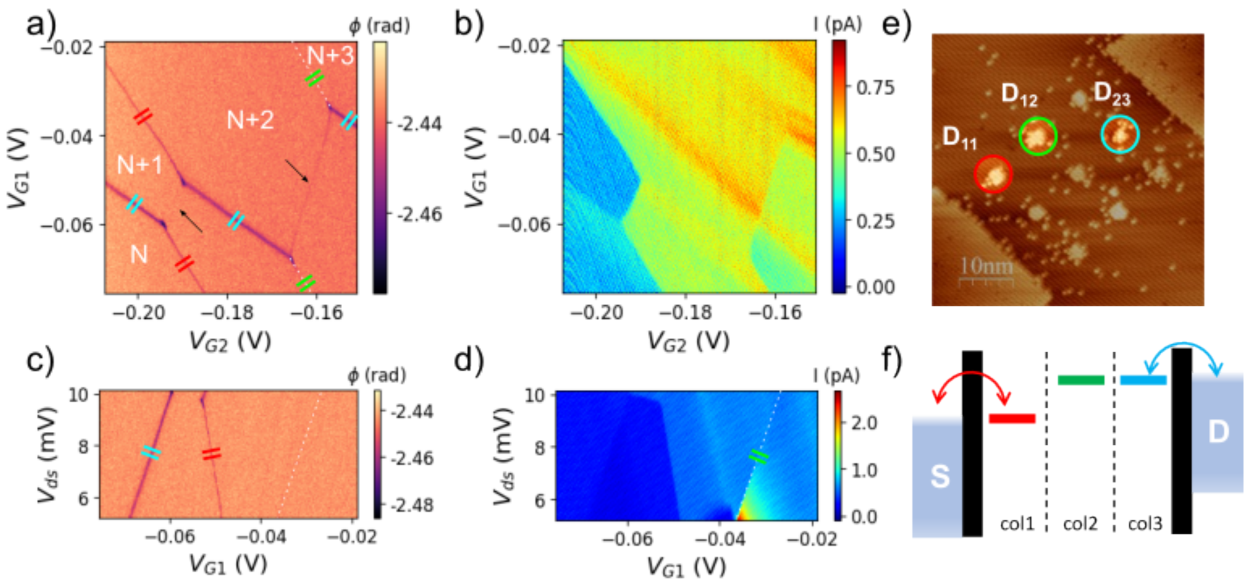

Figure 2. Identifying electron addition sites. (a) and (c) show RF phase and (b) and (d) show transport current near a double ICT region at V_ds = 10mV. Three electron addition lines and two ICTs are observed. Transport current shows distinct patterns in each charge number configuration. In (e) the electron addition sites are identified as D11 (red), D12 (green) and D23 (blue) as explained in the main text. The corresponding electron addition lines are also color labeled in (a). (f) Illustration of charge addition into the array. Column 1 dots need to align with the source and Column 3 dots need to align with the drain. Column 2 dots can either align with the source or the drain.