Atom-based Silicon Devices for Quantum Computing and Analog Quantum Simulation

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NIST is using atomically precise fabrication to develop devices for use in quantum information processing. We are using hydrogen-based scanning probe lithography for deterministic placement of individual dopant atoms with atomically aligned gates to fabricate single/few atom transistors, few-donor/quantum dot devices for spin manipulation, and arrayed few-donor devices for quantum materials and analog quantum simulation research.

In this presentation we characterize tunnel coupling in quantum dot devices where the tunnel gap is varied at the atomic scale. Tunnel coupling is evaluated in the context of few donor/quantum dot devices for single electron manipulation, as well as a method to control tunnel coupling in arrays of few atom clusters. We will present spectroscopy results of few atom transistors used to estimate parametric inputs, such as charge addition and binding energies, for the design of analog quantum systems using arrayed donor atoms or clusters. We then describe STM-fabrication and quantum transport measurement of arrays of few atom clusters ranging from double dots to a multi-gate 3×3 dot array to explore the rich Hubbard physics of quantum dot-arrays. Using an extended Hubbard model we explore the impact of site-by-site disorder on charge occupation and the Hubbard band structure. Numerical simulations of the model reveal charge distributions and magnetic correlations for different parameter sets. We quantify the electron addition energy spectrum through Coulomb blockade and charge stability analysis and demonstrate tuning of the array's energy spectrum using gates.