Fabricating Atomically Precise Devices to Engineer Unique Quantum Properties

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We are using atomically precise manufacturing to fabricate few-donor/quantum dot devices in silicon for use as qubits and arrays of atomic clusters to simulate quantum materials. Central to successful fabrication of atom-based quantum devices is understanding the impact each atom has on device performance. To scale up the number of qubits or number of sites in an atomic array, we must control atomic fabrication processes with true atomic precision and then understand the impact each atom or atomic interface has on device performance. To achieve robust single electron spin initialization, manipulation, and readout we use H-depassivation lithography to deterministically place dopant atoms with single lattice site precision relative to single electron transistor (SET) charge sensors, gates, and other device components.

In this talk I will describe the fabrication and measurement of single and few dopant atom clusters for use as individually addressable qubits or the sites in an array of atomic clusters. We use SET charge sensors, quantum transport, and RF reflectometry with single electron sensitivity to measure the energy level spectrum and spin filling in single and few atom clusters to elucidate the specific number of dopant atoms and the configuration within the device. These electrical measurements are then used as feedback to develop more controlled and robust atomic fabrication processes. Finally we perform analog quantum simulations using atomic arrays to explore how the electron charge configurations and magnetic ordering of electron spins depends on the detailed geometry and array parameters.