Atomic-scale Fabrication of Donor-based Quantum Devices in Silicon

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Atomic scale lithography using scanning tunneling microscopy (STM) allows fabrication of atomically precise device structures with applications ranging from novel low dimensional quantum materials to devices for quantum information processing. Atomic-scale fabrication is achieved using Hydrogen-based scanning probe lithography allowing deterministic placement of individual dopant atoms. Various devices such as single electron transistors (SETs), single and few atom transistors, and few donor/dot devices are fabricated using this technique.

Functionality and repeatability of atom-based devices depends greatly on controlling the material properties at the atomic scale including cleanliness, near perfect atomic order, dopant atom confinement and low temperature epitaxial silicon overgrowth. Robust lithography, device relocation, and contact processes have an emphasis on minimizing process-induced dopant movement and result in well-behaved exponential dependence of transport current on the engineered tunnel gaps in SET devices and demonstrate excellent charge stability. This presentation will cover the design, fabrication, and characterization of multiple STM patterned SETs with a focus on using the SETs as a metrology tool characterize materials and fabrication processes. We will also present our developmental work on the fabrication of on-chip coplanar wave guides intended for coherent manipulation of spin states of donor/dot devices.