Fabrication of Donor-based Quantum Devices in Silicon using Scanning Tunneling Microscopy

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Scanning probes with their ability for atomic scale resolution imaging and patterning have facilitated the fabrication of quantum electronic devices that allows the measurement and manipulation of single or few-dopant atom quantum dots for quantum computation and arrayed devices for analogue quantum simulation. Deterministic placement of individual dopant atoms using hydrogen-based scanning probe lithography (STM) enables fabrication of quantum structures with atomic precision that also have atomically aligned in-plane gates. We have made single electron transistors (SET) and few donor/dot devices for applications in spin-to-charge readout and individual electron spin manipulation as well as arrayed atomically ordered devices for analog quantum simulation. STM fabrication of these devices relies on the unique ability to create near perfect atomic structures on clean atomically ordered silicon in ultrahigh vacuum conditions. We have recently developed new strategies to improve single phosphorous donor atom incorporation to achieve precision control over both atomic position and the number of dopant atoms placed in each site. This presentation will focus on improving the atomic precision fabrication and design of STM patterned single electron transistors that demonstrate stable coulomb blockade oscillations as well as improving device control through top gates. In this talk we will present fabrication of external aligned metal gates that are integrated ex situ using HfO2 as a dielectric and demonstrate that we are able to modulate the chemical potential of the central island in a single electron transistor. We will discuss the design, fabrication, and use of surface top gates to address individual components individually or globally in few-donor/quantum dot devices as well as arrayed 2x2 devices.