Fabrication and Measurement of Atomic-Scale Devices: Toward Quantum Computing in Germanium

UCL Lead department: London Centre for Nanotechnology

Lead Supervisor: Associate Professor Steven Schofield

Project Summary:

It is now possible to position dopant atoms in semiconductors with atomic precision, promising a revolution in semiconductor fabrication for quantum technology and a gateway to uncharted territories in fundamental condensed matter physics research. The ultimate goal of this research is the development of a dopant-based quantum computer.

The fabrication of atomic-scale dopant devices is achieved by the precise positioning of individual dopant atoms within semiconductors using a scanning tunnelling microscope (STM). Despite numerous exciting successes, including the demonstration of a two-qubit gate and devices for exploring Fermi-Hubbard physics and topological Su–Schrieffer–Heeger states, it has emerged that fundamental limitations restrict the scale-up of devices using the current material paradigms. We aim to solve this scale-up problem by moving to arsenic in germanium as the material system to fabricate large numbers of deterministically placed dopants.

In this project, the student will fabricate atomic-scale quantum electronic devices in germanium. This will involve the development of a robust system for performing lithography and the incorporation of donor atoms, combined with cleanroom fabrication methods. Devices will include two-dimensional doping planes (δ-layers), one-dimensional Hall bar devices, and STM fabricated devices at the single-dopant level. Devices will be measured using synchrotron-based methods and electrical transport at mK temperatures. The student will become expert in STM, atomic manipulation and clean-room fabrication. They will become skilled in one or more characterisation method; the list of techniques includes, but is not limited to, soft or hard x-ray angle resolved photoemission spectroscopy (SX or HX-ARPES); cryogenic temperature magnetoresistance electrical transport; x-ray reflectometry/fluorescence; and theoretical simulation. The work will be in collaboration with M. Buitelaar, N. Curson, T. Stock, (UCL) and Gabriel Aeppli (PSI, ETHZ, EPFL, Switzerland).