Fabrication and Measurement of Atomic-Scale Semiconductor Devices for Quantum Computing

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Why This Research Is Important. The ability to position dopant atoms in semiconductor hosts with atomic precision (better than 1 nanometre) has revolutionized semiconductor fabrication for quantum technologies. This capability not only advances the field of quantum computing but also opens doors to new discoveries in condensed matter physics. A key goal of this research is the development of a dopant-based quantum computer, where individual dopant atoms in a semiconductor host act as quantum bits (qubits), as proposed by Kane [1].

While phosphorus has been the primary dopant used in silicon for quantum devices, recent breakthroughs at UCL [2,3] have demonstrated arsenic as a superior alternative. Arsenic not only resolves scalability issues inherent to phosphorus but also enables the fabrication of devices with larger numbers of qubits. These advances are critical for realising the practical potential of quantum computing, bridging the gap between theoretical proposals and scalable solutions.

Who You Will Work With. In the first year, you will work with Prof. Steven Schofield at UCL, an expert in scanning tunnelling microscopy (STM) and atomic-scale science. His lab focuses on fundamental experiments in the deterministic placement of donor atoms in silicon and germanium.

For the second and third years, you will join Prof. Johnson Goh's lab at A*STAR in Singapore, a leading group in solid-state quantum device fabrication. Prof. Goh's lab specializes in building silicon quantum devices and hybrid quantum systems, equipped with advanced STM systems, cleanroom tools, and dilution refrigerators with full qubit manipulation and readout capabilities. As Director of the National Quantum Engineering Programme, Prof. Goh provides access to a vibrant research ecosystem and collaborations spanning Singapore and international institutions in Australia, the UK, the US, and Europe.

What You Will Be Doing. In the first year at UCL, you will conduct foundational experiments on molecular adsorption and the deterministic placement of donor atoms in silicon or germanium. Using STM and scanning tunnelling spectroscopy, you will explore the positioning of dopants and perform experiments mapping the subsurface wavefunctions of donor atoms.

In the second and third years at A*STAR, you will focus on constructing and characterizing solid-state quantum devices. You will fabricate these devices using STM-based atomic positioning and cleanroom tools, followed by electronic measurements in dilution refrigerators equipped with full qubit manipulation systems. The project will also offer opportunities to explore hybrid quantum systems [4], leveraging the advantages of different qubit technologies for robust, scalable devices.

Who We Are Looking For. We are seeking a motivated researcher with a background in physics or materials science. Ideal candidates should have strong analytical skills, a collaborative mindset, and a genuine enthusiasm for atomic-scale science. While training will be provided, a keen interest in quantum computing and semiconductor devices is essential. This studentship offers a unique opportunity to develop expertise at the forefront of atomic-scale science, with exposure to cutting-edge research environments in the UK and Singapore.

[1] Kane, Nature, 393, 6681 (1998); [2] Stock, Advanced Materials, 23, 12282 (2024); [3] Hofmann, Angewandte Chemie, 62, e202213982; [4] Chia, Advanced Quantum Technologies, 7, 2300461 (2024)

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