Materials science and quantum physics of strained germanium semiconductor spin qubit

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Quantum computers promise to be one of the main technical advances of the forthcoming decades. There are several proposed platforms for realising a qubit, the basic unit of quantum information processing used to perform quantum computation. Broadly they can be based on ion-traps, superconducting junctions, photonic circuits and semiconductor quantum dots, each of which can reach different clock speed, gate fidelity and measurement errors, crosstalk and connectivity. While there has been great scientific progress and proof-of-concept demonstrations on all platforms, the main challenge to produce high-fidelity multi-qubit operations in a scalable architecture remains.

Recent breakthrough in enhancement of hole mobility in compressively strained germanium on silicon (cs-GoS) semiconductor led to emergence of new class of quantum material for realisation of scalable quantum computer based on a semiconductor spin qubit.[1] The cs-GoS with unique high hole mobility, the lowest effective mass, the lowest percolation density and electric field tuneable g*-factor is emerging as a new class of versatile quantum material to realize devices capable of encoding, processing and transmitting quantum information and therefor leading to invention of disruptive quantum technologies.[1,2] This material rely on unique properties of holes caused by quantum effects in the superior quality epitaxially grown strained germanium semiconductor material.

This experimental PhD project is an exciting opportunity to be involved in innovative and pioneering research on the intersection of materials science and quantum physics. The project is based on pioneering work at Warwick University, led to invention of high mobility holes in cs-GoS semiconductor material. The experimental information will add greatly to knowledge of materials science, quantum physics and technologies; and is expected to enable novel spin qubit quantum devices architectures. Epitaxial growth of the cs-GoS material for this research will be carried out at Warwick University, using unique to UK academia, epitaxial growth equipment upgraded beyond state of the art. Characterisation of grown materials and fabricated quantum devices will be carried out in-house using a range of sate of the art equipment and techniques, and in collaboration with existing national and international academic and industrial partners. Nanofabrication of spin qubit devices and their electrical characterisation, down to mK temperatures, will involve very close collaboration with scientists from leading universities and research centres. Successful outcome from the project would lead to high impact publications in international scientific journals and creation of intellectual property with enormous impact potential.

The successful PhD candidate is expected to have an outstanding track record, with demonstrable strong background in science and technology of cs-GoS semiconductor material, semiconductor devices, including spin qubits, and quantum physics. The skills and experience learned throughout the PhD will make the candidate an expert in quantum physics and technologies, materials characterisation and quantum devices nanofabrication. These skills can be transferred across the semiconductor and broader condensed matter fields.

[1] *M. Myronov, J. Kycia, P. Waldron, W. H. Jiang, P. Barrios, A. Bogan, P. Coleridge, S. Studenikin* "Holes Outperform Electrons in Group IV Semiconductor Material" Small Science Vol. 3 Issue 4 2200094 (2023).
[2] *G. Scappucci, C. Kloeffel, F. A. Zwanenburg, D. Loss, M. Myronov, J.-J. Zhang, S. De Franceschi, G. Katsaros, M. Veldhorst* "The germanium quantum information route" Nature Reviews Materials Pages 926-943 (2021).

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