

PhD studentship in atomic-scale quantum engineering

Title: PhD Studentship

Stipend: £15,590 per annum plus fees for 4 years

Accountable to: [Dr Steven R. Schofield](#)

Summary:

The ability to confine electrons within structures of reduced dimensions plays a central role in condensed matter physics research. The ultimate limit occurs when electrons are confined within individual atoms, and advances in atomic physics now allow individual ions in electromagnetic traps to be brought together to form quantum coherent systems. However, to build coupled atomic systems in large numbers, as required for applications such as quantum computing, it is highly desirable to develop strategies for fabricating these structures in the solid-state.

Semiconductor materials, such as silicon, routinely display atomic defects that have clear analogies with ion traps; however introducing such defects deterministically to observe the coupling between extended systems of individual defects has so far remained elusive. Dr Schofield runs a research programme exploring the atomic-scale fabrication of interacting atomic states in semiconductors. Recently, his research has shown that quantum states can be engineered on silicon by creating interacting single-atom defects, where each defect consists of a silicon atom with a broken, or “dangling” bond (DB). When created in pairs and extended chains with each DB separated by just less than 1 nanometer, interactions between the orbitals of these atoms leads to the formation of “quantum dot” states, that can also be considered as “artificial molecular orbitals”. Moreover, these extended states form only for the excited states of the individual atomic defects, while their ground states remain only weakly interacting, and this behaviour is analogous to a proposal for quantum bit (qubit) coupling based on hydrogenic impurities in silicon.

These results demonstrate the viability of engineering atomic-scale quantum states on the surface of silicon, and suggest similar states may be fabricated on other surfaces that can be modified using STM in the same way. In this project, the student will explore the fabrication of atomic-scale quantum states on surfaces other than silicon through the direct manipulation of individual atoms using a scanning tunnelling microscope. Materials of interest are larger band gap materials such as silicon carbide, and diamond, where it may be possible to produce states that are only weakly coupled to the electronic bands of the bulk material.

The work will be carried out in collaboration with the group of Dr Schofield and his experimental and theoretical colleagues in the UK and internationally in the USA, Japan and Australia. The student will work within a team of researchers exploring quantum state formation in semiconductor materials and interface with related research exploring the construction of single-atom silicon-based quantum devices.

Duties and Responsibilities

- Perform atomic-scale investigations of semiconductor materials, including single-atom and single-molecule manipulations.
- Become expert in scanning tunnelling microscopy (STM), scanning tunnelling spectroscopy (STS), and related ultrahigh vacuum (UHV) techniques.
- Utilise the semiconductor clean room facilities at LCN for sample preparation, and nanostructure fabrication using electron beam lithography
- Work in close collaboration with density functional theorists (DFT) in the UK and Australia for the simulation of atomic-scale structures.
- Implement techniques for experiment computer automation under the direction of Dr Schofield.
- Perform data analysis and numerical data simulation using software packages such as Mathematica, Matlab, and Igor Pro.
- Develop collaborations and work constructively in teams.
- Prepare progress reports on research as required.
- Prepare manuscripts for submission to peer-reviewed journals.
- Prepare presentations, including text and images, for delivery by self and others.
- Travel for training, experimentation, and collaboration.
- Travel to meetings both domestically and abroad to discuss results and to learn about related developments elsewhere.
- Contribute to the overall activities of the research team and department as required.
- Carry out any other duties as are within the scope, spirit and purpose of the job, as requested by Dr Schofield.
- Maintain an awareness and observation of Fire and Health and Safety Regulations at UCL and other facilities to be visited. Actively follow UCL policies including Equal Opportunities and Race Equality policies.

PERSON SPECIFICATION

Educational Qualifications

Applicants should have an excellent first degree in Physics, Chemistry or a related discipline (first class or high 2.1 or their international equivalents). The post is only open to UK/EU citizens.

Essential

- A demonstrated interest and expertise in condensed matter physics, scanning probe microscopy, quantum information, or materials science.
- Good oral, written, and presentation skills.
- Well-organised, attention to detail, and ability to meet deadlines.
- Ability to think logically, create solutions, and make informed decisions.

Personal

- Fluency and clarity in spoken English.
- Good written English.
- Ability to work collaboratively as part of team.
- Commitment to high quality research.
- Good organizational skills including the ability to set appropriate targets and to take responsibility for meeting them in a timely manner.

London Centre for Nanotechnology

The London Centre for Nanotechnology is an interdisciplinary joint enterprise between University College London and Imperial College London. In bringing together world-class infrastructure and leading nanotechnology research activities, the Centre aims to attain the critical mass to compete with the best facilities abroad. Research programmes are aligned to three key areas, namely Planet Care, Healthcare and Information Technology and exploit core competencies in biomedical, physical and engineering sciences.

The Centre occupies a purpose-built eight storey facility in Gordon Street, Bloomsbury, as well as extensive facilities within different departments at South Kensington. LCN researchers have access to state-of-the-art clean-room, characterisation, fabrication, manipulation and design laboratories. This experimental research is complemented by leading edge modelling, visualisation and theory.

LCN has strong relationships with the broader nanotechnology and commercial communities, and is involved in much major collaboration. As the world's only such facility to be located in the heart of a metropolis, LCN has superb access to corporate, investment and industrial partners. LCN is at the forefront of training in nanotechnology, and has a strong media presence aimed at educating the public and bringing transparency to this emerging science.

About UCL

UCL is one of the UK's premier universities and is ranked in the world's top 10. It is a world-class research and teaching institution based in London whose staff and former students have included 20 Nobel Prize winners. Founded in 1826, it was the only university in England at that time which admitted students regardless of race or religion. UCL was also the first to admit women on equal terms with men. Today, UCL is an inspiring university in which to work and study and it continues to thrive on the diversity and creativity of its community.

UCL is in practice a university in its own right, although constitutionally a college within the federal University of London. With an annual turnover exceeding £ 700 million, it is financially and managerially independent of the University of London.

The UCL community

UCL currently employs approximately 8,000 staff and includes academic units as diverse as the Slade School of Fine Art, the Mullard Space Science Laboratory and the Institute of Child Health, which is associated with Great Ormond Street Hospital. In total, there are 54 Academic Departments and Institutes whose activities span the following: arts and humanities, social and historical sciences, law, architecture and the built environment, engineering sciences, mathematical and physical sciences, life and clinical sciences, and medicine. UCL's academic and research staff are a truly international community with more than a quarter coming from 84 countries outside the UK.

The UCL student community comprises 12,600 undergraduates and 8,500 graduate students, of whom over 30% come from 130 countries outside the UK. UCL currently offers 270 undergraduate programmes and more than 210 taught postgraduate programmes as well as the opportunity to carry out postgraduate research in all of its subjects. Approximately

40% of the student community is engaged in graduate studies, with about 37% of these graduate students pursuing research degrees.

Quality of UCL's teaching and research

Two measures of the current quality of UCL's teaching and research are the results of the external teaching quality assessment reviews and the periodic Research Assessment Exercise (RAE).

The results of the UK's latest research assessment exercise (RAE 2008) confirm the international excellence of UCL's research. The numbers of our researchers shown in RAE 2008 to be carrying out world-leading research place UCL among the top three universities in the UK. Of the 1800 researchers submitted by UCL for RAE 2008, 95% were deemed to have an international level of esteem. The range of UCL's research excellence was demonstrated by outstanding results in RAE 2008 in academic disciplines as diverse as biomedical sciences, architecture and the built environment, economics, law, philosophy and history

Another measure of UCL's research excellence has been its success in bidding for external competitive funds from the Joint Infrastructure Fund (JIF) and the Science Research Investment Fund (SRIF). With the addition of required matching funds, JIF and SRIF are allowing UCL to invest more than £ 350 million into state-of-the-art infrastructure for cutting-edge research and teaching programmes.

Equality

UCL is proud of its longstanding commitment to equality and to providing a learning, working and social environment in which the rights and dignity of its diverse members are respected. The Equalities website has everything you need to know about Equalities at UCL and some initiatives are highlighted below:

- **Sabbatical Leave** following maternity - UCL provides one term of sabbatical leave without teaching commitments for research-active academics returning from maternity, adoption or long-term carer's leave. This support for returners enables staff to more quickly re-establish their research activity.
- **Achievement of five Athena SWAN awards** - for good employment practice for women working in science, engineering and technology (SET) in higher education and research.
- **Tackling underrepresentation** - UCL has two workforce equality targets. These targets are to increase the employment of black and minority ethnic (BME) support staff in grades 1-8 to 31% in line with the economically active BME population of Greater London; and to incrementally equalise the representation of men and women in senior grades (9 and 10) with the ultimate aim of a 50:50 split of women and men at this level.
- **Encouraging flexibility** - 82% of respondents to the 2009 UCL staff survey felt that their working time could be flexible. UCL's [Work Life Balance](#) policy gives employees the right to request a flexible working pattern.

Location and working environment

Based in Bloomsbury, UCL is a welcoming, inclusive university situated at the heart of one of the world's greatest cities.

UCL's central campus is within easy reach of Euston, Kings Cross and Marylebone mainline stations, the new Eurostar terminal at St.Pancras and the following Underground stations - Euston Square, Warren Street, Goodge Street and Russell Square. Road connections to the M1 and M40 motorways give easy access to the north and west road networks. There are also good public transport links to Heathrow airport.

Application procedure

For more details on the project please contact Dr Steven Schofield s.schofield@ucl.ac.uk. For more information regarding the London Centre for Nanotechnology, please contact Dr.Tania Saxl t.saxl@ucl.ac.uk also see www.london-nano.com. For assistance with application details, please contact Ms Denise Ottley (d.ottley@ucl.ac.uk). PhD application forms can be downloaded or completed online at: <http://www.ucl.ac.uk/prospective-students/graduate-study> under "How to Apply".