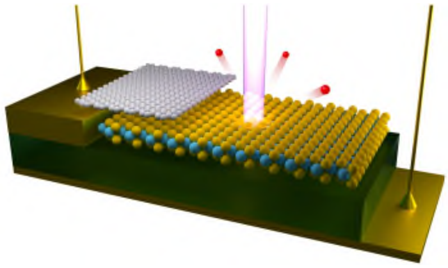
Agile electronics through ferroelectric switching of two-dimensional materials

Microscopy Group and Functional Materials Group



Atomically thin layers of different two-dimensional materials can be stacked with atomic precision to create 2D heterostructures (2D-HS). This has led to the design of more efficient light emitting diodes for example, and the study of new phenomena such as an insulating to superconducting transition in graphene. In these heterostructures, electric fields perpendicular to the layers can be used to engineer the band alignments, control carrier concentrations, and even switch between metallic, insulating and superconducting states. These fields are usually induced by predefined metallic electrodes which give control over the field strength but are of fixed (microscale) geometry and have limited dynamic response. This project will develop an alternative approach.

Strong electric fields can be formed at the surface of thin-film ferroelectric perovskite oxides, with the field patterned with nanoscale precision. The polarity of the field can be switched rapidly and even the spatial arrangement of the field can be controlled dynamically. This presents an exciting opportunity to create agile electronics by integrating perovskite ferroelectrics into 2D-HSs. Creating such a robust platform for electrostatically defining insulating and conducting regions in two-dimensional materials (2DMs), and for dynamically switching their conductivity, will allow us to explore new physical phenomena and to develop new electronic functionalities.

The aim of this project is to explore novel artificial heterostructures that combine ultrathin ferroelectrics with 2DMs, especially 2D van-der-Waals semiconductors, exploiting reduced dimensionality and interfacial interactions to control the properties and engineer new functionalities in these artificial materials.

This PhD project will focus on developing techniques for controlling the interface between the 2D-HSs and high-quality thin-film perovskite oxides grown at Warwick by pulsed laser deposition. Careful characterisation of this interface, and its effect on the electronic properties of the 2D-HSs, will be essential to the wider success of the project. The research will make use of the excellent microscopy and spectroscopy infrastructure at the University of Warwick, as well as international synchrotron-based facilities. The successful applicant will work as part of a team of researchers in this area at the University of Warwick, attached to a funded research project.

Professional duties and responsibilities:

- Fabrication of the ferroelectric-2DM stacks: Isolation of 2DMs by mechanical exfoliation, preparation of the ferroelectric surface, and transfer of the 2DMs.
- Lithography and device fabrication.
- Characterisation of the ferroelectric-2DM interface by a range of microscopies and spectroscopies, including atomic force microscopy, electron microscopy, Raman spectroscopy and photoemission spectroscopy (XPS and ARPES).
- Performing data analysis and modelling the results.
- Preparing manuscripts for publication in peer-reviewed journals.
- Participating in local seminars as well as national and international conferences.
- Contributing to the overall activities of the research team and the department.
- Interacting with national and international collaborators.

Personal qualifications and skills

- This position is only open to UK citizens or EU citizens settled in the UK due to funding restrictions. Applicants should have, or expect to be awarded, an undergraduate degree in Physics or a related discipline at a level of 2.1 or above.
- Good understanding and interest in condensed matter and/or materials physics.
- Strong analytical thinking and creative problem-solving skills.
- Ability to take initiative and to work independently and responsibly.
- Good team-working skills.
- Fluency and clarity in spoken English; good written English.

To discuss this project further contact:

Professor Neil Wilson (Neil.Wilson@warwick.ac.uk) and Professor Marin Alexe (m.alexe@warwick.ac.uk)