CMMP Summer Bursary Application: Atomic-scale manipulation of Co atoms on black phosphorus
Student: Sebastian Gorgon. **Supervisor(s):** Assoc. Prof. Steven Schofield.
Duration: 1 June 2019 for 8 weeks

Abstract: The Nobel-prize winning discovery of graphene and its extraordinary electronic characteristics in 2004 has led to a strong resurgence of interest in two-dimensional (2D) materials. Graphene has known limitations for technological applications due to the absence of an intrinsic band gap and because its surfaces are chemically inert, limiting possibilities for switching and sensor applications. To this end, there is great current interest the transition metal dichalcogenides (TMDs) and other 2D materials such as black phosphorus. These materials exhibit a wide range of (opto)electronic properties and can be insulating, semiconducting, or metallic. In addition, they can exhibit exotic correlated electron phenomena such as superconductivity, charge density waves (CDWs), and metal-insulator transitions.

Steven Schofield is PI of the cryogenic-temperature STM laboratory in the LCN where recent studies of 2D materials include the discovery of a CDW collective ground state in electron-doped molybdenum disulphide (MoS_2) and the observation of separate quasi-particle interference coexisting in the same material; and the discovery that substitutional tin defects in 2D black phosphorus are ambiphilic and support both acceptor-like and donor-like hydrogenic states at the black phosphorus band edges.

In this exciting project, the student will work in close collaboration with PhD student Mark Wentink to investigate the possibilities for cobalt atom manipulation on black phosphorus. Commercial black phosphorus samples will be cleaved under ultra-high vacuum conditions and exposed to an atomic beam of Co via solid-source evaporation for a range of Co coverages. Subsequently, the student will use cryogenic temperature (77 K) scanning tunnelling microscopy to image the surface of the at the atomic scale and identify individual Co atoms. The electronic properties of the Co atoms will be measured with scanning tunnelling spectroscopy and then we will investigate the possibility of manipulating the positions and chemical states of these atoms using the STM. The ability to reposition Co atoms on the surface will open entirely new avenues to the investigation and alteration of the electronic structure of this material via the creation of electronic nanostructures and atomic-scale quantum dots.

Student track record: Sebastian Gorgon is an outstanding student who is coming to the end of his BSc Chemical Physics degree at UCL with an anticipated first-class degree. In addition to this, Sebastian has spent a full year conducting research at the Rutherford Appleton Laboratory where he worked with extreme time resolution laser physics and developed strong practical laboratory skills including the development of advanced electronic/computer control systems at the level of becoming a certified LabView developer.

Key objectives

- Perform UHV STM measurements of Co deposited black phosphorus; topographic and tunnelling spectroscopy measurements and initial investigation of atomic-manipulations.
- Learn the *MATE* control environment of *Omicron-Scienta Matrix* scanning probe environment.
- Adapt existing *MATE* programming in our laboratory for the purpose of atomic-scale manipulation of Co on black phosphorus.

Training

- The student will be trained in STM image acquisition and tunnelling spectroscopy.
- The student will learn aspects of the *MATE* programming environment language, adapt existing code and write new code for the atomic-scale manipulation.

Schedule: The student will have a formal meeting with Dr Schofield at the start of each week in addition to daily informal discussions in the laboratory. He will be accompanied at all times in the laboratory by PhD student Mark Wentink who will directly supervise the practical aspects of the work.

Week 1: literature review: black phosphorus and general methods for STM-based atomic-scale manipulation **Weeks 2-3:** Learning the MATE programming environment. **Weeks 4-7:** Adaptation of existing MATE control programmes in our laboratory for the specific purpose of atomic-scale manipulation on black phosphorus. **Week 8:** Prepare 15-minute presentation for STM group meeting and write short report of the project.