**CaMPUS**
**Research Projects in Cambridge**
**Summer 2024**

You may find it helpful to contact the hosts of the projects in which you have an interest, before you finalise your choices. This is probably best done via email – addresses are included in this document. It may also be advisable to visit the websites of the research groups concerned, in order to obtain information about associated resources, activities etc.

## 1. Research Group: 2D Materials and Devices

Number of placements available: 1

Suitable for: Part IB or II only

Period of placement(s): 8 weeks

Outline of project(s): ***Optimising the composition of LLZO/PEO solid-state electrolytes for use in next-generation all-solid-state batteries***

All-solid-state batteries present one of the most exciting avenues of research for next-generation batteries with higher capacities, longer lifespans and reduced safety concerns. Two of the most promising electrolyte materials are lithium lanthanum zirconium oxide (LLZO) and poly ethylene oxide (PEO). Throughout the project, the student will learn to fabricate solid-state electrolytes and characterise them with basic electrochemical testing techniques. This will guide the student during an optimisation process for the composition of a solid-state electrolyte consisting of LLZO, PEO and lithium salts. The student is expected to contribute their own ideas and will be given freedom to explore these. No prior knowledge of solid-state electrolytes is required but basic understanding of how batteries work will be useful.

Host academic: Prof. Manish Chhowalla

Daily supervisor: James Moloney (PhD student)

Informal enquiries: James Moloney (jm2062@cam.ac.uk)

## 2. Research Group: 2D Materials and Devices

Number of placements available: 1

Suitable for: Part IB or II only

Period of placement(s): 8 weeks

Outline of project(s): ***Li-S battery for next-generation energy storage: the gap between lab and market***

The pursuit of high-energy-density secondary battery systems is crucial to meet the ever-increasing demands of portable electronics and electric vehicles. Lithium-sulfur (Li-S) batteries are

a promising technology due to their tenfold higher theoretical energy density (2600 Wh/kg) than that of state-of-the-art commercial lithium-ion systems (~250 Wh/kg). Our group has recently developed practical Li-S batteries with remarkable performance by using two-dimensional metallic 1T phase molybdenum disulfide nanosheets. Building on these findings, the project will investigate how far is our proof-of-concept technology from read-world market. The project will include not only battery-related experiments, but also a deep dive into the safety, cost, and market analysis of this emerging technology.

Host academic: Prof. Manish Chhowalla

Daily supervisor: Dr Zhuangnan Li

Informal enquiries: Dr Zhuangnan Li (zl450@cam.ac.uk)

## 3. Research Group: Cambridge Centre for Gallium Nitride

Number of placements available: 1

Suitable for: Any student could undertake this project (Part IA, IB or II)

Period of placement(s): 8 weeks

Outline of project(s): ***Cu(InGa)$S_2$ solarcells: Pathway to a green future***

To make a significant impact on the sustainability of our current energy consumption; new, highly efficient and low $CO_2$ emitting power sources have to become available to a wide audience. Next to nuclear and wind power facilities, solar power plants are one of the main options available. Presently the main solar cells used are based on amorphous silicon and work as single absorber cells. These devices are strongly limited in their achievable efficiency as high energy light will be down converted due to inherent bandgap restrictions. The most promising way to increase solar cell performance are tandem solar cells, in which layers of different bandgap are stacked on top of each other, reducing energy loss due to down conversion and enhancing both operation efficiency as well as offering a short energy payback time.

Sulfide chalcopyrites Cu(InGa)$S_2$ are particularly suited for applications in tandem cells as they cover the whole bandgap range of interest for top cells in tandem devices, as well as for single junction devices, from 1.5 to 2.5eV. One of the current main challenges in further enhancing the efficiency of these devices is to increase the open-circuit voltage, which is strongly influenced by non-radiative recombination at either the surface or bulk defects.

In this project the optical and structural properties of Cu(InGa)$S_2$ solarcells will be investigated by state of the art scanning electron microscopy (SEM). An important part of the project will be linking cathodoluminescence hyperspectral maps with secondary electron images and electron backscatter diffraction images to study the influence of defects and grain boundaries on the nano scale.

Host academic: Prof. Rachel A. Oliver / Dr Gunnar Kusch

Daily supervisor: Dr Gunnar Kusch

Informal enquiries: Dr Gunnar Kusch (gk419@cam.ac.uk)

## 4. Research Group: Cambridge Centre of Gallium Nitride

Number of placements available: 1

Suitable for: Any student could undertake this project (Part IA, IB or II)

Period of placement(s): 8 weeks

Outline of project(s): ***Defects in deep UV light emitting diodes***

The development of solid state lightning is revolutionizing the way we see and interact with the world, acknowledged by the 2014 Nobel prize for the inventors of the blue light emitting diode (LED) based on the nitride material system. LEDs are not just much smaller than conventional lightbulbs but are also able to achieve the same brightness with impressively lowered energy consumption.

While blue and white nitride based LEDs are already commercially available, manufacturing efficient LEDs in the UV-C spectral range is still a challenge to overcome. This is partly due to the strong influence of extended and point defects reducing the internal quantum efficiency in these devices. To overcome these challenges, we must study the influence of material and manufacturing parameters on the defect density and device performance.

In this project we will use (time-resolved) cathodoluminescence spectroscopy and secondary electron imaging in a scanning electron microscope to probe the optical properties of a series of UV-C samples. Analysing our acquired multidimensional data will allows us to correlate materials properties with manufacturing parameters (such as growth temperature or quantum well composition) and study the behaviour and origin of non-radiative defects in the material.

Host academic: Dr Gunnar Kusch

Daily supervisor: Dr Gunnar Kusch

Informal enquiries: Dr Gunnar Kusch (gk419@cam.ac.uk)

## 5. Research Group: Electron microscopy group and WEMS

Number of placements available: 1

Suitable for: Part IB or II only

Period of placement(s): 8 weeks

Outline of project(s): ***Advanced materials characterization using multidimensional EM datasets***

Advanced electron microscopes are equipped with multiple detectors that can record rich morphological, crystallographic and compositional information with high spatial resolution. Extracting meaningful information from the datasets is particularly challenging for materials that are sensitive to the (high energy) electron beam, such as hybrid organic-inorganic perovskites or layered Li-transition metal oxides used in energy harvesting and storage applications.

A promising strategy to reduce the effect of beam damage involves acquiring data on multiple detectors with short dwell times and/or different pixel size, performing a careful registration of the datasets to a common reference frame, and then running a detailed analysis of the signal and noise components of the global dataset. This is expected to enable mapping and understanding of materials properties at the nanoscale with unprecedented level of detail.

This project is expected to focus mostly on data analysis. It will involve optimising code for registration of 2 datasets and testing the quantification against standard approaches. A possible outcome could be, for example, the generation of quantitative atomic resolution compositional maps of nanostructured energy materials.

Host academic: Prof Cate Ducati

Daily supervisor: Dr Simon Fairclough

Informal enquiries: Prof Cate Ducati (cd251@cam.ac.uk) and Dr Simon Fairclough (smf57@cam.ac.uk)

Other information: Python coding experience would be highly advantageous

## 6. Research Group: Hybrid Materials Group

Number of placements available: 1

Suitable for: Part II only

Period of placement(s): 8 weeks

Outline of project(s): ***Hybrid glasses for gas uptake***

Porous materials have garnered significant attention in recent years due to their promising chemical and physical properties, as well as their ability to store gases. However, they are typically obtained as microcrystalline powders, which poses challenges for their industrial implementation due to poor processability. This 8-week project involves the synthesis and characterization of new porous hybrid materials capable of melting and forming glasses. Glasses are boundary-free and easily processable.

This innovative family of glasses will be studied for its carbon dioxide uptake capabilities, with potential implications for environmental remediation.

Host academic: Dr Celia Castillo-Blas / Prof. Tom Bennett

Daily supervisor: Dr Celia Castillo-Blas

Informal enquiries: Dr Celia Castillo-Blas (cc2078@cam.ac.uk)

## 7. Research Group: Macromolecular Materials Lab

Number of placements available: 1

Suitable for: Part II only

Period of placement(s): 8 weeks

Outline of project(s): ***A Sustainable Twist on Hair Care with Eco-Friendly Polymeric Materials***

This project will focus on the characterisation and development of new sustainable plastics for hair care products in collaboration with a well-known UK brand (Tangle Teezer), who will supply the materials and advise on commercial applications. The project builds on some existing work in which fossil-based thermoplastic elastomers have been replaced by bio-based polymers with similar or superior mechanical strength and resilience. The work will focus on extending the range of biopolymers that can be used, exploring the use of additives to reduce static charging and development of simple metrics for evaluating performance. It will involve training in experimental techniques for mechanical testing, thermal analysis and X-ray diffraction of polymers, and an opportunity to visit Tangle Teezer headquarters in London to learn more about the commercial aspects of their products.

Host academic: Prof. James Elliott

Daily supervisor: Patience Abugu (PhD student)

Informal enquiries: Prof. James Elliott (jae1001@cam.ac.uk)

## 8. Research Group: Medical Materials

Number of placements available: 1

Suitable for: Any student could undertake this project (Part IA, IB or II)

Period of placement(s): 8 weeks

Outline of project(s): ***Collagen scaffolds***

The project will seek to advance understanding of methods to optimise the production and performance of porous scaffolds for cell delivery. The work will comprise investigation of a series of different potential production methods and chemistries and also a combination of physical, chemical and biological characterisation. Techniques will include X-ray diffraction, thermal analysis, mechanical testing, X-ray microtomography, electron microscopy and in-vitro cell culture.

Host academic: Prof. Serena Best and Prof. Ruth Cameron

Daily supervisor: To be advised

Informal enquiries: Prof. Serena Best (smb51@cam.ac.uk) and Prof. Ruth Cameron (rec11@cam.ac.uk)

## 9. Research Group: Rolls-Royce

Number of placements available: 1

Suitable for: Part IB or II only

Special conditions: There are export control considerations relating to work conducted by others within this group but not specifically for this project.

Period of placement(s): 8 weeks

Outline of project(s): ***Development of novel biomimetic alloys for implant applications***

Titanium and its alloys are commonly used as implant materials in orthopaedic and orthodontic applications due to their biocompatibility, high corrosion resistance in biological environments and good osseointegration. In addition, with careful alloying the elastic modulus of these alloys can be engineered to approach that of natural bone. However, despite these advances, implant failure rates remain high (~10%) with infection often being as the most frequent cause. Therefore, there is great interest in developing new alloys that not only possess favourable mechanical properties but that also have antibacterial characteristics.

Recent work has identified a number of systems based on Ti-Nb that contain elements with antibacterial properties and early investigation has shown particular alloys have exceptionally promising mechanical behaviour. This project will play a role in the continued development of these alloys with scope to include experience of alloy development and processing, microstructural characterisation (X-ray diffraction and electron microscopy), mechanical property evaluation and biocompatibility studies.

Host academic: Prof. Nick Jones

Daily supervisor: Dr Nicole Church

Informal enquiries: Prof. Nick Jones (ngj22@cam.ac.uk)

## 10. Research Group: Rolls-Royce

Number of placements available: 1

Suitable for: Part II only

Special conditions: There are export control considerations relating to work conducted by others within this group but not specifically for this project.

Period of placement(s): 8 weeks

Outline of project(s): ***Transforming steels: Understanding and controlling phase formation under stress***

This project will use advanced characterisation methods to understand the mechanisms that control stress-induced phase transformations in a specially designed austenitic stainless steel. The alloy of interest is unique as it has been tailored, through composition control, to trigger phase transformations at very low strains. This makes direct observations of phase transformations possible, that would otherwise be near-impossible in commercial alloys. Understanding such phase-transformation behaviour is important to inform the design of future ultra-high ductility ferrous alloys such as TRIP steels, with numerous uses in structural applications – particularly the automotive sector.

During the internship, we will explore the relationship between the microstructure and the mechanical behaviour. This will involve controlling the grain structure through heat treatments, and measuring the evolution of macroscopic and sub-grain deformation using SEM, EBSD and XRD. The project will suit an individual who wishes to gain experience on a range of experimental techniques, as well as developing data analysis skills using MATLAB based image analysis and data fitting methods.

Host academic: Dr David Collins

Daily supervisor: Dr Himanshu Vashishtha

Informal enquiries: Dr David Collins (dmc51@cam.ac.uk)