CaMPUS
Research Projects in Cambridge
Summer 2022

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: Materials Theory Group

Number of placements available: 1

Suitable for: Part IB or II students

Special conditions: None

Period of placement: 8-10 weeks depending upon funding source

Outline of project: ***Topological insulators at room temperature***

The discovery of topological insulators (TIs) opened up a new horizon in condensed matter physics and materials science. TIs behave as insulators in their interior but have conductive chiral surface/edge states in which electron backscattering is forbidden, enabling dissipationless transport that could lead to low-power electronics and spintronics. The behaviour of TIs at zero temperature has been well-characterised both experimentally and theoretically, and the field is now moving towards promoting their practical applications. To this end, this theoretical/computational project will explore how temperature affects the properties of TIs to identify a material candidate for room temperature applications. The student will use first principles quantum mechanical calculations of thermal expansion and electron-phonon coupling to explore the interplay between temperature and topology in a candidate 2-dimensional material. To take full advantage of the project (and to enjoy it), you should be comfortable with the level of discussion in these videos:

https://www.youtube.com/playlist?list=PL8W2boV7eVfmMcKF-ljTvAJQ2z-vILSxb

Host academic: Dr Bartomeu Monserrat

Daily supervisor: Siyu Chen

Informal enquiries: Dr Bartomeu Monserrat, bm418@cam.ac.uk

Other information: https://www.tcm.phy.cam.ac.uk/~bm418/index.html

2. Research Group: Rolls Royce UTC

Number of placements available: 1

Suitable for: Part IB or II students

Special conditions: This project may be subject to export control legislation. Please make contact with Prof Stone if considering applying for this project since some nationalities may be excluded from participating in this project work.

Period of placement: 8-10 weeks depending upon funding source

Outline of project: ***Investigating novel Ti-Fe-Al-Mo alloys***

We have recently identified the potential of a novel class of ultra-high strength beta Ti alloys based on the Ti-Fe-Al system. These alloys derive their exceptional properties from precipitates that have a superlattice structure of the beta matrix. However, at this stage very little is known about how additional alloying will affect their microstructure and properties. This project will seek to gain insight into the effect Mo additions on these alloys. During the project, a series of Ti-Fe-Al alloys with systematically varying concentrations of Mo will be prepared by arc melting before being subjected to heat treatments of varying temperatures and durations. The project will then focus on performing detailed characterisation of the structure, morphology and composition of the phases present using scanning electron microscopy and X-ray diffraction. The critical transition temperatures will be determined by differential scanning calorimetry and, for alloys exhibiting suitable microstructures, hardness testing will also be performed. The data obtained will be directly compared with predictions made using thermodynamic modelling with the ThermoCalc software package. These are novel alloys, and it is intended that the results obtained will lead to a journal publication.

Host academic: Prof Howard Stone

Daily supervisor: Rosie Mellor

Informal enquiries: Prof Howard Stone (hjs1002@cam.ac.uk) or Rosie Mellor (rflm2@cam.ac.uk)

Other information: http://www.rrutc.msm.cam.ac.uk/

3. Research Group: Kar-Narayan Lab

Number of placements available: 1

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

Special conditions: None

Period of placement: 8 weeks

Outline of project: ***Fully printed electroactive polymer nanocomposites for actuation and biomedical implants***

Electroactive polymers (EAPs) can be excited using electric fields to change their shape and size, giving rise to biologically inspired capabilities [1]. Broadly speaking, there are two classes of EAPs: field-activated EAP materials are driven by Coulomb forces and require high activation fields that may be close to the level of dielectric breakdown level, and ionic EAP materials that are driven by diffusion of ions, and require relatively low activation voltages. The latter is particularly attractive in biomedical settings where low activation voltages are preferable. However, the application of EAP materials as actuators still involves many challenges related to actuation forces, scalability, durability and reliability. The processes of synthesizing, fabricating, electroding, shaping, and handling need to be understood and optimized to maximize the actuation capability and durability. In this project, ion-based cation systems will be combined with printable polymer hosts such as Nafion, to create voltage-tuneable bending on the nano- to microscale. While on the large scale such bending takes seconds, it is predicted that switching can be much faster as the devices scale down, and dependent on the cation conductivity in the polymer host. The novelty here is to use a state-of-the-art additive manufacturing technique, namely aerosol-jet printing [2], to "print" such devices in their entirety, opening up a wide range of potential applications. Such printing has not been demonstrated previously, and has the potential for rapid prototyping of devices for optimisation and testing. It is expected that developing this type of capability will serve to identify niche applications such as soft robotics and sensor-assisted surgery and insertion of biomedical implants.

[1] Bar-Cohen & Anderson, Mechanics of Soft Materials 1, 5 (2019)
[2] M. Smith, Y.S. Choi, C. Boughey & S. Kar-Narayan, Flex. Print. Electron. 2, 015004 (2017)

Host academic: Prof Sohini Kar-Narayan

Daily supervisor: To be confirmed

Informal enquiries: Prof Sohini Kar-Narayan, sk568@cam.ac.uk

Other information: https://www.kar-narayan.msm.cam.ac.uk/

4. Research Group: Kar-Narayan Lab

Number of placements available: 1

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

Special conditions: None

Period of placement: 8 weeks

Outline of project: ***Conformable force sensors for orthopaedic surgery and telemetry***

The treatment of weight bearing joints such as knees and hips is a complex problem, with challenges ranging from objective assessment of the damage to tissue and understanding of the forces in organic joints, and monitoring the forces within the implant post-surgery. The past five years have seen a growing global interest in technologies to enable biocompatible, implantable mechanical sensing. This project seeks to establish novel printed, flexible and biocompatible force/pressure sensors suitable for orthopaedic surgery and post-operative telemetry, based on novel microfluidic capacitive techniques recently developed in our group [1]. These devices will be optimised through finite element modelling, and compared in view of the requirements set by the clinical application. This project will open up significant opportunities for future work and commercialisation, through establishing new technologies, and taking them forward through optimisation and in-vivo (cadaveric) trials.

[1] Jing, Qingshen, et al. Cell Reports Physical Science 2, 100386 (2021)
[2] Forchelet, David et al. Sensors 14, 15009-15021 (2014)

Host academic: Prof Sohini Kar-Narayan

Daily supervisor: To be confirmed

Informal enquiries: Prof Sohini Kar-Narayan, sk568@cam.ac.uk

Other information: https://www.kar-narayan.msm.cam.ac.uk/

5. Research Group: Kar-Narayan Lab

Number of placements available: 1

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

Special conditions: None

Period of placement: 8 weeks

Outline of project: ***Printed microfluidic bio-sensors based on functional nanomaterials***

Microfluidics has emerged as a powerful analytical tool for biology and biomedical research, with uses ranging from single-cell phenotyping to drug discovery and medical diagnostics, and only small sample volumes are required for testing. Microfluidic devices can combine sensors and biological components onto a single platform, offering challenges and opportunities for novel biosensing applications, with a focus on portability, disposability, real-time detection, and improved accuracy of detection, to name a few. There is therefore enormous interest in developing microfluidic devices with improved capabilities and enhanced functionalities, where higher level of integration can lead to complex and complete microfluidic systems in a single chip. This project aims to explore such integration through the direct incorporation of functional nanomaterials (e.g. piezoelectric, electrochemical, thermoelectric) within microfluidic devices using "aerosol-jet printing" of bespoke inks [1]. This particular printing technique is distinctly versatile when it comes to rapid prototyping of functional inks, and will be used extensively in this work to explore a variety of nanomaterials for microfluidic sensing applications for novel biosensors and bioelectronics. [2]

[1] Kar-Narayan group, Applied Materials Today 19, 100618 (2020)
[2] T Chalklen, Q Jing, S Kar-Narayan, Sensors 20, 5605 (2020)

Host academic: Prof Sohini Kar-Narayan

Daily supervisor: To be confirmed

Informal enquiries: Prof Sohini Kar-Narayan, sk568@cam.ac.uk

Other information: https://www.kar-narayan.msm.cam.ac.uk/

6. Research Group: 2D Materials Devices

Number of placements available: 1

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

Special conditions: None

Period of placement 8-10 weeks depending upon funding source

Outline of project: ***Evaluation of MoS2 nano sheets covered with polysulphides for lithium sulfur batteries.***

Metallic chemically exfoliated nanosheets of MoS2 have been demonstrated to be excellent cathodes for Lithium- Sulfur (Li-S) batteries. One reason for this is that the the sulfur is efficiently adsorbed onto MoS2 and subsequent polysulfide formed during the Li-S battery operation also possess strong affinity to MoS2. In this project, the student will study the adsorption of lithium-sulfur polysulfides on metallic MoS2 nanosheets by UV-VIS spectroscopy, atomic force microscopy, and optical microscopy.

Host academic: Prof Manish Chhowalla

Daily supervisor: Dr Zhuangnan Li, PDRA

Informal enquiries: Prof Manish Chhowalla, mc209@cam.ac.uk

Other information: https://www.chhowalla.msm.cam.ac.uk/

7. Research Group: Optical Nanomaterials

Number of placements available: 1

Suitable for: Part IB or II students

Special conditions: None

Period of placement: 8 weeks

Outline of project: ***Plasmonic and photothermal effects in bimetallic nanoparticles***

In this project, the student will decorate magnesium nanoparticles via galvanic replacement and potential kirkendall effects. He/she will prepare a series of increasingly decorated magnesium particles and characterise the degree of etching of the magnesium via a simple titration. He/she will then measure the bulk heating of these nanoparticle suspensions upon irradiation with lasers of various wavelength and power. This temperature rise will be correlated to the extent and composition of the decorations.

Host academic: Dr Emilie Ringe

Daily supervisor: Vladimir Lomonosov (PDRA) and Claire West (PDRA)

Informal enquiries: Dr Emilie Ringe, er407@cam.ac.uk

Other information: https://www.on.msm.cam.ac.uk/

8. Research Group: Evans Group

Number of placements available: 1

Suitable for: Part IB or II students

Special conditions: None

Period of placement: 8 weeks

Outline of project: ***Calculating the cost of Sustainable Materials Science***

Research into solutions for a sustainable future often begins in a materials chemistry lab. For example, improving our ability to harvest sunlight to generate renewable energy requires breakthroughs developed by materials scientists. Unfortunately, many labs employ unsustainable practices, such as extensive use of disposable plastics and wasteful synthetic procedures.

The Photoactive Materials group is reducing their environmental impact by incorporating green chemistry principles into its day-to-day activities. In order to quantify the positive effects of these new practices, a though analysis of proposed changes must be conducted. This project will involve calculating the resulting energy, water, monetary, and waste savings from the new sustainable measures. It will also analyse working practices to propose a long-term strategy aiming towards a net-zero lab.

Host academic: Prof Rachel Evans

Daily supervisor: Dr Bethan Charles, Dr Michael Bennison

Informal enquiries: Dr Bethan Charles, blc39@cam.ac.uk

Other information: http://www.labevans.co.uk/