You may find it helpful to contact the supervisors of 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. Links to these sites are available via the Department listing of staff at https://www.msm.cam.ac.uk/people/academic-staff-overview.
1. Research Group: GaN Group (Oliver)

Number of placements available: 1

Period of placement(s): 8 weeks flexible

Outline of project(s): \(\alpha\)-Ga\(_2\)O\(_3\) semiconductors: characterisation and device application

Demonstrator: Dr. Fabien Massabuau (fm350@cam.ac.uk)

Ga\(_2\)O\(_3\) is a semiconductor with many crystalline polymorphs. Among these, rhombohedral \(\alpha\)-Ga\(_2\)O\(_3\) is metastable but holds the key to bandgap engineering in ternary and quaternary group III-oxides since Al\(_2\)O\(_3\) and In\(_2\)O\(_3\) can both be found in the same phase. With a band gap ranging from 3.8 eV to 8.8 eV, controlling the growth of \(\alpha\) phase group III-oxides could open a pathway to a number of ultraviolet optoelectronics and power devices [1].

We have recently achieved the growth of \(\alpha\)-Ga\(_2\)O\(_3\) using atomic layer deposition [2]. However the crystal quality and electrical properties of the deposited films require improvements. This project aims to enhance the properties of the films and fabricate a first generation of devices based on \(\alpha\)-Ga\(_2\)O\(_3\). The student will use atomic force microscopy, X-ray diffraction and Hall measurement, and if time allows, test devices.


Contact: Dr Rachel Oliver (rao28@cam.ac.uk)

URL for further information: http://www.gan.msm.cam.ac.uk/

2. Research Group: GaN Group (Oliver)

Number of placements available: 1

Period of placement(s): 8 weeks flexible

Outline of project(s): LED lab – Design and implementation of novel content for educational application on LEDs

Demonstrator: Dr. Fabien Massabuau (fm350@cam.ac.uk)

LED lab is a mobile device application developed by the Cambridge Centre for Gallium Nitride, which aims to introduce light emitting diodes (LEDs) and Nitride semiconductors to a general audience [1]. The application is made of a set of “classes” (e.g. explanations of how an LED light bulb works, applications of LEDs, conduction in materials), and interactive “experiments” (e.g. how colours are tuned in an LED, electrical characterisation of LEDs). This project aims to design new classes and experiments that will be implemented in the next version of the application.

Prior knowledge of coding is preferable. Graphic design skills will also be useful.


Contact: Dr Rachel Oliver (rao28@cam.ac.uk)

URL for further information: http://www.gan.msm.cam.ac.uk/

Number of placements available: 1
Period of placement(s): 8 weeks flexible

Outline of project(s): **Piezoelectric bio-nanomaterials and applications**

Piezoelectric materials are capable of producing electricity when deformed, and have widely used in the creation of scaffolds for bone and tissue regeneration. In the case of bone repair, piezoelectric charges induced by mechanical stress can enhance bone formation, and in neural tissue engineering, in which electric pulses can stimulate neurite directional outgrowth to fill gaps in nervous tissue injuries. Prior to this, the majority of the research effort has been in creating scaffolds with appropriate biocompatibility and microstructure to allow a cell culture to survive and multiply. However, attention is now turning to the possibility of creating functional, 'smart' scaffolds using piezoelectric bio-nanomaterials, that can more accurately recreate the conditions found in vivo. For example, we have recently demonstrated shear piezoelectricity in poly-L-lactic acid nanowires [1], which are biocompatible and can be integrated into scaffolds. The ability to artificially grow new tissue has significant implications in the field of regenerative medicine and also offers insight into the fundamental mechanisms of tissue growth and repair. This project thus focuses on the field of piezoelectric biomaterials and their applications in tissue regeneration, as well as in the development of biocompatible energy harvesting for biomedical implants.


Contact: Dr Sohini Kar-Narayan (sk568@cam.ac.uk)

URL for further information: [http://people.ds.cam.ac.uk/sk568/campl_site/index.shtml](http://people.ds.cam.ac.uk/sk568/campl_site/index.shtml)


Number of placements available: 1
Period of placement(s): 8 weeks flexible

Outline of project(s): **Flexible and printed thermoelectric nanogenerators for wearable devices**

Thermoelectric (TE) generators, which are capable of converting heat into electricity, have enormous potential in thermal energy harvesting. They can be integrated into autonomous systems to enhance the capability and lifetime of self-powered electronic devices by harvesting thermal energy from the environment, or even charging wireless sensors and wearable devices from body heat. There has thus been tremendous interest in the development of low-cost, flexible and efficient TE devices for thermal energy harvesting. The development of new TE materials remains a key challenge, particularly in light of the scarcity or toxicity of traditional inorganic TE materials. This project is aimed at exploring novel polymer-based TE nanomaterials that can be produced using scalable nanofabrication techniques, and which can be incorporated into flexible TE nanogenerators with self-healing capabilities. The eventual goal is to design TE nanogenerators for wearable devices that can survive repeated use and harsh mechanical environments. Functional TE inks will be printed using aerosol jet printing (AJP) technique, and flexible and stretchable interconnects will also be investigated in this context.


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URL for further information: [http://people.ds.cam.ac.uk/sk568/campl_site/index.shtml](http://people.ds.cam.ac.uk/sk568/campl_site/index.shtml)
5. Research Group: Cambridge Centre for Medical Materials (Best and Cameron)

Number of placements available: 1
Period of placement(s): 8 weeks flexible
Outline of project(s): **Collagen-based scaffolds for peripheral nerve regeneration**

Peripheral nerve injury is a substantial clinical problem that can result in loss of communication along the motor and sensory nerves between the central nervous system (CNS) (brain, spine) and the peripheral nervous system (PNS) impairing patient’s quality of life.

Autologous nerve transplantation is the gold standard for the treatment; however, the limited availability and the double incision on the patient are significant drawbacks. The development of nerve conduits with natural or synthetic polymers has attracted interest in the research community. Some of the problems that have arisen during the PNS regeneration and need to be addressed are: slow, insufficient and misdirected axonal outgrowth, failure or poor reinnervation and extensive cell death. To overcome these problems, we are proposing to develop collagen-based scaffolds that will promote cell viability and orientated migration.

Collagen has been widely used since it is the main component of the extracellular matrix (ECM) of most tissues in the body. By incorporating other proteins, such as laminin, fibronectin and elastin on the collagen-based substrate the material becomes more biomimetic. These proteins are known to exist in the peripheral nervous system and have beneficial influence on the neuronal stem cells and the Schwann cells that consist of the main population of the tissue.

In our group, we have the expertise to fabricate collagen-based scaffolds with orientated channels and we aspire to stimulate orientated cell migration that will result in healthy reinnervation.

This project will involve the fabrication of collagen-based substrates with different ECM proteins. The material and the cellular behaviour on the different substrates will be assessed.

URL for further information: [http://www.ccmm.msm.cam.ac.uk](http://www.ccmm.msm.cam.ac.uk)

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

6. Research Group: Rolls Royce UTC (Jones)

Number of placements available: 1
Period of placement(s): 8 weeks flexible
Outline of project(s): **Influence of oxygen on the superelastic behaviour of Ti-Nb-Ta-Zr alloys**

Certain Ti-Nb-Ta-Zr alloys can undergo a reversible martensitic transformation in response to an applied stress. The formation and reversion of the martensite phase gives rise to superelasticity. A number of potential applications have been identified for such materials, across a wide range of engineering sectors. However, these applications require the transformation conditions (combinations of temperature and stress) to be tailored to meet those encountered in service. Alteration of the transformation conditions is known to occur with the addition of certain alloying elements, but the precise role of different alloying elements both individually and in co-additions remains unclear. Oxygen in particular is known to have a significant influence of the deformation behaviour of these alloys but existing data in the literature has not been able to reach an agreement as to how this effect occurs. This project will study the influence of oxygen on the superelastic behaviour through the mechanical testing and microstructural characterisation of a systematically varying series of Ti-Nb-Ta-Zr-O alloys.
7. Research Group: DMG (Barber)
Number of placements available: 1
Period of placement(s): 8 weeks flexible
Outline of project(s): Development of a heater system for temperature-controlled thin film growth
Demonstrator: Samer Kurdi (sk862@cam.ac.uk)

Much thin film deposition work requires growth onto heated substrates, in our ultra-high vacuum deposition systems. A new heater has been designed and built and, during this project, will be installed and trialled. This will involve some vacuum engineering issues, but will focus on film deposition and characterisation. For example, the fabrication of high quality crystalline magnetic alloy films on lattice-matched substrates. In addition to experience with advanced thin film deposition techniques, this project will give the opportunity for precise microstructural characterisation (e.g. X-ray diffraction, atomic force microscopy, electron microscopy) and, if interested, magnetic and electrical measurements.

URL for further information: http://www.dmg.msm.cam.ac.uk
Contact: Prof Zoe Barber (zb10@cam.ac.uk)

8. Research Group: Composites and Coatings Group (Clyne)
Number of placements available: 1
Period of placement(s): 8 weeks between early July and late September
Outline of project(s): Instrumented Indentation of Polycrystalline Superalloy Samples to obtain bulk Plasticity Properties
Demonstrator: J Campbell (jc682@cam.ac.uk)
Industrial partner: Frazer-Nash Consultancy

Instrumented indentation ("nanoindentation") is attractive for material characterization, requiring minimal sample preparation and with potential for mapping of local material response (eg across welds). It has long been possible to obtain elastic moduli, and also hardness values, in this way. However, elastic properties are of limited interest and hardness is not a well-defined property (although it does depend on yielding and work hardening characteristics). There is, however, growing interest in using indentation to obtain bulk properties, including values of parameters characterizing plasticity, creep and superelastic deformation. Challenges including that of ensuring that the indented volume is large enough to capture the macroscopic material response. The main problem, however, is to relate outcomes of indentation experiments (usually load-displacement-time data) to property values as conventionally obtained - ie during uniaxial loading. The only reliable way to do this will be via rigorous (FEM) modelling of the changing stress and strain fields during indentation, iteratively changing the values of input property parameters until optimum agreement is reached between predicted and measured outcomes. This is conceptually simple, but difficult to formulate as a well-defined methodology. However, considerable progress has been made [1-3] in the case of quasi-static plasticity parameters (yield stress and work-hardening characteristics). Procedures and software that have been developed for this purpose will be applied to some Ni-base superalloy samples, with cross-checking against results obtained by conventional uniaxial testing. These samples are likely to
be quite strongly textured, so the possibility of anisotropy (both elastic and plastic) will be taken into account. An industrial partner (Frazer-Nash) will be taking an interest in the project.

References

URL for further information: http://www.ccg.msm.cam.ac.uk

Contact: Prof Bill Clyne (twc10@cam.ac.uk)

9. Research Group: Composites and Coatings Group (Clyne)

Number of placements available: 1
Period of placement(s): 8 weeks between early July and late September
Outline of project(s): Pore Architecture and Properties of Novel Candidate Material for Diesel Particulate Filters (DPFs)

Demonstrator: A Houston (ajh242@cam.ac.uk)
Industrial partner: Cambustion

DPF materials are designed to remove ultrafine (10-100 nm) carbon particulate from high temperature, high flux Diesel engine exhaust, while generating minimal (<~50 mbar) back-pressure [1] and remaining thermo-mechanically stable during regeneration (periodic injection of fuel into the exhaust, designed to burn off accumulated carbon deposits, which can create severe conditions [2] of thermal shock inside the DPF). Novel materials will be produced by mixing fine (~3 µm) oxide fibres with relatively coarse (~50 µm) oxide powders and then extruding and sintering the mixture. The fibres are designed to create a multi-scale pore architecture exhibiting a good combination of filtration efficiency and permeability, while also raising the thermal shock resistance [3]. X-ray tomography will be used to explore the pore architecture in the resulting materials and the COMSOL model will be used to simulate flow of particle-containing gas through it. Permeabilities will be measured [4] and the resistance to thermal shock will also be tested. Promising materials will be manufactured into DPFs, and tested under engine performance conditions, by industrial partners.

References


URL for further information: http://www.ccg.msm.cam.ac.uk

Contact: Prof Bill Clyne (twc10@cam.ac.uk)

10. Research Group: Composites and Coatings Group (Clyne)

Number of placements available: 1

Period of placement(s): 8 weeks between early July and late September

Outline of project(s): *Mechanisms of Crack Formation and Pitting in CMSX-4 under Mechanically Loaded Type II Corrosion Conditions*

Demonstrator: N Glaenzer (ng362@cam.ac.uk)

Industrial partner: Solar Turbines

There is considerable interest in the degradation of turbine blades in service, when they are commonly subjected to a combination of mechanical stress, high temperature and an aggressive chemical environment (particularly the simultaneous presence of sulphur from the fuel and salt from ingested air). The term “Type II Corrosion” is used to describe the degradation that commonly occurs in the temperature range 600–750°C, which is experienced in a wide range of power generation and related types of turbine. Various publications [1-3] cover the details. In many such environments, sodium sulphate (Na₂SO₄) forms. This compound has a melting point of about 880°C, but various other phases can also appear (particularly if the partial pressure of SO₃ is relatively high) and eutectic mixtures with, for example, NiSO₄ or CoSO₄ often melt at temperatures as low as 600°C. The presence of such liquids can promote various types of scale formation, cracking and pitting, leading to rapid degradation of mechanical properties and component failure. Moreover, it’s fairly clear that the presence of relatively high stresses in the component can accelerate these processes, although there have been very few research studies in which mechanical loads have been applied in combination with the presence of sulphur-containing gas and sodium salts. This project will involve usage of a recently-commissioned facility in which Ni-based superalloy (CMSX-4) single crystal samples (pre-coated with NaCl) are subjected to 4-point bending within a high temperature, environmentally-controlled chamber in which the SO₂ and SO₃ levels are held at predetermined levels. By examining microstructural development in different parts of the surface of a sample, study can be made of the effect of stress level (both tensile and compressive) for a given temperature and gas composition. Both the sample stiffness and the optical appearance of the sample surface are monitored in situ. It has already been observed that deep pits and cracks can form, with the γ/γ’ structure being chemically attacked in the vicinity of the tip, and that the nature of applied stress has a significant influence on such developments. The objective of the project will be to explore such phenomena, checking on the phases formed and the influence of the applied stress on the development of cracks and pits under these conditions.

References


URL for further information: http://www.ccg.msm.cam.ac.uk
11. Research Group: Inorganic Microstructures and Atomistic Simulation Groups (Knowles and Bristowe)

Number of placements available: 1
Period of placement(s): 8 weeks flexible

Outline of project(s): Atomistic modelling of twinning modes in alpha-uranium

The stable form of uranium at room temperature, alpha-uranium, has a variety of observed deformation twinning modes. The most detailed analysis of these modes was carried out some years ago by Alan Crocker (J. Nuclear Materials, 16, 306-326 (1965)). Its orthorhombic crystal structure is derived from that of the h.c.p. crystal structure. It is likely that the observed deformation twinning modes arise because of the relative low energy of the twin boundaries formed, and the presumed relatively simple shuffles necessary to bring one twin into registry with the other.

With the advent of robust interatomic potentials to describe the interatomic interactions in alpha-uranium published by Smirnova et al., J. Phys. Condens. Matter, 24, 015072 (2012) and by Li et al., J. Phys. Condens. Matter, 24, 235403 (2012), it is now possible to examine the deformation twinning modes in alpha-uranium using atomistic simulations. Therefore, in this project, atomistic simulations will be made of possible twin configurations in this phase for different twinning modes, with the aim of establishing on a quantitative basis what twin modes are likely to be favoured, and why. This CaMPUS project will follow on from a 2014-2015 Part III project and is suitable for a student who has finished Part II Materials Science and Metallurgy and is intending to read Part III. Using a suitable simulation code, relaxation of initial starting configurations using molecular dynamics and calculation of the boundary energies using the newly developed interatomic potentials for alpha-uranium will be undertaken. The calculations can be undertaken on a PC.

URL for further information: http://www.msm.cam.ac.uk/kmk10 and http://www.asg.msm.cam.ac.uk

Contact: Dr Kevin Knowles (kmk10@cam.ac.uk) or Dr Paul Bristowe (pdb1000@cam.ac.uk)

12. Research Group: Inorganic Microstructures Group (Knowles)

Number of placements available: 1
Period of placement(s): 8 weeks flexible

Outline of project(s): Microstructural aspects of salt glazing

In the technique of salt glazing used in pottery, a glaze is produced on the surface of a pot by adding salt into the chamber of a hot kiln. The salt reacts with both alumina and silica in the clay body to produce a low melting point sodium aluminosilicate which is able to create a thin transparent glaze on the pot. Coloured slips washed over the clay body of a pot prior to salt glazing enhance the salt glazed effect. Once used extensively for ceramic sewer pipes, salt glazing is now only found in niche markets in stoneware and pottery.

A remarkable feature of salt glazing is the relative lack of scientific knowledge about the salt glaze process. Previous summer project work and 2014-2015 Part III project work in this Department of the glazes by optical microscopy and X-ray diffraction has shown extensive crazing and crystallisation in salt glazes, both readily apparent in the SEM.

The aim of this CaMPUS project will be to continue this work by examining further samples of salt glaze by SEM and XRD to ascertain the nature of the crystals clearly visible within the glaze, as well as gaining a firm
scientific understanding of the factors determining the characteristic length scale of the ‘orange peel’
texture often seen on salt glazed pottery.

URL for further information: http://www.msm.cam.ac.uk/kmk10

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13. Research Group: Microstructural Kinetics Group (Greer)
Number of placements available: 1
Period of placement(s): 8 weeks flexible
Outline of project(s): Designer materials (Databases for amorphous materials)
Demonstrator: Jonathan Bean (jb2191@cam.ac.uk)

Metallic glasses (MGs) are usually formed from rapid cooling from the liquid. The cooling is so rapid that
the random structure of the liquid is frozen in. MGs are an interesting class of materials which have
received significant attention due to their interesting properties. (see video below)

https://www.youtube.com/watch?v=Evji4_VUmo

MGs are already in use in sports equipment, transformers and more but have the potential to be used
more widely in different applications.

Computationally, the modelling of MGs and in general amorphous materials is significantly more
challenging than modelling crystalline materials for two main but linked reasons. The first is that the
simulations cells required to represent a glass are significantly larger than their crystalline counterparts
meaning that the computational complexity and degrees of freedom is much larger. The large
computational complexity means that we need bigger and bigger computers to model even comparatively
simple glasses. Second is that the materials do not contain any obvious long range order/ periodicity hence
symmetry operations cannot easily be applied to reduce the computational complexity and increase
throughput of calculations.

An emerging theme in computational materials science is to store the results of calculations in large
databases for other scientists to use. It means that large calculations do not need to be repeated when a
study is started and serves as a digital archive. This has had remarkable success in crystalline materials with
projects such as “Materials project, NOMAD and Aflowlib” etc. However no comprehensive database for
amorphous materials exists. At Cambridge an effort to develop this has been initiated to serve as a catalyst
in the development of MGs.

In this project the goal is to develop a database for amorphous materials by performing molecular
dynamics calculations, ab-initio calculations, creating of MGs from experimental data and replicating data
from the academic literature.

This project requires a good understanding of atomic physics and understanding of programming languages
such as C or python.

The student will learn how to perform molecular dynamics simulations, ab-initio calculations, visualisation
of molecular structures, machine learning and big data.

Depending on the interests of the student the scope of the project can be widened to explore interesting
other novel areas such as developing grain growth models for amorphous materials, development of
interatomic potentials for MGs based on GAP (Machine learning) potentials or simulation of atomic deposition to create MGs. We are happy to talk about the project to any interested student.

Contact: Prof Lindsay Greer (alg13@cam.ac.uk) or Jonathan Bean (jb2191@cam.ac.uk)