MSRC2015/1 Quantum Dots for Enhanced Energy Harvesting and Storage
Supervisor: AP Vincent Gomes vincent.gomes@sydney.edu.au - School of Chemical and Biomolecular Engineering

Electrode materials are critical to energy harvesting and storage and their performance depend on two important factors: optimized composition and nanostructure.

Supercapacitors and catalysts are of great research interest due to their superior energy and power density. Pollution-free operation, high charge/discharge efficiency and cycle life make supercapacitors promising energy storage devices for high-power applications in portable electronics and electric vehicles.

The main objective of this project is to synthesize and characterize graphene-based composites and hybrid materials, and to test the fabricated nanocomposites for energy harvesting and storage applications.

MSRC2015/2 Novel composite nano-catalysts for CO₂ capture and conversion to valuable chemicals
Supervisor: Dr Jun Huang jun.huang@sydney.edu.au - School of Chemical & Biomolecular Engineering

Increased concerns about global warming and greenhouse gas emissions as well as the exhaustion of easily accessible fossil fuel resources are calling for effective carbon dioxide (CO₂) mitigation technologies and clean and renewable energy sources. CO₂ makes up 68% of the estimated total greenhouse gas emissions. Given the relatively high dependence of Australia on high carbon intensity electrical generation processes, the removal of CO₂ from the emission is of paramount importance in ensuring our commitment to preserving the environment. Current CO₂ storage techniques are the high-cost and low-benefit methods, which limit their application in the large scale.

This proposed research aims to develop a combined capture/catalysis process for CO₂ selective separation from flue gas of coal-fired power plants and further conversion with hydrocarbons to produce valuable syngas, as syngas is a versatile building block in the chemical industry. New classes of novel microstructured composite catalysts will be developed in the project. The promising catalysts and their catalytic performances will be studied to optimise the process conditions. We will use this to devise practical routes for the CO₂ capture and conversion to valuable chemicals, which will dramatically improve the sustainability and economic benefit of the greenhouse gas control.

MSRC2015/3 Erosion Wear of Polymer Based Materials
Supervisor: Dr Li Chang li.chang@sydney.edu.au - School of Aerospace, Mechanical and Mechatronic Engineering

Solid particle erosion is a dynamic process which causes material removal from a target surface due to impingement of fast moving solid particles. The process may cause wear of components, surface roughening, surface degradation, macroscopic scooping appearance, and reduction in functional life of the structure. Polymer composite materials are finding increased application under conditions in which they may be subjected to solid particle erosion at applications such as pipe lines carrying sand slurries in petroleum refining, helicopter rotor blades, pump impeller blades, high-speed vehicles, nozzles in cold spray technology, and aircrafts operating in desert environments. The project will study the solid particle erosion behavior of polymer based materials including fiber-reinforced polymer composites using silica sand particles as erodents. Wear mechanism analysis will be carried out by high resolution scanning electron microscopy depending on the impingement angles.
and the CFs orientation. All materials will also be characterized with regard to their basic mechanical performance, and their resistance against abrasion and scratch loading.

Potential Industry Partners:


**MSRC2015/4 Characterizing the Mechanical Properties of Thin Films/Coatings**  
**Supervisor:** Dr Li Chang li.chang@sydney.edu.au - School of Aerospace, Mechanical and Mechatronic Engineering

Thin films/coatings have been widely applied in medical implant [4, 5], semiconductor [6], solar cell [7, 8], and micro-electro-mechanical systems (MEMS) [9], where the films can protect the substrate by increasing the wear and corrosion resistance and other surface functional properties. However, it remains a challenging task to determine the failure properties of thin films such as the fracture toughness and the bonding strength, which consequently cause difficulties and sometime confusions in assessing and designing thin film/coating structures. This project aims to understand and characterise the failure behaviour of thin film/substrate systems by using nano-technology including nano-indentations and a novel cutting method. The work will deliver the necessary experimental data and the basic science for determining the fracture and debonding energy of thin films.

Potential Industrial Partners:

- NKOTE: http://www.nukoteaustralia.net.au/

**MSRC2015/5 Hydromechanics of soft degradable porous materials: from rice bubbles to bones towards design of new materials.**  
**Supervisor:** Prof Itai Einav itai.einav@sydney.edu.au – School of Civil Engineering

Recent work at the School of Civil Engineering has led to the discovery of novel formation of pattern in compressed soft brittle porous media, which have implications on our understanding of the mechanics of wide range of materials, including dry snow, cereals, rocks and bones. These materials are often submerged in interfacial pore fluids, which introduce hydromechanical degrading effects. The purpose of this project will be to discover new emerging patterns in such poorly studied scenarios. Once unraveled and explained, and perhaps controlled, the emergence of the new patterns could be tuned for design of new breed of topological materials.

**MSRC2015/6 Entangled fibres in cement mixing**  
**Supervisor:** Prof Itai Einav itai.einav@sydney.edu.au and Dr Benjy Marks benjy.marks@sydney.edu.au - School of Civil Engineering

Fibre reinforced concrete is difficult to keep well mixed. Often, during transport, fibres become entangled and as a result concrete quality is reduced. This project will involve construction and operation of a small scale laboratory analog experiment, where we can observe this effect in a model material.

**MSRC2015/7 The properties of pouring – designing pharmaceutical tablets using targeted segregation**  
**Supervisor:** Prof Itai Einav itai.einav@sydney.edu.au, Dr Benjy Marks benjy.marks@sydney.edu.au and Dr Milica Vukicevic milica.vukicevic@sydney.edu.au - School of Civil Engineering

When pharmaceutical tablets are produced, a mixture of the active ingredient and excipients are compressed to form the tablet. By changing the pouring method, we can alter how the
The active ingredient is arranged inside the tablet. This project will be a pilot study into tailoring the dissolution rate of tablets by altering the pouring method and excipient size.

**MSRC2015/8 The development and operation of a slurry pot wear tester (with the industrial partner Weir minerals).**  
**Supervisor:** Prof Julie Cairney julie.cairney@sydney.edu.au - School of Aerospace, Mechanical and Mechatronic Engineering

Our industry partner, Weir Minerals, produce metal parts for the minerals processing industry. We are working with them to produce new alloys that have very high wear resistance and last up to three times as longer than their previous product, and can lead to longer-lasting parts. This is critical for the mining sector, as instrument down time for replacement of parts can cost many millions of dollars per day in lost production.

A challenge we have for this research is that current test methods for assessing the wear properties of materials does not adequately simulate wear in practical applications such as the mining industry. The student on this project would modifying an existing design for a wear tester that moves samples through an abrasive slurry. They would then build the equipment and assess the performance on a range of metals.

**MSRC2015/9 Enabling 3D imaging at the atomic scale**  
**Supervisor:** Prof Julie Cairney julie.cairney@sydney.edu.au - School of Aerospace, Mechanical and Mechatronic Engineering

Atom probe tomography is a powerful microscopy technique that provides 3D maps showing the location and species of the individual atoms with a small volume of matter. It involves the preparation of a needle-shaped specimen, which allows the atoms extracted from the tip via field evaporation. Metallic needles can be prepared by chemical processes, but preparing needles from other types of materials, or from specific areas within a sample is far more challenging. Focused ion beams can be used, but this takes enormous expertise, with many months of practice required before specimens can be successfully prepared. Here in Sydney, we have developed a new approach that involves using a far less complex broad ion beam. The student will check the viability of this process and refine it. They will gain experience in a professional research lab, working with high end research infrastructure. This work could lead to an honours or PhD research project.

**MSRC2015/10 The development of new high-porosity food powders by spray drying and post-processing: Addressing the scale-up challenge**  
**Supervisor:** Prof Timothy Langrish timothy.langrish@sydney.edu.au - School of Chemical & Biomolecular Engineering

This Project will develop new methods for creating highly-porous food powders, particularly those containing lactose. A key gap will be addressed in producing these highly-porous food powders at greater scale, where previous high-porosity powders have involved materials that are toxic for foods, and previously food materials have had low porosities. Achieving these aims will give new insights into particle engineering and produce food particles with high porosity for food infusions and drug delivery. With the understanding of the feasibility of this approach, as demonstrated by preliminary work in Saffari *et al.* (2014) and Ebrahimi *et al.* (2014, 2015), critical background knowledge has been established for this Project to deliver such improved particle processing outcomes with strong economic benefits.

What is considered to be a high surface area depends significantly on the field of application; high-surface area porous carbons have been quoted as having specific surface areas of over 3000 m$^2$/g (Masiika and Mokaya, 2012), while spray-dried amorphous lactose has a specific surface area of around 0.18 m$^2$/g (Grigorov *et al*., 2013). For the impregnation of pharmaceutical ingredients, dibasic calcium phosphate has a specific surface area of 15 m$^2$/g (Grigorov *et al*., 2013).
Current approaches to producing high surface-area particles include the use of templating techniques, where one component is selectively removed from a multicomponent mixture. The dominant method for producing porous inorganic particles by spray drying appears to be the use of aqueous solutions containing the main (core) material with a templating agent that is removed by heat treatment, including calcination. The templates have included polystyrene (Balgis et al., 2012; Liu et al., 2011; Lee et al., 2010; Nandiyanto et al., 2013; Zhang et al., 2010) and other polymers (Jang et al., 2013; Majano et al., 2012; Oveisi et al., 2010; Sachse et al., 2012), E. coli (Melo et al., 2013) and lanthanum nitrate (Emmanuelawati et al., 2013). In some cases, sulphuric acid has been used to remove a copolymer template, as by Fiorilli et al. (2013).

We have recently demonstrated preliminary evidence that highly-porous food powders, using lactose as the basic material, can be created by spray drying a main material (lactose, mannitol) with 1-2% (w/w) of a templating additive, such as citric acid. The material has then been post-processed by removing the templating additive with ethanol to simultaneously create a highly-porous lactose powder and crystallize the lactose, thereby stabilizing the powder structure. The resulting particles of lactose (Ebrahimi et al., 2014) and mannitol (Saffari et al., 2014) have surface areas of over 28 m²/g (lactose) and 8 m²/g (mannitol). The process is illustrated schematically in Figure 1.

**MSRC2015/11 Image processing techniques for monitoring laboratory tests on small scale specimens**

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We are currently pushing the boundaries of material science, with new materials being engineered and introduced in industry at a fast pace. The assessment of the properties of these new materials, however, requires advanced experimental set-ups specifically tailored to gain a deep insight of the material response. In this scope, image processing techniques are becoming increasingly popular due to the high-resolution real-time measurements that are possible. However, one of the challenges is the measurement of extremely small strains during such tests. This project aims at investigating the applicability of digital image correlation systems for monitoring the behaviour of small scale specimens, such as steel and magnesium alloys processed through high-pressure torsion, and to develop specific procedures to analyse and extract meaningful data.

This project will involve programming using Matlab so it would be better for the student to have some previous knowledge of the software or at least some programming experience and interest.

**MSRC2015/12 Non-destructive techniques for detecting superficial damage**

*Supervisor: Dr Daniel Dias-da-Costa [daniel.diasdacosta@sydney.edu.au](mailto:daniel.diasdacosta@sydney.edu.au) - School of Civil Engineering*

There are currently many non-destructive techniques available for assessing and measuring different features in existing structures. In particular, thermal variations occurring at the surface of a structure during the day, or even acoustic or ultrasonic measurements, can be quite valuable tools for detecting potential damage. In this project, the student is expected to propose an experimental set-up using thermography and to devise processing algorithms for identifying/quantifying superficial damage. Particular focus will be given to the detection of concrete spalling or detachment of claddings.

This project will involve programming (e.g. using Matlab), so it would be better for the student to have some previous knowledge and programming experience/interest.

**MSRC2015/13 Simulation of permeability in fractured materials**

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This project focuses on the development of a numerical approach for simulating the permeability of fractured materials. The student will develop a formulation using finite elements with embedded cracks. The impact of different crack arrangements on the ingress of chemical agents in structural members will be tested. Different examples will be used for assessing the accuracy of the technique.

This project will involve programming (e.g. using Matlab), so it would be better for the student to have some previous knowledge and programming experience/interest.

**MSRC2015/14 Electrical conduction of binary granular materials**

**Supervisors:** Dr Gwenaelle Proust gwenaelle.proust@sydney.edu.au, Dr Yixiang Gan yixiang.gan@sydney.edu.au and AP Ali Abbas ali.abbas@sydney.edu.au – School of Civil Engineering and School of Chemical and Biomolecular Engineering.

This project focuses on establishing an experimental capability to quantify transport phenomena in granular materials and bridge between experiments and numerical modelling efforts. We will couple experiments and computations to investigate electro-mechanical properties in granular structures. Towards understanding the complex interplay among multiple physical fields, we will use the electrical measurement system with the combination of mechanical loading. Model materials, a combination of conductive and non-conductive grains, will be subjected to different surface modification techniques to achieve a desirable range of surface structures. Moreover, sizes of grains will be changed to cover a wide range of roughness-to-grain size ratios, where the influence of the surface can be alternated. We will use a composition of grains with electrical conductive and nonconductive properties to form a binary granular system. We will study percolation processes with different mixing ratios (grain sizes and volume ratios), and under changing stress conditions.