Overview

The Particulate Fluids Processing Centre (PFPC) is a Special Research Centre of the Australian Research Council (ARC) based at the University of Melbourne, Australia. The PFPC explores interfacial science and engineering for the processing of particulate fluids and advanced materials. The PFPC brings together scientists and engineers across the Department of Chemical and Biomolecular Engineering and the Schools of Mathematics & Statistics and Chemistry to form one of the world’s leading multidisciplinary research centres in interfacial science and engineering.

Mission statement

“To perform basic science in nano and colloid chemistry and interfacial continuum mechanics all set within a process engineering framework.”

Strategic objective

“Development, in Australia, of scientific and engineering expertise and personnel that will ensure that value added advanced particulate fluid and material products are produced from Australian resources.”

Front Cover: Emulsion droplet collision (foreground) using a multi-scale interface-capturing method: droplet-scale dynamics have been simulated using a volume of fluid (VOF) method, while the detail of the thin separating film is resolved using a coupled lubrication model. Fully predictive models of emulsion coalescence are required in the design and optimisation of solvent extraction columns (background).

Image by: Lachlan Mason (PhD student)
# Particulate Fluids Processing Centre

## 2015 Annual Report

### Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Director’s Report</td>
<td>2</td>
</tr>
<tr>
<td>Management Structure and Personnel</td>
<td>4</td>
</tr>
<tr>
<td>Research Program Highlights</td>
<td>7</td>
</tr>
<tr>
<td>Liquid-Liquid Systems</td>
<td></td>
</tr>
<tr>
<td>Sorption at Liquid-Liquid Interfaces</td>
<td>8</td>
</tr>
<tr>
<td>Ultrasonics</td>
<td>12</td>
</tr>
<tr>
<td>Emulsion Behaviour</td>
<td>14</td>
</tr>
<tr>
<td>Surfactant and Polymer Structure in Solution</td>
<td>16</td>
</tr>
<tr>
<td>Solid-Liquid Systems</td>
<td>19</td>
</tr>
<tr>
<td>Minerals - Processing and Materials</td>
<td>20</td>
</tr>
<tr>
<td>Controlled Porous Structures</td>
<td>22</td>
</tr>
<tr>
<td>Suspension Rheology</td>
<td>36</td>
</tr>
<tr>
<td>Surface Forces and Spectroscopy</td>
<td>40</td>
</tr>
<tr>
<td>Education and Training</td>
<td>44</td>
</tr>
<tr>
<td>Students</td>
<td>45</td>
</tr>
<tr>
<td>Seminar Series</td>
<td>50</td>
</tr>
<tr>
<td>Awards and Achievements</td>
<td>52</td>
</tr>
<tr>
<td>Networks</td>
<td>57</td>
</tr>
<tr>
<td>Presentations</td>
<td>64</td>
</tr>
<tr>
<td>Publications</td>
<td>70</td>
</tr>
<tr>
<td>Research Funding</td>
<td>78</td>
</tr>
<tr>
<td>Financial Statement</td>
<td>87</td>
</tr>
<tr>
<td>Research Facilities</td>
<td>88</td>
</tr>
</tbody>
</table>
Director’s Report
The Particulate Fluids Processing Centre (PFPC), a Special Research Centre of the Australian Research Council, is the pre-eminent centre for interfacial science and engineering in Australia focusing primarily on basic science and the engineering applications of interfaces at the mesoscale level. We like to think of the PFPC as the hub that supplies key science and knowledge working intimately with a variety of important applied research centres and associated companies that add value to advanced particulate fluid and material products that are produced from Australian resources; these are our spokes (see image to the right illustrating the largest entities). Most important, they are our ‘market’ face to the world and allow the large variety of researchers in the PFPC to simultaneously engage in both basic and applied research in an innovation environment that continually tests our true state of knowledge. We cover a wide range of application areas of relevance to Australia including health, food, pharmaceuticals, secure supply of water and energy (and the environmental implications of these), environmental cleanup, and mining and metallurgy. The problems that arise from these applications stimulate our scientists, engineers and students, and help to drive the directions of our research.

Our research has always been aligned to two key program areas, liquid-liquid and solid-liquid interfaces. In the last couple of years there has been a strong shift to incorporate a materials development focus to go with the solid-liquid and liquid-liquid process engineering aspects of interfacial science and engineering. Our front cover this year is an example of our more traditional research around the liquid-liquid interfaces theme. The work is from one of our PhD students (Lachlan Mason), supervised by Dr Dalton Harvie, and fits well with our expertise in the use of modelling to understand real process outcomes.

I was humbled to take over the Directorship of the PFPC from Professor Geoff Stevens in early 2015. We honoured the contributions that Geoff has made to the PFPC as Director over the past ten years and to the the science and engineering of interfaces with a conference/workshop in September 2015. A wide range of current PFPC staff, students, collaborators and alumni were present and reflected the great esteem that Geoff has generated. We also welcomed Drs Greg Martin, Daniel Heath and Luke Connal, along with their research groups, into the PFPC.

I would like to congratulate Frank Caruso on being appointed a Melbourne Laureate Professor as well as Professor George Franks and Dr Carolina Tallon who were part of the Defence Materials Technology Centre team (including CSIRO, Swinburne University of Technology, the Victorian Centre for Advanced Materials Manufacturing (VCAMM), and Australian Defence Apparel) that won the CRC Award for Excellence in Innovation 2015. Tom Healy was also recognised with a plaque on Professors Walk at the University of Melbourne, acknowledging staff members who have made a significant contribution to the life of the University. Dr Biao Kong received the Chinese Government award of Academic Star in Victoria for 2014 and Dr Anthony Stickland the Carlton Connect Initiative Research Impact Award for his presentation “High pressure dewatering rolls.” Our postgraduate students also excelled with Hannah Alcantara, Mattias Bjørnmalm, Emma Brisson, Enrico Colombo, Wu-Qiang Wu, Qiong (Ada) Dai, Tessa Evans, Ben Freidman, Junling Guo, Steven Harris Wibowo, Shu Lam, Edward Nagul, Mitchell Nothling, Rohit Pillai, Danzi Song, Leonie van ’t Hag, Samuel Skinner, Wei Sung Ng, Kezia Kezia, Armineh Hassanvand and Yue (Frank) Wu all winning prizes and awards or being recognized for their research. Many of these awards were for research presentations, highlighting a critical element of the PFPC training that is mentored through our fortnightly seminar series.

**Performance Highlights**

**Research Outcomes**

PFPC researchers continued to be very prolific in publishing their research with 233 refereed publications during 2015. These publications included 1 edited book, 1 book chapter, 222 refereed journal articles and 9 international refereed conference papers. Our researchers have a high profile at national and international conferences with over 147 conference and meeting presentations given throughout the year. Ten of these presentations were plenary or keynote lectures. The Centre’s national and international network remains strong. In 2015, 67% of publications involved either national or international collaboration (i.e. collaboration with researchers outside of the PFPC). The Annual Report also highlights the editorial board appointments and editorial roles that our staff contribute. Our researchers received $9 million in nationally competitive peer reviewed project grants including those from the Australian Research Council and other Commonwealth bodies as well as State funding.

**Education and Training**

In 2015, 28 students graduated and 24 new students started, bringing the total of postgraduate students conducting research across the Centre to 168. A key objective of the Centre is to attract the very best students and a significant proportion of our students attract competitive scholarships such as Australian Postgraduate Awards that cover stipends and tuition fees. This represents an additional unlisted income to the Centre of about $4.5 million during the year. Throughout the year the Centre had 50 postdoctoral researchers in residence. Approximately 10% of these postdoctoral researchers were funding their own positions through fellowships that they had obtained, for example, from the Australian Research Council. Without doubt our major strength is the people associated with the Centre. Our academics and research fellows have enormous enthusiasm for undertaking cutting-edge research. This enthusiasm engages the many students working with them in the Centre.

The PFPC is supported in its administration by the University of Melbourne and has maintained its mission of excellence in basic science in support of industry and joint cross disciplinary research initiatives both in Australia and around the world. I thank the University for their continued support. My focus for the next year will be to further enhance our international collaborations through a focus on PhD student exchange and a continued focus on the industrial relevance and impact of our research.

Professor Peter Scales
Management Structure and Personnel

Director

Centre Manager
Administrative Assistant

Executive Committee

Senior Industrial Fellows

Scientific Research and Teaching Programs

Liquid-Liquid Systems
Solid Liquid Systems

Sorption of Liquid-Liquid Interfaces
Ultrasound
Emulsion Behaviour
Surfactant & Polymer Structure in Solution
Minerals-Processing & Materials
Controlled Porous Structures
Suspension Rheology
Surface Forces & Spectroscopy
Executive Committee
The Executive meets on a fortnightly basis to discuss the administration and management of the Centre. Issues discussed at the Executive meetings throughout 2015 included planning related to the Centre’s research directions, new research appointments and research funding applications. In 2015 the Executive Members were:

Professor Peter Scales  
BSc(Hons), PhD, FIChemE, FEA  
Director

Professor Franz Grieser  
BSc, PhD, FRACI, FAA  
Solid-Liquid Systems Program Leader

Professor Muthupandian Ashokkumar  
BSc, MSc, PhD  
Professor Frank Caruso  
BSc(Hons), PhD, FRACI, FAA  
Professor Raymond Dagastine  
PhD

Dr Michelle de Silva  
BSc(Hons), PhD  
Centre Manager

Professor George Franks  
SB, PhD  
Professor Sandra Kentish  
BE, MEngSci, PhD  
Professor Paul Webley  
PhD  
Professor Neil Furlong  
BSc(Hons), PhD Brunel, DEng(Hon), FTSEr  
Professor Geoffrey Stevens  
BE(Chem), PhD, FTSE, FIChemE, FAusIMM  
Professor David Boger  
BS(ChemEng), MS(ChemEng), PhD, DE(Hon), FAA, FTSE, FRS  
Professor Tom Healy  
MSc, PhD, DSc(Hon), LLD(Hon), FRACI, FAA, FTSE, AO

Senior Industrial Fellows
The Centre’s Senior Industrial Fellows are appointed to provide specialist industrial advice to members of the PFPC. The role is varied for each Senior Industrial Fellow and may include participation in collaborative research projects, co-supervision of students, access to the Centre’s extensive infrastructure and a residency term in the Centre. In 2014 the following were appointed as Senior Industrial Fellows to the Centre:

Professor Robin J. Batterham, AO  
Kernot Professor of Engineering, The University of Melbourne, Australia

Professor John Burgess  
Principal, Niche Tasks, Australia

Dr Mark Coghill  
Principal Technologist, Rio Tinto Limited, Australia

Dr David Dixon  
Contractor, Victoria, Australia

Dr Rob Eldridge  
Contractor, Victoria, Australia

Dr Anita Hill  
Executive Director, Future Industries, CSIRO, Australia

Professor Jannie J.S. van Deventer  
Professorial Fellow, The University of Melbourne, Australia  
CEO Zeobond Group, Australia

Dr David Yates  
Principal, Yates Technical Services Pty Ltd, Australia
Centre Membership

Centre Manager
Dr Michelle de Silva

Centre Administrative Assistant
Tabitha Cesnak

Research and Teaching Staff
Professor Muthupandian Ashokkumar
Professor David Boger
Associate Professor Steven Carnie
Professor Frank Caruso
Associate Professor Rachel Caruso
Professor Derek Chan
Dr Luke Connal
Professor Raymond Dagastine
Professor David Dunstan
Professor George Franks
Associate Professor Sally Gras
Professor Franz Grieser
Dr Dalton Harvie
Professor Tom Healy
Dr Daniel Heath
Professor Sandra Kentish
Professor Spas Kolev
Professor Rob Lamb
Dr Gregory Martin
Dr Kathryn Mumford
Associate Professor Andrea O'Connor
Professor Greg Qiao
Professor Peter Scales
Dr Colin Scholes
Professor Geoff Stevens
Dr Anthony Stickland
Professor Antoinette Tordesillas
Professor Paul Webley

Research Fellows
Dr Ines Almeida
Dr Joseph Berry
Dr Nadja Bertleff
Dr Tejas Bhatelia
Dr Julia Braunger
Dr Francesca Cavalieri
Dr Dehong Chen
Dr George Chen
Dr Christina Cortez-Jugo
Dr Jiwei Cui
Dr Yunlu Dai
Dr Augustine Doronila
Dr Xiaofei Duan
Dr Qiang Fu
Dr Paul Gurr
Dr Fatin Hasan
Dr Shinji Kanehashi
Dr Biao Kong
Dr Konrad Krysiak-Baltyn
Dr Katharina Ladewig
Dr Judy Lee
Dr Thomas Leong
Dr Andy Leung
Dr Xu Li
Dr Liang Liu
Dr Srinivas Mettu
Dr Markus Müllner
Dr Nathan Nicholas
Dr Lydia Ong
Dr Jilska Perera
Dr Emma Prime
Dr Jing Ming Ren
Dr Eve Revalor
Dr Jin Shang
Dr Ranjeet Singh
Dr Kathryn Smith
Dr Georgina Such
Dr Huanli Sun
Dr Qiang Sun
Dr Carolina Tallon
Dr Shane Usher
Dr Huabin Wang
Dr Yong Wang
Dr Edgar Hoe Hon Wong
Dr Alex Wu
Dr Yuezhu (Penny) Xiao
Dr Zeyun Xiao
Dr Yan (Annie) Yan
Dr Yanlin Zhang
Dr Meifang Zhou

Research Support Staff
Alita Aguiar
Paul Brannon
Raul Cavalida
Liz Goodall
James Griffith
Benjamin Hibbs
Dr Lauren Hyde
Indrawan Indrawan
Laura Jukes
Adrian Knight
Dr Phoebe Macdougall
Patrick Mornane
Marta Redrado Notivoli
Joseph Richardson
Dr Matthew Rowles
Dr Catherine Sutton
Blaise Tardy
Jenny Tran
Ross Wylie

Postgraduate Students
See pp 45-49

Centre Membership
Research Program Highlights

Liquid-Liquid Systems

The Liquid-Liquid program addresses experimental and theoretical problems, with respect to interfaces under static and dynamic conditions. It is practically divided into four theme areas, namely:

• Sorption at Liquid-Liquid Interfaces
• Ultrasonics
• Emulsion Behaviour
• Surfactant and Polymer Structure in Solution
**Sorption at Liquid-Liquid Interfaces**

**Research Staff**
Associate Professor Steven Carnie
Dr Dalton Harvie
Professor Sandra Kentish
Professor Spas Kolev
Dr Kathryn Mumford
Professor Geoff Stevens
Professor Paul Webley
Dr Ines Almeida
Dr George Chen
Dr Augustine Doronila
Dr Fatin Hasan
Dr Judy Lee
Dr Jilska Perera
Dr Kathryn Smith
Dr Yong Wang
Dr Penny Xiao
Dr Yanlin Zhang
Patrick Mornane

**Research Students**
Hannah Alcantara
Suhaib Ali
Chelsea Bassett
Mandana Ershad
Teobaldo Grabin
Armineh Hassanvand
Kezia Kezia
B. Manori Jayawardane
Wen Li
Zheng Li
Lachlan Mason
Edward Nagul
Yukie O’Bryan
Lenka O’Connor Sraj
Karolina Petkovic-Duran
James Quinn
Adlin Ramdzan
Colin Specht
Jessica Vovers
Fan Wu
Gordon Yi

**Project Updates**

**Onboard synthesis of dimethyl ether from methanol**
Suhaib Ali, Fatin Hasan, Paul Webley

Both from global as well as Australian perspectives on energy security and environmental conservation dimethyl ether (DME) provides a viable alternative to diesel. Australia, in particular, is heavily dependent on diesel as its strategic fuel in almost all economically crucial sectors i.e. transportation, industrial, agricultural and mining. DME is an excellent fuel for compression ignition (CI) engines (hence a replacement for diesel) due to its high cetane number, low ignition temperature, attractive spray characteristic and reduced particulate matter (PM) formation during combustion. However, the distribution and storage of DME is challenging.

DME is produced through catalytic dehydration of methanol. This work proposes a novel approach of on-board conversion of methanol into DME, immediately prior to combustion. This approach combines the advantage of storage characteristics (i.e. better gravimetric density) of methanol with the combustion properties of DME. To achieve this, careful integration of a dehydration reactor, the engine, and the exhaust gas manifold is required.

This model integrates a reactor operating in an unsteady mode, a CI engine operating on a feed whose composition changes in response to the fuel demand of the engine, and a system of exhaust gas treatment that supplies heat to the reactor and treats a gas stream with a constantly varying composition. At present the modified reactor has been designed and commissioned. The experimental rig set up is in completion.
Detection of metal ions in environmental waters with microfluidic paper based analytical devices

Chelsea Bassett, Ian McKelvie, Raquel Mesquita, Spas Kolev

Microfluidic paper-based analytical devices (µ-PADs) have, in recent years, provided a novel approach for conducting inexpensive, onsite analyte determination which is easily used by untrained operators. The small dimensions, minimal reagent/sample consumption, low cost, ease of operation and favourable analytical performance make these µ-PADs attractive for rapid onsite analysis in many fields. The cellulose fibres of the filter paper form a hydrophilic, porous matrix which allows fluid transport only through capillary forces (i.e. no need of a potentially expensive external pump). Hydrophobising the paper allows the control of the fluid transport through desired reagent and detection zones. Colourimetric reactions are employed as the analyte concentration can be directly related to the colour intensity which can be easily measured using a flatbed scanner and computer software (i.e. ImageJ). This work aims to develop accurate µ-PADs for the rapid determination of Ni(II), Fe(III) and Al(III) which can be used for their monitoring in environmental waters. This project also aims to provide proof of concept for an atypical non-printed µ-PAD design.

Stability and selectivity of Polymer Inclusion Membranes (PIMs) containing dinonylnaphthalene sulfonic acid (DNNS)

Mandana Ershad, Ines Almeida, Robert Cattall, Spas Kolev

Polymer Inclusion Membranes (PIMs) are polymer-based liquid membranes, capable of both extraction and back-extraction of ionic species in a single step, requiring little consumption of usually expensive extractants and toxic organic diluents. Therefore, they are viewed as a promising and greener alternative to traditional solvent extraction. PIMs are usually composed of an extractant (carrier), a base polymer and a plasticizer or modifier (if necessary), and they generally demonstrate superior stability in comparison with other liquid membranes (e.g. supported liquid membranes).

The extractant is responsible for binding with the species of interest and transporting it across the PIM. In this study dinonylnaphthalene sulfonic acid (DNNS), a commercially available acidic carrier, has been chosen due to its cationic-exchange properties and high selectivity towards ions of environmental interest (e.g. ammonium, zinc). This extractant is normally supplied as a 50% solution in 2-butoxyethanol, which is soluble in water. As a result, the stability of DNNS-based PIMs is likely to be compromised. Therefore, it can be expected membrane stability can be improved if commercial DNNS is purified before use in order to eliminate 2-butoxyethanol. Hence, the aim of the present work consists of a comparison study of the stability of PIMs prepared with commercial and purified DNNS, using ammonium as a model analyte. The preparation of stable DNNS-based PIMs will then allow the determination of their selectivity towards a wide range of chemical species of environmental concern.

Capacitive deionisation as a novel approach to wastewater treatment

Armineh Hassanvand, George Chen, Paul Webley, Sandra Kentish

Capacitive deionisation (CDI) is an energy-efficient and promising electrochemical desalination technology, especially for low salinity brackish water. In CDI, ions are adsorbed onto the surface of porous carbon electrodes by an electrosorption process. As a result, while the concentration of the ions in the water decreases, that of the electrodes increases. After a period of operation, the capacity of the electrodes is reached and, in order to regenerate them, the cell voltage has to be reversed. In order to improve the performance, ion-exchange membranes (IEMs) are placed in front of the electrodes. This approach is called Membrane Capacitive Deionisation (MCDI).

Although CDI has attracted attention since the mid-1990s, there are still some unresolved issues that we aim to address in this work. Following construction of a bench scale membrane CDI unit, the treatment of different electrolyte solutions has been investigated both in single-salt and multi-salt experiments. The comparative electroosorption of various ions was studied using NaCl, KCl, CaCl₂, NaNO₃, and Na₂SO₄. It was found that the removal of monovalent ions follows similar patterns while that of divalent ions is noticeably different. Energy consumption, charge efficiency and pH fluctuation were compared and studied to clarify the effect of ion properties. As the next step, application of selective monovalent membranes will help us to further investigate the governing role of ion-exchange membranes.

Furthermore, as planned for this project, an ion transport model has been developed to predict the removal efficiency of the (M)CDI unit. The model has been validated using experimental data on NaCl treatment at different concentrations. This theoretical approach must now be expanded to encompass the removal of different ions with various ionic charges and hydrated radii, especially in a comparative condition. This technique will enable us to predict (M) CDI performance in the treatment of real brackish water samples.

Crystallisation and solubility study of calcium phosphate

Kezia Kezia, Judy Lee, Bogdan Zisu, Mike Weeks, Sandra Kentish

Reducing the discharge volume of industrial saline effluent is an issue of paramount environmental concern. Membrane filtration is one of the most versatile technologies for concentrating industrial saline effluent yet its performance, such as flow rate and fouling deposition, is greatly compromised with increasing solids concentration. With increasing concentrations, mineral precipitation and scaling become prominent problems initiated by the precipitation of calcium phosphate salts. Calcium phosphate is one of the most abundant calcium salts in any biological liquid, which can exhibit various calcium to phosphate ratios with significantly low solubility. In order to optimise the crystallisation process i.e. membrane performance, bulk precipitation is attempted to remove solid calcium phosphate salt. Ultrasound assisted crystallisation has been assessed to precipitate the high salinity concentrate stream produced by thermally driven
membrane distillation. It is shown that ultrasound can reduce the induction time and increase the reproducibility of experiments by narrowing the metastable zone. Nonetheless, the solid yield cannot be improved as it is primarily governed by the supersaturation level of the solution. To understand the precipitation behaviour of calcium phosphate, the solubility of calcium phosphate is currently being assessed in the presence of high salinity and trace amounts of impurities such as organic compounds and organic anions. The solubility of calcium phosphate increases with increasing ionic strength (up to 100 g/L NaCl) due to ionic activities. With respect to trace of organic compounds and organic anions, steady yet marginal increase of calcium phosphate solubility is observed in the presence of sugar. The calcium sequestering capacity of lactate and citrate has also been investigated. Precipitation of calcium phosphate is very complex and exhibits dynamic behaviour where the formation of the lowest solubility compound is shown to occur prior to the formation of most stable intermediate product. This study will provide a better understanding of calcium phosphate solubility in a mixture which could potentially assist in the mitigation of equipment fouling.

Solvent extraction column performance: Study of new internals for pulsed solvent extraction columns

Wen Li, Geoff Stevens, Kathryn Mumford, Kathryn Smith

Pulsed columns are used as high efficiency solvent extraction contactors in uranium recovery (Olympic Dam Operations, Australia) and for cobalt and nickel extraction (Goro Nickel, New Caledonia). The disc and doughnut shaped baffles (Bateman standard internals) improve the contact between two immiscible liquids and help with the processes with fast kinetics. This project aims to examine potential improvements to the internals and to develop internals that are applicable to slow kinetic systems. This research will study the effect of operating characteristics (flow rates, pulse frequency and pulse amplitude) on dispersed phase holdup, droplet size, mass transfer coefficient and axial dispersion coefficient. This work will quantify the improvement in column efficiency with the new column internals and also optimise the utilisation of pulsed columns in industrial applications. Currently, a 2 m high pulsed pilot-scale solvent extraction column has been designed and built for this research, and two liquid-liquid systems (fast and slow kinetics systems) will be tested with the applications of Bateman standard internals and new Bateman Pulsed Column Kinetics Internals (BPC-KIs).

Multi-scale interface-capturing methods for thin-film coalescence

Lachlan Mason, Geoff Stevens, Peter Witt, Dalton Harvie

Liquid-liquid extraction units are core separation systems in the metals, pharmaceutical and nuclear reprocessing industries. In Australia, extraction units are widely used for the separation of base metals and rare-earth elements from their leached ores. A throughput-limiting process is the efficient separation of raffinate and loaded organic phases via coalescence of dispersed droplets. New research findings are needed in order to quantify the physical and chemical regimes that favour coalescence, which will aid in the design and optimisation of hydrometallurgical processing equipment; with both economic and environmental benefits.

This project demonstrates the predictive power of multi-scale simulation methodologies, whereby droplet-scale interface-capturing techniques are coupled to a lubrication analysis of thin-film drainage. Following systematic validation with existing emulsion collision data, the modelling framework is used to discriminate between bouncing and coalescence outcomes due to diameter ratio variation in the presence of continuous-phase electrolytes.

Ultra-trace determination of orthophosphate using polymer inclusion membranes and flow injection analysis

Edward Nagul, Ian Mckelvie, Robert Cattrall, Spas Kolev

Orthophosphate is a primary nutrient, the monitoring of which is crucial in both maintaining the health of terrestrial waterways and understanding marine nutrient cycling. However, the standard molybdenum blue method for orthophosphate determination lacks the sensitivity to reliably determine marine orthophosphate concentrations without preconcentration, and such sample pretreatment methods are typically tedious and/or unsuitable for use in the field. Polymer inclusion membranes (PIMs) provide a cheap, environmentally friendly means of chemical extraction and back-extraction across a polymeric film impregnated with an extraction reagent, which are also amenable to use in automated analysis systems.

Recently, small-angle X-ray scattering (SAXS) experiments were carried out at the Australian Synchrotron in order to elucidate a) the nano-scale structure of these membranes, and b) the relationship between PIM composition and nanostructure. Current results suggest the existence of a nanometre-scale pore structure, to be confirmed using electron microscopy.

The main practical difficulty associated with using the molybdenum blue method for orthophosphate determination is the short lifetime of the reducing agents typically employed, which can range from several days down to only a few hours. The need for such a short-lived reducing agent has been eliminated by instead using a UV-induced photoreduction reaction to form the molybdenum blue product, using only ethanol or methanol as the reducing agent, in a flow injection analysis manifold. The sensitivity and precision of this optimised method are superior to others in the literature, and the reagent is stable for at least three months, raising the possibility of its use in autonomous monitoring applications.
Development of novel analytical devices for monitoring NH$_3$/NH$_4^+$ and pH in marine environments

Lenka O'Connor Sraj, Spas Kolev

The development of novel analytical devices for the monitoring and sensing of ammonia nitrogen and carbon dioxide related pH changes in marine environments is being investigated. Currently most water quality monitoring programs involve discrete and spot sampling, sample pre-treatment and subsequent laboratory analysis. Such analyses are typically expensive, laborious, impractical, and episodic pollution events may be missed. The objectives of this research project are to develop cheap, easy-to-use, and reliable monitoring and sensing devices including:

- a time-integrated passive sampling system that accumulates bioavailable NH$_3$/NH$_4^+$ from the marine environment into sampling devices, using novel membrane based technologies;
- paper based microfluidic pH sensors suitable for the determination of seawater pH;
- development of micro flow injection systems for in situ deployment and measurement of NH$_3$/NH$_4^+$ and seawater pH from marine samples.

Environmentally sustainable solvents for natural pharmaceutical extraction processes

Jessica Vovers, Yuka Kobayashi, Kathryn Smith, Geoff Stevens

As climate change becomes increasingly important, regulations around petrochemical usage tighten, and fluctuating oil prices affect the market, industries are becoming more interested in sustainable alternatives to common volatile organic compounds (VOCs). VOCs are used extensively in solvent extraction processes which require a range of physical and chemical characteristics. Solvents derived from biomass, namely bio-derived solvents, have attracted attention as replacements for VOCs due to favourable properties such as low toxicity, biodegradability and renewability.

Natural pharmaceutical extraction, such as the extraction of alkaloids from opium poppy, is a key industry in Victoria where these bio-derived solvent alternatives are of interest. Together with Sun Pharmaceuticals in Port Fairy, Victoria, we will test a range of bio-derived solvents, including p-cymene and 2,5-dimethylfuran, for their use in a solvent extraction process for concentrating and purifying alkaloids. A range of parameters will be investigated in the laboratory, including distribution ratio, kinetics, coalescence time and solvent physical properties, to assess the use of these solvents for alkaloid extraction. In addition to these bio-derived solvents, a series of commercially available extractant molecules are also being studied to assess the best chemical structure for alkaloid extraction. From these experiments a range of bio-solvent and extractant system combinations will be identified for further evaluation and process scale-up.

The development of an intensified process for liquid phase methanol synthesis at moderate conditions

Fan Wu, Fatin Hasan, Penny Xiao, Paul Webley

There are abundant small natural gas (NG) reserves in remote areas in Australia which can be converted into high value and transportable dimethyl ether (DME). Due to the fact that processing NG from those remote reserves using conventional industrial pathways is not economically feasible, the development of a small-scale and movable production process is essential. The overall process consists of three sections, which are NG to syngas, syngas to methanol, and methanol to DME. In this work, the design of the methanol synthesis process and the corresponding reactors are studied from both experimental and modelling perspectives. This project aims to develop a pathway to produce methanol at moderate operation conditions in order to reduce the cost and the energy consumption. A two-step liquid phase methanol synthesis at low temperatures and moderate pressures has been proposed. This new route consists of carbonylation of carbon monoxide with alcohol forming formate, and then hydrogenation of the produced formate to methanol. A bench scale experimental rig has been set up in the lab to study the intrinsic kinetics of both reactions. Hence, a micro-channel reactor will be designed utilising Taylor flow phenomena to maximise the mass transfer and to enhance the productivity of the reactor per unit volume. An experimental system that allows studying Taylor flow domain at various temperature and pressure will be developed.

Multi-scale studies on modeling and scale-up of novel extraction column

Gordon Yi, Geoff Stevens, Kathryn Smith

Solvent extraction is an important separation technology which has been widely used in the hydrometallurgy, pharmaceutical and petrochemical industries. However, industrial fields such as the rare earth elements separation, lithium extraction from salt lakes and lithium isotope separation are still faced with challenges. For example, because the systems in these fields are corrosive, it is necessary to develop new ceramic internals which are corrosion-resistant. This project is intended to study the mathematical modeling and scale up of novel extraction columns to reach higher efficiency, larger capacity and reliable scale up approach based on the population balance model (PBM) and computational fluid dynamics. New kinds of ceramic column internals have been designed and manufactured. Systematic experiments including the measurement of hold up, drop size, axial dispersion and mass transfer are being conducted. Programs to solve population balance equations with quadrature method of moments (QMOM) are being coded to describe the two-phase behaviour. The results will be very helpful to solve many theoretical and industrial problems in solvent extraction column design.
Ultrasonics

Research Staff
Professor Muthupandian Ashokkumar
Professor Franz Grieser
Professor Sandra Kentish
Dr Judy Lee
Dr Srinivas Mettu
Dr Meifang Zhou

Research Students
Sukhvir Kaur Bhangu
Enrico Colombo
Wu Li
Nor Saadah Mohd Yusof
Krishnmurthy Prasad
Akalya Shanmugam
Sinuo Tan
Qianyu Ye
Jinxuan Zhang

Collaborations
Dairy Innovation Australia
Dr Martin Palmer
Osaka Prefecture University, Japan
Professor Kenji Okitsu
RMIT University, Australia
Dr Bogdan Zisu
The University of Auckland, New Zealand
Professor Yacine Hemar
The University of Melbourne, Australia
Professor Jonathan White
Université de Franche-Comté, France
Professor Jean-Yves Hihn

Project Updates

Applications of ultrasound in various industrial chemical processes
Sukhvir Kaur Bhangu, Judy Lee, Muthupandian Ashokkumar
This project investigated the effect of ultrasound on the crystallisation of paracetamol at different ultrasonic frequencies (22, 44, 98, 139 kHz) and powers (3, 6, 10, 13, 16 W) using multifrequency ultrasonic plate transducers. Sonication facilitates the nucleation of crystals and reduces the induction time in a controlled and reproducible way to generate narrow size distribution products. The mean crystal size obtained was around 14 µm as compared to 300 µm when crystallisation was carried out without sonication. In addition, sonication leads to the formation of a mix of polymorphs of paracetamol. In the coming year, the aim is to study the effect of ultrasound on biodiesel production by transesterification of vegetable oil using ultrasonic bath, horn and other ultrasonic reactors. The main objective of this work is to develop an approach that would enable us to enhance the percent conversion of vegetable oil to biodiesel and to understand the relationships between the different sonication parameters, reaction time, and enzyme amount to obtain the optimum conditions required for biodiesel production using ultrasound.

Ultrasonic synthesis of photocatalysts by oil-in-water emulsion method and evaluation of their photocatalytic performance
Enrico Colombo, Muthupandian Ashokkumar
The aim of this project is to develop new photocatalytic materials for the degradation of organic pollutants in aqueous environment. In 2015, I focused on synthesising micrometer-sized photocatalytic particles with high surface area, which would provide the advantage of high activity and easy removability by filtration. I have developed a facile ultrasonic synthetic procedure to convert a nanosized photocatalyst into a micron sized material without losing its efficiency. The synthesis involved sonication of a dispersion of photocatalytic nanoparticles in an aqueous chitosan solution. Their photocatalytic efficiencies were evaluated using two organic dyes as model pollutants. The results showed that the synthesis can be used to produce efficient macro scale photocatalysts with a size range of 7-10 nm starting with 20 - 50 nm nanopowders. The future steps of the project would involve the construction of a pilot-scale photocatalytic wastewater treatment reactor to evaluate the industrial application of the developed photocatalytic system.

Ultrasound-assisted fabrication of mesoporous metal framework
Wu Li, Judy Lee, Muthupandian Ashokkumar
The frequency effect on the size of sonochemically synthesised gold nanoparticles (NPs) was investigated. Plate transducers (22, 44, 98, 128, 139, 300, 500, 1000 and 2000 kHz) were used in these experiments. The results indicated that the average size of the gold NPs can be controlled from 7 nm to 30 nm using different frequencies. Minimum sized gold NPs were chosen to fabricate a mesoporous metal framework via a template coating method. In a typical experiment, gold chloride, reducing agent and template were sonicated in an aqueous medium. Different surface modified polystyrene (PS) beads (carboxylate and amine-modified) were employed as templates. The surface coverage of PS was examined by TEM. In the second stage of this project, experimental conditions will be optimised to improve the coverage, templates will be removed following complete coating with gold NPs and the metal structure will be compressed to form thin films which could be used in membrane filtration applications.
Ultrasonic synthesis of stable chitosan microspheres

Sinuo Tan, Srinivas Mettu, Meifang Zhou, Muthupandian Ashokkumar

The aim of this project is to investigate methods for preparation of stable chitosan microspheres, which involves three stages: modify chitosan by grafting thiol groups into chitosan backbone, fabricate crosslinked chitosan by a sonochemical process and test the strength of modified chitosan microspheres by atomic-force microscopy (AFM). Thiolated chitosan with two different degree of modification were synthesised using DL-N-Acetylhomocysteine thiolactone by covalent attachment. Modified chitosan microspheres were fabricated by ultrasound, characterised by optical, fluorescence and electron microscopies. AFM was used to quantify the mechanical strength of the microspheres, showing modified chitosan microspheres were stronger than the normal chitosan microspheres in terms of stiffness. In the future work includes inserting small particles into the structure of chitosan microspheres in order to improve the strength of chitosan microspheres. After developing a successful procedure, the microspheres will be characterised using a number of techniques that include optical, fluorescence and electron microscopies. AFM will be used to test the mechanical strength of the microspheres. The methodology developed will ultimately be used for the encapsulation and delivery of a variety of food flavour compounds.

Ultrasonic synthesis of nanoparticles-encapsulated microspheres for step-wise release of functional materials

Jinxuan Zhang, Meifang Zhou, Muthupandian Ashokkumar

The aim of this project is to develop a new methodology to encapsulate nanoparticles/nanospheres containing a specific functional material inside larger microspheres containing a second functional material. The goal is to achieve step-wise release of two different functional materials. A method for this process was successfully developed. For example, PLGA nanoparticles, loaded with a water soluble flavour, have been encapsulated within lysozyme microspheres containing an oil-soluble flavour. If successful, the outcome of this project has great potential in encapsulation and release of drugs and flavours.

Ultrasonic preparation of pea protein microspheres

Qianyu Ye, Meifang Zhou, Muthupandian Ashokkumar

Microspheres composed of pea protein as the shell and tetradecane as the core were prepared using a high intensity ultrasound technique. Sono-denaturation was developed for tuning the solubility and hydrodynamic diameter of pea protein dissolved in buffer systems in order to adjust the size, stability, shell stiffness and shell thickness of microspheres. The structural and functional properties of the pea protein-shelled microspheres were studied with a view to develop potential uses for food industry. The buffer solutions used seemed to influence the extent of aggregation of pea protein and the stability of the microspheres significantly. In the future, the aim is to understand the mechanism behind the sono-denaturation and pea protein encapsulation.
**Emulsion Behaviour**

**Research Staff**
Professor Derek Chan  
Professor Raymond Dagastine  
Associate Professor Sally Gras  
Professor Franz Grieser  
Professor Sandra Kentish  
Dr Phoebe Macdougall  
Dr Srinivas Mettu  
Dr Lydia Ong  
Dr Qiang Sun

**Research Students**
Matthew Biviano  
Christopher Fewkes  
Agustina Goh  
Anita Pax  
Kevany Soodam

**Project Updates**

**Investigating sphere to rod transitions through droplet collisions in high concentration surfactant systems**
Christopher Fewkes, Rico Tabor, Raymond Dagastine  
Highly concentrated surfactant systems are commonly used in colloidal dispersions and emulsions in the formulation of complex fluids for a range of applications including personal care products, foods, lubricants, and in pharmaceuticals. At higher surfactant concentrations, surfactant aggregates often transition from smaller aggregate structures (e.g. spheres, ellipsoids, etc) to larger structures including worm like micelles, sponge phases and lamella phases. The influence of aggregate structure on surface forces and the properties of colloidal fluids is an interesting but not well investigated phenomenon. This study examines the effect of micelle aspect ratio on droplet collisions. Measurements were taken using atomic force microscopy (AFM) to investigate the interactions between drop-drop and particle-plate systems. Solutions of hexadecyltrimethylammonium bromide (C16TAB) and sodium salicylate (NaSal) were used to generate micelles of varying profiles. The influence of the micelle shape on both static and dynamic interactions with a particular focus on structural forces was investigated. It was observed that small changes to the micelle shape did not significantly alter the surface force behaviour, however, once the micelles were elongated further the long range forces changed from oscillatory to that of a single attractive force well. A comparison between rigid and deformable interfaces was performed with good agreement regarding the underlying solution structure found.

**Non-singular boundary integral methods**
Evert Klaseboer, Qiang Sun, Boo Cheong Khoo, Derek Chan  
The boundary integral method of solving partial differential equations in science and engineering such as the Laplace equation for electrostatics and potential flow, the Helmholtz equation for acoustics, the Stokes equation for low Reynolds number flow in fluid mechanics and the equations governing linear elastic response of materials is in principle very efficient because it reduces the dimensionality of the problem by 1. This confers significant computational speed advantages. However, the integrals involve nearly singular behaviour that has to date required special numerical algorithms to handle them. We have developed a non-singular formulation of the boundary integral method that totally circumvents such singular behaviour. This formulation is being applied to study a range of problems in the interaction of soft materials, the fast and accurate calculation of electrostatic interactions between objects with complex shapes or molecules with arbitrary charge distributions as well as acoustic and electromagnetic propagation problems.

**The microstructure and functional properties of mozzarella cheese**
Anita Pax, Lydia Ong, Sandra Kentish, Sally Gras  
Mozzarella cheese is typically used on a pizza due to its desirable shredding, melting and stretching characteristics. These functional properties may be impacted when manufacturing processes and conditions are altered. Using advanced microscopy techniques such as confocal laser scanning microscopy (CLSM) and cryo-scanning electron microscopy (Cryo-SEM) we can observe...
changes in the microstructure that occur due to these altered conditions or processes. CLSM also allows us to reconstruct three dimensional stacks which can be used to observe and monitor fat and protein distributions. In conjunction with functionality testing, these results are used to develop structure-function relationships.

This project is studying the impact of variations in cheese composition and processing conditions on the microstructure and functionality of Mozzarella cheese. This will enable dairy manufacturers to better understand the Mozzarella cheese process and provide the tools to consistently produce quality cheese. This may enable the dairy industry to achieve an increase in domestic sales, as well as growth in export markets.

**Emulsion drops stabilised using surfactant mixtures**

Srinivas Mettu, Raymond Dagastine

Many emulsion formulations are stabilised by mixed surfactant systems containing a combination of ionic and non-ionic surfactants, where there has been far more academic study focused on single surfactant systems. There is a body of literature focused on the properties of mixed surfactant systems, notably examining the composition of mixed surfactant micelles in bulk or in the adsorption of mixed surfactant systems at the air-water interface. This work focuses on the stability of emulsion drops in the presence of mixed surfactant systems, using combinations of ionic and non-ionic surfactants. The interaction forces between emulsion drops were measured directly using atomic force microscopy (AFM) to characterise the surface potential of drops as a function of surfactant concentration and mixing ratio of ionic to non-ionic surfactant. Parallel studies measuring the adsorption isotherms of pure surfactants and mixture of surfactants were performed using the pendant drop method. These results were used to calculate the theoretical maximum surface charge of the emulsion drops based on interfacial composition. This surface charge was then compared to the surface charge determined via the AFM measurements to find the fraction of counter ion condensation observed on the emulsion drops of the mixed surfactant system.
Surfactant and Polymer Structure in Solution

Research Staff
Dr Luke Connal
Professor Raymond Dagastine
Professor Dave Dunstan
Associate Professor Sally Gras
Associate Professor Andrea O’Connor
Professor Greg Qiao
Dr Qiang Fu
Dr Katharina Ladewig
Dr Xu Li
Dr Jing Ming Ren
Dr Edgar Hoe Hon Wong
Dr Zeyun Xiao
Blaise Tardy

Research Students
Halleh Atri
Tianyi (Alisa) Bai
Ayana Bhaskaran
Elham Bidram Gorgaby
Joseph Collins
Mina Dokouhaki
Terence Hartnett
Mahshid Kalani
Shu Jie Lam
Tom McKenzie
Eunhyung Nam
Alicia Rasines Mazo
Sara Sayanjali
Barbara Sowa
Suryani Tan
Stephanie Tortorella
Donglin Xie

Collaborations
AgResearch, New Zealand
Dr Li Day
CSIRO, Australia
Dr MaryAnn Augustin
Dr Roman Buckow
Dr Patrick Hartley
Dr Keith McLean
Dr Luz Sanguansri
RMIT University, Australia
Dr Andrew Hung
The University of Melbourne, Australia
Associate Professor Neil O’Brien-Simpson
Professor Alastair Stewart

Project Updates
Synergy in mixture of surfactants and the impact on the formation of polymer-surfactants complex
Tianyi Bai, Blaise Tardy, Raymond Dagastine
Polymer-surfactant (PS) mixtures are widely used to control both solution and surface properties. The behaviours of PS complexes have been of great interest for both academic areas and industry applications over the last 50 years. The mechanisms of interactions among polymer, surfactant and surface, and relevant phase behaviour and adsorption behaviour to dispersion or emulsion have been the focus of a large body of literature. Yet many gaps still remain in the link between the molecular structure of polymers and surfactants and their associative behaviours.

The aim of this project is to determine the structure-function relationships between the molecular structure of PS complexes and their function in a formulation application, for example, in personal care products. Mixed surfactants systems are widely known to have improved performance capabilities due to the synergistic effects between different surfactants. The results from the investigation of synergistic effects can also provide an idea of the structure of PS complex in solution and resulting function in a formulation. To study synergistic effects of surfactants mixtures on PS complex formation, bulk phase diagrams were prepared. Polymer molar mass was varied for the same type of polymer with a constant charge ratio. Different mixtures of anionic surfactants were investigated with varied concentrations at a constant polymer and salt concentration. These studies will help provide a map of solution conditions to probe the interactions between emulsions droplets using atomic force microscopy in future work.

Enzyme mimicry: Novel catalysis inspired by nature
Ayana Bhaskaran, Luke Connal, Zeyun Xiao
Enzymes are amazing macromolecules that control and accelerate the majority of biochemical reactions. The field of enzyme engineering has undergone tremendous growth in recent years owing to the importance of developing novel and improved products. Drawing inspiration from nature, the chemistry of enzymes is mimicked to create artificial bio-catalysts. These biomolecules could be tailor-made for applications which comprise of low-temperature detergents, bio-diesel production and oleo-chemical industries paving way for economical industrial processes with reduced environmental impact. The project explores the synthesis and characterisation of a range of artificial bio-catalysts mimicking various attributes of enzymes like lipases and esterases.

Enzymes are known for their substrate specificity. The specificity of an enzyme is crucial to its efficiency, thus, the pivotal point in modifying its activity too. These characteristics are achieved by tuning the structure and nano-environment of the biocatalyst thereby delivering improved stability, wider range of activity and efficiency comparable to that of native enzymes.

The study of cancer treatment using over-expressed receptors
Elham Bidram, Dave Dunstan, Alastair Stewart
Over-expressed receptors and their role in targeting cancer therapy have been thoroughly studied over the decades to increase the efficiency of cancer treatments reducing the unexpected side effects and total caused death. This has led to some receptors being considered as potential candidates for targeting drug delivery particularly cancer targeting therapy. This project is based on studying the efficiency of the most attractive receptors (folate receptor and Integrin) for advanced cancer therapy without applying any chemotherapeutic drugs.

This project is divided into three main parts. Firstly, to study the separation and fractionation of graphene oxide (GO) and its macromolecular functionalisation. GO as a planar carbon polymer with a wide range of functional groups and photoluminescence properties is one of the attractive polymers for drug delivery and targeting purposes. The fluorescence properties of the functionalised GO sheets is investigated as the second part.
Finally, ligand-PEGylated GO sheets (FA/PEG-GO) were studied as a potential treatment for cancer. As a result, the cytotoxicity of GO and its functionalised derivatives was concentration-dependent. GO fluorescence intensity and its emission spectra appeared to be affected by various factors, including solvent, concentration, and even the attached targeting ligand. The toxicity effects of singular ligand (folic acid or RGD) as well as the efficiency of dual ligand conjugate was investigated. These studies have also shown the synergistic effects of the designed polymeric networks in combination with the common chemotherapeutic drugs, such as doxorubicin (DOX) or methotrexate (MTX).

Oxime click chemistry for the synthesis of dynamic polymers
Joseph Collins, Luke Connal

The oxime click reaction, previously utilised almost exclusively for bioconjugation, has recently gained significant attention for applications in materials science and is fast becoming a valuable tool for the synthesis of novel materials due to the attractive properties of oxime bonds; very rapid formation, high selectivity/biorthogonality, dynamic covalent properties and high yielding reactions. Recently, the oxime click reaction has been utilised to form self-healing hydrogels, stimuli-responsive dynamic materials for drug delivery, bio-adhesives and bio-compatible hydrogels. Our research is focused on synthesising new, high molecular weight step-growth polymers via oxime click chemistry and investigating their dynamic properties for a variety of applications.

The assembly of chaplins in bulk solution and at the air-water interface
Mina Dokouhaki, Sally Gras, Li Day, Andrew Hung

Although amyloid fibrils have been linked with some diseases such as Parkinson’s and Alzheimer’s there are some amyloid-like fibrils that are thought to have beneficial functions. The Chaplin fibrils from Streptomyces coelicolor belong to this class of functional amyloids, as do the curli proteins from Escherichia coli and hydrophobins. Potential applications for such fibrils include: use as affinity tags in protein purification, use as surface active proteins to stabilise foams and use as dispersion agents for insoluble drug molecules. The short Chaplin proteins are known to lower the surface tension of water and to aid the growth of hyphae into the air. Fibrils formed from these proteins also coat aerial hyphae making their surface hydrophobic. This project focuses on the characterisation of the short Chaplin proteins and aims to investigate their functional properties and potential applications using experiments paired with molecular dynamics simulations.

The development of cubosomes as drug delivery vehicles to treat macular degeneration
Terence Hartnett, Katharina Ladewig, Patrick Hartley, Keith McLean, Andrea O’Connor

Diseases of the posterior segment of the eye are the cause of more than 80% of blindness in the developed world. With the recent development of novel macromolecular bioactive therapeutics to treat some of these diseases there is a need to develop drug delivery vehicles that can protect and prolong the lifetime of the therapeutic. One such delivery vehicle is the cubosome. Owing to their energy intensive production techniques, the use of cubosomes in the field of protein drug delivery has been limited to date. We have developed cubosomes using the less toxic cubic phase forming amphiphile, glycerol monoolein (GMO), through the low energy ‘salt-induced’ production technique. A method was then developed to encapsulate hydrophilic proteins in the cubosomes and tested in vitro and in vivo using a therapeutic regularly used to treat one of the most common forms of posterior segment eye disease, age-related macular degeneration.

Combating multidrug-resistant bacteria with peptide stars
Shu Jie Lam, Neil O’Brien-Simpson, Greg Qiao

Antibiotic resistance in bacteria has reached alarming levels in many parts of the world, whereby common infections in some settings have become refractory to available treatment options. Despite the focus on more well-known Gram-positive superbugs such as the methicillin-resistant Staphylococcus aureus (MRSA), Gram-negative bacteria have been recently recognised as a more pressing issue caused by the lack of effective and biocompatible drugs. The dearth of candidates to combat Gram-negative bacteria is possibly attributed to the fact that Gram-negative microbes might be harder to kill than Gram-positive bacteria as a result of the presence of an outer membrane layer and additional resistance mechanisms. Furthermore, most antimicrobial agents exhibit selective activity only towards certain Gram-negative bacterial species, or demonstrate high toxicity towards mammalian cells. In this project, we developed star-shaped polypeptides as antimicrobial agents that have efficacy against normal and multidrug-resistant (MDR) Gram-negative pathogens (in vivo activity demonstrated) and low toxicity towards mammalian cells. The antimicrobial mechanism of such polymers was investigated using microscopy, flow cytometry, membrane interaction studies, and gene expression analysis. It is envisioned that this study may advance the field of antibiotic development and hence contribute towards the fight against infections caused by antibiotic resistant bacteria.

Visible light activation of common RAFT agents for photocontrolled radical polymerisation
Tom McKenzie, Edgar Wong, Qiang Fu, David Dunstan, Greg Qiao

Polymerisation techniques mediated by photochemical means have become a major research interest over the past several years due to their ability to offer externally regulated spatial and temporal control. This has potential for advances in bottom-up patterning applications, or the generation of gradient film structures, simply by controlling the source of activation, i.e. incident light. Many significant advances have come from the utilisation of transition metal complexes to promote redox reactions following excitation by light of an appropriate wavelength. Recently, we demonstrate that commonly used trithiocarbonate RAFT agents can be activated by visible light to afford a controlled radical polymerization without the aid of any photocatalysts or radical initiators. Though similar approaches utilising UV irradiation are reported to suffer from a lack of control at high monomer conversions, our results show the generation of well-defined polymers with excellent chain end fidelity even at (near) complete monomer conversion. This finding presents a novel way to access synthetic polymers with high chemical and structural integrity via reactions under photochemical control.
Versatile approaches towards the fabrication of nanoengineered cross-linked films and their applications
Eunhyung Nam, Greg Qiao

The fabrication of surface coatings to generate nanoengineered ultrathin films is one of the significant areas in nanotechnology. A range of techniques have been developed and employed in various applications, including biomaterials, thin film electronics, separation membranes and functional surface coatings. In particular, film cross-linking was further introduced as this provides higher mechanical stability, improves film adhesion to the substrate, and potentially allows for the formation of free-standing films following template removal. There exists a myriad of cross-linked film fabrication strategies, but every different method has inherent advantages and limitations. Therefore, new fabrication approaches are continuously being developed to provide alternative avenues with the aim of overcoming those limitations of current technologies. Herein, we developed two versatile fabrication technologies termed continuous assembly of polymers in solid state (ssCAP) and touch activated cross-linking (TAC) to generate nanoscale cross-linked films. These novel systems were further employed for several applications such as films for cell adhesion, anti-fogging coatings and conductive honeycomb films.

Peptide-based polymeric bottlebrush polymers as antimicrobial agents
Alicia Rasines Mazo, Jing Ming Ren, Greg Qiao

In recent years, antimicrobial resistance has become a growing concern as difficult infections appear in our hospitals and our wider community. Of particular importance are infections caused by multi drug-resistant bacteria as these strains are not susceptible to most antibiotics and tend to cause severe infections, leading to unnecessary deaths and elevated healthcare costs to society. Bacteria are continuously mutating and developing resistance under evolutionary pressure, yet the discovery of new antibiotics has slowed down. It is a challenge to develop new antibiotics (polymeric or otherwise) that have a good pharmacokinetic profile and are also biocompatible and biodegradable. This project aims to look at the antimicrobial properties of polymeric bottlebrushes of different lengths grafted with peptides. The aim of this project is to study the effect that parameters such as molecular weight, conformation, side chain composition and length, play in the efficacy against pathogenic bacteria strains. It is our aim to develop a macromolecular system that displays promising antibacterial activity both in vitro and in vivo.

The development of extruded ready to eat snacks containing curcumin
Sara Sayanjali, Sally Gras, Roman Buckow, Luz Sanguansri, MaryAnn Augustin

Curcuminoids are polyphenols with many health promoting properties. The incorporation of polyphenolic curcuminoids into foods, including extruded products, can potentially improve nutrition and deliver health benefits. A major challenge, however, is the poor solubility of curcuminoids in aqueous solution (11ng/ml). In this research the potential of oat fibre to interact with curcumin and improve the solubility and stability of curcumin is investigated. An extrusion process is applied to deliver a curcumin-oat fibre complex within a food product and the stability of curcumin in extruded snack products during 80 days of storage at 25°C is examined. In addition the extrudate characteristics including expansion ratio, apparent viscosity, hardness and encapsulation efficiency are evaluated. This study illustrates the potential for foods that incorporate the benefits of dietary fibre from oat fibre and anti-inflammatory and anti-oxidative properties of curcumin.

Motions of nanoparticles in fluids
Donglin Xie, David Dunstan, Greg Qiao

The broad uses of engineered nanoscale materials in scientific research and industry attract interest in nanoparticle motion in suspensions. Most of the studies are done in the quiescent state, where hydrodynamic forces can be ignored. Once a flow is applied to a colloidal system, the hydrodynamic forces increase dramatically and need to be considered properly. The flow induced motion changes the colloidal system properties in bulk. In order to study particle motion in flow, a rheo-optic technique has been used in the experiments, which is based on absorption spectra combining with numerical simulations.

Flow induced aggregation was observed in dilute colloidal suspensions in viscoelastic fluids. The colloid absorbance decreased over time, indicating the particle distribution changed due to the shear flow. Moreover, empirical collision efficiencies were introduced to describe the aggregate processes quantitatively. Suspensions in various media were also studied to evaluate the effects of the media’s rheological properties. FRET labelled polystyrene chains were used to study the concentration effects on the polymer diameter in the semidilute and concentrated region. And the effect of the flow condition is considered in the experiments, which means not only the polymer diameter is measured in the steady state but also in the shear flow.
Research Program Highlights

Solid-Liquid Systems

The range of research applications and problems in terms of new materials, process optimisation, new process development and the understanding of surface adsorption and interfacial molecular transfer issues continue to grow. The core research themes in the Solid-Liquid Systems program are:

• Minerals - Processing and Materials
• Controlled Porous Structures
• Suspension Rheology
• Surface Forces and Spectroscopy

Dr Dalton Harvie
Minerals - Processing and Materials

Research Staff
Dr Luke Connal
Professor George Franks
Professor Peter Scales
Professor Geoff Stevens
Dr Carolina Tallon

Research Students
Emma Brisson
Silvia Leo
Paul Mignone
Wei Sung Ng
Samuel Pinches
Brant Walkley
Michael Wang

Collaborations
Australian Nuclear Science and Technology Organisation, Australia
Dr Daniel Riley
CSIRO, Australia
Dr Elizaveta Forbes
Professor Jun Oshitani
Okayama University, Japan
RMIT University, Australia
Dr Rackel San Nicolas
The University of Melbourne, Australia
Dr Gabriel da Silva
Associate Professor Trevor Finlayson
Dr John Provis
University of California, Santa Barbara, USA
Dr McLean Echlin
Professor Tresa Pollock
University of South Australia
Associate Professor David Beattie
Dr Marta Krasowska
Zeobond Pty. Ltd., Australia
Professor Jennie van Deventer

Project Updates
Functional, temperature responsive polymer flocculants for mineral processing and bio applications
Emma Brisson, Elizaveta Forbes, Luke Connal, George Franks

Temperature responsive polymers, such as poly(N-isopropyl acrylamide) (PNIPAm) undergo a phase transition upon the addition of heat, taking on hydrophobic character as they transition out of solution. The use of temperature responsive polymers in flocculation for mineral processing is a new application of these materials, and the selective binding of these novel flocculants to desired surfaces is the next challenge in this field. For sulphide minerals such as copper, achieving surface selectivity is difficult because the surface of the sulphide changes chemically with time. From current industry practice, sulphide mineral collectors can be used functionalise polymers with metal chelating moieties that will adsorb preferentially to desired mineral surfaces. Taking inspiration from nature and current industry practice, this project aims to synthesise novel temperature responsive polymer reagents, investigating their responsive properties and metal interactions.

Amino acids, our inspiration from nature, are highly functional moieties that play important roles in metal ion interactions in proteins and peptides. Amino acid functional polymers have been synthesised by post polymerisation functionalisation of PNIPAm copolymers with an aldehyde containing monomer using reductive amination, a highly versatile and protecting group free chemistry. The functionalised polymers have temperature responsive behaviours, exhibiting a Lower Critical Solution Temperature. Due to the pH responsive, zwitterionic nature of the amino acid side chains and their biocompatibility, these materials are of interest as antifouling coatings and as metal chelating polymers. The synthesis of temperature responsive, amino acid functional block copolymers is underway. The polymers will be studied as functional antifouling coatings, metal ion coordinating polymers as well as sulphide selective polymers for mining applications.

Novel temperature-responsive polymers as selective flocculants and collectors
Wei Sung Ng, George Franks, Luke Connal, Elizaveta Forbes

The worldwide exhaustion of rich ore sources of valuable metals such as copper, nickel, and gold has prompted a shift to low-grade deposits, which necessitate the use of finer grinding to liberate the desired minerals from the unwanted gangue. However, the presence of fine particles below 20 µm is detrimental for froth flotation, which is the most common mineral separation technique. Entrainment, streamline effects and slime coatings result in a loss of selectivity and hence recovery. Current alternatives such as selective flocculation are inadequate, with severe disadvantages and narrow applications. A novel approach is the use of temperature-responsive polymers, such as poly(N-isopropyl acrylamide) (PNIPAM), which undergo a reversible hydrophilic-to-hydrophobic transition when heated above a lower critical solution temperature (LCST). Above the LCST, PNIPAM is able to aggregate the fine valuables into larger sizes, and provide a hydrophobic surface suitable for recovery in flotation. Below the LCST, PNIPAM is highly soluble and can disperse the particles. The missing piece is selectivity for the desired mineral, a gap to be filled with this research. This project aims to synthesise a temperature-responsive polymer as a selective flocculant and collector, and optimise the performance through flotation studies, with different polymers for sulphide and oxide ores. The success of this research will have a stimulating effect on the minerals industry, increasing production and reducing waste. Additionally, the multiple functionality of the polymer can reduce operational costs by replacing the use of current reagents and thus reducing consumptions. Results thus far demonstrate significant potential for improving the recovery of hematite and copper sulphide ores, through the use of highly selective copolymers of PNIPAM.

Near-net shaping of dense advanced ceramics by freeze casting
Samuel Pinches, George Franks, Carolina Tallon

The characteristic properties of ceramic materials, such as their high temperature and thermal shock resistance, are desirable traits for many applications. Often, operation at high temperatures results in increased efficiencies for engines, while high temperature components are required to enable development of hypersonic vehicles. However, the use of ceramics in
engineering applications is often hindered by both the intrinsic brittle failure and low fracture toughness of these materials, as well as the high cost incurred by diamond milling to obtain complex shaped product components. This project investigates freeze-casting as one possible avenue to obtain complex ceramic components at a lower cost when compared with other production methods. This work continues on from previous work into obtaining dense freeze cast (DFC) components by this method, with a focus on reducing defects in, and improving the properties of, the final product. Initial work has shown that the freeze cast objects are often prone to cracking during firing. One aim of the research is to understand the origin of such cracks. The cracking may arise during freezing, freeze drying or sintering. Precise temperature monitoring and control throughout the process is expected to allow greater control of the final product microstructure while minimising macro defects. Modelling the thermal profile across the object during freezing will provide information about the local freezing rate in the object. Such information will be helpful in trying to understand pore size gradients across the object which could lead to differential shrinkage during firing and possibly cracking.

Understanding geopolymers through synthetic gel systems

Brant Walkley, John Provis, Rackel San Nicolas, Jannie van Deventer

Geopolymers are formed by mixing solid aluminosilicate precursors such as fly ash (FA), granulated blast furnace slag (GBFS) or metakaolin with an alkali activating solution, forming a solid binder with similar properties to Portland Cement (PC). Geopolymers offer an 80% reduction in CO₂ emissions compared to PC, and also provide an avenue for utilisation of industrial waste materials such as FA or GBFS.

Geopolymer use in industry is not yet widespread due to difficulties controlling reproducibility in performance and stoichiometry of phases formed in these systems. This is, in part, due to an incomplete understanding of the thermodynamic relationships and reaction kinetics governing geopolymerisation. If we are to develop further understanding of these relationships, the stoichiometry of the precursor materials and alkali activator must be controlled.

This study develops a method for synthesis of stoichiometrically controlled reactive nanopowders via a novel solution polymerisation method utilising polyethylene glycol to sterically inhibit the movement of precursor cations. These nanopowders were subsequently activated with sodium silicate to form geopolymers. Analysis by advanced characterisation techniques shows that the stoichiometrically controlled geopolymers constitute a chemically simplified model system through which FA and GBFS geopolymers can be studied.

This work provides a platform for study of the role of key cations involved in geopolymer formation and their effect on the composition, structure and properties of the hardened binder. Understanding of these governing principles will enable development of innovative technologies to mitigate the remaining durability issues associated with geopolymers, as well as aiding the development of performance based standards.
Controlled Porous Structures

Research Staff
Professor Frank Caruso
Associate Professor Rachel Caruso
Dr Luke Connal
Professor Dave Dunstan
Professor Sandra Kentish
Dr Daniel Heath
Professor Andrea O’Connor
Professor Greg Qiao
Dr Colin Scholes
Professor Geoff Stevens
Professor Paul Webley
Dr Nadja Bertleff-Zieschang
Dr Tejas Bhatelia
Dr Julia Braunger
Dr Francesca Cavalieri
Dr Dehong Chen
Dr George Chen
Dr Christina Cortez-Jugo
Dr Jiwei Cui
Dr Yunlu Dai
Dr Qiang Fu
Dr Paul Gurr
Dr Shinji Kanekashi
Dr Biao Kong
Dr Katharina Ladewig
Dr Andy Leung
Dr Liang Liu
Dr Markus Mullner
Dr Nathan Nicholas
Dr Lydia Ong
Dr Emma Prime
Dr Eve Revalor
Dr Jin Shang
Dr Ranjeet Singh
Dr Kathryn Smith
Dr Georgina Such
Dr Huani Sun
Dr Carolina Tallon
Dr Penny Xiao
Dr Zeyun Xiao
Dr Yan (Annie) Yan
Alita Aguiar
Indrawan Indrawan
Jenny Tran

Associate Professor Sally Gras
Dr Gregory Martin
Dr Kathryn Mumford
Professor Greg Qiao
Professor Dave Dunstan
Professor Andrea O’Connor
Professor Greg Qiao
Dr Colin Scholes
Professor Geoff Stevens
Professor Paul Webley
Dr Nadja Bertleff-Zieschang
Dr Tejas Bhatelia
Dr Julia Braunger
Dr Francesca Cavalieri
Dr Dehong Chen
Dr George Chen
Dr Christina Cortez-Jugo
Dr Jiwei Cui
Dr Yunlu Dai
Dr Qiang Fu
Dr Paul Gurr
Dr Shinji Kanekashi
Dr Biao Kong
Dr Katharina Ladewig
Dr Andy Leung
Dr Liang Liu
Dr Markus Mullner
Dr Nathan Nicholas
Dr Lydia Ong
Dr Emma Prime
Dr Eve Revalor
Dr Jin Shang
Dr Ranjeet Singh
Dr Kathryn Smith
Dr Georgina Such
Dr Huani Sun
Dr Carolina Tallon
Dr Penny Xiao
Dr Zeyun Xiao
Dr Yan (Annie) Yan
Alita Aguiar
Indrawan Indrawan
Jenny Tran

Research Students
Hirra Azher
Dhee Biswas
Mattias Björn malm
Stephan Burger
Lu Cao
Cesar Castaneda
Chao Chen
Xi (Cathy) Chen
Qiong Dai
David Danaci
Yasmina Dkhissi
Hongzhuan Di
Sarah Dodds
Matt Faria
Ben Freidman
Katelyn Gause
Sook Jin Goh
Sylvia Gunawan
Dunying Gu
Junling Guo
Steven Harris Bibowo
Yingdian He
Timothy Henderson
Guoping Hu
Tao Huang
Javad Jafari
Yi Ju
Inam ur Rehman Junejo
Fatemeh Karimi
Jinguk Kim
Yiqun Li
Bingxin Liu
Hiep Lu
Junchao Ma
William McMaster
Nouman Rafique Mirza
Thomas Moore
Seyed Farshad Motenvalizadeh
Milena Nadgornyi
Sinn-Yao (Kenneth) Ng
Ka Leo Noi
Mitchell Nithling
Augustine Ntiamoah
Natalita Nursam
Paul Osborne
Shuaijun Pan
David Parris
Nasim Pour

Kaiyuan Qin
Md. Arifur Rahim
Hadi Ranjiburachaloo
Camilla Reehorst
Amin Reyhani
Erwin Rodriguez-Tolava
Joel Scofield
Philipp Senn
Aida Shakouri
Steven Shirbin
Tom Statlam
Tomoya Suma
Jeannie Tan
Willie Tang
Blaise Tardy
Claire Tindal
Martin van Koeverden
Zhexing Wang
Hao Wei
Alessia Weir
Marcin Wojnilowicz
Wu-Qiang Wu
Yue Wu
Ke Xie
Joel Yong
Wenjie Zhang
Qinghu Zhao
Collaborations

Anatomics, Australia
Mr Andrew Batty

Australian Antarctic Division, Australia
Professor Ian Snape

Australian Synchrotron, Australia
Dr Qinfen Gu

Bionics Institute, Australia
Professor Rob Shepherd

Baker IDI Heart and Diabetes Institute, Australia
Dr Christoph Hagemeyer
Dr Tom Karagiannis

CSIRO, Australia
Dr Adam Best
Dr Anand Bhatt
Dr David Haylock
Dr Patrick Hartley
Dr Anita Hill
Dr Matthew Hill
Dr Anthony Hollenkamp
Dr Danielle Kennedy
Dr Louis Kyratzis
Dr Keith McLean
Dr Yen Truong
Dr Xingdong Wang
Dr Fang Xia

Kanazawa Institute of Technology, Japan
Professor Yu Komatsu

Macquarie University, Australia
Dr Damian Gore

Mars Petcare, Australia
Dr Brad Woonton

Monash University, Australia
Associate Professor Ben Boyd
Professor Yi-Bing Cheng
Dr Fuzhi Huang
Dr Angus Johnston

Murdoch University, Australia
Dr Fang Xia

NuSep Holdings Ltd, Australia
Ms Alison Coutts

O’Brien Institute, Australia
Dr Keren Abberton
Dr Geraldine Mitchell
Professor Wayne Morrison
Mr Jason Palmer

Queensland University of Technology (QUT), Australia
Dr Phong Tran

RMIT University
Dr Xuehua Zhang

Royal Children’s Hospital, Australia
Professor Igor Konstantinov
Professor Anthony Penington

Royal Melbourne Hospital, Australia
Associate Professor Mark Daniell

South Australian Institute of Ophthalmology, Australia
Professor Dinesh Selva
Dr Michelle Sun

SungKyunKwan University, Korea
Associate Professor Pil Jin Yoo

The Royal Women’s Hospital, Australia
Professor Shaun Brennecke
Dr Bill Kalionis
Dr Christiane Theda

The University of Melbourne, Australia
Professor Peter Cook
Professor Edmund Crampin
Professor Ralf Haese
Professor Stephen Kent
Associate Professor Peter Lee Vee Sin
Professor Gordon Lynch
Dr Kate Murphy
Professor David Solomon

The University of Sydney, Australia
Dr Deanna D’Alessandro
Professor Cameron Kepert

University of Delaware, USA
Professor Stanley Sandler

University of Miyazaki, Japan
Professor Yoshinari Baba

Wuhan University of Technology, China
Dr Fuzhi Huang
Long-term CO₂ containment in a geological storage reservoir is a key criterion for successfully implementing carbon capture and storage (CCS), however, CO₂ leakage through different pathways cannot be completely ruled out in some instances. In this study we investigate the conditions for reactive barrier formation as a technology to mitigate and remediate CO₂ leakage. We propose to inject a liquid reagent consistent of an alkaline sodium-silicate solution on top of the storage caprock, which will lead to silica mineral precipitation when in contact with an acidic, CO₂-enriched fluid. This reaction will create a barrier that seals the leakage by reducing the permeability. Preliminary modelling has shown that the density, viscosity and alkalinity of the reagent fluid are critical for a successful seal formation, whereas differences in formation water composition and in the rock mineral composition are less important. In order to study the reaction through experiments, different reagent solutions were prepared and characterised in terms of silica concentration, density, viscosity and buffer capacity. Batch experiments and core-flood experiments will be carried out to simulate the reaction and barrier formation under reservoir conditions.

**CO₂ capture from natural gas: Development of adsorbents and accompanying processes**

David Danaci, Ranjeet Singh, Penny Xiao, Paul Webley

2015 saw the publication of the CO₂/CH₄ separation work on ZIF materials, and the completion of the data collection required to investigate their fundamental adsorption properties. Advances were made on the core-shell zeolite material and an approach was determined that would enable the successful synthesis of this material. Work is still underway to achieve complete coverage of the CH₄ block layer. Binary CO₂/H₂O data was not able to be collected on the fluorinated zeolite samples in order to determine the true cause of the reduction of H₂O uptake and whether CO₂ adsorption is hampered in the presence of H₂O. This work is on standby until a suitable apparatus is available to undertake this measurement. Work on a zeolite, ZSM-25 began as little work exists on this material and it initial works show it to be promising for CO₂/CH₄ separation. Our work has shown that additional efforts are required on the reproducible synthesis of the material and initial adsorption work has demonstrated that there may be an application in the kinetic separation of CO₂ from CH₄ as the diffusion of CH₄ appears to be slower than CO₂. 2016 will see the completion of the fundamental ZIF study, ideally a successfully synthesised core-shell zeolite and an outcome on the suitability of ZSM-25 for CO₂/CH₄ separations.

**Converting 3D rigid metal-organic frameworks (MOFs) to 2D flexible networks via ligand exchange for enhanced gas separation**

Yingdian He, Jin Shang, Qinfen Gu, Ranjeet Singh, Paul Webley

The last decade has witnessed intensive studies on gas adsorption and separation using flexible metal-organic frameworks (MOFs), since their pore aperture size and pore volume can be tuned in response to external stimuli to achieve the desired separation performance. However, the number of such flexible MOF candidates is relatively small compared with numerous rigid counterparts, because constructing phase-pure MOFs with flexible crystalline structure is difficult by traditional de novo methods. In this study we successfully develop a novel synthetic strategy, termed exchange method using acid-solvent synergy for metal-organic frameworks synthesis (EASY-MOFs), for constructing flexible MOFs from rigid parent structures. To the best of our knowledge, this is the first study introducing flexible heterogeneity into a rigid structure via substantial structural rearrangement. As an illustrating example, one daughter material shows reversible transformation from a non-porous to porous structure induced by CO₂ adsorption and exhibits enhanced gas separation selectivity compared with the parent. In particular, the daughter material exhibits superior ideal CH₄/N₂ selectivity of 8.2 at 10 bar at 273 K, which is comparable to the highest numbers in the open literature and holds promise for recovering CH₄ from low-grade natural gas. This work provides an alternative route to achieve rational material design for advanced gas separation and more information on interpretation of substantial structural rearrangement via ligand exchange.

**Carbonic anhydrase as a potential promoter for CO₂ absorption**

Guoping Hu, Nathan Nicholas, Sandra Kentish, Geoff Stevens

Carbon capture and storage (CCS) techniques are efficient and effective ways to reduce CO₂ emissions and so mitigate climate change effects. However, the cost of carbon capture has to be reduced to manageable levels before it can be deployed at an industrial scale. Potassium carbonate solutions (K₂CO₃) are good solvents for CO₂ capture because they have low regeneration energy, low degradation rates and low corrosiveness. However, one shortcoming of K₂CO₃ is that it has slow reaction kinetics with CO₂. This limitation can be overcome by the addition of promoters to K₂CO₃ such as carbonic anhydrase which is a promising enzymatic promoter. In this study, the kinetic performance of a thermally stable carbonic anhydrase enzyme was tested via the stopped flow technique and shown to have excellent promotion on CO₂ hydration reaction.

**Novel ultra-thin film composite membranes towards post-combustion carbon capture**

Jingkum Kim, Qiang Fu, Sandra Kentish, Greg Qiao

Although recently developed polymeric membranes for CO₂ separation often exceed the upper bound line, the total gas flux of these membranes can be poor. This negative performance is induced by the thick selective layer. Therefore, the gas flux can be enhanced by reducing the layer thickness while maintaining the intrinsic gas separation properties. In addition, further enhancement in CO₂ permeance and CO₂ separation from N₂ can be achieved by incorporation of CO₂ selective nano-sized additives within a PEG-based selective layer. By utilising a recently developed continuous assembly of polymers (CAP) technology allowing defect-free, cross-linked and surface-confined thin films with nanometer scale precision, this research investigates the fabrication of CAP ultra-thin film composite (UTFC) membranes and the development of novel ultra-thin composite mixed matrix membranes (UFC-MMMs) incorporating hybrid organic-inorganic nanoparticles (i.e. iron dopamine nanoparticles (FeDA NPs)) and surface-functionalised SiO₂ nanoparticles (SFSNPs), providing a future direction of CAP UFC membranes for industrial use.
The impact of flue gas impurities on the performance of cellulose acetate membrane for CO₂ separation

Hiep Lu, Colin Scholes, Shinji Kanehashi, Sandra Kentish

Dense cellulose triacetate (CTA) membranes have been widely utilised in industrial gas separation processes. Their commercial readiness, as well as competitive gas separation performance, makes CTA an ideal candidate in capturing carbon dioxide (CO₂). Unfortunately, the presence of impurities in processing gases, including water, hydrogen sulphide (H₂S) and oxides of sulphur (SO₂) and nitrogen (NOₓ), could upset the performance of membrane units. Although the manufacture of membrane modules for CTA is well developed, the effect of these impurities, including the decline of membrane performance by plasticisation, competitive sorption as well as the long term physical aging, is still not fully understood.

This study investigates the impact of water (pH 3 – 13), SO₂ and NO on CTA membrane permeation, including the kinetic sorption, gas separation performance and the aging effect. It is found that the acidic and neutral solutions plasticised and enhanced the membrane performance whereas the existence of highly alkaline conditions decomposes the original membrane structure. The dependencies of SO₂ permeability on temperature and pressure in CTA membrane have provided a detailed database that will enable future modelling. Meanwhile, the aging of CTA in SO₂ and NO conditions throughout 60 days showed only minor impacts of these impurities on membrane performance.

CO₂ capture using deep eutectic solvents (DESs)

Nouman Rafique Mirza, Nathan Nicholas, Sandra Kentish, Geoff Stevens

Deep eutectic solvents (DESs) are novel solvents having multiple applications. Advantages of these solvents lie in their ability to be biodegradable, non-toxic in nature, non-flammable, having negligible vapour pressure, low price and easy manufacturing with high purity. However, for most of these solvents, important physicochemical and thermodynamic properties are still missing in literature. In order to estimate the critical properties of these solvents, a combination of modified Lydersen-Joback-Reid method and Lee-Kesler’s mixing rules has been applied on a sample of 33 different DESs. Normal boiling temperatures and acentric factors have also been determined. The accuracy of the method has been tested by making independent estimates of densities (based upon estimated critical properties) and comparing these with published literature values. The method gives satisfactory results for DESs resulting from different molar ratios of the same precursors. It also takes into account the temperature variation of estimated densities and gives reasonable results. Experiments for CO₂ solubility in three different choline chloride based DESs were conducted in a temperature range of (309 to 329) K at pressures up to 160 kPa. Henry’s constants for CO₂-DES systems have been determined under these conditions with values in the range of (3.7 to 6.1) MPa (on molality basis). Thermodynamic modeling using a modified Peng-Robinson equation of state to correlate to the experimental data showed satisfactory results. The calculated Gibbs free energy, enthalpy of dissolution and entropy of dissolution showed that the CO₂ absorption was exothermic and the entropy of the system decreased as a result of gas absorption. Further experiments to explore a range of DESs with better CO₂ solubility are being conducted in the laboratory.

Encapsulated solvents for post-combustion carbon capture

Thomas Moore, Kathryn Mumford, Geoff Stevens, Paul Webley

The separation of carbon dioxide from flue gases is typically the most expensive stage of a carbon capture and storage operation, and while many solvents and adsorbents could be used for this separation, at present no material is without significant disadvantages. This project aims to develop a new hybrid material, microencapsulated solvents (MECS), in which solvents are encapsulated in small (100-500 micron) polymer shells which are highly permeable to CO₂. Microencapsulation may allow corrosive, viscous or volatile solvents to be used in CCS operations. Further, the very high surface area of these particles enhances the kinetics of absorption, allowing the use of solvents with low regeneration energies, whose kinetics would otherwise be prohibitively slow. This project will investigate the industrial application of MECS for post-combustion capture of CO₂. Through a combination of large-scale process modelling, small-scale transport phenomena analysis and experimental measurements we hope to assess their industrial viability, analyse different process designs, and compare them with existing capture technologies.

Adaptive management system for sustainable bioenergy with carbon capture and storage (BECCS)

Nasim Pour, Paul Webley, Peter Cook

This project concerns the sustainability of bioenergy with carbon capture and storage (BECCS). In BECCS the CO₂ derived from conversion of the biomass to energy is not released to the atmosphere but is sequestered, transported and permanently stored in a suitable geological formation. The biomass for energy generation is seen as carbon neutral in that the carbon released to the atmosphere during conversion of plant matter was first taken from the atmosphere during photosynthesis. Thus, a negative flow of CO₂ from the atmosphere to the subsurface is established. The potential of BECCS to remove atmospheric CO₂ in addition to generating energy makes it one of the more attractive approaches to achieve the ambitious atmospheric temperature targets such as +2°C.

BECCS consists of various variables such as type of biomass resource, conversion technology, CO₂ capture process and storage. Each of these pathways has its own environmental, economic and social impacts. The scope of this study is to integrate these impacts into a three-pillared sustainability framework. This framework is provided to assist decision-makers to evaluate sustainability of different BECCS options in a transparent and timely manner.

Development of novel polymeric membranes for CO₂ capture

Joel Scofield, Sandra Kentish, Greg Qiao

Thin film composite (TFC) membranes containing polymeric selective layers have been investigated for their carbon dioxide (CO₂) separation performance as a potential technology for carbon capture and storage (CCS). One promising approach being considered to enhance membrane performance is the incorporation of highly permeable additives into selective polymers, which are then coated onto membrane supports. Previous work using this approach has demonstrated improved membrane fluxes while maintaining selectivity towards CO₂, which will lead to reduced separation costs.
Block copolymers are one class of membrane materials being investigated. Polymers containing ethylene oxide segments have shown good separation due to favorable interactions between the CO₂ and the ether oxide moieties. Recently block copolymers containing a PEG selective component have been designed to produce additives which are compatible with the selective matrix polymers, such as PEBAX. This approach enables the incorporation of a highly permeable component such as PDMS or fluorinated segments.

In 2015 we completed a study on block copolymer containing fluorinated segment with a range of different additives incorporated into TFC membrane active layers containing up to 60-70 wt. % of the additive. The optimal block length of the fluorinated component was found which demonstrated increases of up to 250% and 400% in the CO₂ flux, with moderate drops in the CO₂/N₂ selectivity when blended with PEBAX® 2533. The use of these additives was extended to higher selective and lower permeable grades of PEBAX with the resulting TFC membranes, which sit well within membrane performance targets.

Modelling precipitating absorption columns using K₂CO₃ solvent in carbon capture

Yue Wu, Kathryn Mumford, Sandra Kentish, Geoff Stevens

Recently some advanced separation technologies including vapour-liquid separation involved in solid precipitation have drawn great interest in capturing carbon dioxide (CO₂) from the flue gas emitted from coal-fired power plants. The use of concentrated potassium carbonate (K₂CO₃) solvent is potentially an effective way, not only to enhance CO₂ absorption capacity, but also to reduce cost, as the formation of precipitation product potassium bicarbonate (KHCO₃) shifts the original vapour-liquid equilibrium and reduces the circulation of water, thus reducing the consumption of energy when regenerating the solvent.

This study conducts a review of high K₂CO₃ concentration based CO₂ absorption processes, along with a kinetic study on the KHCO₃ precipitation behaviours using Focused Beam Reflectance Measurement (FBRM), including particle size distribution, crystal nucleation rate and average growth rate. Based on the Aspen Custom Modeller (ACM) simulation platform, a three-phase equilibrium-based and rate-based absorber model is being developed. In addition, the thermodynamic properties of CO₂ capture based on concentrated K₂CO₃ solvent has been investigated, regressed and modelled using an electrolyte non-random two liquid (ENRTL) method on the CO₂-K₂CO₃-KHCO₃-H₂O three-phase system in Aspen Plus, which can be cooperated in ACM.

The three-phase model provides basic design, information and guidelines to predict KHCO₃ precipitating behaviours, thus avoiding fouling and blocking issues in the absorber. The model and simulation could further support the use of a high concentration of K₂CO₃ based solvent system with a range of promoters.

Polymer metal-organic framework composite structure for CO₂ capture applications

Ke Xie, Qiang Fu, Greg Qiao, Paul Webley

Metal-organic frameworks (MOF) are good candidates for gas separation due to their molecular sieving properties and high thermal stability. MOFs are cast into membranes (MOF membranes) or blended with polymer matrix to produce mixed-matrix membranes (MMM). Neither of these techniques is optimal as the resultant membranes can have poor mechanical strength, defect-prone features and processing difficulties.

In this study, the amino-functionalised MOF (NH₂-Uio-66) and the bromide functionalised MOF (Br@MOF) nanometric crystals (30–50 nm) were successfully prepared and characterised by XPS, XRPD, TGA, SEM and TEM. Br@MOF was used to initiate the polymerisation of polyethylene glycol acrylate (PEGMA) via atom transfer radical polymerisation (ATRP), resulting in a polymer grafted MOF composite (P@MOF). P@MOF was firstly applied as the catalyst carrier by loading Pd nanoparticles. Owing to its absolute water dispersity and pH-sensitive aggregation-deaggregation nature, Pd loaded P@MOF integrated the advantage of both high homogeneous (high activity) and heterogeneous (good recyclability) catalysts. Furthermore, the unique core-shell structure of P@MOF implies its potential for gas separation MMM. Currently, CO₂ separation measurements (over light gases like CH₄ or N₂) are being performed to reveal the CO₂ capture capability of the membranes.

The fabrication of thin films on hollow fibre membrane contactors for promoting the absorption of carbon dioxide

Joel Yong, Sandra Kentish, Frank Caruso

Membrane contactor operations make use of a hydrophobic membrane as a barrier between a gas phase and a liquid phase during the gas-liquid absorption of CO₂. The CO₂ in the gas phase diffuses through the pores of the membrane into the liquid solvent and can then be carried away for stripping and purification. However current membranes face serious issues with pore wetting which significantly reduces the rate of CO₂ mass transfer. Previous studies have shown that a monolayer chemical adsorption of carbonic anhydrate (CA) onto membrane contactor surfaces can enhance the CO₂ absorption activity significantly. We have developed a technique to fabricate a thin film containing CA in multilayers on top of a porous flat sheet membrane through layer-by-layer (LbL) electrostatic adsorption. These CA films are found to be useful for enhancing the mass transfer of CO₂ into potassium carbonate solvents. We are currently investigating the deactivation kinetics of CA in long-term absorption operations and will be looking into the adverse effects of toxic gases on the activity of the CA.

Electrical swing adsorption: A low energy option for carbon dioxide capture

Qinghu Zhao, Penny Xiao, Paul Webley

Compared with conventional temperature swing adsorption (TSA), electric swing adsorption (ESA), as an emerging CO₂ capture technology, has certain advantages including shorter regeneration time, and higher adsorbent regeneration efficiency. Most of studies of ESA have been done with activated carbon monoliths from MAST Carbon (UK) as adsorbents without considering fluid dynamics in the monoliths channels. The lower CO₂ adsorption capacity of activated carbon however, compared with zeolite, adversely affects its performance; its resistance is very small, and a high current has to be applied, which results in high heat loss. In this project we will develop zeolite/phenolic resin composites to form composite adsorbents to increase the adsorption capacity and resistance at the same time. In addition, we are using CFD based fluid profiles together with MATLAB adsorption models to simulate CO₂ breakthrough and study how fluid dynamics factors affect CO₂ adsorption. Finally, we will combine Vacuum Swing
Adsorption (VSA) with ESA to develop new EVSA process to increase the total system efficiency and reduce energy consumption.

**Photocatalytic and energy storage applications**

As technology grows ever more rapidly, more powerful energy storage devices are necessary to accommodate the ever-increasing energy requirement.

**Monodisperse titania microspheres featuring high-temperature stability and large pore size are efficient photocatalysts**

Lu Cao, Rachel Caruso

Titania (TiO₂) is amongst the most widely investigated semiconductor materials for photocatalytic applications. The most photoactive polymorph, anatase, is metastable and can be readily transformed to the thermodynamically stable, less photoactive, rutile at temperatures of 500-700 °C. This restricts the use of titania photocatalysts for some applications (e.g. self-cleaning or antibacterial coatings on ceramic substrates) that need to be processed at high temperatures (≥800 °C). A spherical morphology is regarded as the optimal material morphology for forming a uniform compact coating layer on substrates because microspheres have a high packing density as well as good particle mobility, thereby resulting in high and reproducible performance. Moreover, the presence of large pores in the catalyst can facilitate efficient separation of photogenerated charge carriers, high light harvesting and fast mass diffusion, thus benefiting photocatalytic performance.

A facile route for the synthesis of monodisperse anatase titania microspheres with high-thermal stability (up to 900 °C) and large pore size (77 nm) has been demonstrated by combining sol-gel and solvothermal treatment processes. The high-temperature stable anatase spheres show remarkable activity for the photodegradation of methylene blue, an organic dye, under UV light irradiation compared to P25 (a benchmarked photocatalyst) thermally treated at the same temperature.

**Solid-state thin film solar cells on flexible polymer substrates**

Yasmina Dkhissi, Rachel Caruso

To meet the world’s ever-growing energy needs while facing current environmental challenges, solid-state thin film solar cells offer a low-cost renewable alternative for generating electricity. Constructing efficient flexible photovoltaics on plastic substrates remains difficult due to the substrates intrinsic low-temperature limitation. In the past year, attention has been drawn towards photovoltaics utilising inorganic-organic perovskites, an emerging technology with recently reported efficiencies rivalling existing commercial solar cell technologies. Nevertheless, the majority of these devices constructed on glass employ a high temperature processed inorganic layer (≥500 °C), non-compatible with flexible applications. In this regard, a method to produce efficient and reproducible perovskite solar cells on plastic substrates has been developed, with the entire device fabrication process conducted at 150 °C or below. Power conversion efficiencies over 13% have been attained for small flexible devices, with an average efficiency of 11.8% ± 1.8%. In addition, practical industrial concerns such as the stability and the manufacturing processability of these devices are currently under investigation.

**Engineering electrochromic materials for multifunctional smart windows**

Yiqun Li, Rachel Caruso

This project focuses on electrochromic materials for multifunctional smart windows that can undergo reversible changes in optical properties upon application of a low voltage. WO₃ is a traditional electrochromic material. A facile one-step hydrothermal method has been developed to grow WO₃ nanowires directly onto FTO substrates without the tedious procedure of building a seed layer onto the FTO first. After optimising the synthesis conditions, the electrodes based on WO₃ nanowires prepared with and without a seed layer were compared. As there was no compact crystal seed layer and the nanowires were in direct contact with the FTO substrate, the electrode prepared without a seed layer showed higher transparency in bleaching state, faster response time and better cycling life than the electrode with a seed layer. To strengthen the electrode an annealing process under the protection of N₂ was applied. There was no significant difference between the non-annealed and annealed electrodes in optical modulation, response time and efficiency, however due to increased crystallinity and a stronger structure, the cycling life of the annealed electrode was 10 times better than the non-annealed one.

**Porous titania-based materials and their high-throughput photocatalytic screening for environmental remediation**

Natalita Nursam, Xingdong Wang, Rachel Caruso

In an attempt to yield high efficiency photocatalysts, the optimisation of titania materials has been conducted and will continue to be an active research area. Methods to fabricate porous titania-based materials with high photocatalytic performance, including under visible light, were developed in this project using combined doping and templating synthesis. Mesoporous anatase titania with nitrogen doping was prepared by a template-free, sol-gel synthesis route in the presence of diethanolamine followed by a single step low temperature calcination treatment. The effect of calcination conditions and the type of titania precursor were investigated, highlighting their profound influence upon the adsorption and visible light activity. To further enhance the practicality of the titania composites with nitrogen modification, the synthesis method was then extended to obtain porous monolithic structures. The goal of these studies was to investigate the relationship between the photocatalytic activity and the diverse porous morphologies produced using soft (i.e. via phase separation) and hard templating techniques (using agarose gels). In addition, as part of the hard templating route, colloidal silica spheres packed into a three dimensional opal structure were also used as the sacrificial template, combined with the addition of nitrogen and silver nanoparticles. All of the porous samples prepared using nitrogen doping and hard templating route in this work produced better visible light photocatalytic activity than the commercial titania, P25.

**Titanium base oxides as high performance materials for lithium ion batteries (LIB)**

Erwin Rodriguez-Tolava, Rachel Caruso, Anthony Hollenkamp, Dehong Chen

Currently most portable gadgets use lithium ion batteries (LIB) due to their high specific energy. However, to apply this energy technology in larger devices, such as electric cars, safety and life-span issues must be resolved. Safety can be improved by employing materials that
intercalate lithium at higher potentials, such as titanium-based oxide anodes. Hierarchical mesoporous structures can enhance the rate capability and improve the energy density in LIBs. In this project, monodisperse mesoporous titania beads with different structural properties were synthesised by a hydrothermal crystallisation, and the influence of their physical properties such as bead diameter, pore diameter and degree of sintering was investigated on the electrochemical performance for LIBs. High surface area, small primary particle size and optimal sintering conditions influenced the electrochemical performance. In addition, Li$_4$Ti$_5$O$_{12}$ (LTO) material was hydrothermally synthesised as mesoporous structures with high surface area and narrow pore diameter distribution. The thermal phase transformation from orthorhombic protonated titanate (LHT) to spinel LTO was followed by in situ high temperature X-ray diffraction and thermal analysis to obtain an optimal annealing temperature that provided high LTO performance for LIBs.

Mesoporous titanium-based microspheres for high-performance visible-light photocatalysts and Li-S battery

Hao Wei, Dehong Chen, Adam Best, Anthony Hollenkamp, Rachel Caruso

To extend the photocatalytic activity of TiO$_2$ with a wide band gap (3.2 eV) in the visible light range, mesoporous TiO$_2$/$g$-C$_3$N$_4$ hybrid microspheres were prepared with TiO$_2$ as the active scaffold and $g$-C$_3$N$_4$ as the visible light sensitizer. Nitrogen substituted into the TiO$_2$ lattice enhanced photocatalytic activity of the composite (8.5 times higher than pristine $g$-C$_3$N$_4$), assessed by degrading phenol under visible light irradiation. In addition, the open porous structure and accessible interface provided fast mass transfer.

Li-S batteries have attracted attention due to their high energy density (1672 mAh g$^{-1}$) and low cost, however the performance of Li-S batteries depends on reversible conversion between pristine sulphur and Li$_2$S. To overcome the intrinsic drawbacks of sulphur, such as low conductivity and capacity decay during cycling, functional additives have been developed to improve the electrochemical performance of the electrodes. Until now, various metal oxides have been investigated reported as conductive hosts, however, only physical trapping or poor chemical bonding between oxides and intermediate lithium polysulphides (LiPSs) or Li$_2$S was not sufficient, leading to inevitable capacity fading during cycling.
were successfully synthesised through a carbothermal procedure at high temperature. As the active cathode material this composite exhibited high capacity (1317.6 mAh g⁻¹) and stability (12 % decay after 400 cycles). Ti₃O₂ of the magneli phase revealed strong chemical binding to intermediate LiPSs during the charge/discharge process, while a matrix of porous microspheres could simultaneously physically trap sulphur species.

**Nanostructured titania thin films for high-performance perovskite solar cells**

Wu-Qiang Wu, Rachel Caruso

Nanostructured materials of different nanoscale dimensions are playing an important role in the recent advancement of solar energy conversion technologies. These materials have the advantages of offering tunable bandgap, controllable optical absorption, favourable charge transport properties, as well as other promising physical and chemical properties. The photovoltaic performances of solar cells are dependent on the controlled nanostructuring of the individual components making up the cell. In the present work, a facile solvent-mediated solvothermal route has been developed to fabricate diverse nanostructured TiO₂, thin films including 0D nanoparticles, 1D nanowires and 2D nanosheets on transparent conducting oxide (TCO) substrates by varying the organic solvents used. These nanostructured TiO₂ layers showed a ~2 to 5% optical transparency enhancement as compared to pristine TCO substrates, thus minimising light absorption losses. Perovskite solar cells (PSCs) fabricated using the 1D nanowires or 2D nanosheets yield significantly improved photovoltaic performances compared to the 0D nanoparticles. This could be ascribed to improved infiltration of the perovskite (light absorber) in the highly porous nanowire or nanosheet network, and facilitated charge extraction at the perovskite/nanowire or perovskite/nanosheet interfaces for reduced interfacial recombination losses. The PSC based on optimised nanowire thin films yielded an efficiency exceeding 16%. This work shows that the solvothermal technique is very promising for the fabrication of titania nanostructures with various dimensions and geometries, allowing optimisation of light trapping and harvesting as well as the control of interfacial charge extraction and collection for high-performance thin film optoelectronic devices.

**Biological Applications**

**Porous hydrogel antimicrobial nanocomposites**

Dhee Biswas, Phong Tran, Carolina Tallon, Andrea O’Connor

The naturally derived polymer chitosan, from byproducts of the marine industry, has found wide ranging usage in the field of tissue engineering. Its polymer backbone is known to be similar to that of glycosaminoglycans present in the extracellular matrix of human tissues, making it an attractive polymer to mimic aspects of the natural structure of ECM. In our studies we have utilised chitosan for macroporous hydrogel development. Manipulation of pore properties was achieved via change of freezing temperature during thermally induced phase separation and introduction of polyvinyl alcohol (PVA) as a surfactant during foaming. Mechanical, swelling and biocompatibility of the scaffolds were probed and have shown promising properties for future tissue engineering applications. Antimicrobial nanoparticles of both silver and selenium were incorporated into these porous hydrogels and their subsequent toxicity against mammalian fibroblasts was assessed. Specificity of these nanoparticles against Staphylococcus aureus, its drug resistant form, MRSA (Methicillin resistant Staphylococcus aureus), and Escherichia coli were investigated and selenium doped hydrogels have shown promise. The mechanisms of killing the bacteria were probed and selenium has been shown to kill bacteria by damaging its cellular membranes and cell walls. These hydrogel nanocomposites will be beneficial in an age of growing antimicrobial resistance for antimicrobial wound healing applications.

**Engineering and evaluating drug delivery particles in microfluidic devices**

Mattias Björnalm, Frank Caruso

Nanostructured particles hold great promise to treat diseases as they can increase the efficacy of current therapies, as well as enable new ones. However, clinical translation of drug delivery particles remains difficult, due to challenges associated with both synthesis and characterisation, as well as with the evaluation of their biological performance. Microfluidics is emerging as a powerful complement to existing technologies by providing new and improved means of engineering particles, as well as by enabling the evaluation of particles in vitro in microenvironments that mimic in vivo conditions. In this project, we design and develop microfluidic strategies covering aspects of both engineering and evaluation of polymer drug delivery particles.

**Nanoengineered polymer capsules with tailored physicochemical properties for bio-nano interactions**

Xi Chen, Frank Caruso

The interactions between biological systems and nanostructured materials (bio-nano interactions) are of considerable research interest. Polymer capsules with tailored physicochemical properties (e.g., size, shape and stiffness) are engineered through layer-by-layer assembly or surface polymerisation methods, and the effect of these physicochemical properties on cellular binding, internalisation and response is investigated via advanced characterisation techniques, including super-resolution microscopy. The obtained results provide insights to guide the rational design of polymer carriers for biological applications.

**Differential roles of protein coronas in cellular uptake and immune responses of polymeric particles**

Qiong Dai, Frank Caruso

Over the past few decades, nanoengineered particles with specific abilities have been investigated for their potential as smart carrier systems. It has been shown that the formation of protein coronas impacts on the surface properties and abilities of the functionalised particles. The protein corona determines how cells ‘see’ the surface of the particles by providing them with a ‘biological identity’. Thus, it is of high importance to study the influences of protein coronas on both the properties of particles and the subsequent bio-nano interactions, such as cell membrane recognition and binding, cellular uptake and immune responses. This project aims to investigate the formation of protein coronas in variable biological environments, the effects of these various coronas on the physicochemical properties and the cell association ability of polymeric particles,
and the impact of protein coronas on the following immune responses of these particles after their interaction with immune cells. The results are expected to provide useful information for the design of next-generation drug delivery systems by taking advantage of preformed protein coronas.

Nanoparticle dosimetry prediction
Matt Faria, Frank Caruso

Understanding the cellular response to a nanoparticle system is an essential step to characterising the biological activity of that nanoparticle. This is usually determined in vitro by incubating cells with a solution of particles and then measuring cellular association or uptake. However, these measurements are downstream of a number of complex interacting effects which can mask the biological interactions of interest. For instance, consider a solution with particles that sediment rapidly compared to a well-dispersed colloidal suspension of particles. Clearly, if incubated in vitro with cells at the bottom of a well, the former solution will sediment onto the cells and a greater percentage of particles will be presented. We have previously built computational models using partial differential equations that can predict and control for major particle-fluid effects. These models allowed us to understand “how many particles get to the cell”. Now, we are developing models of the biological interactions of cells and particles to predict association and uptake. We are also examining cellular response in systems that more closely resemble in vivo conditions, for instance, with particles in a fluid under flow. These models will allow us to answer the question “what happens to particles when they reach the cell?”

Amphiphilic core cross-linked star polymers as key building blocks of the hydrogels with hydrophobic domains for drug delivery
Dunyin Gu, Andrea O’Connor, Katharina Ladewig, Greg Qiao, David Haylock, Keith Mclean

Core cross-linked star (CCS) polymers represent an intriguing platform in the application of drug delivery. CCS polymers as drug carriers are more robust to environmental variations, compared with the self-assembled micelles or vesicles, which tend to disassemble below their critical association concentration or under external stimuli, followed by an undesired burst release of drugs. Also, the ease of designing the size or functionality of arms and cores separately makes CCS polymers more attractive than other types of unimolecular containers. Like many other molecular carriers, however, the limited circulation period of CCS polymers in the body would decrease the duration of drug action. In order to overcome this constraint, CCS polymers can be built into hydrogels to form a stable drug-delivery implant. We have adopted a facile two-step Ring-Opening Polymerization (ROP) approach to synthesise a library of well-defined amphiphilic poly(ethylene glycol)-poly(ε-caprolactone)-poly(4,4’-bioxepane)-7,7’-dione) (PEG-PCL-BOD) CCS polymers which exhibit a unimolecular state in both organic and aqueous solutions. The presence of PCL components endows these CCS polymers with large loading capacities for hydrophobic drugs and the CCS-drug complex displays high stability at neutral pH and a fast release under acidic conditions. In addition, flow cytometry analyses indicated that the unimolecular drug containers are cyto-compatible and can be internalised by cells with high efficiency.

Cryogels for soft tissue engineering and regeneration
Timothy Henderson, Katharina Ladewig, Andrea O’Connor, Keith McLean, David Haylock

Macro-porous hydrogels are promising candidates for many cell culture and tissue engineering applications by virtue of a number of physical and chemical properties that closely resemble the extra-cellular matrix, including gel-like mechanical properties and plausible biochemical composition. Chemically crosslinked cryogels are a unique type of macro-porous hydrogels that are formed below the solvent melting point. The resulting gels are highly porous with inherently interconnected pores. Recent work has focused on the development and application of hyaluronic acid cryogels for soft tissue engineering. Hyaluronic acid is a major component of the extracellular matrix and a highly favourable biomaterial for use in cell culture and tissue engineering applications. We have investigated the suitability of these gels for soft tissue regeneration via a number of in vitro cell culture and in vivo studies showing significant promise.

Magnetic manipulation of cells for soft tissue engineering
Javad Jafari, Phong Tran, Andrea O’Connor

Challenges can arise in the application of scaffolds in tissue engineering due to issues including inflammatory reactions caused by the biomaterials or their degradation products. In addition, the rate and extent of cell migration and vascularisation may not be adequate, and cell-cell interactions in hetero-culture may be lacking, especially in large constructs. Recently, some studies have aimed to use scaffold-free tissue engineering approaches to address these issues. One such approach is the use of magnetic particles to label and thereby manipulate cells by application of an external magnetic field. In this study, 3T3 fibroblast and 3T3-L1 preadipocyte cells were labelled with functionalised magnetic microparticles to investigate the potential of using magnetic manipulation to enhance soft tissue engineering. A cytotoxicity study showed differences in the cells’ sensitivity to the presence of the magnetic particles. The particles did not adversely affect the proliferation of fibroblasts but a degree of cytotoxicity was observed for preadipocyte cells at higher magnetic particle loadings. The effects of magnetic forces on the cells’ proliferation, differentiation and migration have been studied. By using an external magnetic field, these labelled cells were also able to be manipulated and cultured in desired patterns, to assemble a variety of 3D constructs.

Multi-scale design of cardiovascular biomaterials
Fatemeh Karimi, Andrea O’Connor, Greg Qiao, Daniel Heath

Cardiovascular disease is a leading cause of death worldwide. The development of blood compatible biomaterials would enable the development of much needed blood contacting biomedical devices such as vascular grafts, stents, and artificial heart valves. Endothelial cells line all native vasculature and are responsible for imparting blood compatibility. Therefore, an attractive strategy for improved blood compatibility is to generate materials.
that foster a confluent and functioning endothelial cell layer. This project aims to develop a next generation biomaterial platform that will promote the growth of an endothelial cell layer through the use of nanotechnology and functionalisation with endothelial cell specific ligands. In addition, these characteristics will be incorporated to fabricate a three-dimensional scaffold in order to mimic the native extracellular matrix and to observe the synergistic effect that arises from combining molecular-, nano-, and micro-scale design of cardiovascular biomaterials.

**Biomaterial porous networks of hydroxyapatite and titanium dioxide**

William McMaster, Rachel Caruso

A critical size bone defect requires filling with a biomaterial scaffold in order to heal. In situ delivery of medicinal drugs may aid healing, but current drug delivery vehicles (DDVs) lack control over targeted delivery and release. Porous networks of hydroxyapatite (HA) or anatase titanium dioxide (TiO₂) could be utilised as biomaterial scaffolds or DDVs. Four different sponges were used as templates for open-cell HA networks. Two concentrations of sol-gel precursor were employed; high concentration obscured the template structure in the final network. The choice of template, multiple sol-gel coating, and the rate of temperature increase during calcination led to evolution of the HA fibre surface. All final networks were HA, but other calcium species were present as well.

One alternative to HA is TiO₂. Using sol-gel chemistry, a collagen gel template and solvothermal treatment, high surface area TiO₂ networks composed of mesoporous fibres were fabricated. The morphological transition from the collagen to TiO₂ network structures, and various solvothermal fluid compositions were explored. Solvothermal treatment and calcination time altered the fibre morphology and influenced the surface area, mesopore diameter and total pore volume. Selected TiO₂ networks were studied for possible biomedical applications. Biomineralisation took place in a simulated body fluid: Apatite growth indicated in vitro bioactivity, but high surface area may affect sustained biomineralisation. Ibuprofen drug delivery was monitored by two methods, with a maximum loading of 58.9 mg g⁻¹. Ibuprofen could be stored in mesopores, with drug release modelled as a sustained diffusion mechanism.

**3D printing smart materials**

Milena Nadgorny, Luke Connal, Zeyun Xiao

3D printing is a rapidly growing technology which attracts attention in fields of tissue engineering, medicine, pharmaceutics and smart devices. Unlike standard methods such as lithography, 3D printing allows the fabrication of complex objects within minutes and with an improved control of size and geometry. Although advances have been demonstrated during past decades, there is still a limited range of 3D printing-compatible materials. An increasing demand in high resolution smart devices shifts the need towards functional materials. A narrow number of materials inhibits the technology growth and restricts the applications range. While major efforts are invested in biomedical materials, there is still a limited number of works addressing 3D printable, stimuli-responsive materials. The objectives of this project are to develop novel, stimuli-responsive polymers for the field of smart devices (actuators, microfluidic devices, sensors, responsive surfaces). In particular, we are interested in synthesis, characterisation, investigation of processing conditions and functionalisation of pH and temperature responsive polymers for fused deposition modelling.

**Fabrication of pH-responsive nanogated mesoporous silica by selective functionalization**

Kaiyuan Qin, Rachel Caruso, Michelle Gee, Andrea O’Connor

Templated mesoporous silicas are synthetic materials with uniform pores in the range of 2-50 nm. The studies of mesoporous silicas utilised in bio-systems have been widely developed due to their uniform pore sizes, high surface areas and pore volumes and relevant sizes for macromolecules. Introducing plenty of functional groups onto the surface of mesoporous silicas could enable diverse potential applications of these materials, for example, catalysis, drug delivery and protein separation. The potential applications of functional silicas are somewhat limited by the low selectivity of functionalisation. It can be desirable to immobilise functional groups selectively only on the exterior or interior surfaces of silicas to control the pore structure and complement potential size selectivity of adsorption in the pores.

This study developed a straightforward method to selectively functionalise the exterior surface of FDU-12, a mesoporous silica with uniform pore entrances, large cage size and interconnected pore structure. This was achieved by using sucrose to protect the interior pore surface, with gas sorption analysis showing the interior surface of silicas can be protected by the polysaccharide after a sugar fusing procedure and be deprotected after sugar extraction to enable selective functionalisation.

**A mechanical approach to cancer treatment**

Camilla Reehorst, Dave Dunstan

Every year millions of dollars worldwide are invested in cancer research and development which is aimed at eradicating cancer, being the second leading cause of death globally. Despite this the return on investment carries few breakthroughs. Treatment is consistently getting more efficient with cancer patients experiencing increased life expectancy; however, their quality of life is often compromised as severe side-effects are common results of cancer treatment. The consequence of treatment is often associated with non-specificity towards cancerous tissue of the active agent used to treat the disease. In case of chemical treatment (e.g. nanotherapy), specificity may be improved by passive and active targeting, but unless the chemical substance is quickly broken down after being released it may damage nearby healthy tissue. To address this issue, this project aims to develop a stimuli-responsive system that mechanically lyses cancer cells. A mechanical approach would reduce residual danger to healthy tissue after treatment, especially when the system is made using biodegradable and non-toxic substances.

**Smart, engineered polymer vehicles for therapeutic delivery**

Ka Fung (Leo) Noi, Frank Caruso, Kristian Kempe

Advanced nanoparticles and nanocarriers have been of intense interest for the past decade as they promise to revolutionise
the field of medicine. Nanoparticles assembled via the layer-by-layer (LbL) deposition technique have been demonstrated as a promising system for drug and gene delivery. However, the relationship between particle properties, including size, shape, surface chemistry and mechanical properties, and its influence on interaction with cells in a biological setting is under-researched. In this regard, a well-understood model polymer, thiol-modified poly(methacrylic acid) (PMA$_{th}$), has been used to fabricate LbL capsules to gain an in-depth understanding of size-dependent cellular interactions. LbL PMA$_{th}$, core-shell particles and hollow capsules with diameters ranging in size from 100 nm to 1 µm, in conjunction with multiple cell lines of different biological and physiological functions, are being utilised to investigate the effect of size in vitro, including cellular association, uptake and internalisation pathway. Furthermore, carrier size is likely to influence its pharmacokinetics and biodistribution in vivo.

**Application of nanoparticles with dual enzyme-like activities in cancer treatment**

Hadi Ranjiburchaloo, David Dunstan, Greg Martin

Cancers are a huge family of diseases characterised by the growth of abnormal cells with the ability to invade or spread to other parts of the body. Recent statistics show that population of the world is expected to have increased to 7.5 billion by 2020. Thus, approximately 15 million new cancer cases will be diagnosed, and 12 million people will die from cancer. Complete removal of the tumour cells without damaging the healthy cells is the ideal aim of cancer treatment and is often the goal in practise. Different treatment approaches can be divided in two broad groups of traditional and novel cancer therapy. Reactive oxygen species therapy is a new treatment strategy and has a great potential in cancer treatment. In this method, nanoparticles react with hydrogen peroxide and produce hydroxyl radicals inside the cancer cells. These radicals are very reactive and can damage cellular constituents effectively at high concentrations. This project aims to develop dual enzyme-like nanoparticles like iron oxide and copper oxide which are stable in neutral pH, while they can produce hydroxyl radicals inside the cancer cells to damage them. As a result, the success of this research will reduce treatment costs and remove cancer cells selectively.

**Development of substrates for improved expansion of mesenchymal stem cells**

Aida Shakouri, Andrea O’Connor, Shaun Brennecke, Bill Kalionis, Daniel Heath

Mesenchymal stem cells (MSCs) exist in many tissues in the human body and serve as a natural tissue repair mechanism throughout a person’s life. Due to their multi-potency, self-renewal capacity and high proliferation rates, MSCs have been explored as a potential therapy for many diseases including myocardial infarction, diabetes, and spinal cord injuries. However, for such clinical applications large quantities of high quality MSCs are needed. Unfortunately, these cells are present at low frequencies in tissue biopsies requiring prolonged ex vivo expansion in order to obtain clinically relevant cell numbers. This expansion results in loss of desired stem cell characteristics due to senescence, lineage commitment, or loss of differentiation potential. Current ex vivo expansion protocols do not preserve MSC properties limiting the development of many promising cell therapies. In this project, we aim to meet this need by developing a platform for the improved ex vivo expansion of MSCs.

**Engineering proapoptotic peptide nanoparticles with tuneable cytotoxicity via modulated traceless release of peptides**

Tomoya Suma, Jiwei Cui, Markus Müllyn, Frank Caruso

Peptides feature highly developed and diverse physiological functions, which makes it advantageous to formulate nanoparticles from functional peptides. Mitochondria-disrupting (KLAKLAK), peptides were assembled into proapoptotic peptide nanoparticles using mesoporous silica nanoparticles as sacrificial templates. To this end, the peptide nanoparticles were reversibly stabilised using three types of cross-linking strategies based on disulfide chemistry, i.e. 4-dithiobenzyl urethane (4-DBU), 2-dithioethyl urethane (2-DEU), and 3-dithiopropyl amide (3-DPA), and the cytotoxicity of the peptide nanoparticles was compared. The strongest cytotoxicity was observed for the peptide nanoparticles using 4-DBU chemistry, which was approximately 4-fold stronger than the peptide nanoparticles using 2-DEU chemistry. The peptide nanoparticles using 3-DPA chemistry showed negligible cytotoxicity. The difference in cytotoxicity was attributed to kinetics of disulfide cleavage and subsequent self-immolation of the molecular pendant groups on the peptides, as well as to cellular association. On the other hand, the peptide nanoparticles were also loaded with a model small molecule drug (doxorubicin hydrochloride) allowing co-delivery of functional peptides and small molecules for synergistic cell killing. The potential utility of the peptide nanoparticles for therapeutic delivery was demonstrated.

**The effect of impact loadings on chondrocytes’ mechanical properties**

Zhexing Wang, Andrea O’Connor, Peter Vee Sin Lee, Geoff Stevens

In this research, we focused on single cell mechanics and how impact loads on cartilage tissue can affect the properties of chondrocytes, and whether any effects are load related. The micropipette aspiration technique was the main experimental method used to study single cell mechanics, in which the surface of a cell is aspirated into a small glass tube and by analysing the deformation and force response of the cell its mechanical properties can be calculated. The results of our study showed that both of the elastic and viscoelastic properties of chondrocytes from impacted cartilage are significantly different from those of non-impacted cartilage. Fluorescently labelled F-actin images of chondrocytes from impacted and control groups were analysed using imageJ software and Matlab-based image-processing functions. The results showed the F-actin fluorescence intensity from the impacted group is significantly higher than that from the control group, which indicated that cytoskeletal properties could be altered by the impact injury. A 3D finite element analysis (FEA) method was developed to examine the single cell mechanical models.

**Zwitterionic replica particles for drug delivery**

Alessia Weiss, Markus Müllyn, Frank Caruso

Nanoscopic polymeric particles exhibiting protein resistance are of interest in diverse areas, ranging from biomedical applications like drug delivery systems...
to catalysis. In this study, functional zwitterionic replica particles are synthesised via surface-initiated atom transfer radical polymerization (SI-ATRP) on mesoporous silica templates. Subsequent core removal yields discrete polymer particles. In general, zwitterionic materials are highly resistant to non-specific protein adsorption, even from undiluted blood plasma and serum, and bacterial adhesion. Furthermore, they exhibit very low association to human cancer cells.

Zwitterionic monomers, such as 2-methacryloyloxyethyl phosphorylcholine (MPC), or sulfobetaine methacrylate (SBMA) are copolymerized with an ethylene glycol-based crosslinker. Utilising a redox-responsive crosslinker allows for particle disassembly in a reducing environment. Furthermore, different functionalities such as azide-, hydroxyl-, or amine-groups can be additionally incorporated via comonomers that can be used for ligand immobilisation. Particle characterisation has been carried out using atomic force microscopy (AFM), transmission electron microscopy (TEM), scanning electron microscopy (SEM), and high resolution fluorescence microscopy. Cellular internalisation and association to human cancer cells has been investigated using deconvolution microscopy and flow cytometry in in vitro experiments.

This approach is open to a wide range of different monomers and crosslinkers whereby the composition of the replica particles simply depends on the monomer mixture. Furthermore, it offers the opportunity to incorporate different functionalities and may allow fine-tuning of the particle stiffness by varying the crosslinking density. With this approach, it becomes feasible to produce monodisperse, degradable, stealth particles over a large size range. These advantages render the polymer replicas a modular and versatile class of highly functional carriers with application in drug delivery.

**Engineering novel microRNA-polymer nanocarriers with bioresponsive properties**

Marcin Wojnilowicz, Francesca Cavalieri

The discovery of short interfering (siRNA) and microRNA (miRNA) has opened up the challenge of developing miRNA-based nanomedicines. Since siRNAs and miRNAs do not cross the cell membrane easily and are rapidly degraded in the blood, effective delivery by nanocarriers is necessary to exploit their therapeutic potential. SiRNAs and miRNAs are involved in silencing of messenger RNA (mRNA) and post-transcriptional regulation of gene expression, providing a mechanism for regulating the production of proteins that may cause disease.

The objective of my research project is to develop a drug delivery system based on glycosen nanoparticles. Glycogen is a hyper-branched natural polysaccharide composed of linear chains of 10-14 glucose residues and connected together via α-(1,4)-glycosidic bonds. Each chain is further branched by α-(1,6)-glycosidic bonds in distance of approximately ten glucose units per linker. This so highly-branched structure organises into spherical particles with diameters of 20-40 nm (β-particles), however, they may associate into larger structures, referred to as α-particles, with diameters between 60-200 nm. The approach used in my research project is to introduce cationic groups into the glycogen chains that can bind with negatively charged nucleic acids. Glycogen nanoparticles resulted to be non-toxic, biocompatible and biodegradable material. In addition, they are easily accumulated inside the cells.

**Ion-exchange and bioseparation technology**

**Controlled release nutrient materials for hydrocarbon bioremediation: Implications for bio-reactive barriers in low nutrient environments**

Ben Freidman, Kathryn Mumford, Sally Gras, Geoff Stevens

A bio-reactive barrier is established when biodegradation of hydrocarbons occurs through a more permeable filling material, as replacement for soil material at the water table. The advantage of a bio-reactive barrier is that limitations due to soil heterogeneities, hydraulic conductivity and biofilm detachment can be reduced. However, in low nutrient environments such as Antarctica, the establishment of bio-reactive media at hydrocarbon contaminated sites is challenged in the absence of a controlled release nutrient source to promote microbial growth. In collaboration with the Australian Antarctic Division, this works aims to better understand the contribution of controlled release nutrient materials to bio-reactive barrier performance.

Granular nutrient materials, to enhance bio-reactive barrier performance, have been examined across batch and column studies with findings indicating that nutrient materials maintain their slow release patterns under freeze-thaw cycling. Recent experimental works have shown that nutrient amended zeolites encourage high biofilm density, with hydrocarbon contaminants degraded more rapidly in the presence of this material when compared with zeolites without nutrient amendments. Similarly, nutrient amended zeolites have been shown to support a higher biomass concentration when compared with activated carbon in laboratory scale sequenced bio-reactive barriers. This finding suggests that hydrocarbons adsorbed to activated carbon may not be accessible to biofilms as a source of carbon for growth. A bio-reactive barrier was installed to monitor microbial activity and biodegradation at a hydrocarbon contaminated site on sub-Antarctic Macquarie Island. To date, the barrier is demonstrating hydrocarbon capture with an assessment of degradation indices to be undertaken during 2016.

**Development of contaminant removal system suitable for implementation in cold regions**

Junchao Ma, Kathryn Mumford, Geoff Stevens

Considering the serious contamination problems and complicated environmental conditions in many remote locations, it is necessary to improve the performance of permeable reactive barriers installed in situ. Previous tests have demonstrated that microorganisms present in soil and water can breed in and between adsorbent materials in PRBs and degrade the captured hydrocarbon, which not only clean up the contamination but also fit the sustainable development strategy. Among adsorption materials, zeolite has shown a better performance than Granular Activated Carbon (GAC) as contaminants are not extremely tightly adsorbed and can be easily utilised by microbes. Over the past year, research has focused on development of modified zeolite with higher hydrocarbon adsorption capacity compared with the natural zeolite.

Among existing methods, chlorosilane modification was chosen as it can be attached to the zeolite surface via a stable covalent bond, which greatly enhances the sorption behaviour. As
A fundamental study of skim milk ultrafiltration

Sinn-Yao (Kenneth) Ng, Dave Dunstan, Gregory Martin

The Australian dairy industry is the third largest rural industry in Australia, with a vast portion of its revenue contributed by value-added dairy products. Skim milk ultrafiltration (UF) is a key unit operation in the manufacturing process, in which milk proteins are concentrated. Filtration holds several advantages over conventional thermal separation/concentration methods – it is less energy intensive, and allows the preservation of milk’s functional, nutritional and sensory qualities. Unfortunately, filtration performance is severely impacted by concentration polarisation (CP), i.e. the accumulation of retained solutes at the membrane surface, as well as membrane fouling. CP is typically mitigated by operating at higher flow rates, but incurs additional pumping energy requirements. Chemical cleaning effectively removes fouling, but interrupts operation, reduces membrane life and increases water and chemical consumption.

To date, CP and fouling are still not fully understood due the complex physicochemical nature of milk. The aim of this project is to develop a fundamental understanding of the physicochemical processes that contribute to flux decline in skim milk UF, which will enable us to optimise filtration performance. Current work is focused on investigating the influence of casein micelle alterations on its intrinsic filtration properties.

This project is carried out in collaboration with Dairy Innovation Australia Limited (DIAL).

Nanostructured interfaces and materials

Manipulation of size, composition and structural order at the nanoscale allows the directed fabrication of materials with functional properties. This tailoring of properties is finding use in innovative materials for chemical engineering, pharmaceutical and biological applications where the demand is for greater structural and compositional complexity. To deliver such products, there exists a need for facile and flexible methods to engineer surface properties.

Synthesis of hierarchically porous materials by the co-micelle/emulsion templating method

Stephan Burger, Michelle Gee, Paul Webley, Andrea O’Connor

The co-micelle/emulsion templating (Co-MET) method was recently developed to create hierarchically macro/mesoporous silica beads. These beads have potential in separation and adsorption processes as well as a support material in biocatalysis due to enhanced diffusion in the macropores while the mesopores provide a high surface area for active sites. In the co-MET synthesis a block copolymer is used to stabilise an oil emulsion while also forming micelles in the continuous aqueous phase. The silica precursor (TEOS) undergo a condensation reaction and capture the hierarchical structure of the emulsion and micelles. After calcination a hierarchically porous material is obtained.

The project focuses on the effect of different synthesis parameters on the material properties to enable the synthesis of a material which can be tailored for a specific application. We have shown that the macropore sizes and strengths of the beads can be controlled by decreasing the emulsion droplet sizes by means of a higher block copolymer concentration or stirring speed. Furthermore, we managed to synthesise Co-MET beads by using a co-axial flow device. This resulted in hierarchically macro/mesoporous beads of controlled sizes. Future work includes the synthesis of inorganic hierarchically porous materials other than silica and to test a possible application.

Self-assembly and shape control of block copolymers

Chao Chen, Luke Connal, Sandra Kentish

Nanoparticles assembled from block copolymers (BCPs) hold great promise in applications ranging from biomedicine to electronics. To this end, the development of techniques to control the shape of BCP particles becomes the key. This research project aims to develop a toolbox to control the morphology and overall shape of BCP nanoparticles with a phase separated interior. Using various diblock copolymers as model systems, we investigated the evolution of BCP morphology with results showing a tunable transition from onion-like spheres to axially stacked lamella through the precise control of interfacial properties between copolymers and the medium. The influence of block ratio on the particle morphology was also studied and a unique nanoparticle with patchy decoration has been discovered. In further studies, we synthesised BCPs with controlled molecular weight for fluorophore incorporation via RAFT polymerisation. The success of this research will reveal the orientation of polymer chain and self-assembly mechanism with the help of super-resolution microscopy.

Filtration of model colloidal particles

Hongzhan Di, David Dunstan

Membrane technology has been widely employed in dairy filtration processes over the last two decades, and has taken a significant place in the manufacture area of dairy products. In spite of great developments in membrane technology, an important issue, membrane fouling, still remains an issue. With the presence of membrane fouling, permeate flux decreases severely during filtration, which results in less efficiency and higher cost. We demonstrate the use of a novel microfluidic system using confocal microscopy to visualise fouling processes during the filtration of model polystyrene latex particles (0.2 µm). Both direct visualisation and total fluorescence intensity are used to quantify the fouling mechanisms. A specific 50 µm thin transparent microfluidic filtration device has been developed to satisfy the short working distance (100 µm) of high resolution confocal microscope objectives. Furthermore, this methodology allows...
Boronic acid–phenolic network capsules with dual-response to acidic pH and cis-diols

Junling Guo, Frank Caruso, Jiwei Cui

Synthetic capsules responsive to biological triggers are of particular interest for biomedical applications because of their functional similarity to natural biological systems. However, most stimuli-responsive capsules are engineered towards a single biological trigger, and therefore lack the capacity to respond to complex physiological microenvironments. Biologically relevant, dual-responsive boronic acid–phenolic network (BPN) capsules that combine pH responsiveness with cis-diol responsiveness are being researched. Dual responsiveness is achieved through reversible boronate covalent chemistry. The governing dynamic interactions and stimuli-responsiveness were investigated by NMR. The cargo release rate from the capsules was slow in physiological pH, but could be increased by decreasing pH and/or by adding cis-diols. Stability experiments showed that the BPN capsules were stable in the presence of competing carbohydrates, which is fundamental for exploring future biological applications.

Cancer cell targeting using nanoengineered capsules

Yi Ju, Frank Caruso, Jiwei Cui

Nanoengineered capsules have gained increasing interest due to their application in drug delivery area. The development of a facile strategy for preparing particles via a one-pot strategy was recently published by our group (Ejima, H., et al., Science, 2013, 341, 154). We reported that utilisation of coordination interactions between metal ions and natural polyphenol offers an extremely simple and rapid way to prepare metal-polyphenol networks (MPNs) via one-step assembly. However, current MPN films and particles using tannic acid as a building block exhibit high fouling properties, limiting their applications in the biomedical area. Here, we engineered the capsules for low-fouling interactions with cells.

Functionalised yolk-shell structures as a multifunctional catalysts for cascade reactions

Seyed Farshad Motevalizadeh, Rachel Caruso

A rationally designed cascade reaction sequence can simplify the synthetic route, reduce the amount of waste and lower the operation cost. The key for a successful cascade reaction sequence is the multifunctional catalyst. With a suitable multifunctional catalyst, multiple synthesis steps can proceed in one pot with high yield toward the target products. The heart of a cascade reaction is a multifunctional catalyst. In comparison with solid catalysts without well-defined morphology, yolk–shell nanoparticles (YSNs) with unique core@void@shell nanostructure are promising candidates as nanoreactors for cascade reactions owing to the easy functionalisation of both the core and the shell, the high density of exposed active sites endowed by the movable core, and the protection effect endowed by the shell, especially under harsh reaction conditions. The objective of this research project is to design multifunctional yolk-shell nanoparticle catalysts.

Enzyme-inspired catalysts

Mitchell Nothing, Luke Connal, Greg Qiao

Nature has developed a multitude of complex and elegant survival techniques via evolution. Natural systems have truly amazing control over the detailed chemistry involved in biological processes, including energy conversion and immune defenses. At the heart of many biochemical reactions lies an amazing class of molecules that catalyze the very reactions that make life possible – enzymes. Their impressive catalytic power as well as their remarkable specificity has made them a prerequisite in almost all major physiological functions, from the digestion of food and excretion of waste, to the autoimmune response and repair of cell damage in humans. Their unrivalled catalytic ability has seen them employed commercially in many industries such as washing detergents, alcoholic beverages, bread production and the synthesis of drugs. However, the full potential of enzymes in industry settings has been limited by their restricted operating conditions, low stability and high cost.

This research project aims to design new enzyme mimics inspired by nature and employing the mechanism of natural enzymes for industrial application as synthetic catalysts. The overarching aim is to create brand new functional materials that are more stable, versatile, and cheaper than natural enzymes while maintaining their catalytic efficiency. The family of enzymes that will be initially targeted – the serine proteases – catalyze the breakdown of proteins and lipids and can be found in human digestive juices as well as being a common component in modern detergents. The bioinspired catalysts developed here will be based on the idea of an ‘active-site mimic’. That is, a low-weight molecule that incorporates the functional core of the natural enzyme and is targeted specifically for a selected application (such as biodiesel production). This approach is truly innovative, having never been attempted before, and has the potential to create new avenues of research in enzyme mimics and industrial catalysis.

Surface-confined amorphous films from metal-coordinated simple phenolic ligands

Md. Ariful Rahim, Frank Caruso

Coordination chemistry of natural polyphenols and transition metals allows rapid self-assembly of conformal coatings on diverse substrates. This coordination-driven self-assembly process also applies to simple phenolic molecules with monotopic or ditopic chelating sites (as opposed to macromolecular, multitopic polyphenols), leading to surface-confined amorphous films upon metal coordination. Films fabricated from gallic acid, pyrogallol, and pyrocatechol, which are the major monomeric building blocks of polyphenols, have been studied in detail. Pyrocatechol, with one vicinal diol group (i.e., bidentate), has been observed to be the limiting case for such assembly. This study expands the toolbox of available phenolic ligands for the formation of surface-confined amorphous films, which may find application in catalysis, energy, optoelectronics, and the biomedical sciences.
Characterising the biophysical and dewatering properties of microalgae

Érico Baroni, Paul Webley, Peter Scales, Gregory Martin

Microalgae are ubiquitous organisms that are currently considered promising sources of natural products of industrial interest, such as lipids for biodiesel production, natural pigments for the food industry, and a wide variety of bioactive compounds. However, for the economically competitive use of these organisms as biorefinery feedstocks, several technical and economical obstacles have to be overcome. On an industrial scale, microalgae are usually grown in diluted conditions (~0.1 – 1.0 g L⁻¹) requiring extensive and efficient concentration. The cells are small, typically less than 10 µm, at a density close to that of the growth medium, and have a net negative surface charge that provides stability to the algal suspension. These facts pose technical challenges to concentration and dewatering, which represent up to 30% of the total production cost. Traditional solid-liquid separation methods are hindered by these characteristics presenting shortcomings of being energy-intensive (drying and centrifugation), undergoing clogging with low solids concentration in the final product (filtration), or presenting high capital and operating costs (flotation). In order to compare different separation methods on industrial scale this project aims to characterise the fundamental dewatering properties of microalgae suspensions across a diverse range of species. Standardised jar-tests, LUMiFuge® and pressure filtration experiments will be used to define the suspensions’ compressibility, permeability, and solids diffusivity. These principles will be correlated with changes in physicochemical intrinsic characteristics such as density, morphology, and physiological state during the life cycle of each species. Density gradient centrifugation, image analysis, Nile red staining and Bligh and Dyer extraction routines will be respectively applied. This understanding will be applied to novel strategies including the use of natural low-cost flocculants and ultrasound harvesting to target reductions in operational costs and improved dewatering efficiency.

Phage treatment of wastewater foam

Wilhelm Burger, Konrad Krysiak-Baltyn, Gregory Martin, Peter Scales, Anthony Stickland, Sally Gras

In the activated sludge process for wastewater treatment, filamentous bacteria become dominant under certain operating conditions or feed compositions. Excessive filamentous growth normally results in the formation of stable foam due to the hydrophobic cell walls of these species and their
ability to produce surfactants. Foam and solids on the surface of aeration tanks is a common problem encountered at wastewater treatment plants. Some of the current treatment methods involve operating at lower solids retention times, mechanical removal of the foam, and the use of chlorine sprays and chlorination of the return activated sludge line. These methods are not target specific and are mostly not very effective. It is therefore proposed to use target specific bacteriophages to reduce the filamentous bacteria to quantities lower than the foaming threshold.

The project is investigating the feasibility and effectiveness of the use of bacteriophages to treat wastewater foaming while considering its effect on the downstream processing performance. This includes investigating the structural role of the filamentous bacteria in activated sludge flocs, as well as studying the interactions that exist between the phage and floc components.

**Understanding solar drying practices of wastewater treatment sludges**

Sriharini Chellappan, Anthony Stickland, Peter Scales

Melbourne Water’s Western Treatment Plant (WTP) and Eastern Treatment Plant (ETP) produce significant quantities of digested wastewater (WWT) sludge that is dried in open air solar drying pans. The fundamental understanding of the various operating procedures involved in these solar drying practices such as filling and turning is lacking. These open air drying pans also require a large space to operate and therefore result in potential capacity issues. This presents an opportunity to implement innovative operating practices like dry stacking, originally used in the minerals industry with an increased throughput per unit area compared to conventional tailings dams. This project aims to develop fundamental understanding of the dry stacking process, which has potential impacts in both the wastewater treatment and minerals processing industries. This will be achieved through:

(i) Development of a general rheological model of evaporation and drying of compressible sediments;

(ii) Understanding the effect of sludge cracking and provide insights to the wastewater industry to optimise their current turning operations in their drying pans; and

(iii) Optimisation of existing drying pan design and operation to adopt dry stacking practices.

Laboratory studies have been conducted to understand the stages of sludge drying and cracking behaviour. A model is currently being developed to describe the sludge behaviour during solar evaporation, which will enable optimisation of pan operation. Three full scale trials have been conducted at WTP, which successfully demonstrating that WWT sludges can be stacked, while further trials are planned for this year at ETP.

**Optimisation of thickener performance through incorporation of shear effects**

Adam Crust, Peter Scales, Shane Usher

Many industries, particularly mineral processing, employ large scale gravity thickeners to recover water and valuable process liquor while concentrating residue solids. These thickeners are often greater than 40m in diameter and can cost in excess of $10 million to build. Accurate sizing is still a challenge even after 100 years of research. Predictive modelling of gravity thickener performance from experimentally determined material properties has been shown to under predict throughput by a factor of up to 100. The phenomenon of aggregate densification has been proposed to account for some of this discrepancy. Aggregate densification is where flocculated aggregates compact due to shear. This compaction can alter the material properties and hence increase the rate and extent of dewatering.

Aggregate densification characterisation has been conducted via lab scale batch settling experiments and subsequent analysis. The work has streamlined current methods for the characterisation of aggregate densification within a thickener. The results have been incorporated into thickener modelling to allow for improved design and operation. This work aims to provide further insight into aggregate densification and its role within gravity thickening allowing a greater capacity for thickener modelling and prediction, moving into design and operation.

**Superposition of compression and shear in filtration**

Eric Höfgen, Anthony Stickland, Peter Scales, Robin Batterham

In times of ever increasing energy costs and environmental consciousness, the optimisation of filtration processes for more efficient operation and for reuse of material streams is of high importance. The filtration of suspensions aims to increase the solids concentration. A particular network forms at a material specific concentration, called the gel point. At concentrations greater than the gel point, suspensions exhibit a strength against deformation. In shear this resistance is called the shear yield stress \( \tau \), and in compression it is the compressive yield stress \( P_y \). For further dewatering of a suspension, an applied force has to be greater than the apparent network strength. In many industrial processes, some shear is applied to the suspension during the compression process due to machine design and/or operation. Combining shear and compression in filtration is purported to increase dewatering efficiency, however the interrelated influence of shear and compression is still unclear and needs further investigation. A novel dewatering device, called High Pressure Dewatering Rolls (HPDR), has been developed at the University of Melbourne that combines shear and compression. The operating principle of the HPDR entails two counter-rotating semi-permeable rollers, with vacuum applied onto the rollers for filtration. The rollers are pushed together by a pressure system. The rotation of the rolls provides the compressional forces and, due to individual control of the rollers, a differential speed can be set and thus shear induced. With this device, the extent of shear and compression can be adjusted and thus superposition of the two can be investigated.

**The effect of oscillatory strain and pH on the formation of heat-induced WPI gels**

Stephen Homer, Leif Lundin, David Dunstan

The visco-elastic properties of heat-set whey protein isolate gels composed of spherical aggregates and produced under oscillatory shear during aggregation and gelation have been further investigated. It was determined that the application
of shear above a critical strain results in a decrease in the gel elastic modulus (G'), the extent of which is governed by the magnitude of the strain. Further investigations into the mechanical properties of the gels illustrated a strain hardening effect that was only present in gels produced during the application of elevated strains. Confocal laser scanning microscopy indicated that gels formed at elevated strains had larger pores and a less homogeneous microstructure than those produced under lower strains. Additional work has focused on how pH alters the rheology and microstructure of heat-set WPI gels in the acidic pH regime. A slight reduction in G' was found around the isoelectric point. G' as a function of pH showed two peaks, one at pH 4.0 and another at pH 5.6. Below pH 4.0 and above pH 5.6, G' dropped dramatically as the type of aggregates shifted from spherical to fine-stranded aggregates. Fracture stress and strain are currently being evaluated along with the denaturation temperatures and enthalpies over the acidic pH range.

**The relationship between inter-particle interaction and shear properties of particulate suspensions**

Tiara Kusuma, Raymond Dagastine, Anthony Stickland

The rheology of particulate suspensions is of interest to many industries for improving efficiency of processes and product performance. At the gel point, φs such suspensions are able to form a continuous interconnected solids network. Conventionally, the strength of this network is well-known as the yield stress. Upon the application of a shear stress, the basic understanding of suspension behaviour is flow or no-flow. When the applied shear stress is lower than the network strength, the suspension behaves as an elastic solid. Otherwise, the network structure will collapse and the suspension will flow as a viscous fluid. This yielding behaviour is often modelled by viscoplastic models, such as Bingham fluids and Herschel-Bulkley.

Yielding behaviour of particulate suspensions is more complex than viscoplastic models. Many phenomena in the suspension cannot be predicted by viscoplastic models, for example, retarded elasticity, time-dependent yield, and shear-thickening. These phenomena require thorough investigation of linking the particle properties and network structures to bulk rheology of suspensions.

A novel experimental setup was developed to investigate friction force between micro-spheres. A single particle was immobilized on a glass slide and scanned by a colloidal probe. This setup allows one to investigate wider regimes of friction phenomenon between particles in a sheared suspension. The results will be used to serve as an input of particle-scale simulation to predict bulk suspension behaviour and explain the correlation between the particle friction and the bulk rheology of particulate suspensions.

**Separation kinetics of lipids and solvents from high-solids microalgae slurries during centrifugation**

Sam Law, Peter Scales, Gregory Martin

Microalgae are a promising feedstock for biofuels and other products due to their high productivity and ability to be grown on non-arable land. To achieve a positive energy ROI outcome for biofuels production, thermal drying must be avoided and the oils must instead be extracted from concentrated microalgae slurries (15-25% dried weight) that can be reached by physical dewatering. To extract algal lipids for biofuel conversion, the microalgae cells in the slurry must be ruptured before application of a solvent extraction step, typically with hexane. However, the intracellular constituents and cell wall fragments are natural emulsifiers that can promote and stabilise the formation of a hexane-water emulsion. In addition, the rupture of algal cells results in a highly viscous biomaterial that can hinder hexane recovery from the biomass slurry. Thus, a solid-liquid separation step is required to recover the hexane and the dissolved lipids.

Centrifugation is a promising separation technique for recovering hexane from the microalgae emulsion as the facilities and technologies are readily available at industrial setting. However, it can be a relatively energy and capital intensive process. Thus, it is important to minimise the centrifugation time and force by improving the separation rate (kinetics). In this project, the physical properties of the emulsion and the rheological properties of the hexane-mixed ruptured microalgae slurry are being investigated for the first time in relation to phase separation kinetics during centrifugation. By developing a new understanding of the separation mechanism during centrifugation, it will be possible to develop an optimal strategy for recovering the hexane with minimal energy requirement.

**Utilisation of glycerol as carbon source for mixotrophic growth of microalgae for lipid accumulation**

Nature Poddar, Gregory Martin, Ramkrishna Sen

Increased population, advanced technology and economic growth have caused depletion of non-renewable fossil fuels and contributed to increased levels of atmospheric carbon dioxide. The development of sustainable sources of biofuel from biomass or biological sources is urgently required. After first generation (e.g. sugarcane) and second generation (e.g. lignocellulosics) feedstocks, third generation biofuels based on micro-algae offer potentially significant advantages to overcome current energy shortages.

However, low lipid content in microalgae has significantly restricted its development and needs to be increased to improve the overall cost of microalgal based biodiesel. The large number of algal species and their versatility and adaptability make “mixotrophic” culture a suitable subject for applied research and development of new technologies for commercialisation.

The proposed work aims to survey different potential industrially important microalgae to develop knowledge of microalgal metabolism required to understand how mixotrophic growth using glycerol, a by-product of biodiesel production, as an inorganic carbon source, can be utilised most efficiently to enhance lipid productivity in microalgae. The proposed study also focuses on the development of a mathematical model for growth and lipid accumulation that will, for the first time, incorporate mixotrophic growth.

The success of this research will add value to the productive chain of the biofuel industry, contributing to their competitiveness and will test the feasibility of glycerol supplementation for large-scale cultivation. This will allow the development of an optimised growth regime for outdoor cultivation of microalgae to reduce the overall cost biodiesel production.
**Combined shear and compression suspension rheology**

Sayuri Nadeeka Rubasingha, Anthony Stickland, Peter Scales

The behaviour of particulate suspensions under the combined effect of shear and compression is of significant importance since a lot of industrial applications add shear during dewatering to improve solid-liquid separation, such as in thickeners and roller belt presses. Analysing the constitutive rheological behaviour is required to describe the response of a suspension to superimposed shear and compressive stresses. This study focuses on collecting and analysing 1-D compression, pure shear and superimposed shear and compression data. The combined data is obtained from the triaxial soil testing technique. This testing technique is novel to the rheological analysis of fragile suspensions. Coagulated calcium carbonate suspension is used as a model system for this rheological analysis. This analysis will give a better understanding of yielding behaviour under very low shear rates and under the combined effect of shear and compression. The outcome of this study will help to design and optimise dewatering applications which use combine shear and compression for improved efficiency of suspension dewatering.

**Understanding filtration of wastewater sludges for improved water recycling**

Samuel Skinner, Anthony Stickland, Peter Scales

As freshwater resources continue to be stretched, recycling of polluted and waste waters to potable is an important consideration to improve water availability. The high cost of potable water production has limited the widespread construction of advanced wastewater treatment plants and the fouling of the membranes used in many of these plants is a key issue. Biological fouling, or biofouling, reduces the output rate of purified water and increases the capital and operating costs. There are a number of potential methods for reducing biofouling, such as denaturing the solid and molecular components causing the issues and decreasing the operating pressure. A quantitative assessment of the filterability of wastewater treatment sludges indicates that the sludges show significantly different filtration behaviour depending on the biological component of the biofouling layers. This improved understanding of the fouling layer filtration behaviour will allow more accurate modelling of filtration processes in advanced wastewater treatment devices, such as the membrane bioreactor. The development of a mathematical model for a membrane bioreactor will provide a method for predicting the output rate of purified water for given operating pressures and membrane configurations. The results will provide insights into the best optimisation protocols for membrane utilisation in water recycling, thus helping to reduce capital and operating costs.

**The yielding of strongly flocculated suspensions**

Hui-En Teo, Anthony Stickland, Robin Batterham, Peter Scales

The flow and deformation behaviour of particulate suspensions significantly affects process performance in many industries. To that end, research on suspension rheology has resulted in the simplification of yield behaviour through the shear and compressive yield stresses: \( \sigma_y \) and \( \sigma_p \). These parameters successfully predict suspension processability in one dimension but are pathologically inaccurate and unable to be applied to multi-dimensional processes which form the majority of industrial techniques. To further the understanding of yield, a systematic study of yielding mechanisms in strongly flocculated suspensions must be undertaken firstly in pure shear, followed by combined shear and compression. In order to avoid wall slip and particle jamming, rheometric tests were conducted using the vane geometry in a wide gap. The profiles of a model calcite system and an industrial brown coal sample in three types of rheometric testing were obtained. Findings from controlled rate tests indicate rich detail in the transient model system response and non-monotonic flow that was attributed to strain-rate softening of the elastic stress. This could potentially be incorporated into a modified Herschel-Bulkley model that separates the yield stress into a degradable rate dependent elastic component and an isotropic elastic stress. Critical strain and strain energy were identified and tested as potential alternative yield parameters and found to be promising in both model and industrial systems. The addition of compressional loads was observed to promote strain hardening and subsequently increase stress and delay shear yielding in both systems examined. These findings point to significant interaction between shear and compressive loadings in suspensions and will guide constitutive rheological modelling into the multi-dimensional era.

**Economic delivery of carbon dioxide to algal ponds**

Qi Zheng, Sandra Kentish, Greg Martin

Due to the increasing CO\(_2\) concentration in the atmosphere, global warming is causing severe damage, such as sea level rise and ice melting. Researchers have tried several technologies such as chemical absorption, physical adsorption, membrane and cryogenic fractionation to capture CO\(_2\). These technologies either require high energy or are unable to operate at large-scale. This project demonstrates a novel combination of solvent absorption, membrane desorption and microalgae cultivation to capture carbon dioxide and convert it to a lipid-rich biomass. In the system, carbon dioxide is absorbed into a potassium carbonate solvent and this gas is desorbed directly into a microalgal medium via a non-porous polydimethylsiloxane (PDMS) hollow fibre membrane. This single step approach provides a paradigm shift in the cost of carbon delivery to the microalgae, as the very large reboiler energy demand of standard carbon capture solvent regeneration is avoided, as is the energy associated with gas compression. Specifically, the use of a 20%wt potassium carbonate solvent with 0.2, 0.5 and 0.7 CO\(_2\) loading was evaluated as a mechanism to deliver carbon dioxide to cultures of a salt tolerant Chlorella sp. microalgae. In all cases, accelerated growth of Chlorella sp. was observed, relative to a control. The use of carbonate solutions of 0.5 and 0.7 loading resulted in the highest volumetric productivity and biomass concentration by completely avoiding carbon limitation of the cultures. The system has demonstrated potential for the generation of biofuels that utilise carbon dioxide generated from power station flue gases with minimal parasitic energy demand.
Surface Forces and Spectroscopy

Research Staff
Professor Frank Caruso
Professor Derek Chan
Professor Raymond Dagastine
Professor Dave Dunstan
Associate Professor Sally Gras
Professor Franz Grieser
Dr Dalton Harvie
Professor Robert Lamb
Dr Gregory Martin
Professor Greg Qiao
Dr Joseph Berry
Dr Jiwei Cui
Dr Xiaofei Duan
Dr Xu Li
Dr Srinivas Mettu
Dr Huabin Wang
Dr Alex Wu
Marta Redrado Notivoli

Research Students
Jaimey Arnott
Christopher Biscombe
Christopher Bolton
Christine Browne
Matthew Burton
Malavika Haribabu
Wei-Lun Hsu
Anna Mularski
Michael Neeson
Rohit Pillai
Andrew Rapson
Tomer Simovich
Danzl Song
Leonie van ’t Hag
Chang Wang
Chu Wu
Chenglong Xu

Collaborations
Boeing, Australia
Dr Michelle Gee
Monash University
Dr Rico Tabor
RMIT University
Dr Charlotte Conn
Professor Calum Drummond
Dr Xuehua Zhang
Swinburne University of Technology, Australia
Associate Professor Andrew Clayton
The University of Melbourne, Australia
Dr Gabriel da Silva
Dr Malcolm Davidson
Associate Professor Neil O’Brien-Simpson
Professor Frances Separovic
Associate Professor Trevor Smith

Project Updates
Anisotropic nanoparticle diffusion
Christopher Bolton, Raymond Dagastine

We are interested in the way small, strangely shaped or composed (anisotropic) particles move, interact with each other and ultimately assemble into macroscale materials. Hydrogen and oxygen come together on an atomic scale to make water, whose familiar properties only arise when this particular combination is present. It turns out that nanoparticle building blocks around 100-1,000 times the size of water can also combine in unique ways to make new materials with desirable properties (e.g., solar cells comprising layers of zinc oxide nanocrystals, or kevlar vests reinforced with carbon nanotubes). A problem we encounter is that nanoparticle building blocks which are useful often have irregular shapes and compositions, and we do not fully understand the influence these factors have on the way they move and fit together. This makes it more difficult to design things like nanoparticle drugs that move and interact with biological interfaces in a predictable way, or to design materials containing self-assembled nanoparticles that are arranged precisely enough to confer a particular set of properties (e.g. high electrical/thermal conductivity, or high tensile strength). Most of our recent work in this area has focused on developing new methods for observing the behaviour of these nanoparticles; our aim is to validate a general physical theory for nanoparticle interactions that takes into account the effects of shape and composition. This could open up a large number of applications, facilitating the design of anisotropic nanoparticles and materials with deliberately tuned properties.

Oscillatory forces between deformable bubbles in the presence of polyelectrolytes
Christine Browne, Rico Tabor, Franz Grieser, Raymond Dagastine

The interactions between bubbles in a liquid are important in a number of commercial applications. For example, the stability of food products containing foams, separation processes such as mineral flotation and in some personal care products. Forces between bubbles in aqueous solutions containing solutes in general and polyelectrolytes in particular, are not fully understood. Therefore an improved understanding of these interactions can be expected to lead to improvements in many consumer products and industrial processes. Direct force measurements between air-bubbles in the presence of the polyelectrolyte sodium poly(styrene sulfonate) (PSS) were conducted with an atomic force microscope (AFM). The interaction of bubbles, which inherently possess deformable interfaces, results in an enhancement of the measured interaction force when compared to interactions between rigid interfaces. This work also focuses on the effects of polyelectrolyte concentration, collision velocity and molar mass variations. Whether a depletion or a structural force response was present in the force of interaction between bubbles was explored by varying the molar mass distribution of the PSS. The presence in solution of a polydisperse molar mass gave a depletion force response between interacting bubbles and a monodisperse molar mass gave a structural force response. This differing behaviour was explored further by dialysing a polydisperse sample of PSS to remove part of the molar mass material and lower the polydispersity of the polyelectrolyte. The force measurements between bubbles in such a dialysed sample system revealed the presence of structural forces. Also, two different monodisperse molar masses were combined to create a bimodal-disperse sample and a loss of solution structuring was measured between interacting bubbles. These measurements have provided further insight into the effects that deformable interfaces, such as those associated with bubbles, have on depletion and structural forces between interacting objects in solution.
Fluorescence investigations into the interactions of antimicrobial peptides with model and living cellular membranes

Matthew Burton, Neil O’Brien Simpson, Michelle Gee, Andrew Clayton, Trevor Smith

Antimicrobial resistance remains a serious global health issue, with an increasing prevalence of multi-drug resistant bacteria throughout the biosphere. Antimicrobial peptides offer a promising therapeutic alternative to conventional antibiotics, which act by directly permeating and disrupting bacterial cell membranes at relatively very low micromolar (µM) concentrations. Much contention persists surrounding the precise mechanism of action responsible for cell death, even for a given peptide. Numerous sources of influence, such as the presence of salts, sugars, pH, and, perhaps most importantly, membrane lipid composition, can all alter the observed behavioural outcome of peptides, complicating our mechanistic understanding of these compounds.

This work makes use of fluorescence imaging techniques; namely, Fluorescence Lifetime Imaging and Structured Illumination Microscopies; to monitor the evolution of peptide-membrane interactions in both artificial and living cell membranes. A model lytic peptide, Melittin P14K Alexa Fluor 430, based off the main component of European Honeybee (Apis mellifera) venom, has been well-characterised and shares similar interactions in both artificial and living cell membranes. A model lytic peptide, Melittin P14K Alexa Fluor 430, based off the main component of European Honeybee (Apis mellifera) venom, has been well-characterised and shares similar activity to the native form. Changes in the fluorescence response of the peptide during interaction are monitored as a function of both concentration and time in order to gather mechanistic information regarding its behaviour with both giant vesicles and Gram-negative bacteria. It is hoped a more complete understanding of this peptide, and the potential implications with other systems, will be gained as a result.

Surface engineering for mechanically robust superhydrophobic films

Brendan Dyett, Alex Wu, Robert Lamb

The use of superhydrophobic films in self-cleaning and fouling prevention is complicated by the fragile nature of surface roughness. The requisite roughened surface topologies are highly prone to abrasion and loses superhydrophobicity as a result of mechanical damage smoothing the interface. This apparent dichotomy between durability and superhydrophobicity can be explained by conflicting design principles deriving from the geometry of the interface. To overcome this, it is necessary to explore rationalised asperities to resist mechanical failures. Natural materials including nacre and enamel exhibit tailored assembly of nano/micro ‘building blocks’ which induce interfacial effects responsible for enhanced toughness. Mimicking these principles within surface asperities has been explored to enhance the robustness of superhydrophobic coatings. Polyaniline fibres were prepared, which in the presence of specific soft dopants during polymerisation, leads to both hydrophobic and intricate hierarchical assemblies. Future work is now focused on improving the interparticle adhesion between these fibres to further enhance mechanical resilience.

Simulating the behavior of skim milk during ultrafiltration

Malavika Haribabu, David Dunstan, Gregory Martin, Malcolm Davidson, Dalton Harvie

During the ultrafiltration of skim milk, smaller species (in the permeate) such as serum proteins, lactose, water and other dissolved minerals leave the system through a semi-permeable membrane, leaving behind larger particles (in the retentate) such as casein and whey proteins. Hence the concentration of the retained particles builds up near the membrane in a phenomenon known as concentration polarisation (CP). CP contributes significantly to the resistance of the membrane, limiting the efficiency of the ultrafiltration process. In this study, we are developing a comprehensive model of skim milk ultrafiltration, which will be employed to improve filtration performance. Since casein is the major constituent of the retained species (80% by weight), we currently consider it as the primary species of the retentate. We employ a multi-fluid approach to model the particle-particle and fluid-particle interactions in regions with high particle concentration. Presently, the model accounts for various interactions such as shear-induced diffusion, osmotic pressure, drag force and mass transfer. Preliminary results obtained from our current pseudo one-dimensional model were in good agreement from previously developed semi-empirical models. Our objective is to validate our multi-dimensional model using previously published experimental data for skim milk ultrafiltration.

This project is part of a larger dairy program supported by ARC (Linkage) and Dairy Innovations Australia (DIAL).

Meso-scale capillary phenomena

Michael Neeson, Rico Tabor, Derek Chan

We study a much overlooked area of meso-scale capillary phenomena where by the conditions of the formation of different classes of compound sessile drop, the evaporation of small liquid bridges trapped by particles and substrates and compound pendant drops. The have applications in fluid encapsulations technologies, autonomous particle alignment and the development of novel solutions to a hitherto unsolved problem of measuring the interfacial tension at low Bond numbers.

Investigating the capillary bridge between a particle and a substrate

Michael Neeson, Rico Tabor, Franz Grieser, Ray Dagastine, Derek Chan

Capillary bridges are formed when a small volume of liquid sits between two solid surfaces. These bridges have wide ranging applications from evaporative lithography to particle coalescence. By considering a capillary bridge between a spherical particle and a flat substrate, we investigate how the physical properties of a given system affect the resulting configuration.

Through a careful analysis of the Gibbs free energy, the shape of the resulting configuration can be found, revealing a critical liquid volume for which the configuration switches from a spherical interface with zero capillary force between the particle and the substrate, to an axisymmetric collar interface with an attractive capillary force. Having established a theoretical model, a series of key experiments were studied, showing good agreement between theory and experiment. Fitting the theoretical model to experimental images provides important physical insights into the underlying dynamics of such systems.

An electrokinetic study of electro-coalescence of a microfluidic drop on a planar interface

Rohit Pillai, Joseph Berry, Dalton Harwie, Malcolm Davidson

Electric fields have been employed in many industrial processes to produce and manipulate liquid drops, with
applications including atomisation, enhanced coalescence and purification of oils. Recent developments in lab-on-a-chip microfluidic devices also provide a host of novel applications for multiphase electrokinetic flow including medical diagnostics and chemical synthesis. Our research focuses on the fundamental understanding of the problem of electrically induced deformation, breakup and coalescence of a microfluidic drop, which is essential prior to proceeding to more complex electrokinetic systems. This is done by numerical modelling of simplified drop scenarios using a two-phase electrokinetic model.

The current research focuses on studying the effects of electric fields on coalescence of a drop and a planar interface. Electric fields have been known to accelerate the coalescence process by aiding the rupture of the interfacial film at the point of contact. However, incomplete coalescence can also occur, when a secondary drop pinches off without entering the bulk, the reasons for which are poorly understood. In addition to electric forces, the drop deformation behaviour is influenced by the inertial, viscous and interfacial tension forces. The goal of the project is to characterise the coalescence behaviour of the drop and develop an understanding of the physical mechanisms involved. Past research has been focused on studying the electrically induced drop deformation and breakup. The effects of electric field strength and drop ion concentration were shown to play a prominent role in the different dynamic behaviours observed. The stability conditions were also characterised.

Understanding the effect of surface chemistry on polymeric nanoparticles in vivo
Danzi Song, Frank Caruso, Jiwei Cui

The development of drug carriers that have long circulation times in the bloodstream after parenteral administration is highly desired in drug development as it reduces dosing intervals and improves patient compliance. It is crucial to understand how the drug carrier properties can be tailored to avoid immune recognition and therefore prolong circulation time. Polymer-based particles are of particular interest in drug delivery as their physicochemical properties can be tailored. However, in vitro and in vivo behaviour of nano-sized polymeric particles with tuneable properties have not been widely assessed. In this study we seek to assess the role of material properties (e.g., surface chemistry) on pharmacokinetics and biodistribution; this will be evaluated to enable a rational selection of nanoparticle composition for future development.

In meso crystallisation of integral membrane proteins
Leonie van ’t Hag, Xu Li, Charlotte E. Conn, Sally Gras, Calum Drummond.

A novel in meso crystallisation method has facilitated the structural determination of several biologically relevant integral membrane proteins. However, the method remains poorly understood as membrane proteins are difficult to express and handle. Bicontinuous cubic phases are the most commonly used lipid phases for in meso crystallisation. The effect of transmembrane proteins on the cubic phase is important; if the underlying 3D cubic nanostructure is destroyed, the protein/lipid combination may not be suitable for in meso crystallisation experiments. The lipid nanostructure upon incorporation of synthetic peptides and integral membrane proteins with varying hydrophobic and hydrophilic domain sizes is being studied using Small Angle X-Ray Scattering and Small Angle Neutron Scattering. The secondary structure of the peptides and proteins when incorporated in the lipidic cubic phase is being studied using Synchrotron Radiation-Circular Dichroism spectroscopy. An improved understanding of the effect of proteins and peptides on the cubic mesophases and vice versa can lead to an improved understanding of the in meso crystallisation technique.

Hydrodynamic drag at high Reynolds numbers
Ivan Vakarelski, Erqiang Li, Sigurdur Thoroddsen, Derek Chan

This project aims to elucidate the effect solid/liquid boundary properties on drag reduction and the onset of the drag crisis in bluff bodies. Systematic studies in to the effects of surface hydrophobicity, surface mass transport and phase change are being carried out. These studies provide fundamental understanding on the important role of surface properties in hydrodynamic drag.

Applications of the Stokes Reynolds Young Laplace model
Chu Wu, Rico Tabor, Derek Chan

The Stokes Reynolds Young Laplace (SRYL) model is used to describe the interaction of two surfaces where at least one of the surfaces is deformable. When two surfaces with a thin film in between are pushed together they experience a mixture of hydrodynamic pressure due to film drainage and disjoining pressure due to surface chemistry. This poses problems for deformable surfaces since the pressures can cause the surface to deform which in turn can then influence film drainage. Thus the SRYL model consists of two coupled PDEs which are made up of the Stokes Reynolds equation for film drainage and the Young Laplace equation for surface deformation. Previously the SRYL was used to model experimental data from the AFM. However it is now increasingly used as a theoretical tool to analyse systems that may be difficult to access experimentally. Below is a summary of the projects conducted this year.

1. Oil drop and air bubble in water: The SRYL was used to model a bubble-drop system which consisted of two different deformable objects in water. Drag effects were also incorporated into the modelling due to the high linear drive velocities used to push the bubble-drop systems together.

2. Drop deformations: The deformations of individual bubbles or drops could now be calculated. Previously the SRYL only produced results for the film thickness, which gives no information regarding bubble deformation unless one of the surfaces is solid and its shape known.

3. Pumping drives: Two drops were wobbled together with different retraction speeds to determine whether the retraction velocities influence coalescence. The SRYL model was able match experimental results that demonstrate increasing retraction velocities alone, is sufficient to cause coalescence.

4. Modelling flows of porous anodic aluminium membranes (PAAMs) – Recent experimental work on PAAMs have demonstrated that they display enhanced flow behaviour. This leads to their potential application in the area of water treatment but little is known about their hydrodynamic properties. In collaboration with the University of Bath, experimental and modelling work was conducted to gain a better understanding of the hydrodynamic behaviour of not only PAAMs, but also of membranes as well.

5. Calculating structure factor using Ginoza’s method – The solution to the Ornstein-Zernike equation with mean-spherical-approximation closure can be used to can be used to obtain the structure factor for colloidal systems. Currently, software used to solve this
problem utilise the method outlined in Hayter-Penfold with renormalisation outlined in Hayter-Hansen, which required a solution of a quartic equation. An alternative method was developed by Ginoza which circumvented the difficulties presented by the quartic equation. Due to the simplicity of Ginoza’s method we were able to develop an Excel Spreadsheet that is able to calculate the structure factor.

6. Structural forces at higher velocities: The SRYL is used to predict the behaviour of systems with nanoscale colloids trapped between two surfaces driven at velocities greater than 0.2nm/s.

**Nanolens and nanobubbles**

Chenglong Xu, Xuehua Zhang, Greg Qiao

A contact angle subtended by a sessile droplet is a standard measure of wetting properties of a surface. In this study, we show that the morphology of surface nanodroplets with the height less than 1 um is sensitive to the molecular size of a self-assembled monolayer on the substrate. We examined the morphological characteristics of three types of oil-like polymerisable droplets on thiol-coated gold surfaces immersed in water. As the alkyl chain length of the alkanethiol extended from 8, 10, 12, to 14, the nanodroplets became noticeably flatter and their contact angles in water decreased accordingly with the chain extension. Our results that the shape of surface nanodroplets responds to the molecular size of the monolayer on the surface have some implications for microwetting and the origin of three-phase contact line pinning for the stability of surface nanobubbles and nanodroplets.
During 2015, 24 new postgraduate students commenced with the PFPC bringing the total number of current postgraduate students in the Centre to 168. We congratulate the 28 students who successfully completed their postgraduate studies in 2015. These students have accepted varied appointments across academia and industry both within Australia and overseas. By the end of 2015 a further 10 students had submitted their theses for examination and await their final results.

Our students are a major strength and focus of the Centre with 80% of them receiving competitive scholarships; 30% of our students received Australian Government awards and 40% were awarded University of Melbourne Research Scholarships.

A major goal of the Centre is to ensure that our students are well prepared for a career in research, technology and/or education. A number of students are either co-supervised by research staff across more than one discipline or co-supervised by at least one of our external collaborators. The PFPC encourages and supports students to attend national and international conferences and to visit our associates whilst interstate or overseas. Students have the opportunity to conduct part of their research project in the laboratories of our collaborators. Whilst this is incredibly beneficial to our students it also gives them the opportunity to act as ambassadors of the Centre, highlighting our research activities on a national and international scale.

The Centre has a number of undergraduate students working on research projects in the final year of their undergraduate degree throughout the year. During 2015, over 40 undergraduate students worked on projects within the Centre. This brings the total number of students working on research projects within the Centre to over 200, either in progress or completed in 2015.
<table>
<thead>
<tr>
<th>Student &amp; Supervisors</th>
<th>Degree</th>
<th>Stipend</th>
<th>Thesis Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tianyi (Alisa) Bai R Dagastine S Koyle</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Structure function relationships in complex fluids: Relevance to application in personal care products</td>
</tr>
<tr>
<td>Chelsea Bassett S Kolev</td>
<td>MSc</td>
<td>Self-funded</td>
<td>Development of microfluidic paper-based analytical devices for environmental water monitoring</td>
</tr>
<tr>
<td>Ayana Bhaskaran L Connal, Z Xiao</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Enzyme mimicry: New catalysis inspired by nature</td>
</tr>
<tr>
<td>Matthew Biviano R Dagastine, R Tabar, G Franks</td>
<td>MPhil</td>
<td>Research Group Funds</td>
<td>Capsule characterization and compression behaviour, with analysis of stability of mono-dispersed emulsion droplets in an oil based continuous phase</td>
</tr>
<tr>
<td>Chao Chen L Connal, S Kentish</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Shape control of block copolymers</td>
</tr>
<tr>
<td>Erico de Godois Baroni G Martin, P Scales, P Webley</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Evaluating the relative potential of various microalgae as biorefinery feedstocks</td>
</tr>
<tr>
<td>Eric Hoefgen A Stickland, P Scales, R Batterham</td>
<td>PhD</td>
<td>MIFRS</td>
<td>Combining shear and filtration: A new perspective on dewatering</td>
</tr>
<tr>
<td>Tao Huang A O’Connor, D Heath</td>
<td>PhD</td>
<td>APA, IPRS</td>
<td>Multifunctional gold shell polymeric particles for biomedical applications</td>
</tr>
<tr>
<td>Inam ur Rehman Junejo G Qiao, J Ren</td>
<td>PhD</td>
<td>APA, IPRS</td>
<td>Surface wetting of nanengineered metal-phenolic networks</td>
</tr>
<tr>
<td>Taei Cho, Kim K Ram</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Utilization of glycerol as a carbon source for mixotrophic growth of microalgae for lipid accumulation</td>
</tr>
<tr>
<td>Hadi Ranjiburachaloo D Dunstan, G Martin</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Cancer therapy using nano-particles</td>
</tr>
<tr>
<td>Erico de Godois Baroni G Martin, P Scales, P Webley</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Engineering novel microRNA-polymer nanocarriers with bioresponsive properties</td>
</tr>
<tr>
<td>Nature Poddar G Martin, R Sen</td>
<td>PhD</td>
<td>MIEA</td>
<td>Cryogels for soft tissue engineering and regeneration</td>
</tr>
<tr>
<td>Gordon Heng Yi G Stevens, K Smith</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>The development of cubosomes as drug delivery vehicles to treat macular degeneration</td>
</tr>
<tr>
<td>Wenjie Zhang F Caruso</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Single chondrocyte mechanics and the effect of impact loading</td>
</tr>
<tr>
<td>Camilla Reehorst D Dunstan</td>
<td>PhD</td>
<td>Self-funded</td>
<td>Novel strategies for cancer therapeutics</td>
</tr>
<tr>
<td>Aida Shakouri D Heath, B Kallianis, A O’Connor</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Improving ex-vivo expansion of mesenchymal stem cells</td>
</tr>
<tr>
<td>Terence Hartnett A O’Connor, K Ladewig, K Mclean, P Hartley</td>
<td>PhD</td>
<td>STRAPA, MMI-CSIRO Studentship</td>
<td>Engineering novel microRNA-polymer nanocarriers with bioresponsive properties</td>
</tr>
<tr>
<td>Andrew Rapson M Gee, T Smith, A Clayton, E Nice</td>
<td>PhD</td>
<td>SFS</td>
<td>Novel methods for nanengineered biocompatible films</td>
</tr>
<tr>
<td>Joel Scofield G Qiao, S Kentish</td>
<td>PhD</td>
<td>APA</td>
<td>Development of novel polymeric membranes for CO₂ capture</td>
</tr>
<tr>
<td>Willie Tang P Webley, R Singh, P Xiao</td>
<td>PhD</td>
<td>CO2CRC</td>
<td>Low cost oxygen production by swing pressure adsorption with oxygen selection absorbents</td>
</tr>
<tr>
<td>Zhexing Wang G Stevens, A O’Connor, P Lee</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Structured protein particles for the therapeutic delivery</td>
</tr>
</tbody>
</table>

**Work Submitted for Examination 2015**

<table>
<thead>
<tr>
<th>Student &amp; Supervisors</th>
<th>Degree</th>
<th>Stipend</th>
<th>Thesis Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teobaldo Grabin G Stevens, K Mumford</td>
<td>MPhil</td>
<td>APA</td>
<td>Influence of plate material on performance of disc and doughnuts column</td>
</tr>
<tr>
<td>Steven Harris Wibowo G Qiao</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Development of novel polymer inclusion membranes by electrospinning and casting and study of their extraction and transport</td>
</tr>
<tr>
<td>Terence Hartnett A O’Connor, K Ladewig, K Mclean, P Hartley</td>
<td>PhD</td>
<td>STRAPA, MMI-CSIRO Studentship</td>
<td>The development of cubosomes as drug delivery vehicles to treat macular degeneration</td>
</tr>
<tr>
<td>Anat Kiviti-Manor P Scales, P Powell</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Thickener dewatering optimisation in the minerals industry</td>
</tr>
<tr>
<td>Yukie O’Bryan S Kolev</td>
<td>PhD</td>
<td>APA</td>
<td>Development of novel polymer inclusion membranes by electrospinning and casting and study of their extraction and transport</td>
</tr>
<tr>
<td>Andrew Rapson M Gee, T Smith, A Clayton, E Nice</td>
<td>PhD</td>
<td>SFS</td>
<td>Interactions of a lytic peptide with supported lipid bilayers investigated using surface - selective techniques</td>
</tr>
<tr>
<td>Joel Scofield G Qiao, S Kentish</td>
<td>PhD</td>
<td>APA</td>
<td>Development of novel polymeric membranes for CO₂ capture</td>
</tr>
<tr>
<td>Willie Tang P Webley, R Singh, P Xiao</td>
<td>PhD</td>
<td>CO2CRC</td>
<td>Low cost oxygen production by swing pressure adsorption with oxygen selection absorbents</td>
</tr>
<tr>
<td>Zhexing Wang G Stevens, A O’Connor, P Lee</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Single chondrocyte mechanics and the effect of impact loading</td>
</tr>
</tbody>
</table>
# Successful Completions 2015

<table>
<thead>
<tr>
<th>Student &amp; Supervisors</th>
<th>Degree</th>
<th>Stipend</th>
<th>Thesis Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hirra Azher</td>
<td>PhD</td>
<td>BCIA</td>
<td>Water recovery from brown coal flue gases</td>
</tr>
<tr>
<td>S. Kentish, G. Stevens, C. Scholes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sukhvir Kaur Bhangu</td>
<td>MSc</td>
<td>Self-funded</td>
<td>Sonocrystallisation</td>
</tr>
<tr>
<td>M Ashokkumar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Christian Biscombe</td>
<td>PhD</td>
<td>Special Postgrad Scholarship</td>
<td>Microfluidic circuit analysis</td>
</tr>
<tr>
<td>D Harvie, M. Davidson</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wei-Lun Hsu</td>
<td>PhD</td>
<td>MIRS</td>
<td>Electrokinetics at the silica/water interface, with application to protein focusing and separation in a nanofluidic channel</td>
</tr>
<tr>
<td>D. Harvie, M. Davidson, D. Dunstan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Badra Manori Jayawardane</td>
<td>PhD</td>
<td>MIRS</td>
<td>Self-funded</td>
</tr>
<tr>
<td>S. Kolev</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silvia Leo</td>
<td>PhD</td>
<td>APA</td>
<td>Development of highly sensitive and selective microfluidic paper-based analytical devices (µPADs) for environmental monitoring</td>
</tr>
<tr>
<td>G. Stevens, C. Tallon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wu Li</td>
<td>MSc</td>
<td>Self-funded</td>
<td>Ultrasound-assisted fabrication of mesoporous metal framework</td>
</tr>
<tr>
<td>M Ashokkumar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zheng Li</td>
<td>PhD</td>
<td>CSC</td>
<td>Thermodynamic modelling of liquid-liquid equilibria using the nonrandom two-liquid model and its applications</td>
</tr>
<tr>
<td>G. Stevens, K. Mumford, K. Smith</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>William McMaster</td>
<td>PhD</td>
<td>SFS</td>
<td>Biomaterial porous networks of hydroxyapatite and titanium dioxide</td>
</tr>
<tr>
<td>R. Caruso</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paul Mignone</td>
<td>PhD</td>
<td>DMTC Scholarship</td>
<td>Thermo-mechanical modelling of materials for ultra-high temperature applications</td>
</tr>
<tr>
<td>G. Franks, D. Riley, P. Lee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nor Saadah Mohd Yusof</td>
<td>PhD</td>
<td>Government of Malaysia, University of Malaya</td>
<td>The effect of sonication on micelle micro-structural changes</td>
</tr>
<tr>
<td>M Ashokkumar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Michael Neeson</td>
<td>PhD</td>
<td>APA</td>
<td>Dynamic interactions of soft matter</td>
</tr>
<tr>
<td>D. Chan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Augustine Nitamoah</td>
<td>PhD</td>
<td>CO2CRC</td>
<td>Developing advanced vacuum swing adsorption and temperature swing adsorption cycles for post-combustion CO₂ capture</td>
</tr>
<tr>
<td>P. Webley, F. Xiao</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krishnamurthy Prasad</td>
<td>M Phil</td>
<td>MIFRS, MIRS</td>
<td>Scale up processes associated with ultrasounds and sonochemistry</td>
</tr>
<tr>
<td>M Ashokkumar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kalyan Qin</td>
<td>MSc</td>
<td>Self-funded</td>
<td>Developing the applications of 3-dimensional mesoporous silica FDU-12 by selectively functionalizing and nano-casting</td>
</tr>
<tr>
<td>M. Gea, R. Caruso, A. O’Connor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philipp Senn</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Peripheral nerve stimulation for treatment of chronic neuropathic pain</td>
</tr>
<tr>
<td>J. Fallon, R. Shepherd, F. Caruso</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akalya Shamnugam</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Ultrasonic formation of stable food emulsions for the delivery of nutrients</td>
</tr>
<tr>
<td>M Ashokkumar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keveny Soodam</td>
<td>PhD</td>
<td>DIAL</td>
<td>Microstructure in mature Cheddar cheese</td>
</tr>
<tr>
<td>S. Gras, S. Kentish</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barbara Sowa</td>
<td>PhD</td>
<td>MIFRS, CSIRO</td>
<td>Oil dispersals in aqueous phases and their stability without the use of surfactants</td>
</tr>
<tr>
<td>D Dunstan, N. Maeda</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tom Statham</td>
<td>PhD</td>
<td>APA</td>
<td>Zero-valent iron for the in situ remediation of Antarctic contaminated sites</td>
</tr>
<tr>
<td>G. Stevens, J. Snape, K. Mumford</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suryani Tan</td>
<td>PhD</td>
<td>MIFRS, CSIRO</td>
<td>Interactions of intestinal microbiota with functional foods and nutraceuticals</td>
</tr>
<tr>
<td>S. Gras, C. Oliver, M. Augustin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blaise Tardy</td>
<td>PhD</td>
<td>MIFRS, ARC Project Funds</td>
<td>Supramolecular polymers as building blocks for the formation of particles</td>
</tr>
<tr>
<td>F. Caruso</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Martin van Koeverden</td>
<td>MPhil</td>
<td>APA</td>
<td>Engineering of nanostructured polymer and hybrid thin films</td>
</tr>
<tr>
<td>F. Caruso</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fulcher Wu</td>
<td>PhD</td>
<td>APA</td>
<td>Applications of the Stokes Reynolds Young Laplace model</td>
</tr>
<tr>
<td>D. Chan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jinxuan Zhang</td>
<td>MSc</td>
<td>Self-funded</td>
<td>Ultrasonic synthesis of nanoparticles-encapsulated microspheres for step-wise release of functional materials</td>
</tr>
<tr>
<td>M Ashokkumar</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Glossary**

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>APA</td>
<td>Australian Postgraduate Award</td>
</tr>
<tr>
<td>APA(I)</td>
<td>Australian Postgraduate Award (Industry)</td>
</tr>
<tr>
<td>APAnet</td>
<td>Australian Postgraduate Award International</td>
</tr>
<tr>
<td>ARC</td>
<td>Australian Research Council</td>
</tr>
<tr>
<td>BCA</td>
<td>Brown Coal Innovation Australia</td>
</tr>
<tr>
<td>CRCBID</td>
<td>Cooperative Research Centre for Biomedical Imaging Development</td>
</tr>
<tr>
<td>CO2CRC</td>
<td>Cooperative Research Centre for Greenhouse Gas Technologies</td>
</tr>
<tr>
<td>CSC</td>
<td>China Scholarship Council</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organisation</td>
</tr>
<tr>
<td>DIAL</td>
<td>Dairy Innovation Australia Limited</td>
</tr>
<tr>
<td>DMC</td>
<td>Defence Materials Technology Centre</td>
</tr>
<tr>
<td>IPCA</td>
<td>International Postgraduate Coursework Award</td>
</tr>
<tr>
<td>IPRS</td>
<td>Endeavour International Postgraduate Research Scholarship</td>
</tr>
<tr>
<td>KACST</td>
<td>King Abdulaziz City for Science and Technology, Saudi Arabia</td>
</tr>
<tr>
<td>KAE</td>
<td>Melbourne International Engagement Award</td>
</tr>
<tr>
<td>MEngSc</td>
<td>Master of Engineering Science</td>
</tr>
<tr>
<td>MIEA</td>
<td>Melbourne International Research Scholarship</td>
</tr>
<tr>
<td>MIRS</td>
<td>Melbourne International Research Scholarship</td>
</tr>
<tr>
<td>MMI</td>
<td>Melbourne Materials Institute</td>
</tr>
<tr>
<td>MPhil</td>
<td>Master of Philosophy</td>
</tr>
<tr>
<td>MSc</td>
<td>Masters of Science</td>
</tr>
<tr>
<td>NHMRC</td>
<td>National Health and Medical Research Council</td>
</tr>
<tr>
<td>PPFPC</td>
<td>Particulate Fluids Processing Centre</td>
</tr>
<tr>
<td>PhD</td>
<td>Doctor of Philosophy</td>
</tr>
<tr>
<td>RTS</td>
<td>Research Training Scheme</td>
</tr>
<tr>
<td>SACM-AU</td>
<td>Saudi Arabian Culture Mission</td>
</tr>
<tr>
<td>SFS</td>
<td>Science Faculty Scholarship</td>
</tr>
<tr>
<td>STRAPA</td>
<td>Strategic Research Australian Postgraduate Award</td>
</tr>
</tbody>
</table>
### Continuing Postgraduate Students 2015

<table>
<thead>
<tr>
<th>Student &amp; Supervisors</th>
<th>Degree</th>
<th>Stipend</th>
<th>Thesis Title</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hannah Alcantara</strong></td>
<td>PhD</td>
<td>AusAID Australian Leadership Award Scholarship</td>
<td>Chemically-enhanced phytoextraction of mercury and gold in contaminated mine tailings and biosolids</td>
</tr>
<tr>
<td><strong>Suhaib Ali</strong></td>
<td>PhD</td>
<td>STRAPA</td>
<td>Application and development of heterogeneous catalyst bed reactors, gas-phase separation strategies for onboard DME synthesis</td>
</tr>
<tr>
<td><strong>Jaimys Arnott</strong></td>
<td>PhD</td>
<td>MRS</td>
<td>Determining the fundamental mechanisms governing the availability and retention of air layers apparent on submerged superhydrophobic surfaces, and understanding the implications in respect to developing anti fouling technologies</td>
</tr>
<tr>
<td><strong>Halleh Atri</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>A study of modified secondary structure of natural protein fibres: From macro to nano structures</td>
</tr>
<tr>
<td><strong>Elham Bidram Gorgaby</strong></td>
<td>PhD</td>
<td>APAInt</td>
<td>Drug delivery using polymeric nanoparticles</td>
</tr>
<tr>
<td><strong>Dhee Biswas</strong></td>
<td>PhD</td>
<td>APA</td>
<td>Engineered nanocomposites for tissue engineering and infection control</td>
</tr>
<tr>
<td><strong>Mattias Björnalm</strong></td>
<td>PhD</td>
<td>IPRS, APA</td>
<td>Antibiotic delivery using polymer capsules</td>
</tr>
<tr>
<td><strong>Chris Bolton</strong></td>
<td>PhD</td>
<td>Research Group Funds</td>
<td>Controlling dispersion forces to probe diffusive transport properties in confined systems</td>
</tr>
<tr>
<td><strong>Emma Brisson</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Novel temperature responsive polymers and collectors and flocculants</td>
</tr>
<tr>
<td><strong>Christine Browne</strong></td>
<td>PhD</td>
<td>APA</td>
<td>Effects of solutes on bubble interactions</td>
</tr>
<tr>
<td><strong>Stephan Burger</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Nanoporous materials for biomedical devices, drug delivery and bioseparations</td>
</tr>
<tr>
<td><strong>Wilhelm Burger</strong></td>
<td>PhD</td>
<td>IPRS, APAInt</td>
<td>Bacteriophage treatment of wastewater foam</td>
</tr>
<tr>
<td><strong>Lu Cao</strong></td>
<td>PhD</td>
<td>STRAPA</td>
<td>Synthesis of hierarchically porous titania materials and their application in energy and environment fields</td>
</tr>
<tr>
<td><strong>Cesar Castaneda</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Subsurface barrier formation as a CO2 leakage mitigation technology</td>
</tr>
<tr>
<td><strong>Siirhariini Chellappan</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Dry stacking - A new paradigm in design and operation of solar evaporation pans for sludge treatment</td>
</tr>
<tr>
<td><strong>Xi (Cathy) Chen</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Impact of geometry and surface chemistry of nanoengineered materials on cellular interactions</td>
</tr>
<tr>
<td><strong>Joseph Collins</strong></td>
<td>PhD</td>
<td>APA</td>
<td>Oxime click chemistry for polymer synthesis</td>
</tr>
<tr>
<td><strong>Enrico Colombo</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Synthesis of new catalysts with ultrasound</td>
</tr>
<tr>
<td><strong>Adam Crust</strong></td>
<td>PhD</td>
<td>APA</td>
<td>Optimisation of thicker performance through incorporation of shear effects</td>
</tr>
<tr>
<td><strong>Giong (Ada) Dai</strong></td>
<td>MPhil</td>
<td>MIFRS, MIRS</td>
<td>Intracellular dynamics of nanoengineered materials</td>
</tr>
<tr>
<td><strong>David Danaci</strong></td>
<td>PhD</td>
<td>Research Group Funds</td>
<td>Developing ultra-low fouling polymer capsules for targeted delivery</td>
</tr>
<tr>
<td><strong>Mina Dokouhaki</strong></td>
<td>PhD</td>
<td>IPRS, APA</td>
<td>The assembly and function of chaplin peptides</td>
</tr>
<tr>
<td><strong>Brendan Dyett</strong></td>
<td>PhD</td>
<td>APA</td>
<td>Durable ultra-rough coatings through surface engineering</td>
</tr>
<tr>
<td><strong>Mandana Ershad</strong></td>
<td>MSc</td>
<td>Self-funded</td>
<td>Application of polymer inclusion membranes (PIMs) for ammonia monitoring in fresh water</td>
</tr>
<tr>
<td><strong>Matt Faria</strong></td>
<td>PhD</td>
<td>NICTA</td>
<td>Computational modelling of interactions between nanomaterials and biological systems</td>
</tr>
<tr>
<td><strong>Christopher Fewkes</strong></td>
<td>PhD</td>
<td>APA</td>
<td>Interactions of structured fluids in soft colloidal systems</td>
</tr>
<tr>
<td><strong>Benjamin Freidman</strong></td>
<td>PhD</td>
<td>Engineering Studentship</td>
<td>Biofilm formation within permeable reactive barriers: Implications for media reactivity and hydrocarbon degradation in cold regions</td>
</tr>
<tr>
<td><strong>Agustina Goh</strong></td>
<td>PhD</td>
<td>APA, CSIRO</td>
<td>Oral rheology and its relationship to sensory perception in emulsion based food systems</td>
</tr>
<tr>
<td><strong>Sook Jin Goh</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Development of peptide based star polymers as antimicrobial agents</td>
</tr>
<tr>
<td><strong>Dunyin Gu</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Development of cryogels for biomedical applications</td>
</tr>
<tr>
<td><strong>Junling (John) Guo</strong></td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Biotemplated morph-materials for templated assembly of polymer-drug system</td>
</tr>
<tr>
<td>Student &amp; Supervisors</td>
<td>Degree</td>
<td>Stipend</td>
<td>Thesis Title</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------</td>
<td>---------</td>
<td>--------------</td>
</tr>
<tr>
<td>Malavika Haribabu, D Harvie, M Davidson, D Dunstan</td>
<td>PhD</td>
<td>ARC Project Funds</td>
<td>Simulating the behaviour of milk during ultrafiltration</td>
</tr>
<tr>
<td>Armineh Hassanvand, S Kentish, P Webley, P Tran</td>
<td>PhD</td>
<td>IPRS, APAInt</td>
<td>Capacitive deionisation as a novel approach to wastewater treatment</td>
</tr>
<tr>
<td>Yingdian (Frank) He, P Webley</td>
<td>PhD</td>
<td>CSC</td>
<td>Responsive metal-organic frameworks (MOFs) for gas adsorption and separation</td>
</tr>
<tr>
<td>Stephen Homer, D Dunstan, L Lundin</td>
<td>PhD</td>
<td>Self-funded</td>
<td>Hierarchical structure function relationships in mined biopolymer systems</td>
</tr>
<tr>
<td>Guoping Hu, G Stevens, S Kentish, N Nicholas</td>
<td>PhD</td>
<td>IPRS, APA</td>
<td>Carbon dioxide capture using promoted potassium carbonate solutions</td>
</tr>
<tr>
<td>Javad Jafari, A O’Connor, P Tran</td>
<td>PhD</td>
<td>IPRS, APA</td>
<td>Magnetic manipulation of cells for soft tissue engineering</td>
</tr>
<tr>
<td>Yi Ju, F Caruso, J Cui</td>
<td>PhD</td>
<td>ARC Project Funds</td>
<td>Bioresponsive dopamine particles (degradable)</td>
</tr>
<tr>
<td>Mahshid Kalani, S Gras, A O’Connor</td>
<td>PhD</td>
<td>IPRS, APA</td>
<td>Peptide based materials and their assembly</td>
</tr>
<tr>
<td>Kezia Kezia, S Kentish, J Lee</td>
<td>PhD</td>
<td>Research Group Funds</td>
<td>Salt recovery in dairy operation using membrane distillation technique</td>
</tr>
<tr>
<td>Jinguk Kim, S Kentish</td>
<td>PhD</td>
<td>CO2CRC</td>
<td>Polymer synthesis for CO₂ separation membrane</td>
</tr>
<tr>
<td>Ashish Kumar, P Scales, A Stickland</td>
<td>PhD</td>
<td>APA(I)</td>
<td>Measuring the critical strain of flocculated particulate networks</td>
</tr>
<tr>
<td>Tiara Kusuma, A Stickland, R Dagastline</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>The link between shear rheological behaviour and microstructure of particulate suspensions</td>
</tr>
<tr>
<td>Shu Lam, G Qiao, N O’Brien-Simpson</td>
<td>PhD</td>
<td>IPRS, APAInt</td>
<td>Engineering targeted peptide-based polymer architectures</td>
</tr>
<tr>
<td>Sam Law, G Martin, P Scales</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Lipase based in-situ transesterification for biodiesel production from wet microalgal paste</td>
</tr>
<tr>
<td>Wen (April) Li, G Stevens, K Mumford, K Smith</td>
<td>PhD</td>
<td>APA, CSRF</td>
<td>Solvent extraction column performance study of pulsed columns for solvent extraction</td>
</tr>
<tr>
<td>Thomas McKenzie, G Qiao, D Dunstan</td>
<td>PhD</td>
<td>APA</td>
<td>Polymer deformation in flow</td>
</tr>
<tr>
<td>Nouman Rafique Mirza, G Stevens, N Nicholas, S Kentish</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Evaluation of alternative solvents for recovery of CO₂ from flue gases</td>
</tr>
<tr>
<td>Seyyed Farshad Motelvalizadeh, R Caruso</td>
<td>PhD</td>
<td>APA</td>
<td>Functionalisation of porous inorganic structures</td>
</tr>
<tr>
<td>Anna Mularski, M Gee, F Separovic, D Strugnell</td>
<td>PhD</td>
<td>APA</td>
<td>Interaction of antimicrobial peptides with bacterial cells</td>
</tr>
<tr>
<td>Edward Nagul, K Mumford, G Stevens</td>
<td>PhD</td>
<td>APA</td>
<td>Ultra-trace determination of orthophosphate using polymer inclusion membranes and flow injection analysis</td>
</tr>
<tr>
<td>EurHuyng Nam, G Qiao</td>
<td>PhD</td>
<td>APA</td>
<td>Development of continuous assembly of polymers (CAP) and its application in electronic devices</td>
</tr>
<tr>
<td>Sinn-Yao (Kenneth) Ng, D Dunstan, G Martin</td>
<td>PhD</td>
<td>ACA Project Funds</td>
<td>A fundamental study of skim milk ultrafiltration</td>
</tr>
<tr>
<td>Wei Sung (Will) Ng, G Franks, L Connal</td>
<td>PhD</td>
<td>APA</td>
<td>Novel temperature-responsive polymers as flocculants and collectors</td>
</tr>
<tr>
<td>Ka Fung (Lei) Noi, F Caruso, K Kempe</td>
<td>PhD</td>
<td>Research Group Funds</td>
<td>Smart, engineered polymer vehicles for therapeutic delivery</td>
</tr>
<tr>
<td>Mitchell Nothing</td>
<td>L Connal, G Qiao</td>
<td>PhD</td>
<td>APA, John Stocker Postgraduate Scholarship</td>
</tr>
<tr>
<td>Natalita Nursam, R Caruso, X Wang</td>
<td>PhD</td>
<td>MIRS, CSRF</td>
<td>Preparation and characterization of porous semiconductor materials for photocatalysis using high-throughput technique</td>
</tr>
<tr>
<td>Lenka O’Connor Sraj, S Swearer, S Kolev</td>
<td>PhD</td>
<td>APA</td>
<td>Development of novel analytical devices for monitoring NH₃/NH₄⁺ and pH in marine environments</td>
</tr>
<tr>
<td>Paul Osborne, R Caruso, D Dunstan</td>
<td>PhD</td>
<td>APA</td>
<td>Quantum dot sensitized solar cells</td>
</tr>
<tr>
<td>David Parris</td>
<td>PhD</td>
<td>APA</td>
<td>Photochemical reactions</td>
</tr>
<tr>
<td>Anita Pax, S Gras, L Ong, S Kentish</td>
<td>PhD</td>
<td>APA</td>
<td>Microstructure and functionality of mozzarella cheese</td>
</tr>
<tr>
<td>Karolina Petkovic-Duran</td>
<td>PhD</td>
<td>CSIRO</td>
<td>Electrophoretic control of molecules in microchannels with nanostructures</td>
</tr>
<tr>
<td>Rohit Pillai, M Davidson, J Berry, D Harvie</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Electrohydrodynamics of microfluidic drop deformation, breakup and coalescence</td>
</tr>
<tr>
<td>Student &amp; Supervisors</td>
<td>Degree</td>
<td>Stipend</td>
<td>Thesis Title</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------</td>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>Samuel Pinches</td>
<td>PhD</td>
<td>APA</td>
<td>Net-shaping techniques for MAX phases</td>
</tr>
<tr>
<td>G Franks, C Tallon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nasim Pour</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>High temperature CO₂ capture</td>
</tr>
<tr>
<td>P Webley, G Stevens</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>James Quinn</td>
<td>PhD</td>
<td>RTS</td>
<td>Synergistic solvent extraction of rare earth elements</td>
</tr>
<tr>
<td>K Saldenhoff, G Stevens</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Md. Ariful Rahim</td>
<td>PhD</td>
<td>IPRS, APA</td>
<td>Metal-phenolic complexes for soft materials synthesis: From surface confined films to gels</td>
</tr>
<tr>
<td>F Caruso</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adlin Ramdzan S Kolev</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Analysis methods for the determination of acetaldehyde and other suitable biomarkers in saliva</td>
</tr>
<tr>
<td>Erwin Rodriguez-Tolava R Caruso, D Chen, A Hollenkamp</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Synthesis of material for lithium ion batteries and study of their electrochemical performance</td>
</tr>
<tr>
<td>Sara Sayanjali S Gras</td>
<td>PhD</td>
<td>IPRS, APAint</td>
<td>The production of extruded starch materials with encapsulated bioactive compounds</td>
</tr>
<tr>
<td>Steven Shirbin G Qiao</td>
<td>PhD</td>
<td>STRAPA</td>
<td>Improved biomaterials for biological applications</td>
</tr>
<tr>
<td>Tomer Simovich R Lamb</td>
<td>PhD</td>
<td>MRS</td>
<td>The fundamental properties of non-wetting topography</td>
</tr>
<tr>
<td>Sarina (Snow) Tan M Ashokkumar</td>
<td>PhD</td>
<td>IPCA</td>
<td>Ultrasonic synthesis of chemically-modified chitosan microspheres</td>
</tr>
<tr>
<td>Hui-En Teo A Strickland, R Batterham, P Scales</td>
<td>PhD</td>
<td>BCA</td>
<td>Probing the yield behaviour of suspensions</td>
</tr>
<tr>
<td>Claire Tindal N Tseng, D Lei, A O'Connor, P Nel</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Replicating the past: Integrating cultural heritage conservation with 3D imaging and printing processes</td>
</tr>
<tr>
<td>Stephanie Tortorella S Gras, T Caragiannis, K Howell</td>
<td>PhD</td>
<td>Baker IDI Bright Sparks Stipend</td>
<td>Combinations of DNA-targeted therapeutics with dietary antioxidants and chromatin modifying compounds for therapeutic and imaging applications</td>
</tr>
<tr>
<td>Leonie van 't Hag S Gras, C Drummond, C Conn</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>In meso crystallisation of amphiphilic peptides</td>
</tr>
<tr>
<td>Brant Walkley A O'Connor, J Pravilis, J van Deventer, R San Nicolas</td>
<td>PhD</td>
<td>APA</td>
<td>Understanding geopolymers through synthetic gel systems</td>
</tr>
<tr>
<td>Chang Wang R Lamb</td>
<td>PhD</td>
<td>Research Group Funds</td>
<td>Development and application of non-wetting surfaces</td>
</tr>
<tr>
<td>Michael Wang G Franks, D Riley, P Scales</td>
<td>PhD</td>
<td>DMTC Scholarship</td>
<td>Thermal modelling and characterisation of ultra-high temperature ablation materials</td>
</tr>
<tr>
<td>Hao Wei R Caruso</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Fabrication and application of hierarchical porous carbonaceous monoliths</td>
</tr>
<tr>
<td>Alessia Weiss F Caruso</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Zwitterionic replica particles for drug delivery</td>
</tr>
<tr>
<td>Fan Wu P Webley, P Xiao, F Hasan</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Development of mini-DME plant</td>
</tr>
<tr>
<td>Wu-Qiang (Mike) Wu R Caruso</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Porous structure for solar cells</td>
</tr>
<tr>
<td>Yue (Frank) Wu G Stevens, K Mumford</td>
<td>PhD</td>
<td>MIEA</td>
<td>Separation of CO₂ from flue gas</td>
</tr>
<tr>
<td>Donglin Xie D Dunston, G Qiao</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Single macromolecule deformation in flow</td>
</tr>
<tr>
<td>Ke Xie G Qiao, P Webley</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>Engineering graphene-based novel structures</td>
</tr>
<tr>
<td>Chenglong Xu G Qiao, X Zhang</td>
<td>PhD</td>
<td>MIFRS, MIEA</td>
<td>Nanodroplets and nanobubbles</td>
</tr>
<tr>
<td>Benjamin Yap P Scales, G Martin, G Dumsday</td>
<td>PhD</td>
<td>STRAPA</td>
<td>Nutrient deprivation effects on microalgae processing for biofuel production</td>
</tr>
<tr>
<td>Qianyu (Matilda) Ye M Ashokkumar</td>
<td>PhD</td>
<td>Self-funded</td>
<td>Ultrasonic encapsulation of food flavours</td>
</tr>
<tr>
<td>Joel Yong S Kentish, F Caruso</td>
<td>PhD</td>
<td>MIFRS, MIRS</td>
<td>The development of thin films for efficient carbon capture and storage</td>
</tr>
<tr>
<td>Qinghu Zhao P Webley, P Xiao</td>
<td>PhD</td>
<td>MIEA</td>
<td>Electrical swing adsorption (ESA) study and process development</td>
</tr>
<tr>
<td>Qi Zheng S Kentish, G Martin</td>
<td>PhD</td>
<td>MIEA</td>
<td>Economic delivery of carbon dioxide to algal ponds</td>
</tr>
</tbody>
</table>
Seminar Series

The PFPC Student Seminar Organising Committee arrange a series of seminars to give postgraduate students and postdoctoral scientists the opportunity to present their work to their peers and senior researchers within the Centre. The seminar series provides members with the opportunity to keep abreast of the research taking place within the PFPC.

In 2015 members of the Seminar Organising Committee were:

- Christopher Bolton
- Yasmina Dkhissi (resigned during 2015)
- Guoping Hu
- Jeannie Tan
- Martin van Koeverden (resigned during 2015)
- Alessia Weiss
<table>
<thead>
<tr>
<th>Date</th>
<th>Speakers</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 February</td>
<td>Yi Ju, Stephen Homer</td>
<td>Engineering low-fouling and pH-degradable capsules through the assembly of metal-phenolic networks. Assembly of whey protein isolate gels under large deformation oscillatory strains - Examining their microstructure and rheological behaviour.</td>
</tr>
<tr>
<td>17 February</td>
<td>Rohit Pillai, Ben Freidman</td>
<td>Electrophorescence of a dielectric, microfluidic drop on a planar interface. Design and installation of a permeable reactive barrier to treat hydrocarbon contamination at Sub-Antarctic Macquarie Island.</td>
</tr>
<tr>
<td>3 March</td>
<td>Terry Hartnett, Leonie van 't Hag</td>
<td>Phase transitions in charged cubosome dispersions induced via an electrostatic switch: applications in protein encapsulation and release. Characterising lipid mesophases during crystallisation using small-angle X-ray scattering techniques.</td>
</tr>
<tr>
<td>17 March</td>
<td>Joel Yong, Dhee Prakash Biswas</td>
<td>Hollow fibre membrane contactors for efficient CO₂ absorption. A combined gas templating and phase separation approach towards soft tissue engineering scaffolds.</td>
</tr>
<tr>
<td>31 March</td>
<td>Brendan Dyett, Timothy Henderson</td>
<td>Surface engineering for mechanically robust superhydrophobic films. Hyaluronic acid cellular scaffolds for soft tissue engineering.</td>
</tr>
<tr>
<td>28 April</td>
<td>Ka Noi (Leo), Hao Wei</td>
<td>Effect of nanoparticle size and rigidity on their cell interactions. Mesoporous TiO₂-C₃N₄ hybrid microbeads for visible photocatalyst.</td>
</tr>
<tr>
<td>12 May</td>
<td>Danzi Song, Wuqiang Wu</td>
<td>Shape dependent in vivo behaviours of polymeric particles. Perovskite solar cells based on 3D dendritic anatase titania nanowire thin films.</td>
</tr>
<tr>
<td>9 June</td>
<td>Armineh Hassanvand, Marie Jehannin, CEA, Atomic Energy &amp; Alternative Energy Commission, France; Max Planck Institute of Colloids and Interfaces, Germany</td>
<td>Capacitive deionization as a novel approach to wastewater treatment. Formation of periodic patterns during coalescence of reactive sessile drops.</td>
</tr>
<tr>
<td>23 June</td>
<td>Jeannie Ziang Yi Tan, Emma Brisson</td>
<td>TiO₂ of tunable crystal phase grown on PVDF membranes: synthesis, mechanism and applications in photocatalysis. Histidine functionalized thermoresponsive polymers synthesized by reductive amination.</td>
</tr>
<tr>
<td>7 July</td>
<td>Xi (Cathy) Chen, Wei Sung (Will) Ng</td>
<td>Polymer-based particle shape independently influences on cell processing by human leukemia cells. Xanthate-functional temperature-responsive polymers: Effect on the hydrophilic-hydrophobic transition behaviour.</td>
</tr>
<tr>
<td>21 July</td>
<td>Natalita Nursam, Sriharini Chellappan</td>
<td>Templated fabrication of macro-/mesoporous nitrogen doped titania monoliths for photocatalytic applications. Determination of breakthrough concentration and cracking time during drying of wastewater sludge.</td>
</tr>
<tr>
<td>18 August</td>
<td>Brant Walkley, Zheng Li</td>
<td>Effect of MgO incorporation on the structure of synthetic alkali-activated calcium aluminoisilicate binders. Solution structure of isoactivity equations using the nonrandom two-liquid model for two-phase liquid-liquid equilibrium calculations.</td>
</tr>
<tr>
<td>1 September</td>
<td>Dr Yuzo Baba, Enrico Colombo</td>
<td>Development of polymer inclusion membrane with amide acid type extractant for separation of cobalt(II) from manganese(II). Forming stable emulsions without the addition of external emulsifiers and stabilizers.</td>
</tr>
<tr>
<td>15 September</td>
<td>Mattias Bjömmalm, Tiara Kusuma</td>
<td>Micro- and nanoparticles under flow. The relationship between microscale particle interaction and bulk suspension rheology of strongly flocculated particulate suspensions.</td>
</tr>
<tr>
<td>29 September</td>
<td>Tomoya Suma, Guoping Hu</td>
<td>Mode of cleavage modulates cytotoxic potency of pro-apoptotic peptide particles from template assembly. An overview of CO₂ capture in promoted potassium carbonate solutions.</td>
</tr>
<tr>
<td>13 October</td>
<td>Dr Qiang Sun, Junling Guo</td>
<td>Boundary regularised integral equation formulation of the Debye-Hückel Mode. Nanoporous metal-phenolic particles as ultrasound imaging probes for hydrogen peroxide.</td>
</tr>
<tr>
<td>27 October</td>
<td>Wei Sung Ng (Will), Wilhelm Burger</td>
<td>Selective flocculation and hydrophobic modification with xanthate-functional temperature-responsive polymers. The use of image analysis to quantify the growth of filamentous bacteria in activated sludge.</td>
</tr>
<tr>
<td>10 November</td>
<td>Malavika Haribu, Christine Browne</td>
<td>Model development for ultrafiltration of soft colloids in dead-end mode. Direct AFM force measurements between air bubbles in aqueous polyelectrolyte solutions.</td>
</tr>
<tr>
<td>8 December</td>
<td>Adam Crust, Yi (David) Ju</td>
<td>Shear induced dewatering in networked suspensions. Cancer cell targeting using nano-engineered capsules.</td>
</tr>
</tbody>
</table>
Awards and Achievements
Professors

**Professor Frank Caruso** was appointed as a Melbourne Laureate Professor. The University reserves this honour for its most distinguished academic staff including Nobel Laureates, scholars equivalent in standing to Nobel Laureates and distinguished professors. Professor Caruso was invited to deliver the 13th Professor J.W. McBean Memorial Lecture at the Council of Scientific and Industrial Research (CSIRO)-National Chemical Laboratory, Pune, India in November.

**Professor George Franks** and Dr Carolina Tallon are part of the defence materials technology Centre team including CSIRO, Swinburne University of Technology, the Victorian Centre for Advanced Materials Manufacturing (VCAMM), and Australian Defence Apparel that won the CRC Award for Excellence in Innovation 2015, presented at the CRC Association Annual Conference, 26 May 2015, Canberra, ACT, Australia for the DMTC team working on Light Weight Boron Carbide Personal Armour.

The contributions of **Professor Tom Healy** to the University of Melbourne were recognised with the installation of a plaque along Professors Walk. The University of Melbourne Awards recognise significant staff or Council members who have made a lasting contribution to life at the University.

**Dr Jiwei Cui** received an Honourable Mention - Oral Presentation by an Early Career Researcher for his presentation Biologically responsive polymer particles via mesoporous silica templating for drug delivery at the 6th International Nanomedicine Conference, Sydney, NSW, Australia, 6-8 July. He also received the award for most significant CBNS publication of 2015 at the 1st Centre for Bio-Nano Science Annual Workshop, staged by the ARC Centre of Excellence in Convergent Bio-Nano Science and Technology (CBNS), 2-4 December. The award was shared with joint first author Dr Rob De Rose (the University of Melbourne).

**Dr Biao Kong** received the Chinese Government award of Academic Star in Victoria for 2014. This accolade recognises the most academically outstanding Chinese scholar or student studying overseas; only one is granted each year for Victoria. The ceremony was held at the Consulate-General of the People’s Republic of China in Melbourne in April 2015.

Awarded by the Victorian Government **Dr Jing Ming Ren** was successful in his application for a Victorian Postdoctoral Research Fellowship. The fellowship allows Jing Ming to spend two years with Professor Craig Hawker at University of California Santa Barbara, USA, before returning for his third year with Greg Qiao at the University of Melbourne.

**Dr Anthony Stickland** was awarded the Carlton Connect Initiative Research Impact Award for his presentation “High pressure dewatering rolls” at the Carlton Connect Initiative Fund Innovation Showcase, Melbourne, VIC, Australia, 8 December. The award was for the best 3 minute elevator pitch.

**Postgraduate Students**

Hannah Alcantara won the first prize in the 2015 science imaging competition, Under the Coverslip, organized by the Postgraduate Students of Anatomy Society (PSONAS) and Department of Anatomy and Neuroscience at the University of Melbourne. Hannah’s winning image, Star of Life, was a cross section of a cassava root.

Mattias Björnsmal was awarded the Best Student Presenter for his presentation Microfluidic blood capillary model with super-soft hydrogel particles at the 6th Australia and New Zealand Nano- Microfluidics Symposium (ANZNMF), Melbourne, VIC, Australia, 31 March-2 April.

Emma Brisson won the Treloar Prize for the Best Oral Presentation by a Young Scientist at the 35th Australasian Polymer Symposium (35APS), Gold Coast, QLD, Australia, 12-15 July.

Enrico Colombo and Wu-Qiang Wu were awarded T.W. Healy travel grants from the School of Chemistry to attend Pacificchem 2015: International Chemical Congress of Pacific Basin Societies, Honolulu, HI, USA, 15-20 December.

Qiong (Ada) Dai won Best Oral Presentation by a PhD Student for her talk Monoclonal antibody-functionalized multilayered particles: Targeting cancer cells in the presence of protein coronas at the 6th International Nanomedicine Conference, Sydney, NSW, Australia, 6-8 July.

Tessa Evans was awarded the Ronald Riseborough Prize from the School of Chemistry. The prize is awarded to the student who submits the best research report in applied chemistry.

**Ben Freidman**, along with his collaborators and supervisors, Dr Kathy Northcott, Ms Peta Thiel, Dr Kathryn Mumford, Associate Professor Sally Gras, Professor Ian Snape and Professor Geoff Stevens, won the 2015 Postgraduate Water Prize for the project Comparison of biofilm activity on filtration media: implications for municipal water treatment and contaminated land and fuel spill at the Australian Water Association Victorian Water Awards.

Junling Guo was awarded the 2014 Chinese Government Award for Outstanding Self-Financed Students Abroad by the China Scholarship Council (CSC). This award was founded by the Chinese government in 2003 to reward the academic excellence of self-financed Chinese students studying overseas with only 500 awarded each year worldwide. The ceremony was held at the Consulate-General of the People’s Republic of China in Melbourne in April 2015.

Steven Harris Wibowo travelled to London as part of a team that reached the semi-finals of the OneStart life sciences and health care accelerator, organised by SR One and the Oxbridge Biotech Roundtable (OB). Their entry, Eira Biotech, Nanocarrier technology: Delivering neurotrophic factors beyond the blood-brain barrier, is the only Australian team within 70 shortlisted from the almost 650 applications received from around the world. **Steven** was also selected to compete in the Grand Final of the University of Melbourne’s 2015 Three Minute Thesis Competition (3MT) with his three minute research pitch, “Can Spiders Save Soldiers?”

Shu Lam was second runner up for the ATA Young Scientist Encouragement Award. This has provided her with $600 in travel funds.

**Edward Nagul** was a joint winner of the Royal Society of Victoria Young Scientist Research Award in the Physical Sciences category. The award is given to PhD students who demonstrate excellence in scientific research and an ability to communicate scientific information clearly and succinctly to an audience of scientists and members of the general public.

**Mitchell Nothing** was awarded an Endeavour Postgraduate Research Fellowship and an Australian Nanotechnology Network Travel Award to conduct a 7-month research visit with Professor Craig Hawker at University of California, Santa Barbara, USA. This visit was also supported by an ongoing John Stocker Postgraduate Fellowship (since 2013). Mitchell is one of only two nationwide to receive this award from...
CSIRO for industry engagement through his research project.

Rohit Pillai was awarded “Best Student Presentation” for his paper Electrophoretic effects on satellite droplet formation during electrocoalescence of microdrops at the *Eleventh International Conference on Computational Fluid Dynamics in the Minerals and Process Industries*, Melbourne, VIC, Australia, 7-9 December.

At the 5th Australia China Biomedical Research Conference, Melbourne, VIC, Australia, 30 October-1 November 2015, Danzi Song won 3rd prize in the 5 Minutes Science Competition for her talk “Can viruses/bacteria teach us how to fight cancer?”.

Leonie van ‘t Hag was awarded an Australian Nanotechnology Network Overseas Travel Fellowship to spend one month in Aarhus, Denmark, for Synchrotron Radiation Circular Dichroism Spectroscopy Beamtime at ASTRID2 and to attend the *16th International Conference on Small Angle Scattering* (SAS2015), Berlin, Germany, 13-16 September. Leonie won a Postgraduate Research Award from the Australian Institute of Nuclear Science and Engineering (AINSE) for 2015/2016.

The Clive Pratt Scholarships are made possible through a bequest in memory of Henry Reginald Clive Pratt. The Travel Scholarships are open for award annually, for students in Chemical Engineering and/or Biomolecular Engineering at the University. In 2015 the recipients were Samuel Skinner, Wei Sung Ng, Kezia Kezia and Armineh Hassanvand.

Yue (Frank) Wu was awarded the Best Tutor in Chemical and Biomolecular Engineering Semester 1 2015. PPFC students Sui So, Brant Walkley and Armineh Hassanvand received honourable mentions for this award.

Fan Wu was awarded the Best Tutor in Chemical and Biomolecular Engineering Semester 2 2015. PPFC students Sui So, Sam Skinner and Armineh Hassanvand received honourable mentions for this award.

**Academic Promotions**

Associate Professor Antoinette Tordesillas was promoted to full professor

Dr Kathryn Mumford was promoted to Level C

Dr Paul Gurr was promoted to Level B

Dr Andy Leung was promoted to Level B

**University Portfolio Holders**

Muthupalidhan Ashokkumar, Associate Dean (Engagement and International), Faculty of Science

Raymond Dagastine, Chair, Materials Research Hallmark Initiative

Sally Gras, Associate Director, Molecular Systems Biology, Bio21 Institute

Dalton Harvie, Deputy Head of Department of Chemical and Biomolecular Engineering

Sandra Kentish, Head of Department of Chemical and Biomolecular Engineering Appointed Associate Dean (Industry), Melbourne School of Engineering

Andrea O’Connor, Deputy Head of Department of Chemical and Biomolecular Engineering

Greg Qiao, Assistant Dean (Research), Melbourne School of Engineering

Geoff Stevens, Associate Dean (Engagement), Melbourne School of Engineering

**Serving the Scientific Community**

Conference Contributions

Muthupalidhan Ashokkumar
Conference Co-Chair and Member of the International Advisory Committee: AOSS-2: 2nd Asia-Pacific Sonoc hemistry Conference, Kuala Lumpur, Malaysia, 25-28 July.

Session Co-Organiser: Specific Effect(s) in Chemical Reactions by Innovative Technologies (#157), Pacifichem 2015: International Chemical Congress of Pacific Basin Societies, Honolulu, HI, USA, 15-20 December.

Frank Caruso
Session Chair: Functional Nanoparticles, 6th International Nanomedicine Conference, Sydney, NSW, Australia, 6-8 July.

Organising Committee: 249th ACS Spring National Meeting and Exposition, Denver, CO, USA, 22-26 March.

Rachel Caruso
Session Co-Chair, Energy, 9th International Mesostructured Materials Symposium (IMMS 9), Brisbane, QLD, Australia, 17-20 August.

Francesca Cavalieri
Organising Committee: Theo Murphy Australian Frontiers of Science Symposium, Materials for the 21st century: From design to application, Melbourne, VIC, Australia, 9-11 December.

Raymond Dagastine

**George Franks**

Conference Co-Chair: ECI Conference on Ultra-high Temperature Ceramics: Materials For Extreme Environment Applications III, Surfer’s Paradise, QLD, Australia, 12-16 April.

Member, Technical Committee, Asian Pacific Confederation of Chemical Engineering (APCCHE 2015) Congress incorporating Chemeca 2015, Melbourne, VIC, Australia, 27 September-1 October.


**Franz Grieser**

Co-organiser and Session Chair of the Symposium “Applications of Ultrasound to Nanoscience” Pacifichem 2015: International Chemical Congress of Pacific Basin Societies, Honolulu, HI, USA, 15-20 December.

**Daniel Heath**


**Sandra Kentish**


**Spas Kolev**


**Nathan Nicholas**


**Andrea O’Connor**

Member, Organising Committee, 9th International Mesostructured Materials Symposium (IMMS 9), Brisbane, QLD, Australia, 17-20 August.
Session Chair, Bio Materials, 9th International Mesostructured Materials Symposium (IMMS 9), Brisbane, QLD, Australia, 17-20 August.

Member, Technical Committee, Asian Pacific Confederation of Chemical Engineering (APCChE 2015) Congress incorporating Chemeca 2015, Melbourne, VIC, Australia, 27 September-1 October.

Stream Leader, Biomedical and Tissue Engineering, Asian Pacific Confederation of Chemical Engineering (APCChE 2015) Congress incorporating Chemeca 2015, Melbourne, VIC, Australia, 27 September-1 October.


Greg Qiao
Member, Conference Committee: 35th Australasian Polymer Symposium (35APS), Gold Coast, QLD, Australia, 12-15 July.

Colin Scholes
Member, Organising Committee and Convenor, Chem-E-Car Competition, Asian Pacific Confederation of Chemical Engineering (APCChE 2015) Congress incorporating Chemeca 2015, Melbourne, VIC, Australia, 27 September-1 October.


Anthony Stickland
Moderator, Rheology Session, Asian Pacific Confederation of Chemical Engineering (APCChE 2015) Congress incorporating Chemeca 2015, Melbourne, VIC, Australia, 27 September-1 October.

Carolina Tallon
Conference Co-Chair: ECI Conference on Ultra-high Temperature Ceramics: Materials For Extreme Environment Applications III, Surfer’s Paradise, QLD, Australia, 12-16 April.


Jannie van Deventer
Member of International Organising Committee and Round Table Chair of the ECI Conference on Geopolymers, Herrnstein, Austria, 24-29 May.

Session Chair: VI Geopolymers in the Context of Sustainable Development, ECI Conference on Geopolymers, Herrnstein, Austria, 24-29 May.

Member of Advisory Committee, 11th International Mineral Processing Conference, Procemin 2015, Santiago, Chile, 21-23 October.

Editorial Board Appointments

**Muthupandian Ashokkumar**
Editorial Board Member of the Elsevier journal Ultrasonics Sonochemistry

Editorial Board Member of the Journal of Photocatalysis Science

Editorial Board Member of the Open Acoustics Journal

Editorial Board Member of International Journal of Agriculture and Food Research

**Frank Caruso**
Member of the Editorial Advisory Board of the Wiley-VCH journal Advanced Functional Materials, 2001-present

Member of the Editorial Advisory Board of the Dove Medical Press journal International Journal of Nanomedicine, 2006-2015

Member of the Editorial Board of Nano Today, 2009-present

Member of Editorial Advisory Board of the Elsevier journal Advances in Colloidal and Interface Science, since 2010

Member of the Editorial Advisory Board of the Wiley-VCH journal Advanced Materials: Advanced Healthcare Materials, since 2011

Member of the Editorial Advisory Board of the RSC Publishing journal Biomaterials Science, from 2013

Member of the Editorial Advisory Board of the American Chemical Society journal ACS Nano, since 2013

Member of the International Advisory Board, Angewandte Chemie (Wiley-VCH), since 2014

Member of the Executive Advisory Board, Advanced Science (Wiley-VCH) since 2015

Editorial Advisory Board, ACS Central Science (American Chemical Society) since 2015

**Rachel Caruso**
Member of the Editorial Advisory Board of the RSC Publishing journal Materials Horizons, from 2013

**Raymond Dagastine**
Member of the Editorial Advisory Board of the Elsevier journal Journal of Colloid and Interface Science, since 2012

**George Franks**
Member of the Editorial Board for the Elsevier journal Advanced Powder Technology, since 2006

**Neil Furlong**
Member of the Editorial Board of Colloid and Surfaces A (Elsevier)

**Dalton Harvie**
Member of the Editorial Board for the Elsevier journal Advanced Powder Technology

**Tom Healy**
Founding Editor and Member of the Editorial Board of Colloid and Surfaces A (Elsevier)

**Sandra Kentish**
Editorial Board Member of Recent Innovations in Chemical Engineering (Bentham Science), 2007-present

Editorial Board Member of Food Engineering Reviews (Springer), 2008-present

Editorial Committee Member of Chinese Journal of Chemical Engineering (Elsevier)

Editorial Board, Sustainable Water Developments - Resources, Management, Treatment, Efficiency and Reuse, CRC Press

**Greg Qiao**
Member of the International Advisory Board for Macromolecular Bioscience (Wiley)

Member of the International Advisory Board for Macromolecular Materials and Engineering (Wiley)

**Peter Scales**
Member of the Editorial Board of Transactions of the Filtration Society, 2003-present

Member of the Advisory Board of the Elsevier journal Advanced Powder Technology, 2008-present

**Geoff Stevens**
Member of the Editorial Board of the Elsevier journal Hydrometallurgy, 1994-present

Member of the Editorial Board of the Chemical Engineering Journal (Elsevier), 1999–present

Member of the Editorial Board of the Elsevier journal Separation and Purification Technology, 2014-present

**Jannie van Deventer**
Member of the Editorial Advisory Board of the Elsevier journal Minerals Engineering, since 1992

Member of the Editorial Board of the Elsevier journal Hydrometallurgy, 2001-present
Appointed Member of the Editorial Board of the Elsevier journal *Heliyon*

**Paul Webley**
Member of the Editorial Board and Separations Subject Editor, *Chemical Engineering Research and Design*, a publication of the Institution of Chemical Engineers.

**Editorial Roles**

**Muthupandian Ashokkumar**
Appointed Asian Editor of *Ultrasonics Sonochemistry* (Elsevier) in 2015.


**Rachel Caruso**
Associate Editor of the RSC Publishing journal *Chemical Communications*, since 2014

**Frank Caruso**
Associate Editor, American Chemical Society journal *Chemistry of Materials*, since 2005

**Raymond Dagastine**
Associate Editor for the open access journal *Frontiers in Chemistry* (Chemical Engineering specialty)

**George Franks**
Associate Editor, *Journal of the American Ceramic Society* (Wiley), since 2004

**Franz Grieser**
Editor, *Colloid and Surfaces A* (Elsevier), from 2013

**Gregory Martin**
Appointed Associate Editor, *Journal of the American Oil Chemists’ Society* (Springer), from 2011

**Andrea O’Connor**
Associate Editor, *Journal of Biomaterials and Tissue Engineering*, from 2011

Guest Editor, Special Edition of *Microporous and Mesoporous Materials*, for the Proceedings of the 9th International Mesostructured Materials Symposium (IMMS 9), Brisbane, QLD, Australia, 17-20 August.

**Peter Scales**
Regional Editor, Australia, *Journal of Dispersion Science and Technology* (Taylor & Francis), since 2002

**Geoff Stevens**
Associate Editor of the Taylor & Francis journal *Solvent Extraction and Ion Exchange*, 1996-present

Associate Editor-in-chief, *Chinese Journal of Chemical Engineering* (Elsevier), from 2013

**Anthony Stickland**
Review Editor for the open access journal *Frontiers in Chemistry* (Chemical Engineering specialty), from 2014

**Jannie van Deventer**
Founding Associate Editor, *Waste and Biomass Valorisation*, since 2009

**Paul Webley**
Editor, *Separation and Purification Technology*, from 2014

**Other Roles**

**Muthupandian Ashokkumar**
Board Member of the European Society of Sonochemistry
Member of the International Association for Radiation Research
International Advisor to the Center for Environment Education and Technology

**Raymond Dagastine**
is a regular guest host on the radio 3RRR Sunday science program Einstein-a-go-go with an audience of approximately 100,000 listeners.

**Sandra Kentish**
Research Advisory Committee: National Centre of Excellence in Desalination, April 2010 onwards

Invited Professor, Centre for Water, Earth and the Environment, INRS, Canada

Chair, Review of the School of Chemical Engineering, University of Queensland, July 2015.

**Peter Scales**
Council member of the Australian Society of Rheology, since 2002

Australian representative, International Society of Rheology, since 2006

Board Member, Water Resources Center for Agriculture and Mining (CRHIAM), CONICYT/FONDAP Project, Santiago, Chile

**Geoff Stevens**
Australian Representative on the International Committee for Solvent Extraction

International Honorary Member of the Japan Society of Ion Exchange (JSIE), 2011-present

**Anthony Stickland**
Council member of the Australian Society of Rheology, since 2010

**Carolina Tallon**
Federal Councillor: Australian Ceramic Society, since 2012

Editor of the Newsletter of the Australian Ceramic Society, since 2012

**Leonie van ’t Hag**
Appointed to the User Advisory Committee, Australian Synchrotron

**Paul Webley**
Member of the Board of Directors, International Adsorption Society, since 2010

**Public Outreach and Publicity**

The research headed by Professor Frank Caruso on nano-sized biologically friendly drug delivery vehicles was showcased in *Stories of Australian Science* 2015, published by Science in Public. This publication features cutting edge scientific research by prominent Australian scientists. The publication is available online at http://stories.scienceinpublic.com.au/


**Yasmina Dkhissi** was interviewed by the Beyond Zero - Science and Solutions Program on 3CR Community Radio on 28 August 2015 regarding perovskite solar cells. The interview can be found at http://bze.org.au/media/radio/yasmina-dkhissi-phd-candidate-university-melbourne-150828

**Steven Harris Wibowo’s** performance in the grand final of the University of Melbourne’s 2015 Three Minute Thesis Competition (3MT) was featured in the Melbourne Herald Sun newspaper on Monday 14 September 2015
Networks

The PFPC has developed an extensive network of collaborations across universities, industry and publicly funded research organisations. Our collaborative network is highly advantageous in advancing our research by providing our staff and students the opportunity to visit and share research facilities and scientific knowledge. A tangible measure of the success of our networks is the number of joint publications and funding grants that result from these collaborations. In a number of instances this network has assisted with the recruitment of postdoctoral research fellows and the employment of PFPC graduates. A number of our active collaborations are highlighted.
International Links

Partnerships with Indian Institute of Petroleum and Bharat Petroleum

Professor Paul Webley, Dr. Fatim Hasan, Dr. Tejas Bhatelia and Ms. Fan Wu have engaged in a 3 year Grand Challenges project to develop a clean burning synthetic fuel. The project team, which consists of CSIRO, the Council of Scientific and Industrial Research-Indian Institute of Petroleum (CSIR-IIP), the Indian Institute of Technology (IIT-Roorkee), Bharat Petroleum Corporation Limited, RMIT University and the University of Melbourne, will work with producers and refineries to deploy the technology, resulting in opportunities for Australia and India to develop capabilities and manufacturing in this sector, with the possibility for new industries to emerge.

The project, named “Mini-DME for Stranded Gas Applications” is a new research partnership. The $2.5 million partnership focusses on improving processes involved in the production of dimethyl ether (DME), an environmentally friendly liquid fuel produced from resources including natural gas, coal, biomass, or directly from carbon dioxide. Dimethyl ether has the potential to provide substantial economic benefits to Australia and India by reducing the need to import petroleum products. The project focusses specifically on reducing the size of gas-to-liquids (GTL) processing plants, allowing natural gas to be converted to transportable fuel at the source. The three-year project is jointly funded by the Australian and Indian governments, through the Australia-India Strategic Research Fund (AISRF) Grand Challenges Initiative.

Australia-China Joint Research Centre on River Basin Management (ACJRCRBm)

The Australian Government’s Department of Environment has funded six new research centres between Australia and China. The ACJRCRBm is led by Professor Peter Scales and looks to bring researchers and industry from both countries together to improve the delivery of water to agriculture in China and develop technologies for identifying water pollution and treating water to potable standard for re-use. The centre involves a number of researchers from the PFPC as well as other researchers from the University of Melbourne and CSIRO. It has developed a strong research overlap with Tsinghua University, Beijing, China particularly with the Department of Civil and Hydraulic Engineering and the School of Environment. The interaction also involves two Institutes of the Chinese Academy of Sciences and five other government, semi-government and industrial organisations in China.

Remediation of petroleum contaminated soils, Kanazawa Institute of Technology, Japan

Professor Geoff Stevens holds an Adjunct Professorial appointment at Kanazawa Institute of Technology, Japan where he collaborates with Professor Yu Komatsu in the Environmental Engineering Department and is involved in the supervision of a number of Masters and PhD students in the area of environmental remediation and materials development. There has been an ongoing exchange of researchers between the PFPC and KIT. A Memorandum of Understanding signed by the two institutions formalises the exchange arrangement.

The Australia-China Young Scientists Exchange Program (YSEP)

Dr Kathryn Smith was one of 13 Australians selected to visit China for 2 weeks in November 2015 as part of The Australia-China Young Scientists Exchange Program (YSEP) which is a joint initiative funded by the Australian Department of Industry Innovation and Science and the Chinese Ministry of Science and Technology (MOST). It is supported by the Commonwealth of Australia under the Australia-China Science and Research Fund.

YSEP aims to provide a catalyst to bring together future science leaders from Australia and China to foster long term relationships to

- Increase early and mid-career Australian and Chinese researchers understanding of the cultures, particularly the science and research practices and systems, of the two countries;
- Develop the researchers’ leadership skills as future “science ambassadors” for Australia and China; and
- Provide a catalyst for future Australia-China research collaboration.

During the 2 week exchange Kathryn visited several universities and research institutions where she gave seminars related to CO2 capture and solvent extraction research and toured the hosts’ laboratories. Her hosts included the Chinese Academy of Sciences in Beijing (Institute of Process Engineering and Institute of Engineering Thermophysics), Department of Chemical Engineering at Tsinghua University, School of Chemical & Pharmaceutical Engineering at Hebei University of Science & Technology and Qingdao Institute of Bioenergy and Bioprocess Technology (QIBEBT) at the Chinese Academy of Sciences in Qingdao.

Mechanobiology Network

Associate Professor Andrea O’Connor is part of an international network of researchers investigating in the role of mechanical forces in cell and tissue behaviour. The network includes colleagues from the University of Melbourne, Professor Peter Lee in the Department of Mechanical Engineering and Professor Alastair Stewart in the School of Pharmacology, and was awarded a 2014 University of Melbourne International Research and Research Training Fund workshop grant on “Expanding International Collaborative Links in Mechanobiology”. This enabled the group to host the “Workshop on expanding collaborative links in mechanobiology” in Melbourne in April 2015. Leading researchers from Tsinghua University, Shanghai Jiao Tong University, China, Hokkaido University, Japan, University of Auckland, New Zealand and National University of Singapore participated in the workshop, building new collaborations. A second workshop is planned for 2016 in Beijing.

Collaboration with the Cement Materials Science and Engineering Group at The University of Sheffield, UK

Continuing collaboration between the Geopolymer and Mineral Processing Group (GMPG) within the Particulate Fluids Processing Centre (PFPC) and the Cement Materials Science and Engineering Group (CMSEG) at The University of Sheffield focusses on the development, characterisation and exploitation of advanced and non-traditional cement and concrete technology. Many projects involve alkali-
activated and geopolymer binders, for use in construction, infrastructure and waste immobilisation applications. The collaboration involves co-supervision of a number of PhD students both at the University of Melbourne and The University of Sheffield and exchange of PhD students between the Geopolymer and Mineral Processing Group and the Cement Materials Science and Engineering Group.

Links with Industry

Melbourne Water, Australia
PFPC researchers Professor Peter Scales, Associate Professor Sally Gras, Dr Greg Martin, Dr Anthony Stickland and Dr Shane Usher have now developed a strong research association with Melbourne Water in the areas of foam regulation in wastewater treatment and dry stacking of wastewater treatment sludges. These projects are funded through an ARC Linkage along with SA Water and Water Corporation of Western Australia in the case of foam regulation. This project looks to use bacteriophage to specifically target foam stabilising bacteria and involves LaTrobe University, Bendigo. The dry stacking project is also funded as an ARC Linkage project and looks to bring technology from the minerals industry across to the wastewater industry by reducing the land requirements for solids disposal.

GlasoSmithKline, Australia
Professor Geoff Stevens has a long and ongoing relationship with a range of companies operating in Australia. These relationships are centred around key technologies developed by Geoff and his team which the companies access as a resource to supply critical knowledge and support. Geoff has nurtured such relationships and the companies have employed many of his graduates over the years. An example in the pharmaceutical industry is GlasoSmithKline (GSK) in Australia where Geoff serves on the GSK International Science Innovation and Review Committee, Opiates Division, and has ongoing research programs with them. GlasoSmithKline’s alkaloids business in Australia is a significant rural business generating export earnings for Australia. More than 95% of the refined product from this facility is exported. Geoff has been working together with GSK on various aspects of separation technology for the past 20 years with a range of important outcomes, including the development of a new extraction plant for Oripavine which is now in operation.

BHP Billiton, Australia
Professor Geoff Stevens has a number of projects with BHP Billiton aimed at developing the next generation of solvent extraction processes and equipment in the minerals extraction industry.

Callington Haven, Australia
Professor Sandra Kentish has been working with this company to develop new formulations of their insecticides using ultrasound.

MBD Energy and Visy, Australia
PFPC researchers Dr Anthony Stickland, Professor Peter Scales and Associate Professor Antoinette Tordesillas, with Professor Robin Batterham, are investigating a novel concept for the dewatering of algal biomass and waste recycling streams through the use of combined shear and compression. The addition of shear during dewatering can significantly enhance the efficiency of the process. A configuration that is easily scalable is high pressure grinding rolls, albeit designed and operated in a novel fashion. This work involves two projects, one with MBD Energy in collaboration with the Victorian Government via a Technology Development Voucher, and the other with Visy in collaboration with the Carlton Connect Initiative Fund. The projects aim to design, construct and commission a novel, prototype high pressure dewatering rolls to demonstrate that combining compression and shear can deliver a high throughput and flexible dewatering process.

Dairy Innovation Australia Ltd (DIAL)
The ARC Dairy Innovation Hub brings together three of Australia’s leading dairy research groups, the University of Melbourne, the University of Queensland and DIAL, in a five-year research program co-funded by the Australian Research Council (ARC). The Hub was established in early 2014, following receipt of a grant of $5 million from the ARC Industrial Transformation Research Program in May 2013. The ARC Dairy Innovation Hub was one of the first ITRP grants awarded nationally.

The Hub has been structured to address some of the major dairy research and technical challenges that DIAL and its member companies have identified as constraints to business growth and productivity in the dairy manufacturing sector. The Hub program comprises six integrated, strategic research themes, employing innovative science and engineering approaches to address the technical challenges for the dairy manufacturing industry. Under the leadership of the Hub Director, Associate Professor Sally Gras (The University of Melbourne), theme leaders from UoM (who include PFPC members Professor Muthupandian Ashokkumar, Professor David Dunstan, Professor Sandra Kentish and Dr Greg Martin) and the University of Queensland are taking responsibility for projects in their specialist areas. Over the five years, ten postdoctoral fellows, graduate research assistants as well as at least three PhD students will join the teams. Each project involves multiple investigators from each of the three research groups leveraging synergies between research teams. International collaboration will provide access to skills and technologies developed overseas to achieve the Hub’s objectives.

Mondelēz International
Professor Raymond Dagastine, Professor Muthupandian Ashokkumar, Professor Greg Qiao, Dr Paul Gurr, Joel Scofield and Bingxin Liu work within the collaborative Food Research Hub (Unlocking the Food Value Chain: Australian food industry transformation for Australian Research Council Association of South-East Asian Nations (ASEAN) markets) to apply leading-edge research and development with novel market insights and manufacturing innovation to grow Australian exports into key ASEAN markets. The Food Research Hub is an Australian Research Council (ARC) supported initiative delivering interdisciplinary research to unlock a significant market opportunity for exporting premium Australian products. Through the Food Hub programs, Mondelēz International and the University of Melbourne will gain insights to unlock Asian consumer behaviour and market levers, and inform innovation in ingredient use, consumer experience and product design and packaging.
Australian Antarctic Division (AAD)
Dr Kathryn Mumford and Professor Geoff Stevens have strong ties with the AAD through projects funded out of the AAD science program. Working with Professor Ian Snape (AAD) and Associate Professor Damian Gore (Macquarie University), the team are demonstrating that contaminated sites in Antarctica can be effectively and economically remediated in situ with low risk of adverse environmental impacts. The sequential permeable reactive barrier (PRB) installed at the Main Power House site at Casey Station Antarctica demonstrates a low cost bioremediation technology that can be easily installed and achieves positive environmental outcomes in a timely manner. The technology has also been expanded to treat a fuel spill at Macquarie Island station.

A project involving the development of an advanced water treatment plant to produce water of such a quality as to ensure that discharges from Antarctic bases do not harm the marine environment is being led by Professor Peter Scales along with colleagues from Victoria University, AECOM, Veolia, Coliban Water, Curtin University and CAPIM at the University of Melbourne. Subsidiary funding is supplied by the Australian Water Recycle Centre of Excellence. The plant is being tested in Tasmania and will be transferred to Davis Station in Antarctica.

Tissue engineering and The O’Brien Institute
PFPC researchers Professor Geoff Stevens, Associate Professor Andrea O’Connor, Professor Greg Qiao and Dr Daniel Heath have a strong collaboration in the area of tissue engineering with a multidisciplinary team of researchers led by Professor Wayne Morrison at the O’Brien Institute (OBI). The PFPC is expert in the development and testing of biomaterial constructs for the culture and differentiation of cells used in regenerative medicine. We are playing a major role in researching tissue engineering with OBI. In particular, members of the PFPC are instrumental in the development of biomaterials as well as the design and fabrication of medical devices and tissue engineering constructs, including controlled delivery vehicles, bioreactors, scaffolds and hydrogels. We also undertake investigations of in vitro and in vivo biocompatibility and biostability, cell and tissue interactions with biomaterials, surface modification and optimisation of our biomaterial constructs for particular applications in tissue engineering and regenerative medicine.

The Royal Women’s Hospital (RWH)
PFPC researchers Dr Daniel Heath and Associate Professor Andrea O’Connor have a strong collaboration in the area of stem cell expansion and tissue engineering with stem cell biologists Professor Shaun Brennecke and Dr Bill Kalionis at the Royal Women’s Hospital Pregnancy Research Centre. The PFPC is expert in developing biomaterials that direct stem cell fate during ex vivo culture. We are working with stem cell biologists in order to improve the large-scale expansion of primary MSC for use in basic biology research and for use in therapeutic applications.

Cardiovascular devices with St Vincent’s Hospital/Northern Hospital
PFPC Researcher Dr Daniel Heath is working with Associate Professor Peter Barlis at St Vincent’s Hospital/Northern Hospital. This collaboration builds on the PFPC’s expertise in biomedical device fabrication towards the development of next generation cardiovascular devices. In particular we are interested in developing biodegradable stent technologies to improve the outcomes of patients with coronary artery disease.

Partnerships with the Commonwealth Scientific and Industrial Research Organisation (CSIRO)
The PFPC has long had links with the CSIRO. Many of our alumni have held positions with the organisation and PFPC member Associate Professor Rachel Caruso is an Office of the Chief Executive Science Leader within CSIRO Manufacturing Flagship. From 2012 a number of our postgraduate students were jointly supervised by researchers from the PFPC and CSIRO. Outstanding joint students were awarded scholarships through the CSIRO-Melbourne Materials Institute Materials Science PhD Scholarship Program (pp xx-xx). In addition, Professor Peter Scales received renewal of funding to continue work on AMIRA project P266, Improving Thickener Technology. This project has been going since 1991 and the PFPC has been strongly associated since 2003. The project is led by Dr Phil Fawell from CSIRO Process Science and Engineering.

Defence Materials Technology Centre (DMTC)
Professor George Franks has strong ties to the Australian Defence Force through projects funded by the Defence Materials Technology Centre. He works with collaborators in BAE systems, DSTO, ANSTO, University of Queensland and Swinburne University on the development of ultra-high temperature materials for hypersonic rocket applications such as the leading edges and combustors of such vehicles. George is also a member of a team developing personal protective systems (armour) in collaboration with researchers in Australian Defence Apparel, CSIRO, DSTO and VCAMM. The project won the National Industry Innovation Award of Land Defence Australia, presented at the Land Forces conference in September, 2014 in Brisbane and the CRC Award for Excellence in Innovation 2015, presented at the CRC Association Conference in May 2015, for Light Weight Boron Carbide Personal Armour.

Defence Science and Technology Organisation (DSTO)
Dr Kathryn Mumford has been working with Dr Steve Pas and Dr Tristan Simons of Defence Science and Technology Organisation (now ‘Group’) to develop ionic liquids for air purification purposes. This has involved understanding the vapour-liquid equilibria and reaction kinetics of this solvent class. It has also involved investigating their use in hollow fibre membrane contactors, which are often considered superior to packed bed arrangements due to their higher interfacial areas.
National Linkages

Western Australia
Murdoch University
University of Western Australia
Water Corporation of WA

South Australia
BHP Billiton Olympic Dam Corporation Pty Ltd
Ian Wark Research Institute
SA Water
South Australian Institute of Ophthalmology
South Australian Research and Development Institute
University of Adelaide
University of South Australia
Uranium One Australia Pty Ltd

Tasmania
Australian Antarctic Division

Queensland
International Water Centre
Queensland University of Technology (QUT)
University of Queensland

New South Wales
Australian Nuclear Science and Technology Organisation (ANSTO)
Callington Haven P/L
Macquarie University
NuSep Holdings Ltd
University of NSW
University of Newcastle
University of Sydney

ACT
Australian National University

Victoria
AECOM Australia Pty Ltd
AMIRA (27 companies)
Anatomics
ATC Williams
Australian Defence Apparel Pty Ltd
Australian Synchrotron
BAE Systems Australia
Baker IDI Heart and Diabetes Institute
BHP Billiton Ltd
Bilfinger
Bionics Institute
CSIRO
CSL Bioplasma
Dairy Innovation Australia Ltd (DIAL)
Deakin University
Defence Science and Technology Organisation (DSTO)
Department of Environment, Land, Water & Planning (State Government)
GlaxoSmithKline
La Trobe University
Mars Petcare Australia
Melbourne Water
Metabolomics Australia
Monash University
O’Brien Institute
Process Solutions
Rio Tinto Ltd
RMIT University
Royal Children’s Hospital
Royal Melbourne Hospital
St Vincent’s Hospital
Sun Pharmaceutical Industries Australia Pty Ltd
Swinburne University of Technology
The Royal Women’s Hospital
Veolia Australia
Victoria University
Victorian Centre for Advanced Materials Manufacturing
Yates Technical Services Pty Ltd
Zeobond Pty Ltd
International Linkages

**UK**
- MRC Centre for Regenerative Medicine
- MSACT Consulting
- The University of Warwick
- University of Bath
- University of Bristol
- University of Leeds
- University of Nottingham
- University of Sheffield
- University of Surrey

**Ireland**
- University College Dublin

**Germany**
- Karlsruhe Institute of Technology
- Max-Plank Institute for Colloids and Interfaces
- Max-Plank Institute for Polymer Research
- Philipps-Universität Marburg
- Technical University of Munich
- University of Göttingen
- University of Heidelberg

**Italy**
- Fondazione ICRSS Istituto Nazionale dei Tumori
- Università degli Studi di Roma “La Sapienza”
- University of Milan

**Canada**
- L’Institut National de la Recherche Scientifique
- University of Alberta

**USA**
- Asylum Research
- Bucknell University
- Carnegie Mellon University
- Cornell University
- ERC for Particle Science & Technology, Florida
- Georgia Tech
- Massachusetts Institute of Technology (MIT)
- Oakridge National Laboratory
- SCG Energia
- University of California, Berkeley
- University of California, Santa Barbara
- University of Delaware
- University of Florida
- University of Illinois at Urbana-Champaign
- University of Notre Dame
- University of Washington
- Vanderbilt University
- Virginia Tech
- Worcester Polytechnic Institute

**Chile**
- Universidad de Concepción

**France**
- Inserm Strasbourg
- Institut Charles Sadron
- Université de Franche-Comté
- Université Joseph Fourier

**Portugal**
- Universidade Católica Portuguesa

**Switzerland**
- ETH Zürich
- University of Basel

**Spain**
- CIC biomaGUNE

**Sweden**
- Linköping University
- Lund University
- Stockholm University

**South Africa**
- University of Stellenbosch

**Saudi Arabia**
- King Abdullah University of Science and Technology (KAUST)

**Israel**
- Technion – Israel Institute of Technology

**China**
- Chinese Academy of Sciences
- Huaneng Clean Energy Research Institute (CERI)
- Nanjing University of Science and Technology
- National Institute of Clean-and-low-carbon Energy (NICE)
- Northeastern University
- Shanghai Jiao Tong University
- Tianjin University
- Tsinghua University
- Wuhan University of Technology

**Korea**
- Hanyang University
- Korea Carbon Capture and Sequestration R&D Center (KCRC)
- Korea University
- Korean Institute of Geoscience and Mineral Resources (KIGAM)
- Myongji University
- Seoul National University
- SungKyunKwan University

**Japan**
- Advanced Institute for Materials Research (WPI-AIMR)
- International Center for Materials Nanoarchitectonics (WPI-MANA)
- International Institute for Carbon-Neutral Energy Research (WPI-I2CNER)
- Kanazawa Institute of Technology
- Kitakyushu Foundation for Advancement of Industry, Science and Technology
- Kyoto University
- Kyushu University
- Meiji University
- Nagoya University
- National Institute of Advanced Industrial Science and Technology (AIST)
- National Institute for Materials Science (NIMS)
- Okayama University
- Osaka Prefecture University
- Shinshu University
- Tohoku University
- Tokyo Institute of Technology
- University of Miyazaki
- University of Tsukuba

**India**
- CSIR-Indian Institute of Petroleum
- Jadavpur University
- National Institute of Technology
- University Institute of Chemical Technology
- University of Madras

**Thailand**
- Chiang Mai University

**Singapore**
- Institute of High Performance Computing
- Nanyang Technological University
- National University of Singapore
- Singapore Polytechnic

**New Zealand**
- AgResearch
- The University of Auckland
Presentations
Keynote and Plenary Lectures


Caruso, R.A., Wu, W., Chen, D., Huang, F. and Cheng, Y.-B. (2015) Controlling the mesostructure of titania for application in solar cells. 9th International Mesostructured Materials Symposium (IMMS 9), Brisbane, QLD, Australia, 17-20 August. (Keynote lecture)


Van Deventer, J.S.J. and Provis, J.L. (2015) Low carbon emission geopolymer concrete: from research into practice. Concrete 2015: 27th Biennial National Conference of the Concrete Institute of Australia in conjunction with the 69th RILEM Week, Melbourne, VIC, Australia, 30 August-2 September. (Keynote lecture)

Conference and Meeting Presentations


Cui, J., Bjørnmalm, M. Gunawan, S.T., Richardson, J.J. and Caruso, F. (2015) Hard mesoporous silica templates in the nanomanufacturing of soft polymer therapeutic particles. 9th International Mesostructured Materials Symposium (IMMS 9), Brisbane, QLD, Australia, 17-20 August.


Euromembrane, Aachen, Germany, 6-10 September.


droplet formation during electrocoalescence of microdrops. 
December, 2015: International Chemical Congress of Pacific Basin Societies, Honolulu, HI, USA, 15-20 December.


Stevens, G. (2015) Solvent extraction in the pharmaceutical, mining and recycling industries. International Forum on Separation Sciences and Technology, Tianjin, China, 16-17 November. (Invited speaker)


Van ’t Hag, L., Darmanin, C., Le, T.C., Mudie, S., Conn, C.E. and Drummond, C.J. (2015) in meso crystallization: Compatibility of different liquid biocatalystic cubic mesophases with the cubic crystallization screen in aqueous solution. 7th Biennial Australian Colloid & Interface Symposium, Hobart, TAS, Australia, 1-5 February.

Van ’t Hag, L., Gras, S. L., Conn, C.E. and Drummond, C.J. (2015) Exploring the in meso crystallization mechanism by using synchrotron small angle x-ray scattering. 16th International Conference on Small Angle Scattering (SAS2015), Berlin, Germany, 13-16 September. (Poster presentation; Flash Talk)


Invited Lectures and Seminars
Ashokkumar, M. (2015) Delivered 10 Lectures to undergraduate and postgraduate students on ‘Ultrasonics and sonochemistry’, Exchange of Professors Scheme, Department of Chemistry, University of Rome, Rome, Italy, 4-28 May.


Sun, Q. (2015) Why should boundary element methods have to deal with singularities? Applied Mathematics Seminars at Swinburne University of Technology, Melbourne, VIC, Australia, 22 September.
Publications


surfaces of different hydrophobicity. ACS Nano, 9, 95-104.


Refereed Conference Papers


Research Funding

PFPC researchers actively seek funding for their research from nationally competitive research funding schemes including the Australian Research Council (ARC) and the National Health and Medical Research Council (NHMRC). They are successful in winning funding from the Victorian Government, from the host institutional grants schemes and attract both in-kind and cash support from industry. The ARC Special Research Centre grant did not provide direct funds to support these additional research grants, however the research projects listed in this section use the research facilities established by the Centre.

The following grants were awarded to PFPC members in 2015.
ARC Fellowships/Awards

<table>
<thead>
<tr>
<th>Researcher</th>
<th>Fellowship Type</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frank Caruso</td>
<td>Laureate Fellowship</td>
<td>2012-2017</td>
</tr>
<tr>
<td>Francesca Cavalieri</td>
<td>Future Fellowship</td>
<td>2015-2019</td>
</tr>
<tr>
<td>Franz Grieser</td>
<td>Australian Professorial Fellowship</td>
<td>2011-2015</td>
</tr>
<tr>
<td>Greg Qiao</td>
<td>Future Fellowship</td>
<td>2011-2015</td>
</tr>
<tr>
<td>Georgina Such</td>
<td>Future Fellowship</td>
<td>2012-2016</td>
</tr>
<tr>
<td>Qiang Sun</td>
<td>Discovery Early Career Researcher Award (DECRA)</td>
<td>2015-2017</td>
</tr>
<tr>
<td>Yan (Annie) Yan</td>
<td>Discovery Early Career Researcher Award (DECRA)</td>
<td>2013-2015</td>
</tr>
</tbody>
</table>

ARC Discovery - Projects

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Administering Institute</th>
<th>Partner Organisations</th>
<th>Application ID</th>
<th>Title</th>
<th>Sponsor Funding*</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.Caruso, G.G.Qiao</td>
<td>The University of Melbourne</td>
<td></td>
<td>DP130101846</td>
<td>Development of next-generation nanoengineered advanced materials for targeted applications</td>
<td>$201,468</td>
</tr>
<tr>
<td>D.Y.Chan</td>
<td>The University of Melbourne</td>
<td></td>
<td>DP140100558</td>
<td>Modelling of soft multi-scale systems</td>
<td>$112,208</td>
</tr>
<tr>
<td>D.Y.Chan, R.R.Dagastine, R.F.Tabor</td>
<td>The University of Melbourne</td>
<td>Monash University</td>
<td>DP140100677</td>
<td>Breaking emulsions</td>
<td>$115,354</td>
</tr>
<tr>
<td>R.R.Dagastine, O.Manor</td>
<td>The University of Melbourne</td>
<td></td>
<td>DP150101156</td>
<td>Surface forces and confinement of anisotropic particles</td>
<td>$162,866</td>
</tr>
<tr>
<td>G.V.Franks</td>
<td>The University of Melbourne</td>
<td></td>
<td>DP150102788</td>
<td>Wet particulate materials - Flow or fracture?</td>
<td>$101,791</td>
</tr>
<tr>
<td>F.Grieser, M.Ashokkumar, K.Yasui</td>
<td>The University of Melbourne</td>
<td></td>
<td>DP110101090</td>
<td>Free radical generation and reactions in ultrasound assisted processes</td>
<td>$114,938</td>
</tr>
<tr>
<td>S.E.Kentish</td>
<td>The University of Melbourne</td>
<td></td>
<td>DP150100977</td>
<td>The permeation of water through industrial membrane systems</td>
<td>$111,970</td>
</tr>
<tr>
<td>G.G.Qiao, W.Duan, K.Dawson</td>
<td>The University of Melbourne</td>
<td></td>
<td>DP140100002</td>
<td>Peptide-based star polymers for improved biointeraction and targeted anticancer therapies</td>
<td>$225,464</td>
</tr>
<tr>
<td>P.A.Webley, Z.Liu</td>
<td>The University of Melbourne</td>
<td>Monash University</td>
<td>DP130103708</td>
<td>Advanced adsorbents for gas separations</td>
<td>$119,792</td>
</tr>
</tbody>
</table>

* Reported figures are actual income received by PFPC researchers in the 2015 calendar year
### ARC Centre of Excellence

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Administering Institute</th>
<th>Partner Organisations</th>
<th>Application ID</th>
<th>Title</th>
<th>ARC Funding*</th>
<th>UniMelb Contribution*</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.Davis, <strong>F.Caruso</strong>, C.Porter, J.Gooding, N.Voelcker, T.Nann, A.Whittaker, N.Bunnett, M.Kendall, E.Crampin, S.Kent, R.Parton, B.Boyd, M.Kearnes, K.Thurecht, A.Johnson, M.Kavallaris, S.Corrie, P.Thordarson</td>
<td>The University of Melbourne</td>
<td>CSIRO, Australia; Sungkyunkwan University, South Korea; University of Wisconsin, USA; University of Warwick, UK; University of Nottingham, UK; Australian Nuclear Science and Technology Organisation, Australia; Imperial College London, UK; Memorial Sloan-Kettering Cancer Center, USA; University College Dublin, Ireland; University of California, Santa Barbara, USA</td>
<td>CE140100036</td>
<td>ARC Center of Excellence in Convergent Bio-Nano Science and Technology</td>
<td>$568,917</td>
<td>$177,667</td>
</tr>
</tbody>
</table>

### ARC Linkage - Industrial Transformation Research Hubs

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Administering Institute</th>
<th>Partner Organisations</th>
<th>Title</th>
<th>ARC Funding*</th>
<th>Industry Contribution*</th>
<th>UniMelb Contribution*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S.L.Gras, S.E.Kentish, M.Ashokkumar, G.J.Martin, D.E.Dunstan, B.R.Bhandari, M.S.Turner, N.Bansal, S.Prakash, M.V.Palmer, I.B.Powell, M.Weeks, B.Meurer, C.J.Pillidge, M.C.Broome, B.Zisu</strong></td>
<td>The University of Melbourne</td>
<td>The University of Queensland, Dairy Innovation Australia</td>
<td>Dairy Innovation Hub: transformational research to underpin the future of the Australian dairy manufacturing industry</td>
<td>$1,000,000**</td>
<td>$300,000**</td>
<td>$124,999*</td>
</tr>
</tbody>
</table>

* Reported figures are actual income received by PFPC researchers in the 2015 calendar year
** Reported figures are the contract amount of the grant
### ARC Linkage - Infrastructure, Equipment and Facilities

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Administering Institute</th>
<th>Partner Organisations</th>
<th>Application ID</th>
<th>Sponsor Funding**</th>
<th>UniMelb Contribution*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F.Caruso</strong>, J.Rosjohne, J.McCluskey, J.Villadangos, E.Reynolds, <strong>Y.Yan</strong>, G.McArthur, P.Neeson</td>
<td>The University of Melbourne</td>
<td>Monash University, Peter MacCallum Cancer Institute</td>
<td>LE150100100</td>
<td>$440,000</td>
<td>$520,000</td>
</tr>
<tr>
<td><strong>G.G.Qiao</strong>, N.H.Voelck, A.K.Whittaker, G.P.Simon, <strong>S.E.Kents</strong>, R.D.Short, A.Blencowe, H.J.Gries, <strong>E.H.Wong</strong></td>
<td>The University of Melbourne</td>
<td>University of South Australia, The University of Queensland, Monash University</td>
<td>LE140100087</td>
<td>$0</td>
<td>$28,700</td>
</tr>
</tbody>
</table>

* Reported figures are actual income received by PFPC researchers in the 2015 calendar year
** Reported figures are the contract amount of the grant

### ARC Linkage - Projects

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Partner Organisations</th>
<th>Industry Sponsor</th>
<th>Application ID</th>
<th>Title</th>
<th>ARC Funding*</th>
<th>Industry Contribution*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>S.D.Kolev</strong>, J.D.Gregory, S.Ebbs, M.Miro, K.J.Zuccala</td>
<td>Melbourne Water Corporation, Southern Illinois University, Carbondale, University of the Balearic Islands, Victorian Environmental Protection Authority</td>
<td>Seagull Technology Pty Ltd</td>
<td>LP120200628</td>
<td>The pollution potential of mercury in legacy biosolids and possibilities for its minimisation by phytoremediation and phytostabilisation approaches</td>
<td>$110,265</td>
<td>$40,000</td>
</tr>
<tr>
<td><strong>G.G.Qiao</strong>, R.J.Prander, A.Blencowe, <strong>P.A.Gurr</strong>, R.J.Tait, A.C.Donohue</td>
<td>Monash University</td>
<td>PolyActiva Pty Ltd</td>
<td>LP120200010</td>
<td>Novel click assembled drug-polymer conjugates as next generation drug delivery systems</td>
<td>$0</td>
<td>$5,084</td>
</tr>
<tr>
<td><strong>P.J.Scales</strong>, A.D.Stickland, S.P.Usher, C.A.Rees, M.Devadas</td>
<td>Melbourne Water Corporation</td>
<td></td>
<td>LP130100395</td>
<td>Reducing land and infrastructure requirements for water evaporation from biosludge through dry stacking</td>
<td>$98,012</td>
<td>$120,000</td>
</tr>
<tr>
<td><strong>G.W.Stevens</strong>, K.Mumford, K.A.Dudley</td>
<td>BHP Billiton Olympic Dam</td>
<td>GlaxoSmithKline Australia Pty Ltd</td>
<td>LP130100305</td>
<td>Improving performance of solvent extraction equipment for the minerals processing industry</td>
<td>$108,902</td>
<td>$100,000</td>
</tr>
<tr>
<td><strong>G.W.Stevens</strong>, E.Neff, T.A.Bowser</td>
<td></td>
<td></td>
<td>LP140100650</td>
<td>Environmentally sustainable solvents for natural pharmaceutical extraction processes</td>
<td>$133,048</td>
<td>$60,000</td>
</tr>
</tbody>
</table>

* Reported figures are actual income received by PFPC researchers in the 2015 calendar year
** Reported figures are the contract amount of the grant
## Industry and Contracts

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Sponsor</th>
<th>Partner Organisations</th>
<th>Title</th>
<th>UniMelb Contribution*</th>
<th>UniMelb Contribution*</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.R.Dagastine</td>
<td>Unilever UK Ltd</td>
<td>N/A</td>
<td>Gas hydrates</td>
<td>$12,500</td>
<td>$12,500</td>
</tr>
<tr>
<td>D.E.Dunstan</td>
<td>CSIRO Manufacturing Flagship</td>
<td>Hallmark Materials Research Initiative (HMRI); Morgan Traditional Ceramics Australia Pty Ltd</td>
<td>Industry Seed Funding Scheme - Evaluating alternative manufacture techniques for ceramics</td>
<td>$15,000</td>
<td>$15,000</td>
</tr>
<tr>
<td>G.V.Franks</td>
<td>HMRI, CSL Limited</td>
<td>CSIRO Manufacturing Flagship</td>
<td>Industry Seed Funding Scheme - Blood coagulation rate constants in flow: A CFD optimisation study</td>
<td>$15,000</td>
<td>$15,000</td>
</tr>
<tr>
<td>D.J.E.Harvie</td>
<td>CSL Limited</td>
<td>Australian Mathematical Sciences Institute (AMSI)</td>
<td>Techniques for modelling droplet-droplet coalescence</td>
<td>$17,000</td>
<td>$17,000</td>
</tr>
<tr>
<td>D.J.E.Harvie, I.Muir, S.Dower, C.Biscombe</td>
<td>CSL Limited</td>
<td>Australian Mathematical Sciences Institute (AMSI)</td>
<td>AMSI Intern Program - Understanding flow and spatial effects on blood coagulation using computational fluid dynamics</td>
<td>$17,000</td>
<td>$15,000</td>
</tr>
<tr>
<td>S.E.Kentish</td>
<td>NuSep Holdings Ltd</td>
<td>Membranes for biological separation</td>
<td>$25,000</td>
<td>$25,000</td>
<td></td>
</tr>
<tr>
<td>S.D.Kolev</td>
<td>Environment Protection Authority (EPA) Victoria</td>
<td>The development and validation of passive samplers containing polymer inclusion membranes (PIMs) as their semi-permeable barriers and paper-based devices for simple and cost effective monitoring of metals</td>
<td>$15,000</td>
<td>$15,000</td>
<td></td>
</tr>
<tr>
<td>A.J.O'Connor, G.J.O.Martin</td>
<td>Development Technology Voucher - Department of Economic Development, Jobs, Transport and Resources (DEDJTR); Yarra Valley Caviar Pty Ltd</td>
<td>Process development</td>
<td>$56,819</td>
<td>$56,819</td>
<td></td>
</tr>
<tr>
<td>P.J.Scales, P.Fawell</td>
<td>AMIRA P266G Project</td>
<td>CSIRO</td>
<td>Thickener optimisation for the minerals industry</td>
<td>$20,000</td>
<td>$20,000</td>
</tr>
<tr>
<td>G.W.Stevens</td>
<td>BHP Billiton Olympic Dam Corporation Pty Ltd</td>
<td>Rio Tinto Services Ltd via CO2CRC Ltd</td>
<td>Optimising Bateman Pulsed Column technology at Olympic Dam</td>
<td>$6,000</td>
<td>$6,000</td>
</tr>
<tr>
<td>G.W.Stevens, K.Day</td>
<td>Rio Tinto Services Ltd via CO2CRC Ltd</td>
<td>Peter Cook Centre for CCS Research - Phase 2</td>
<td>Options for the remediation of heavy metal contaminants at two antarctic stations: Wilkes and Davis</td>
<td>$670,000</td>
<td>$670,000</td>
</tr>
<tr>
<td>G.W.Stevens, I.Snape, K.Mumford</td>
<td>Australian Antarctic Division</td>
<td>Options for the remediation of heavy metal contaminants at two antarctic stations: Wilkes and Davis</td>
<td>$21,500</td>
<td>$21,500</td>
<td></td>
</tr>
</tbody>
</table>

* Reported figures are actual income received by PFPC researchers in the 2015 calendar year
### Host Institution (The University of Melbourne)

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Partner Organisations</th>
<th>Grant Type</th>
<th>Title</th>
<th>UniMelb Funding*</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.Bolton, R.R.Dagastine</td>
<td>Le Centre national de la recherche scientifique (The National Centre for Scientific Research): École Normale Supérieure</td>
<td>Research Product Realisation Working Group Mini-Grant</td>
<td>Printed optics</td>
<td>$5,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CNRS Researcher Visits scheme</td>
<td>Novel directions in energy generation and mechano-biology</td>
<td>$5,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hallmark Research Initiative</td>
<td>Materials Research, Hallmark Initiative</td>
<td>$150,000</td>
</tr>
<tr>
<td>R.R.Dagastine, C.Tallon</td>
<td>Research Engagement Grant</td>
<td>Early Career Researcher Grant</td>
<td>Micro- and nano-scale design of bio-active polymeric scaffolds for cardiovascular applications</td>
<td>$39,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dyason Fellowship</td>
<td>Developing novel carbon capture technology for climate change mitigation</td>
<td>$1,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Melbourne Research Fellowships (Career Interruptions)</td>
<td>N/A</td>
<td>$75,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Joyce Lambert Antarctic Research Seed Funding Scheme</td>
<td>Development of environmental remediation technologies for Australian Antarctic stations</td>
<td>$10,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Early Career Researcher Grant</td>
<td>Vibration of drops on soft surfaces: Fundamental science in everyday life</td>
<td>$10,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dyason Fellowship</td>
<td>Macrocycle based ‘catalytic triads’ for the degradation of nerve agents</td>
<td>$19,968</td>
</tr>
<tr>
<td></td>
<td></td>
<td>University College Dublin, Ireland</td>
<td>Systems analysis of endocytic perturbation by nanoparticles</td>
<td>$1,000</td>
</tr>
</tbody>
</table>

### Other Competitive Grants

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Administering Institute</th>
<th>Partner Organisations</th>
<th>Funding Body</th>
<th>Grant Type</th>
<th>Title</th>
<th>Sponsor Funding*</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.Connal</td>
<td>The University of Melbourne</td>
<td></td>
<td>US Army Research Office</td>
<td>Research Grant</td>
<td>Enzyme mimics: New advanced materials</td>
<td>$157,077</td>
</tr>
<tr>
<td>L.Connal</td>
<td>The University of Melbourne</td>
<td></td>
<td>Victorian Endowment for Science, Knowledge and Innovation (VESKI)</td>
<td>Victorian Innovation Fellowship</td>
<td>Design and synthesis of enzyme mimics: Materials of the future</td>
<td>$50,000</td>
</tr>
<tr>
<td>L.Connal, M.Nothingling</td>
<td>The University of Melbourne</td>
<td></td>
<td>Science and Industry Endowment Fund (SIEF)</td>
<td>John Stocker Postgraduate Scholarship</td>
<td>Enzyme mimicry: New active detergents</td>
<td>$17,000</td>
</tr>
</tbody>
</table>

* Reported figures are actual income received by PFPC researchers in the 2015 calendar year
### Other Competitive Grants

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Administering Institute</th>
<th>Partner Organisations</th>
<th>Funding Body</th>
<th>Grant Type</th>
<th>Title</th>
<th>Sponsor Funding*</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.V.Franks</td>
<td>The University of Melbourne</td>
<td></td>
<td>CSIRO</td>
<td></td>
<td>Novel temperature responsive polymer as a flocculant and collector</td>
<td>$6,490</td>
</tr>
<tr>
<td>G.V.Franks, C.Tallon</td>
<td>The University of Melbourne</td>
<td></td>
<td>Defence Materials Technology Centre</td>
<td></td>
<td>Project 7.1.1 Ceramic protective systems</td>
<td>$112,277</td>
</tr>
<tr>
<td>S.Gray, M.Duke, J.Zhang, P.J.Scales, V.Pettigrove, M.Allinson</td>
<td>Victoria University</td>
<td>The University of Melbourne</td>
<td>Australian Water Recycle Centre of Excellence; Australian Antarctic Division</td>
<td></td>
<td>Demonstration of robust water recycling</td>
<td>$24,442</td>
</tr>
<tr>
<td></td>
<td>CO2CRC</td>
<td>Education Investment Fund (EIF)</td>
<td></td>
<td></td>
<td></td>
<td>$887,365</td>
</tr>
<tr>
<td></td>
<td>D.Heath</td>
<td>Equity Trustees</td>
<td>James &amp; Vera Lawson Trust</td>
<td></td>
<td>Multi-scale design of bio-functionalized cardiovascular biomaterials for enhanced endothelialization</td>
<td>$28,000</td>
</tr>
<tr>
<td></td>
<td>S.E.Kentish, H.Liu</td>
<td>Brown Coal Innovation Australia (BCIA)</td>
<td>PhD Top-Up Scholarship</td>
<td></td>
<td>The impact of impurities on the performance of cellulose acetate membranes for CO₂ separation</td>
<td>$10,000</td>
</tr>
<tr>
<td></td>
<td>S.E.Kentish, B.Abrahams, R.Robson (UniMelb CIs)</td>
<td>University of Sydney, Monash University, The University of Melbourne, University of Adelaide, University of NSW, ANSTO, CO2CRC</td>
<td>Science and Industry Endowment Fund (SIEF)</td>
<td>SIEF Research Grant Scheme</td>
<td>Solving the Energy Waste Roadblock: Addressing one of the foremost challenges for reducing greenhouse gas emissions on a national and international scale, namely, the development of new materials and processes for the capture and utilisation of carbon dioxide</td>
<td>$64,809</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CO2CRC</td>
<td>Australian Government Cooperative Research Centres Programme, other Federal and State Government programs, CO2CRC participants, and wider industry</td>
<td>Cooperative Research Centre</td>
<td></td>
<td>$866,742</td>
</tr>
</tbody>
</table>

* Reported figures are actual income received by PFPC researchers in the 2015 calendar year
## Other Competitive Grants

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Administering Institute</th>
<th>Partner Organisations</th>
<th>Funding Body</th>
<th>Grant Type</th>
<th>Title</th>
<th>Sponsor Funding*</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.Kolev</td>
<td>The University of Melbourne</td>
<td></td>
<td>Australian Institute of Nuclear Science and Engineering (AINSE)</td>
<td>Research Award</td>
<td>Cellular localisation of mercury (Hg) and gold (Au) in selected plant species grown in substrates composed of mine tailings and heavy metal contaminated biosolids using micro-PIXE</td>
<td>$10,500</td>
</tr>
<tr>
<td>R.Lamb</td>
<td>The University of Melbourne</td>
<td>Ruhr-Universität Bochum</td>
<td>Group of Eight Australia-German Academic Exchange Service (DAAD)</td>
<td>Joint Research Co-operation Scheme</td>
<td>Novel ultra-rough antifouling surfaces through air engineering</td>
<td>$20,000</td>
</tr>
<tr>
<td>A.O’Connor, A.Deva, P.Tran, W.Morrison</td>
<td>The University of Melbourne</td>
<td>O’Brien Institute</td>
<td>Defence Health Foundation</td>
<td>Establishment Grant</td>
<td>Material technology to prevent infection to injured soldiers</td>
<td>$4,967</td>
</tr>
<tr>
<td>G.G.Qiao, D.H.Solomon, G.Senior</td>
<td>The University of Melbourne</td>
<td>Participants from Australian and global industry, universities and other research bodies from Australia and New Zealand, and Australian Commonwealth, State and international government agencies</td>
<td>CRC for Polymers</td>
<td>Project 2.2</td>
<td>System for controlling the air-water interface and reducing evaporation from water storages</td>
<td>$350,426</td>
</tr>
<tr>
<td>J.M.Ren</td>
<td>The University of Melbourne</td>
<td>VESKI; University of California, Santa Barbara (UCSB)</td>
<td>Department of Economic Development, Jobs, Transport and Resources (DEDJTR)</td>
<td>Victorian Postdoctoral Fellowship</td>
<td>Next-generation nature-inspired polymer nanomaterials for sustainable energy storage</td>
<td>$100,000</td>
</tr>
<tr>
<td>C.A.Scholes</td>
<td>The University of Melbourne</td>
<td>New York Academy of Science, USA</td>
<td>Department of Education and Training</td>
<td>Endeavour Executive Fellowship</td>
<td>N/A</td>
<td>$6,000</td>
</tr>
<tr>
<td>J.Shang</td>
<td>The University of Melbourne</td>
<td></td>
<td>Ian Potter Foundation</td>
<td>Travel Grant</td>
<td>N/A</td>
<td>$3,000</td>
</tr>
<tr>
<td>G.W.Stevens, D.Gore, K.Mumford (incl $536,020 in kind in 2014)</td>
<td>The University of Melbourne</td>
<td>Macquarie University</td>
<td>Australian Antarctic Division</td>
<td>Australian Antarctic Science (AAS) Grant</td>
<td>Development of contaminant metal removal systems suitable for implementation in cold regions</td>
<td>$22,000</td>
</tr>
</tbody>
</table>

* Reported figures are actual income received by PFPC researchers in the 2015 calendar year
## Other Competitive Grants

<table>
<thead>
<tr>
<th>Chief Investigators (PFPC members in bold)</th>
<th>Administering Institute</th>
<th>Partner Organisations</th>
<th>Funding Body</th>
<th>Grant Type</th>
<th>Title</th>
<th>Sponsor Funding*</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. Such, X. Hao</td>
<td>The University of Melbourne</td>
<td>CSIRO Molecular Science</td>
<td>Joint Research Co-operation Scheme</td>
<td>Engineered theranostic nanoparticles</td>
<td>$25,000</td>
<td></td>
</tr>
<tr>
<td>A.D. Stickland, U.A. Peuker, P.J. Scales</td>
<td>The University of Melbourne</td>
<td>TU Bergakademie Freiberg</td>
<td>Group of Eight Australia-DAAD</td>
<td>Filtration and separation properties of complex suspensions</td>
<td>$21,000</td>
<td></td>
</tr>
<tr>
<td>A.D. Stickland</td>
<td>The University of Melbourne</td>
<td>Department of Environment and Primary Industries</td>
<td>Smart Water Fund</td>
<td>Improving sludge drying pan efficiency using lessons from the minerals processing industry</td>
<td>$47,064</td>
<td></td>
</tr>
<tr>
<td>A.D. Stickland, S. Chellappan</td>
<td>The University of Melbourne</td>
<td>Water Research Australia</td>
<td>Postgraduate Scholarship</td>
<td>The implementation of dry stacking operating methods in wastewater treatment evaporation pans</td>
<td>$10,000</td>
<td></td>
</tr>
<tr>
<td>A. Tordesillas</td>
<td>The University of Melbourne</td>
<td>Asian Office of Aerospace Research &amp; Development (AOARD)</td>
<td>US Air Force Defense Research Sciences Program</td>
<td>Directing transmission patterns in granular materials from the grain scale</td>
<td>$56,437</td>
<td></td>
</tr>
<tr>
<td>A. Tordesillas</td>
<td>The University of Melbourne</td>
<td>US Army Research Office</td>
<td>Travel Grant</td>
<td>Support to visit ERDC GSL and ITL in Vicksburg, MS, USA to discuss characterisation and modeling of granular systems from data</td>
<td>$4,623</td>
<td></td>
</tr>
<tr>
<td>P.A. Webley</td>
<td>The University of Melbourne</td>
<td>CO2CRC</td>
<td>Australian National Low Emissions Coal Research &amp; Development (ANLEC R&amp;D)</td>
<td>Large scale cost reduction through adsorption</td>
<td>$8,370</td>
<td></td>
</tr>
<tr>
<td>P.A. Webley, A. Chaffee</td>
<td>The University of Melbourne</td>
<td>Monash University</td>
<td>Brown Coal Innovation Australia (BCIA)</td>
<td>Evaluation of carbon monoliths for capture of CO₂ by electrical swing adsorption</td>
<td>$25,000</td>
<td></td>
</tr>
<tr>
<td>A.K. Wise, F. Caruso, R. Shepherd, L. Gillespie, J. Cui</td>
<td>The University of Melbourne</td>
<td>National Health and Medical Research Council (NHMRC)</td>
<td>Project Grant</td>
<td>Nanoengineered drug delivery to the inner ear to prevent progressive hearing loss</td>
<td>$90,422</td>
<td></td>
</tr>
<tr>
<td>H. Zhang, M. Daniell, G. Qiao, H. Unger, E. Chan, K. Ladewig, J. Crowston</td>
<td>Centre for Eye Research Australia Ltd</td>
<td>The University of Melbourne</td>
<td>NHMRC</td>
<td>Development Grant</td>
<td>Non-invasive therapy for keratoconus - Ultrasound enhanced delivery of riboflavin to cornea for transepithelial corneal collagen crosslinking</td>
<td>$122,759</td>
</tr>
</tbody>
</table>

* Reported figures are actual income received by PFPC researchers in the 2015 calendar year
Financial Summary

Sources of Income
The total income to the PFPC in 2015 was over $12.5 million. This included financial and infrastructure support from The University of Melbourne, including direct funds from the Melbourne School of Engineering, which allowed us to continue as a Centre, support some core activities and leverage on our combined strengths.

Leveraging on the Particulate Fluids Processing Centre
The Centre enables us to bring together a group of exceptional researchers who work together to leverage research funding from many sources. As shown in the graph below our momentum has gathered over the life of the Centre and despite the cessation of ARC Special Research Centre funding at the end of 2008, we now receive approximately $9 million of competitive funding.
The Centre has built extensive state-of-the-art research facilities over 18 years of continuous funding from the Australian Research Council’s Special Research Centre scheme. Together with other research funding the Special Research Centre grant enabled the purchase of a range of instrumentation for chemical analysis, rheological characterisation, particle size analysis as well as surface and microscopic analysis.

**Microscopy, Particle and Surface Analysis**
- AcoustoSizer (Colloid Dynamics)
- Atomic Force Microscopes (Asylum MPF-3D AFM; Asylum Research Cypher AFM; Digital Instruments Dimension 3100; Digital Instruments Multimode; Nanowisard BioAFM)
- Confocal Microscope (Olympus FV500)
- Confocal Time Correlated Single Photon Counting Fluorescence Microscope (Leica)
- Dynamic Interfacial Tension Measuring Device (FTA)
- Dynamic Light Scattering / Photon Correlation Spectrometer (Malvern Autosizer 4700)
- Electro-Kinetic Analyzer (Brookhaven Instruments)
- Ellipsometer
- Flow Cytometer (Imaging, Amnis; Partec CyFlow; Apogee Micro Flow)
- Fluorescence Microscope Digital Widefield (Olympus IX71)
- Gravimetric Sorption Analyser (High Pressure; VTI)
- Inverted Microscope (Motic AE20)
- Inverted Microscope with CCD Digital Camera and Image Processing Software (Malvern Mastersizer 3000)
- Microtester (Instron 5848)
- Particle Sizer (High Performance DLS, Malvern; Micromeritics Elzone 5380)
- Surface Area and Porosity Analyser (Tristar and ASAP 2010, Micrometics)
- Surface Force Apparatus
- Tensiometer (DataPhysics OCA20)
- Xray Diffraectometry (XRD)
- Zetasizer (Malvern 2000)

**Spectroscopic Analysis**
- Atomic Absorption Spectrometer (AAS)
- Fluorescence Spectrophotometer (Fluorolog; Horiba)
- Fourier Transform-IR Spectrometer (Varian 7000)
- Inductively Coupled Plasma Optical Emission Spectrometer (Varian 720-ES)
- OWLS 210 (Optical Waveguide Lightmode Spectroscope)
- Spectrophotometer (Nanodrop 1000)
- Stopped-Flow Spectrometer (Applied Photophysics)
- Surface Plasmon Resonance Spectrometer
- UV-Visible Spectrophotometers (various)

**Thermal Analysis**
- Differential Scanning Calorimeter (Perkin Elmer)
- Thermogravimetric Analyser (Mettler Toledo)
- Thermogravimetry/Differential Thermal Analysis (Perkin Elmer)
- Thermomechanical Analysis (Perkin Elmer)

**Rheometry**
- Intrinsic Viscometer (Schott ViscoDoser AVS 20)
- Rheometer (Capillary; Custom Made)
- Rheometer (Controlled Stress; AR-G2)
- Rheometer (Controlled Stress; SRS)
- Rheometeter (Controlled Strain; HAAKE)

**General**
- 3D Printer (Objet Eden 260 V)
- Centrifuges (various)
- Chamber Furnaces (Shimadzu FP21 and FP 93 controller)
- Compressive Strength Testing Instrument (ELE Universal Tester)
- Freeze Dryers (Dynavac FDS and Heto Drywinner)
- Gel Documentation System (BioRad)
- High Performance Liquid Chromatograph (Shimadzu LC-10AT; Agilent 1200)
- Incubators (various)
- Ion Chromatograph (Dionex; Thermo Fisher Scientific)
- Quartz Crystal Microbalance (Frequency and Q-sense)
- Real Time PCR Cycler (BioRad Mini Option)
- Robotic Dipper (Stratosequence VI)
Contact Details

Professor Peter Scales, Director
Particulate Fluids Processing Centre
Department of Chemical and Biomolecular Engineering
The University of Melbourne
Victoria 3010 Australia

Tel:  61 3 8344 6480
Fax: 61 3 8344 8824
Email:  peterjs@unimelb.edu.au

www.pfpc.unimelb.edu.au