The University of Sydney
School of Chemical and Biomolecular Engineering

Undergraduate thesis topics available in 2007

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The Laboratory for Sustainable Technology undertakes multidisciplinary research to develop sustainable products and processes that maximise resource and energy efficiency and minimise environmental impact. We are offering thesis projects in greenhouse gas mitigation, nanotechnology, renewable energy, the hydrogen economy and advanced reactor design in 2007.

1. Greenhouse gas mitigation from coal mine ventilation air using porous burner reactors

Coal mine ventilation air (MVA) emissions are characterised by very low methane concentrations (typically less than 1%), high flow rates (up to 1900 m^3/s) and significant short and long term fluctuations in both concentration and flow. These attributes constitute the major technical barriers to the capture and use of the methane in MVA. A cost effective method of MVA mitigation, which does not require either a supplementary fuel source or a large-scale infrastructure for power generation, has yet to be proven.

Porous burners have the ability to burn lean fuel/air mixtures, and it has additionally been shown that the combustion process is stable against changes in fuel concentration and flow rate. The objective of this project is to demonstrate the suitability of porous burner technology for MVA mitigation. This will be achieved through:

i) A laboratory experimental study to examine the mechanisms of ultra-lean combustion.
ii) A computational fluid dynamics (CFD) and kinetic modelling study to investigate scale-up parameters.

2. Development of nanoporous, high temperature, silicon carbide, gas separation membranes

High temperature separation of gases with small kinetic diameters such as hydrogen, carbon dioxide, carbon monoxide and methane is applicable to industrial processes involving the reforming of hydrocarbons and biomass gasification. Polymeric membranes are unstable at high temperatures, while silica membranes suffer densification under hydrothermal conditions, resulting in a loss of selectivity and permeance (i.e. they stop working). Silicon carbide's ability to withstand high temperatures, mechanical stress and corrosive environments makes it a promising material for high temperature gas separation membranes.

Pyrolysis of pre-ceramic polymeric precursors is one method commonly used for the preparation of porous silicon carbide. The precursor chemistry and the pyrolysis conditions influence both the final composition (i.e. Si/C ratio) and the pore sizes of

the resulting membrane. To obtain membranes capable of separating small gas molecules and withstanding hydrothermal conditions, knowledge of the effects of various pyrolysis conditions and precursors on the final composition and structure of the membrane is required. Whilst pyrolysis mechanisms have been extensively studied, the pore size and structure has received far less attention and few comparisons have been made between precursors.

This project involves the preparation, characterisation and comparison of porous, silicon carbide films utilising various polymeric precursors. The effect of pyrolysis temperature, pyrolysis environment and curing technique are parameters requiring investigation. Characterisation techniques will include pore size analysis by gas adsorption, thermogravimetric analysis, x-ray diffraction, Fourier transform infrared spectroscopy and scanning electron microscopy.

3. Parametric investigation of carbon nanotubes synthesis (with Prof Thomas Maschmeyer, School of Chemistry)

Carbon nanotubes (CNTs) are a form of crystalline carbon with extraordinary mechanical, chemical, optical and electrical properties. These unique properties make CNTs potentially valuable in an array of end use applications including electronic, medical, structural, space, sporting, energy and environmental. Currently, research into nanotubes and their applications is hampered by the lack of a suitable technique for manufacturing them in large quantities. In 2004 worldwide production of nanotubes was estimated at 36500 metric tons, compared with a predicted market in 2010 of 9.6 million metric tons. Furthermore the low production through-put influences the price of nanotubes, which can be as high as US$2000 per gram. The current production capacity and cost illustrate the huge market pull which exists for the development of improved manufacturing processes.

One of the principle issues is that of catalyst design, as the catalyst influences the rate of production as well as the product distribution significantly (straight, spiral, single/multi-walled). Although some fundamental work has been carried out probing mechanistic and structural aspects of the active site, much remains to be done, not only to improve catalyst performance, but match it to the possibilities enshrined in the new manufacturing technology based on fluidised beds developed at the University of Sydney.

This project brings together catalyst design/testing and process development in a powerful combination of chemical engineering (Harris) and chemistry (Maschmeyer). The catalyst design will not only focus on the active site itself, but also on its surroundings by exploring self-assembled hierarchical porous structures as supports. Robotic synthesis methods will be used to probe a large synthetic space for the active site (Maschmeyer). The resulting catalysts will be screened for activity, selectivity and stability using novel small-scale fluidised bed reactors (Harris).

4. Phytosynthesis of metallic nanoparticles

At the cutting edge between materials science and biotechnology lies the emerging field of nanobiotechnology, where the relationship between living systems and advanced materials is being explored.

This project seeks to investigate one of the more interesting results to emerge from research into nanobiotechnology in recent years. Researchers have discovered that the plant species *Medicago sativa* is able to extract gold and other metals from solutions containing very small quantities of the metal. The metal forms discrete, nano-sized spherical particles within the cellular structure of the plant. The advantage of this is that gold nanoparticles are extremely difficult and expensive to make using physico-chemical methods.

The aim of the project is to investigate this new method of nanoparticle synthesis. The student will make use of advanced electron microscopy facilities to detect and analyse the nanoparticles produced.

5. The feasibility of phytomining in Australia

Phytoextraction can be defined simply as the recovery of metals using plants. There are two basic applications: phytomining, where valuable naturally occurring elements are harvested and phytoremediation, where non-naturally occurring contaminants are recovered for secure disposal or reuse. Both are relatively new technologies and require fundamental research before becoming widely adopted by either the mining industry or environmental practitioners.

The most likely commercial targets for phytomining technologies are the precious metals (Au, Pt and Ag) although it is also possible to phytoextract iron, zinc, copper, cadmium, nickel, lead and cobalt. The investigator in this project will conduct a series of experiments investigating the accumulation of metal species by different hyper-accumulator plants under various experimental conditions. The influence of pH and metal concentration will be investigated. They will support this work with a paper study designed to assess the feasibility of phytomining in rural Australia. The results of the study will be widely applicable to the global mining industry and so the student should find no shortage of well paid job offers at the end of their degree.

6. Hydrogen production from biomass and waste fuels

Australia is the highest per capita greenhouse gas emitter in the developed world, and relies heavily on coal production for both domestic energy and export income. The long term viability of Australia's coal industry will be enhanced by developing advanced techniques to capture and store CO_2 emissions. The aim of this project is to develop tailored nanoparticle adsorbents for CO_2 and other greenhouse gases using advanced chemical techniques. When these sorbents are used in conjunction with biomass and waste fuels it is possible to increase the hydrogen production rate from around 40% to 80% by volume. Alumina and $CaTiO_3$ would be investigated as likely solids to form the inert matrix. A wet impregnation technique would be employed (i.e., mix $CaCO_3$ with inert solid in ethanol or water and agitate). The mixture is then dried and calcined.

-The ratio of sorbent-to-inert solid and the calcination conditions, i.e., temperature and time, would be investigated in this project.

-Sorbent characterisation would be conducted based on N_2 adsorption and SEM imagery.

-Sorbent performance would be determined in terms of g-CO_2 captured/ g-sorbent. These tests would be conducted using the TGA, through multiple reaction cycles.

7. Functionalisation of carbon nanotubes using supercritical fluids (jointly with A/Prof Fariba Dehghani)

Carbon nanotubes are exceptionally inert materials and so are often purified and functionalised using harsh oxidative treatments, e.g. boiling in acid for several hours. In this project we will explore the purification of CNT/substrate mixtures and the functionalisation of carbon nanotubes with precious metals using supercritical CO_2. This method avoids the harsh oxidative pre-treatments typically used to functionalise CNTs. The project will involve experiments to determine the optimum functionalisation conditions.

A/Prof Geoff Barton *(Rm 404; ext 9351 3780; email barton@chem.eng.usyd.edu.au)*

8. Pollutant Characterisation in a Wastewater Treatment Train (jointly with Dr Dan Ryan)

Abstract: Molasses is a common feedstock in many biotechnology based processes. However its use is associated with high concentrations of coloured compounds in the process wastewater remaining after product recovery. The most important of these is a dark brown material called melanoidin which is typically present as a highly dispersed colloid that is notoriously difficult to separate out. The School is currently conducting research with an industrial client on cost-effective ways to remove melanoidin from their process wastewater. This project will thus have three objectives:

(i) To collate and analyse process data collected on our client's plant with a view to assessing variability in both the feed to the wastewater treatment train and the operating efficiency of the train itself (which includes both anaerobic and aerobic treatment stages).

(ii) Biological treatment removes pollutant material from the wastewater, however it also returns material as 'soluble microbial products'. This part of the thesis will characterise the pollutant profile in detail as the wastewater passes through the treatment plant.

(iii) Use insights from the above to recommend more cost-effective means for melanoidin removal.

Resources/safety/student skills: This thesis should appeal to students who enjoy working on operational processing plants. It will also require a significant amount of analytical work (using facilities in both the School and elsewhere on campus). There do not appear to be any safety issues. This thesis will involve working closely with other students and members of the research team.

9. Costing of Electrocoagulation as a Melanoidin Removal Option (jointly with Dr Dan Ryan)

Abstract: Electrocoagulation (EC) is an attractive option for removing melanoidin from process wastewater – see previous thesis description. In summary, EC works by

passing an electrical current between electrodes resulting in metal ions going into solution (and acting as a coagulant species) at the anode and forming hydrogen bubbles (which 'float' the flocculated material) at the cathode. To date our EC experiments have used relatively pure electrodes. In an industrial context however, the aim would be to use electrodes that are as cheap as possible. This project will thus have two objectives:

(i) To experimentally investigate the impact of electrode purity (and thus electrode cost) on the efficiency of the EC process.
(ii) To develop a realistic costing model that allows alternative melanoidin removal options (both currently used and being considered by our industrial client) to be quantitatively compared.

Resources/safety/student skills: The first part of this thesis is experimental and will be carried out using an existing bench-scale batch EC system (in Room 460) and analytical equipment within the School. The second part of the thesis should appeal to students who have an interest in process costing. No safety issues are envisaged. This thesis will involve working closely with other students and members of the research team.

10. Effect of Aeration in Electrocoagulation

Abstract: One of the inherent features of electrocoagulation (EC) is that small hydrogen bubbles are created at the cathode. When EC is applied to the removal of melanoidin particles from process wastewater, these bubbles are remarkably efficient at floating flocculated material to the surface of a batch reactor. Continuous flow pilot-plant options built around EC are currently being considered for an industrial client. One option involves a draught tube arrangement within a bubble column where the hydrogen bubbles would be augmented by air bubbles. This project will thus have the following objectives:

- To investigate alternative ways of introducing appropriately sized air bubbles into an EC reactor system.
- To examine the impact that an air injection/draught tube system has on melanoidin removal via the EC process.
- To determine whether the hydrogen generated by an industrial scale EC process (i) has any economic recovery value (noting that the present plant already has a bio-gas recovery system from the anaerobic digestion stage), or (ii) poses any safety issues.

Resources/safety/student skills: This thesis is largely experimental and will be carried out using existing bench-scale EC systems (in Room 460) and analytical equipment within the School. No safety issues are envisaged. This thesis will involve working closely with other students and members of the research team.

11. Development of Hysys Teaching Modules

Abstract: Hysys is currently the flowsheeting package of choice within the School being introduced to students in second year and used extensively during the remainder of the degree. However there is no suitable textbook available that covers all the necessary features of Hysys. Although a large number of examples have been developed within the School by various people, there is a real need to imbed these

within a suite of teaching modules for student use. This project will thus have the following objectives:

- Collate all available Hysys examples within the School.
- Extend these to cover all required Hysys features (*eg* dynamic simulation and flowsheet optimisation).
- Imbed the example set within a graded program of teaching modules available over the internet.
- Refine the teaching material by having it critically assessed by students within the key units of study.

Resources/safety/student skills: This thesis should appeal to students interested in computing and process modelling/simulation. The School already has a significant set of working Hysys examples available. A dedicated computer will be made available if needed. No safety issues are envisaged.

12. Commissioning of a Pilot-Scale Crystallisation Plant (jointly with Mr Javier Orellana)

Abstract: A pilot-scale plant originally purchased to research reactive crystallisation is to be used for undergraduate teaching from 2008. This plant is highly flexible in terms of the way it can be operated and controlled. This project will thus have the following objectives:

- Examine the crystallisation literature to determine a suitable test system that is low-cost, inherently safe and with material that can be readily recycled. This phase may well involve some bench-scale crystallisation studies.
- Quantify the impact of the key operating parameters (*ie* nucleation, supersaturation, cooling rate) on crystallisation rate and crystal size distribution (CSD).
- Develop a first-pass crystallisation model that allows students to examine the impact of the key operating parameters before they use the actual crystallisation plant.
- Prepare an operating manual for student use, including instructions on CSD measurement using facilities within the School.

Resources/safety/student skills: This thesis involves both experimental and (Matlab) modelling aspects. The crystallisation plant is a complex process and detailed instruction will be provided for its safe operation by Javier Orellana (who is the joint supervisor for this thesis). This thesis will involve another (international) student who will be working full-time on this plant in first semester as an internship project.

Prof Hans Coster (*Rm 468; ext 9351 2256; email hcoster@chem.eng.usyd.edu.au*)

13. Dielectrophoretic Coagulation (H.Coster and G. Barton)

AC electric fields induce electric dipoles in particles which interact with each other and the applied field to coagulation. The efficacy of this as a means of coagulationg melanoidin particles in suspension will be evaluated.

14. Monitoring fouling in Reverse Osmosis membranes (J. Kavanagh and H. Coster)

Reverse osmosis membranes are used in desalination processes. The project aims to investigate the monitoring of fouling of the membranes in-situ using electrical impedance spectroscopy.

15. Monitoring drying of Timber (H. Coster/J. Kavanagh and T. Langrish)

The optimum rate of drying of timber is a crucial parameter for quality control. The project aims to use a novel AC impedance technique to quantify this process.

16. Formation of Biofilms (H. Coster and T. Chilcott)

The formation of biofilms on surfaces is a first step in the eventual fouling of surfaces by organisms. The evolution of the biofilm and the effects of chemical pre-treatment of the surfaces is thus a crucial parameter in reducing biofouling. In the project electrical impedance spectroscopy will be used to follow the development of biofilms on a solid (metal) substrate.

17. Electrochemistry of organic films on silicon substrates (H. Coster and T. Chilcott)

The development of hybrid organic-inorganic materials is gaining great prominence for the development of devices such as biosensors and molecular electronic systems. The project is aimed at determining the electro-chemical properties of such films using electro-chemical voltametry techniques.

18. Electrodisinfection of marine and waste water (J. Kavanagh and H.Coster)

Disinfection of waste water and sea water is essential in many cases to prevent growth of organisms in cooling towers or pollution of discharge waters. Disinfection is currently achieved using chemical disinfectants such as chlorine. This is unsatisfactory because of costs as well as the formation of potentially harmful chloro-organic compounds some of which are carcinogenic. There are also strict limits set on the discharge of chlorine laden waste water. Heavy chlorination is also costly. One way to potentially dramatically reduce the concentration of chemical disinfectants required is to expose organisms in the feed waters to pulsed, large, electric fields. The latter can induce a state in the plasma membrane of these organisms that makes them transiently highly permeable to solutes such as chlorine. The project will investigate the possibility of using hybrid electro-chemical disinfection to treat waste and sea water. An exploration will be made of the effects of parameters such as the field frequency, field strength, disinfectant concentration and exposure time with the aim of defining optimal operating conditions.

Dr Marjorie Valix *(Rm 444; ext 9351 4995; email mvalix@chem.eng.usyd.edu.au)*

Please note that there are three groups of research projects which are subdivided to give 11 research projects. All resources, as stated after each of the projects, are available. Safety concerns are generally associated with the chemicals and materials and these will be handled according to their particular MSDSs.

19. ION-EXCHANGE RECOVERY OF NICKEL AND COBALT FROM METAL-ORGANIC COMPLEXES GENERATED IN BIOLEACHING OF LOW GRADE NICKEL LATERITE ORES

Bioleaching of nickel laterite ores is based on the use of heterotrophic fungi organisms and their metabolites (organic acids) to dissolve nickel and cobalt from oxide minerals to form metal-organic complexes. Metal recovery will be conducted using ion exchange resins including an aminophosphonic acid based chelating resin (Purolite S950) and sulphonic based resin (Purolite S930) as a function of metal concentrations, complexing agent including citric, dL-malic and lactic acids. Batch adsorptions will be conducted using synthetic leachate solutions of nickel and cobalt with concentrations from 15 to 2000 mg/L prepared in 0.01 and 0.1 M organic acids.

19a) Equilibrium Adsorption

Adsorption equilibrium data will be interpreted using the Langmuir, Freundlich and Dubinin-Kagner-Radushkevich (DKR) models.

19b) Adsorption Kinetics

The kinetic study will consider factors including solution pH , metal concentrations and temperature. The models considered will include pseudo- first and second orders, Elovich equation, mass transfer diffusion based models.

19c) Design of an Adsorption Column

Mathematical models based on the equilibrium and kinetic models will be used in designing a metal adsorption column. The models will be validated in pilot column tests considering factors including flow rate, bed height and the distribution of metal concentration along the bed height on column efficiency of the column.

19d) Cyclic testing and ion exchange resins

The aim of this investigation is to establish the factors affecting the life of ion exchange resins. The factors which will be considered include cyclic use of the resin and temporary and permanent foulants.

Resources Required

Chemicals

Metal Salts
Metal Standards
Bioacids

Equipment

ICP AES
Shaker
Pilot adsorber column apparatus

20. DYE ADSORPTION

The environmental problems and health concerns associated with synthetic dye effluents are well recognised Various processes including chemical oxidation, biological treatment, coagulation-flocculation and membrane processes have been shown to be effective in reducing dye concentrations in waste water. These treatment processes, however, are expensive and often fail to treat the wide range of dyes in wastewaters. Numerous adsorbents including inorganic, agricultural and shell-fish by-products have been considered for the adsorption on dyes. The use of activated carbons however, has been widely favoured because of their high adsorption capacities and amphoteric properties which enable their adsorption of both cationic and anionic dyes.

A series of activated carbons have been prepared from bagasse, a biomass by-product from sugar milling process, using chemical and physical methods. The aim of this investigation is to establish their potential in adsorbing basic and acidic dyes. This investigation will involve two parts:

20a) Equilibrium adsorption

Adsorption equilibrium data will be interpreted using empirical models including Langmuir, Freundlich and Dubinin-Kagner-Radushkevich (DKR) models.

20b) Kinetic adsorption

Adsorption kinetic data will be modelled according to the pseudo- first and second orders, Elovich equation, mass transfer diffusion based models.

Resources Required

Chemicals

CIBA Specialty Chemicals Acid and Basic Dyes
Activated Carbons (have been prepared and characterised)

Equipment

UV/Vis Spectrophotometer
Shaker

21. BIOLEACHING OF MINERAL OXIDES AND WASTES

The aim of this study is to establish the leachability of various mineral oxides and wastes to bioleaching.

Specific Objectives.

a) Consider the effect of solid/liquid ratio (pulp density), bioacid concentration and agitation on the efficiency (kinetics and overall metal recoveries) of leaching.
b) Mass balance analysis of the system.

This study will consider various ores and wastes:

21a) Ilmenite minerals

21b) Nickel laterite ores

21c) Zirconia Ores

21d) E-wastes

21e) Cement

Resources Required
Ores
Nickel laterite ores
Ilmenite ores
Zirconia ores
E-wastes
Cement

Chemicals
Bioacids
Metal Standards

Equipment
Agitated tank leach
ICP AES

Dr Howard See (*Rm 434; ext 9351 3832; email howards@chem.eng.usyd.edu.au)*

22. Magnetically Responsive Particulate Suspensions - The Relationship Between Particle Clusters and Viscosity

A magneto-rheological suspension is an example of a so-called "smart fluid". It consists of magnetisable, micron-sized particles dispersed in a carrier liquid. When a magnetic field is applied, magnetic interactions between the particles lead to the formation of large particle clusters, which cause a dramatic increase in the viscosity of the material. The tunable flow behaviour of these suspensions have made them the focus of intense research and development efforts in recent years, with possible engineering applications including adjustable vibration damping systems and fluid clutches.

There are still many fundamental aspects of these systems which are not well understood. The Department has a specially constructed magnetic test cell, which enables the flow properties of these suspensions to be tested under various magnetic field strengths and profiles (eg step field, steady field, etc). This experimental project will involve the production of a range of these fluids and measurement of their response under different flow and field conditions. The aim is to explore the relationship between the strength of the particle clusters and the overall viscosity increase of the material. There will be opportunities to use many of the concepts

learned in courses on Particle Mechanics and Fluid Mechanics. Some numerical modelling of the results using existing physical models will also be carried out.

Prospective students must consult with Dr See beforehand.
Physical plant / laboratory space / analytical facilities required: Physica TEK 70MR Magneto-rheological system
Computing facilities required: PC laboratory (Excel, Matlab)

23. Electro-rheological Fluids - Particle Suspensions that "Thicken" Electrically

Electro-rheological Fluids are "smart fluids" made up of semi-conducting particles dispersed in an insulating liquid such as silicone oil. When a voltage is applied across the fluid, the particles experience electric interactions causing them to aggregate. This results in a large increase in the overall fluid viscosity. The "tunable viscosity" nature of these fluids has been the object of intense research and development activity worldwide, with the aim of using this technology in engineering applications such as adjustable shock absorbers in vehicles.

The experimental strand of this project will explore how the mechanical properties (essentially viscosity and elasticity) of these fluids vary with the magnitude of the applied voltage and the voltage waveform (eg square wave, DC). The response of the fluid will be measured using a high precision, electro-rheological test cell available in the Department. Preparation of various types of electro-rheological fluids using spherical, elongated and irregularly shaped particles dispersed in a variety of oils will be carried out. Many of the key concepts learned in courses on Particle Mechanics and Fluid Mechanics will be put to use in this project. Some numerical modelling of the results using existing physical models will also be carried out.

Prospective students must consult with Dr See beforehand.
Physical plant / laboratory space / analytical facilities required: Electrorheological cell
Computing facilities required: PC laboratory (Excel/Matlab)

24. Crystallization in polymers under shearing

Polymers are an important class of engineering materials, and many industrial processes involve them being cooled down from a molten state (eg injection moulding). As the temperature is reduced, micron-sized crystalline structures form within the polymers and the orientation and size of these have a profound influence on the properties of the final product. It is known that subjecting the polymer to shearing or other deformations during cooling can dramatically alter the nature of these structures, and this is an important phenomenon that requires further investigation. This experimental project will use an optical microscope and a heating stage to study the effects of external flow on the development of structures within polypropylene samples as they are cooled from the melt. These observations will be related to the flow behaviour measured macroscopically.

Physical plant / laboratory space / analytical facilities required:
Linkam Microscopic Optical Shearing System and Heated Stage CSS450

25. Microscopic observation of structures in flowing suspensions

Suspensions, which consist of particles dispersed in a carrier liquid, are a major class of engineering fluid, and an understanding of the flow behaviour of these materials is important for many industrial processes. When these fluids are made to flow, it is known that the particles often arrange themselves into "structures" in the flow field (eg alignment of the particles in the shear direction), and these structures lead to quite complex non-Newtonian flow behaviour. This phenomenon is still not well understood. This project will use a start-of-the-art microscopic flow cell to experimentally examine the structures which form within a variety of suspensions under a range of shear flow conditions. These will be related to the flow behaviour measured macroscopically.

Physical plant / laboratory space / analytical facilities required:
Linkam Optical Shearing System – Nikon microscope

26. Flow behaviour and microstructure of foodstuffs

Properties such as crispiness, crunchiness or spreadability are important for making foodstuffs appealing to consumers – taste alone may not make a product a winner. These properties are often called the "texture" of the foodstuff, and they are closely related to the way the material flows as well as to the internal, microscopic structure. There are many examples of foodstuffs with complex flow behaviour due to their microscopic structures, such as dairy products, sauces, yoghurt, mayonnaise, etc.

The rheological properties (or flow properties) of foodstuffs also play a key role in their manufacture. For example, spray drying is often used to make foodstuffs in a solid powder state from a liquid feed, and it is known that the rheological properties of the feed can dramatically affect the formation of the droplets. In this project, the rheology of a variety of foodstuffs will be examined using state-of-the-art instruments, and related to the internal structure via an optical microscope. Key issues associated with the rheology include the degree of elasticity the material possesses (ie how solid-like it is), as well as its yield stress, and the degree of shear-thinning or shear-thickening it displays when it flows.

Physical plant / laboratory space / analytical facilities required:
Physica MCR301 Rheometer; Peltier temperature control system
Linkam Optical Shearing System (temperature controlled) – Nikon microscope
Computing facilities required: PC laboratory (Excel/Matlab)

27. Suspension rheology

Although very common in our everyday lives and in industry, there is still much unknown about the flow behaviour of suspensions, which consist of solid particles dispersed in a carrier liquid. In particular, the behaviour at higher shear rates, which is relevant to many industrial problems such as mixing and transportation through pipes, has been difficult to explore with conventional instruments. This project will use two state-of-the-art instruments to tackle this problem, a Physica MCR301 rheometer and

a Gottfert capillary rheo-tester. The latter instrument is specially designed to explore high shear rate properties.

Physical plant / laboratory space / analytical facilities required:
Physica MCR301 rheometer and Gottfert capillary rheo-tester (delivery and installation in March 2007).

Dr John Kavanagh *(Rm 421; ext 9036 9642; email kavanagh@chem.eng.usyd.edu.au)*

28. Electrical Impedance Study of Reverse Osmosis and Nanofiltration Membranes (with Prof Hans Coster and Dr Dan Ryan)

Abstract: Membranes are seeing increasing industrial application. A significant operating issue with any membrane system is that of fouling, which is difficult to measure in situ. In this thesis Electrical Impedance Spectroscopy will be used to monitor the build up of foulant for two systems:

- Sea Water Desalination
- Industrial Water Reuse

This project will have three main objectives:
(i) To measure the flux decline as fouling layers build up for both systems.
(ii) To measure the electrical properties of foulant layer on the membrane.
(iii) To develop a relationship between the flux decline and the measured electrical properties.

Resources/safety/student skills: Experimental apparatus will be complete before project starts, and will involve work in labs 314 and 460. The project involves the use of low voltage electricity with water. The project will suit a student who has an interest in practical experimental work and mathematics.

29. Focussed Electro disinfection of Sea Water (with Prof Hans Coster and Terry Chilcott)

Abstract: Sea Water is widely used for cooling in a range of large industrial complexes. Several problems are associated with its use, particularly the growth of organisms such as barnacles. This is also a potential problem for sea water reverse osmosis plants.

This project will look at adapting focussed electro disinfection, which has previously been used to destroy parasites in drinking water, to prevent the growth of marine organisms which foul sea water cooling systems.
This project has industry interest and the potential

This project will have five main objectives:
(i) To determine the relevant marine microorganisms/macroorganisms that cause significant bio-marine fouling
(ii) To test standard methods for determining the viability of relevant marine organisms.

(iii) To determine the effectiveness of chlorine in preventing the survival of such organisms
(iv) To determine the effect of focussed electrodisinfection parameters (voltage, spacer dimensions and chlorine level) on the survival rates of such organisms
(v) Draw conclusions as to the large scale economic feasibility of focussed electrodisinfection for sea water.

Resources/safety/student skills: The electrodisinfection apparatus needs to be recommissioned, microscope is available. This project will suit a student with experience in microbiology, biology or microscopy, as significant microscopy work is essential for this project.

30. Novel electro coagulation methods (with Dr Dan Ryan and A/Prof Geoff Barton)

Abstract: A number of novel techniques have been tested in the laboratory to enhance electrocoagulation, including switching currents, the use of low frequency AC, ultrasonics and sound waves. This thesis involves the testing of such methods with a waste stream containing melanoidins, the brown pigment from molasses which is resistant to treatment by most microorganisms.

This project will have three main objectives:
(i) To determine the effect of low frequency AC electricity on electrocoagulation.
(ii) To determine the effect of switching DC on electrocoagulation.
(iii) To determine the effect of sound waves/utlrasonics on the performance of the electrocoagulation.

Resources/safety/student skills: The experimental work for the project will be carried out in lab 460. This project will suit a student with an interest in practical work as it will involve the commissioning of small scale apparatus and hands-on experimental work.

31. Electrical Impedance Spectroscopy of Timber (with Prof Hans Coster and A/Prof Tim Langrish)

Abstract: Electrical Impedance Spectroscopy is a technique that has been used to measure the properties of materials down to the molecular level. In this application we are seeking to use determine the relationship between the electrical properties of timber and its moisture content/distribution. Such work will enable validation of drying models and real time control of timber drying processes.

This project will have two main objectives:
(i) To determine the relationship between moisture content and electrical properties of timber.
(ii) To determine the relationship between the moisture gradient of the timber and the electrical properties of the timber

Resources/safety/student skills: Most of the experimental work will be conducted in Laboratory 314. This project will suit a student with a strong aptitude for mathematics.

32. Feasibility study for the production of Bio-Butanol as a fuel

Abstract: High Oil prices and concerns over global warming have led to an increased interest in bio fuels. Most interest has centered around ethanol and biodiesel, however bio-butanol is another alternative.

This project will have three main objectives:
(i) To review the relevant literature on the acetone butanol fermentation.
(ii) To determine the concentration of butanol that can be achieved by fermentation using a variety of carbon sources.
(iii) To simulate the recovery of butanol using Hysys and carry out a preliminary feasibility study into the production of bio-butanol.

Resources/safety/student skills: This project will suit a student with practical experience and interest in fermentation. PC1 bacteria will be used. The project requires the use of an incubated shaker/50L fermenter.

A/Prof Tim Langrish *(Rm 457; ext 9351 4568; email tim.langrish@usyd.edu.au)*

33. A New Approach to Producing Functional Foods by In-Chamber Blending Inside Spray Dryers

This project will develop new approaches to product development by studying in-chamber blending of powders produced in spray dryers with externally-produced and introduced dry powders as a method to produce functional dairy products. This approach to developing functional food powders does not appear to have been used before, although fines return systems are available in industrial spray dryers to recover fine product and include it in the main products from these dryers.

This is an opportunity to develop new technology for product development in powders for functional foods. Rather than add powders, such as lactose, to the wet slurry feed and then spray drying the mixture, usually but not always cocurrently, we will investigate blowing dry powder into the chamber directly as a dried product to combine, in the spray-drying chamber, with the sprayed droplets.

These methods of in-chamber blending may give new products, may be useful in increasing yields and may reduce the amounts of wall deposits. The dosage control of the extracts or sprayed liquid to the fibres or dry powders may also be effectively managed, and any problems with the ability of the liquid feeds to be pumped may be minimized.

A tool that is available for this new method development includes a dry powder feeder unit that utilizes a compressed air supply to drive dry powders through piping and potentially into a spray dryer.

This in-chamber blending is a type of agglomeration process in a spray dryer. At a fundamental level, a key scientific challenge in the agglomeration of functional food products by spray drying is to model the effect of stickiness in moist particles on the collision efficiency in agglomeration. While coalescence processes between liquid droplets are becoming increasingly well understood (Nijdam *et al*., 2004), the collision processes between moist particles are not. Work in 2006 by Doaa Ali established the feasibility of studying the agglomeration process in this way, and there

is considerable opportunity to extend the study to a wider range of experimental conditions and to model the collision rate process to establish the factors that are most important in determining the collision efficiency.

Nijdam, J.J., Guo, B., Fletcher, D.F. and Langrish, T.A.G. (2004), "Challenges of simulating droplet coalescence within a spray", *Drying Technology - An International Journal*, **22**(6), 1463-1488.

Physical plant / laboratory space / analytical facilities required: spray dryer (Tim Langrish)
Computing facilities required: PC laboratory
Workshop time required: None

34. The Degree of Crystallisation of Spray-Dried Products

Spray dryers are known to produce largely amorphous powders. The physical reason is that the atoms or molecules in the spray-dried substance are formed from a liquid into a solid form within seconds, sometimes fractions of a second, without allowing them time to crystallise. The subsequent amorphous products are disordered, allowing a considerable amount of moisture to be trapped within such disordered and tangled atomic or molecular arrangements, giving them higher moisture contents than the corresponding crystalline products. The amorphous products have the potential to become sticky, while the crystalline forms are not so sticky. It is also found that amorphous solids tend to transform to crystalline ones as time progresses, even within a spray dryer, so that the final product contains both crystalline and amorphous regions to varying extents.

The degree of crystallisation, or extent of amorphous relative to crystalline solid form, is therefore an important parameter to be measured in spray-dried powders. Once this parameter (degree of crystallisation) can be measured, then we can control it by varying the drying conditions, such as residence time.

It is also known that the rate of moisture absorption and desorption is much greater in amorphous products than in crystalline ones, and this is the basis of a technique known as dynamic sorption analysis. The basis of the technique is to take a sample of powder and subject it to a sudden change in relative humidity, causing it to gain or lose moisture, while weighing it to measure the rate of gain or loss. Expensive equipment is currently sold to do this. However, this measurement could be done more simply by measuring the rate of moisture change in a fixed mass of powder in a predetermined layout while exposed to ambient air, providing that the relative humidity and temperature of the ambient air does not change too rapidly.

We will test the effect of different feed mixtures and operating conditions in the spray dryer on the degree of crystallinity for thr powders produced from the spray dryer.

Physical plant / laboratory space / analytical facilities required: spray dryer, weighing balances (Tim Langrish)
Computing facilities required: PC laboratory
Workshop time required: None

35. Comparing Wall Deposition Rates in Pharmaceutical-Scale and Pilot-Scale Spray Dryers

An aspect of the fundamental science underlying the development of useful bioproducts from wastes is the understanding of how to produce powder products from them without excessive amount of wall deposition. Although many gadgets have been attempted to reduce the rates of wall deposition, it appears that more fundamental understanding is needed to resolve the problem. In this project, experimental data will be gathered by two different methods in two different scales of dryer (pharmaceutical and pilot scales) in order to create a database of information to allow comparisons with the results of model simulations for the process. Using these data may also allow the effects of varying different input parameters on the wall deposition rates to be assessed.

One method is to measure the wall deposition rates using water alone in a cold dryer. Another method is to use salt solutions and measure the amount of salt deposited on the walls by dissolving the salt in a known volume of water, where the concentration of salt can be subsequently measured using atomic absorption analysis or other instrumental methods. An important immediate outcome from this work, using both water and salt methods, is to confirm (or otherwise) the relationship between the wall deposition rate and the yield, which is the ratio of the solids coming out of the cyclone to the solids entering with the liquid feed. It is expected that the higher the wall deposition rate, the lower the yield. However, this expectation may be complicated by the function of the cyclone in separating particles from the gas, and a low yield may simply be caused by poor gas-particle separation performance. The different techniques to be used in the project will allow the wall deposition process in the dryers to be distinguished from the separation performance of the cyclone.

Physical plant / laboratory space / analytical facilities required: spray dryers (Tim Langrish)
Computing facilities required: PC laboratory
Workshop time required: None

36. Wetting Kinetics

The measurement, modelling and control of drying kinetics (loss of moisture) has been extensively studied, as have the adsorption and desorption equilibrium behaviour. To what extent is the existing understanding of drying kinetics (moisture loss), say by diffusion, satisfactory for describing wetting (adsorption) kinetics? Some drying experiments, followed by wetting experiments, in which the relative humidity of the air is raised, should be carried out on a variety of materials, including wood, foodstuffs and fruits.

Physical plant / laboratory space / analytical facilities required: drying tunnel (Tim Langrish)
Computing facilities required: PC laboratory
Workshop time required: None

37. Extraction and Drying of Bioproducts from Wastes (with Dr J. Shi)

We will study the extraction, identification and analysis of valuable bioproducts, such as pectins and peel oils, from orange skins, which would otherwise be waste materials. The concentrations of these compounds will be measured before and after spray drying them in our mini spray dryer, to produce dried powder products.

The work is experimental in the first instance, including a critical review of the literature, and will involve instrumental analysis of the compounds using ion chromatography and viscometry. Modelling of the reaction rates involved in degradation reactions will then provide a framework for generalising the results.

Strong analytical and experimental skills are required for this project. It is advisable for prospective students to consult with Associate Professor Langrish beforehand.

Physical plant / laboratory space / analytical facilities required: IC and viscometer (Jeffrey Shi), spray dryer (Tim Langrish)
Computing facilities required: PC laboratory
Workshop time required: None

Adjunct A/Professor Don White *(Rm 458; email: dwhite@chem.eng.usyd.edu.au; Tel: 9389 6728 (Don White and Co))*

Note: In the non semester periods please contact Don at his office/home number which is his base for work. In Semester periods Don works at Uni approx three days a week. (Monday, Wednesday, Friday. Its best to make arrangements by Email to meet but you can call on spec. Office is 458 – next to Tim Langrish

38. Re-use of Bioretention Area water

As part of the Campus 2010 programme a new elevated walkway has been constructed to the south of the Chemical and Biomolecular engineering (CBE) Building. The rain water collected from this structure and its surrounds all drains through a bioretention system and is stored in an underground tank ($75M^3$). The university is desirous to use this water as make up water for cooling towers. However, this would appear to be a novel application for this type of water. Consequently there is a need to research the water quality that could be anticipated and probably undertake a testing programme (on this system and/or a similar system) to establish its quality and it suitability for cooling tower make up

This will involve liaison with Richard McManus at Ecological Engineering to establish a methodology, and testing regime, some collaboration with Ms Christine Cowie, School of Public Health, to set health standards, John Dahlenburg, Water Sensitive Urban Design (www.wsud.org)and possibly interface with A Prof. Gavin Birch in the School of Geosciences who has quite some experience in this area.

The client for this project will ultimately be the Campus Property and Services Office of the University, (Janet Broady, Environment Manager).

Supervisors: Adjunct A/Professor Don White

Skills required: Computer literacy, good organizational and communication skills
Resources: PC and appropriate software (MS Office,)
Safety issues: None
Testing : NB Unclear what sort of testing and where it is to be done!!!!!!

39. Carbon sequestration to offset Green House gas emissions caused by travel by members of the University of Sydney

The University is under pressure (from the undergraduate population and enlightened schools, departments and facilities) to reduce its contribution to Green house gas production. Obvious options are to sign up for a proportion of its electrical power from renewable (Green) sources. However Green power is currently more expensive (in $terms) than energy from conventional (largely coal) sources so the University senate rejected this option in 2006. In 2006 the thesis student used a computer model produced by the National Greenhouse Gas Office to explore the possibility of Usyd offsetting at least a portion of its CO2 production from Power consumption by the planting of trees on propertied owned by the University. It was found that successful planting of 6ha per year on the University's degraded property 'Arthursleigh' [1](7900 ha) located at Marulan near Goulburn would be adequate to offset 6% [2] of the Green house gas production from USyd's power consumption.

However, the Travel undertaken by USyd academics contributes nearly as much to green house gas problems as power consumption. This year the thesis student will explore the relationship between the green house gas effects caused by air travel and ultimately relate this to the potential for tree planting to off set a portion of these emissions

By the end of semester 1 the student will:

1. Conduct a comparative literature study of the various tools available for calculation of green house gas emissions from air travel (particularly CO2 but also looking at effects of sulphur emissions at high altitude).

2. Become familiar with the use of the National Carbon Accounting Toolbox [3]. In particular - replicate the estimate of greenhouse gas emissions and carbon stock changes from land use and management made by Phil Lois in 2006 to off set the Universities Power usage.

In Semester 2

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[1] For details see http://www.greeningaustralia.org.au/GA/ACT/News/improvingarthursleigh.htm

[2] 6% off set is required of major Government Departments so would bring the University into parity with these other major users.

[3] The National Carbon Accounting Toolbox assists in estimating and predicting greenhouse gas emissions and carbon stock changes from land use and management. It is issued by The Greenhouse Gas office of the Department of Environment and Heritage. It contains the Full CAM modeling software and a complete set of supporting technical documentation. Details at http://www.greenhouse.gov.au/ncas/

Use the results from 1 and the skill developed by operation of the model in 2 to propose options for the University to off set its green house gas production resulting from travel by carbon sequestration in trees and forests.

The project will involve considerable interaction with the Campus Property and Services Office of the University, (Janet Broady, Environment Manager), the emissions working Group in the University and has considerable potential for interaction with the Student Environment Activist Network, Greenpeace, Power 2 Change, consultants working in this area, Conservation groups and other interested Stakeholders within the University. Qantas are known to be working on a policy on this matter, European airlines are up in arms over a European Commission proposal to limit their emissions by including them in Emissions Trading Scheme (ETS) and it could well be that the subject receives considerable attention during 2007.

Supervisors: Adjunct A/Professor Don White
Skills required: Computer literacy, good organizational and communication skills
Resources: PC and appropriate software (MS Office,) A reasonably powerful laptop to run the CAM software
Safety issues: None

40. Battery Recycling

Australia uses an increasing number of batteries to power a plethora of electronic gadgets which are commonplace in our homes, in offices, in transport and in industry. However batteries not only consume resources which have a finite life but they also have hazardous properties which manifest themselves after the productive life of the battery. This thesis will investigate the magnitude of these issues as part of the contribution to the debate around this issue.

In Semester 1

- Conduct a literature review of the established methods for recycling batteries containing lead, nickel cadmium, nickel hydride, mercury and lithium.
- Review the facilities available world wide for reprocessing of these batteries but particularly in Europe, USA, Canada, India, Asia (including China and Korea if possible) and Australia.
- Conduct a review of the legislative requirements for the production and recovery of batteries in the jurisdictions above.
- Review the hazards presented by the materials used in the manufacture of batteries and the environmental risks posed by their end of life disposal

In Semester 2

- Use the information gathered to review the position in NSW with regard to batteries. [4] In particular batteries have been identified as one of the wastes of concern in the Extended Producer Responsibility Statement issued by the NSW Department of Conservation's Environment Protection Agency for 2005-6

Test the hypnotises

[4] Available from www.environment.nsw.gov.au

- That alkaline batteries present an equally significant problem as NiCad's due to the volumes disposed of and the lack of collection or drop off, recycling or education programs.
- Despite a high recovery rate for lead acid batteries, the current practice of enabling export of used lead acid batteries limits the ability of Australian smelters to implement new technology to reduce residual wastes from the recycling of used lead acid batteries due to lack of available feedstock.

As an extension

- Consider the possibilities for industry to move to phase out the use of non-removable NiCad batteries in favour of less hazardous battery technologies.

There is potential for interaction with relevant policy officers in the NSW Department of Conservation who will be preparing a review of the EPR statement during the life of this thesis project. There is also scope for interaction with the Waste Industry, probably through the Waste Management Association of Australia (WMAA) The project has potential for interaction with the Campus Property and Services Office of the University, (Janet Broady, Environment Manager), who have concerns about the University's policy in this matter, and potential for interaction with the Student Environment Activist Network.

Supervisors: Adjunct A/Professor Don White
Skills required: Computer literacy, good organizational and communication skills
Resources: PC and appropriate software (MS Office,)
Safety issues: None

A/Prof Vincent Gomes *(Rm 452; Ext. 9351 4868; email: vgomes@chem.eng.usyd.edu.au)*

41. Synthesis of Designer Nanoparticles by Emulsion Polymerisation

The aim of this project is to develop a process for fabrication of nano-sized particles which have well-defined molar and particulate characteristics. These are essential particularly for manufacturing advanced polymeric products, pigments, coatings, micro-sensors, and drug delivery systems. These applications require monodisperse particles of a specific size, composition, and morphology.

Emulsion polymerisation is the method of choice for implementing free-radical polymerization. On an industrial scale, its attractiveness is due to its considerable technical, commercial and environmental advantages. The process is widely used globally to produce products ranging from adhesives and paints, through to high-tech biomedical preparations. The polymerisation process involves reactions in a multivariable, multiphase, multi-component system. Key product characteristics depend substantially on the fundamental properties such as the polymer structure, the molecular weight and the particle size distributions.

The characterisation of the reaction in terms of conversion, or extent of reaction is challenging when multiple monomers and chain transfer agents (CTA) interact. Conversion is important for both polymer molecular weight and particle size distributions. On-line measurements for emulsion multi-polymerisation are either

expensive or inadequate. This thesis will investigate the use of soft-sensors to facilitate characterisation of the process and to control particle size and molar mass of products. The results will be of interest to process industry. Skills with experimental work and programming (Excel/Matlab) are essential. There will be a postgraduate student to support this work. Training with operating the reactor and instruments will be provided.

Prospective students must consult A/Prof Gomes beforehand.

Resources and safety:

- Computing resources: Pentium computers are available in the Lab. Software for carrying out computing and data analyses are available.
- Lab requirements: Equipment and utilities exist in department laboratory.
- Safety issues: Postgraduate student has already completed Hazop, thus safety procedures are in place.

42. Microstructure and Physical Property Inter-relationship for Multi-Polymer Consumer Products

The relationship between microstructure on the one hand and product properties on the other is an important problem in the science and technology of polymer colloids. This study will involve understanding of how changes at the molecular level affect physical properties.

The project aim is first to analyse the polymerisation data base for understanding how a range of final properties depend on the experimental parameters in free-radical polymer colloid synthesis. This will be followed by formulating recommendations for process and its operation to obtain desired final properties of polymer products. The skills required include knowledge in chemistry and data analysis for understanding correlations between processes and products. There will be a postgraduate student to support this work. Experiments with differential scanning calorimetry (DSC) and other analytical instruments will be performed by the student under supervision after appropriate training is provided by postgraduates.

Prospective students must consult A/Prof Gomes beforehand.

Resources and safety:

- Computing resources: Pentium computers are available in the Lab. Software for computing and data analyses are available.
- Lab requirements: Equipment and utilities exist in department laboratory.
- Safety issues: Postgraduate student has already completed Hazop, thus safety procedures are in place.

43. Fixed-Bed Adsorber for Innovative Separation

Following recent discoveries of efficient adsorbents, adsorption-based processes have gained substantial industrial importance. Hydrogen recovery from refinery off-gases, separation of azeotropic mixtures, automotive fuel from fuel-cells, energy recovery, products from air, heatless gas drying, pollutant removal from flue gases and car

exhausts, industrial effluent remediation, water purification are a small number of examples involving adsorptive processes used in industry.

The technology is applicable not only in chemical process industries (CPI) but also in the energy, environmental, biochemical and pharmaceutical sectors. A fixed-bed adsorber will be used for separating gases from air using new adsorbents based on zeolites for generating high purity commodity gases such as nitrogen and oxygen. Pressure-mediated separation will enable increase of separation efficiency and adsorbent regeneration. The project is experimentally based with available simulation package as an important tool for analysis. There will be a postgraduate student to support this work.

Resources and safety:

- Computing resources: Pentium computers are available in the Lab. Software for computing and data analyses are available.
- Lab requirements: Equipment and utilities exist in Department laboratory.
- Safety issues: Postgraduate student already completed Hazop, thus safety issues were identified and requisite procedures are in place.

44. Catalytic Reaction Enhanced by in situ Separation

Adsorption-based processes have emerged as major industrial enterprise, producing some of the most important bulk commodities. Industrial adsorptive processes involve periodic separation in fixed-beds. The adsorption is followed by regeneration in one or more columns with operation that ensures continuous product delivery. The sorption and regeneration steps are usually accomplished through pressure variations. Thus the process is a cyclic batch process that involves flow and pressure switching and timing control.

Adsorptive reaction presents a way for removing product or reaction inhibiting species from the reaction zone by combining the catalytic reaction with the adsorption separation at the same unit. This results in favourable shift in the reaction equilibrium and improvement in product selectivity. Heterogeneous catalysis is of fundamental importance in the chemical industry and considered the most dominant (over 90%). More recently, catalytic reaction has been coupled with industrial cyclic-adsorption processes, such as those based on pressure swing technology. In this work, equilibrium and/or multiple reactions will be investigated experimentally under the pressure swing effect.

For future economies, the efficient production of selective products is a key requirement. In order to explore this aspect, computational and experimental work will be conducted. The simulations will be based on available literature data. Computational tools such as MATLAB and Excel for optimisation and control of the process will be used.

Resources and safety:

- Computing resources: Pentium computers are available in the Lab. Software for computing and data analyses are available.
- Lab requirements: Equipment and utilities exist in Department laboratory.
- Safety issues: Postgraduate student already completed Hazop, thus safety issues were identified and requisite procedures are in place.

45. Sono-Chemistry Application for Innovative Polymer Products

Recent innovations in polymer synthesis in our Laboratories permit the making of high value-added products such as block copolymers, star polymers and polymers having complex architectures. These are valued in several high-tech and bio-medical applications. The fundamental process is a variation on dispersion and emulsion polymerisation with the addition of sono-chemistry.

The main aim of this work is to create miniemulsions through sonication and combine the process with "living" free-radical polymerisation process to obtain block and star-shaped molecular architectures. The products will be characterised by our molecular and morphological testing instruments.

The project will require a good understanding of fundamental polymer and sono-chemistry. Ability to use sophisticated laboratory equipment and to perform process modelling would be of advantage.

Prospective students must consult A/Prof Gomes beforehand.

Resources and safety:

- Computing resources: Pentium computers are available in the Lab. Software for carrying out computing and data analyses are available.
- Lab requirements: Equipment and utilities exist in department laboratory.
- Safety issues: Postgraduate student has already completed Hazop, thus safety procedures are in place.

46. Intelligent Process Monitoring and Diagnosis in Polymer Synthesis

Emulsion polymerisation is widely used in industry to produce products ranging from adhesives and paints, through to high-tech biomedical preparations. The polymerisation
process is complex and involves reactions in a multivariable, multiphase, multicomponent system. Thus timely interpretation of process data and process analysis are important.

This project will involve investigating the knowledge base for process and data analysis for understanding the trends and preventing any potential fault development. The knowledge would also be important in avoiding process operation that is sub-optimal or ineffective. The results will be of great interest to process industry and operating engineers. This project will use an expert system (already developed) coupled with statistical control for supervisory control of the process. There will be a postgraduate student to support this work. Skills with programming in Excel and Matlab are required.

Resources and safety:

- Computing resources: Pentium computers are available in the Lab. Software for computing and data analyses are available.
- Lab requirements: Equipment and utilities exist in department laboratory.
- Safety issues: Postgraduate student has already completed Hazop, thus safety procedures are in place.

47. Assessment and Integration in the New Chemical Engineering Curriculum

(Advisors: V Gomes & H See)

Globally, education has been receiving increasing attention from diverse sectors and stakeholders in terms of the efficacy and potential improvements of the system. However, the issues are complex and comprise a large number of variables. Our School recently established a new curriculum with a number of novel aspects implemented for the first time. The Professional Accreditation Panels (Engineers Australia and IChemE) have assessed the curriculum to be an exemplar of a high standard. However, there is a great need to critically examine the implementation of the curriculum in its current form. In particular, issues regarding graduate attributes (technical, generic, etc) , unit of study assessments (competency, graded, mixed, etc) and integration of units within the curriculum need to be examined critically.
Some of the basic questions to be addressed are: How effective is our new curriculum? What are the best practices in our profession? What steps are needed to incorporate good teaching practice and student learning outcomes?
Initially, a targeted literature review will be carried out and cases will be analysed. These will help create a database of relevant practices within our profession. The research will also conduct surveys and critically examine student feedback and responses from the various stakeholders. This project is expected to provide crucial inputs into our teaching and learning framework. The project would be ideal for students with an interest in the education of professional engineers.

A/Prof Fariba Dehghani *(Rm 453; email fdehghani@usyd.edu.au; ext 9351 4794)*

48. Precision Cleaning of Surgical devices by a Solvent Free Technique
[experimental based study**]**
Cleaning of surgical devices and biomaterials requires the removal of all foreign materials. Because of infection risks associated with the reuse of certain medical instruments, such as endoscopes, effective cleaning is essential. Precision cleaning is required for thorough removal of oil residue retained on the surface of surgical devices and fine biomaterials fabricated from metal or ceramics. Current methods for cleaning rely on hand or machine washing with aqueous detergents, organic solvents such as alcohols, or enzymatic solutions. Current cleaning processes while are not efficient for entire cleaning of medical devices are also associated with consumption of large amount of organic solvents and surfactants provoking an environmental concern.

Dense CO2 is being evaluated as an alternative, chemically-benign technology for simultaneously cleaning certain biomaterials [1]. Its chemical inertness, non-toxicity, and low critical temperature (31.1ºC) make CO2 an especially attractive option for cleaning and removing bacteria, endotoxins, and other debris from surgical instruments and orthopedic implants [3].

The aim of this study is to assess the potential of dense gas CO2 for cleaning the surface of various surgical devices and biomaterials manufactured by the Australian Surgical Design and Manufacturing (ASDM) Company. Cleaning and sterilization with CO_2 depends on many parameters such as temperature, pressure, moisture content, and treatment time [2, 3]. The effect of these variables on the removal of oil and other contaminant residues will be evaluated to determine the optimum conditions.

References

1. Kaiser, H., Warner, L., Matthews, M.A. Exploring the feasibility of using dense phase carbon dioxide for sterilization. Med Device and Diag Ind 2001; 140.
2. Debs-Louka, E., Louka, N., Abraham, G., Chabot, V., Allaf, K. Effect of compressed carbon dioxide on microbial cell viability. Applied and Environmental Microbiology 1999; 65: 626-631.
3. Kamihira, M., Taniguchi, M., Kobayashi, T. Sterilization of Microorganisms with Supercritical Carbon Dioxide. Biol. Chem. 1987; 51 (2): 407-412.
4. Rutala, W. A., Weber, D. J. Infection control: the role of disinfection and sterilization. Journal of Hospital Infection 1999; 43 (Supplement): S43-S55.

49. Sterilization of Biomaterials and Pharmaceuticals by a Non-destructive Technique [experimental based study]

Polymeric biomaterials such as ultra high molecular weight polyethylene (UHMWPE) play an increasingly important role in the biomedical field. As with all materials, any polymeric biomaterial used for surgery or implantation must be sterilized prior to use. A critical objective of any sterilization process is destruction of bacteria without damaging the surface of the device, or compromising either its bulk material strength or its biocompatibility. In addition, the bioavailability of active pharmaceutical ingredient may be decreased upon sterilisation with various techniques. It is evident that current sterilisation techniques such as gamma irradiation and ethylene oxide (ETO) have negative impacts on the longevity of UHMWPE. In addition, there are safety and health concerns for using chemicals such as ETO. Alternative processes that can clean and sterilize biomaterials at moderate to low temperatures without detrimental effects continue to be developed.

Dense CO2 is currently being evaluated as a viable alternative, chemically-benign technology for simultaneously cleaning and sterilizing certain biomaterials and pharmaceuticals. Its chemical inertness, non-toxicity, and low critical temperature (31.1ºC) make CO2 an especially attractive option for cleaning and removing bacteria, endotoxins, and other debris from surgical instruments and orthopedic implants.

The aim of this study is to assess the potential of dense gas CO_2 for sterilisation of biomaterials. Cleaning and sterilization with CO_2 depends on many parameters such as temperature, pressure, moisture content, and treatment time. The effect of process variables on the bulk material properties of biomaterials, adhesives and packaging materials will be assessed. The bioavailability of active compound and biomaterial will be assessed after processing and will be compared with current sterilization process.

References

1. Kaiser, H., Warner, L., Matthews, M.A. Exploring the feasibility of using dense phase carbon dioxide for sterilization. Med Device and Diag Ind 2001; 140.

2. Debs-Louka, E., Louka, N., Abraham, G., Chabot, V., Allaf, K. Effect of compressed carbon dioxide on microbial cell viability. Applied and Environmental Microbiology 1999; 65: 626-631.
3. Kamihira, M., Taniguchi, M., Kobayashi, T. Sterilization of Microorganisms with Supercritical Carbon Dioxide. Biol. Chem. 1987; 51 (2): 407-412.
4. Rutala, W. A., Weber, D. J. Infection control: the role of disinfection and sterilization. Journal of Hospital Infection 1999; 43 (Supplement): S43-S55.

50. Fabrication of Nano-Composite of a Polymer-Hydroxyapatite for Bone Tissue Engineering Scaffold

In large bone defect caused by tumour or injury, bone is unable to regenerate spontaneously. In this case, a biomaterial is required to be inserted in defected area to support bone cells and act as a temporary scaffold to conduct new bone formation. The bone graft biomaterial should be ideally biodegradable and replaced by new formed bone. The bone graft biomaterial should possess a interconnected porous structure allowing cells, growth factors and nutrition to infiltrate into the biomaterial, leading to bone ingrowth and formation inside of the biomaterial. The aim of this study is to fabricate and characterise a porous structure composed of biodegradable polymer such as poly caprolactone and nano-particles of hydroxyapatite (HAP) using gas foaming technique. The mineral phase of bone consists of nano-size hydroxyapatite (HAP) crystals and combination of polymer and HA provides a surface chemistry close to that of bone mineral. Polycaprolactone is a biocompatible and biodegradable polymer which has widely been used as a graft biomaterial.

The use of highly diffusive DGs such as carbon dioxide will assist in fabrication of controlled, uniform, interconnected nano-structure throughout the whole matrix. These materials will interact optimally with the body and will remove the necessity for cell and tissue grafting, and their inherent risks. Dense gas carbon dioxide penetrates into the polymer matrix, plasticizing the material, decreasing the viscosity and allowing the polymer composites to integrate homogeneously. The technology also overcomes disadvantages of conventional techniques by eliminating the use of organic solvents, enabling fabrication at ambient temperature and tailoring the porosity characteristics to the desired architecture. Moreover, processing by dense gas carbon dioxide has advantages of sterilising the final product without affecting the physical and mechanical properties of biocompatible polymers. Thus, issues related to current sterilisation techniques such as autoclaving, gamma radiation, and the use of gases such as ethylene oxide can be addressed.

References:

Baji A, Wong S-C, Srivatsan T S, Njus G O, and Mathur G; Processing Methodologies for Polycaprolactone-Hydroxyapatite Composites: A Review, Materials and manufacturing Processes, 20: 211–218, 2006

Helen M. Woods,a Marta M. C. G. Silva,a,b Ce´cile Nouvel,a Kevin M. Shakesheffb and
Steven M. Howdle, Materials processing in supercritical carbon dioxide: surfactants polymers and biomaterials, J. Mater. Chem. 2004, 14, 1663-1678.

Cooper A. I., Porous Materials and supercritical Fluids, Adv. Mater. 2003, 15, No 13, 1049,-1059.

51. Fabrication of Porous Drug Matrices by a Hybrid Technique [Experimental based project]

The aim of this study is to assess the feasibility of utilising a hybrid technique to generate dry composite drug-excipient matrices with large surface area for various administration routes such as parenteral, mucosal, oral and topical. Microparticles of drug-excipient-pore forming agent (PFA) will be formed by the spray drying technique followed by extracting the PFA from the mixture using a technique such as dense gas process.

Background

Inhaled aerosol technology offers not only effective carriers for the treatment of respiratory disorders but presents the potential for non-invasive delivery of pharmaceuticals as well as slow and controlled release characteristics.

Inhalation aerosols traditionally comprise airborn suspensions of 1-5 μm liquid or solid particles in variable states of aggregation. The respiratory fraction of inhalation aerosol mass decreases due to aggregation between the particles. The goal of the pharmaceutical industry has been to design inhalers capable of reproducibly deaggregating aerosols, often at the expense of inhaler size and cost. It has been shown that by designing therapeutic aerosol particles with very low mass density (<0.4 g/cm^3), relatively large particles (>5 μm) can be successfully inspired into the lungs (Edwards et al., 1997).large porous particles aggregate less and de-aggregate more easily under shear forces than smaller, non-porous particles, hence they appear to more efficiently aerosolize from a given inhaler device than conventional therapeutic particles. In addition, since large particles are less likely to be phagocytosed than small particles, inhalation aerosol containing of large porous particles appear to have a special capability to release active pharmaceutical ingredient (API) into the lungs over a relatively long periods of time, an attribute that might be exploited by designing large porous particles of relatively low water solubility.

Porous particles are of particular interest in the fields of inhalation and oral drug delivery systems. The large surface area and low mass density of porous particles results in more effective aerosolization of the particles from Dry Powder Inhalers (DPIs). Modification of surface characteristic of a dry powder can have significant impact on the aerosol performance of the active compound.

In addition, the bioavailability of class II drugs is limited by poor dissolution of the drug into aqueous bodily fluids following administration. The rate limiting step may therefore be critical to rapidly attaining therapeutically effective drug levels. Traditional approaches to parenteral delivery of poorly soluble drugs include using large volumes of aqueous diluents, solubilising agents, detergents, non-aqueous solvents, or non-physiological pH solutions. These formulations, however, can increase systemic toxicity of the drug composition or damage body tissues at the site of administration.

The dissolution rate of a drug particle is directly related to its surface area available to contact the aqueous media at the site of administration or site of absorption. Particle

size reduction to micron or sub-micron range is therefore one approach to enhance the dissolution rate of a poor water soluble drug upon increasing the surface area. Submicron particles, however, have tendency to agglomerate, particularly without the presence of surface-modifying agents adsorbed or coated on the particles. Alternative methods such as utilising a hydrophilic polymer in the drug formulation can substantially promote the dissolution rate of a low soluble drug.

The objective this study is to manufacture porous micro particles of a drug and/or excipient to enhance the dissolution rate of active compound as well as promoting the aerosol performance of an API used for inhalation delivery adminstration. The combination of these two physical properties, micronization and porosity, has the potential to be utilised to greatly improve drug delivery. The porous matrix will be in a dry powder form with a TAP density of less than 1 g/mL.

Experimental
A preliminary experiment will be undertaken to assess the feasibility of generating porosity in the drug-excipient matrices using various PFA. The process involves spray drying the drug-excipient-PFA as a suspension, emulsion or solution. The pore forming agent will then be extracted from the matrix using a drying technique such as dense gas drying process at moderate temperature. The result of various drying processes on the characteristics of the powder will hence be assessed.

The optimum operating conditions for spray drying and dense gas process will be determined to fabricate drug with large surface area and low TAP density suitable for aerosol delivery. The primary system for investigation include an excipient such as mannitol and a pore forming agent such as benzoic acid and menthol with high solubility in dense gas CO_2. The feasibility of utilising polyethylene glycol (PEG, MW= 3000) as a PFA will be assessed in this study. It has been demonstrated in the literature that the melting point of PEG can substantially depressed when expose to dense gas CO_2 at high pressures. It is proposed to extract molten PEG from the solid matrix of dry powder and fabricate porosity. Once the optimum condition for generating porosity has been established an active compound will be incorporated into to the formulation.

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52. Microencapsulation Of An Enzyme/Protein With Natural Polymers Such As Polysaccharides [Experimental based project**]**

Alginate is a non-toxic, biocompatible, biodegradable, cheap and freely available polymer with numerous applications in food and pharmaceutical sciences. Alginate enhances efficient treatment of esophageal reflux, creates multiquality calcium fibers for dermatology and wound healing. It is also used for high- and low-gel strength dental impression materials. Moreover, it is an effective natural disintegrant, table to binder and offers an attractive alternative for sustained-release systems. It is a natural gum and offers advantages over synthetic polymers as it form hydrogels, All these advantages make alginates very useful material for biomedical applications, especially for controlled delivery of drugs and other biologically active compounds. Alginate is widely known to be potent metal adsorbent and therefore can be used for removing heavy metal ions from body fluids. Subsequently the alginate with adsorbed heavy metal is discharged from the body as none of the enzymes in the human body digest alginate.

A narrow size distribution of alginate beads with a high production rate is desirable to facilitate the scale-up of the process. The alginate beads are traditionally prepared by extrusion through needles into calcium solutions. Various techniques have been assessed to promote the throughput as well as alleviate the particle size distribution. However, the issues for large quantity production of alginate beads have not been addressed yet. The aim of this study is to develop a process for bulk production of micron sized beads of alginate containing a biologically active compound such as enzyme and protein. The effect of various mixing processes such as a high rotating device and/or sonication on the microencapsulation of active compound with alginate will be assessed.

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53. Fabrication Of Polyurethane Scaffolds For Soft Tissue Applications

[Experimental based project]

Scaffolds with high elasticity and strength with controllable biodegradable properties are required for soft tissue engineering. However, the majority of the developed hydrolytically degradable polymers often possess undesirable mechanical properties for soft tissue applications that are attributed to their high glass transition temperature

and high modulus. Various types of biodegradable polyurethanes have been synthesized, which are highly flexible and strong.

Different fabrication technologies have been applied to process biopolymers scaffolds, however their main disadvantages are the use of toxic solvents, removal of solvent by evaporation (days-to-weeks), labour intensive fabrication process, thin structures, irregular shaped pores, and insufficient interconnectivity. These disadvantages may be eliminated with dense gas technology.

The use of highly diffusive DGs such as carbon dioxide will assist in fabrication of controlled, uniform, interconnected nano-structure throughout the whole matrix. These materials will interact optimally with the body and will remove the necessity for cell and tissue grafting, with their inherent risks. Dense gas carbon dioxide penetrates into the polymer matrix, plasticizing the material, decreasing the viscosity and allowing the polymer composites to integrate homogeneously. The technology also overcomes disadvantages of conventional techniques by eliminating the use of organic solvents, enabling fabrication at ambient temperature and tailoring the porosity characteristics to the desired architecture. Moreover, processing by dense gas carbon dioxide has advantages of sterilising the final product without affecting the physical and mechanical properties of biocompatible polymers, hence addressing the issues related to current sterilisation techniques such as autoclaving, gamma radiation, and the use of gases such as ethylene oxide.

The aim of this study is to manufacture porous scaffold of polyurethane for soft tissue application using dense gas technology. The effect of process parameters on the mechanical properties, polymer degradation in phosphate buffered saline, scaffold characteristics, and ultimately smooth muscle cell growth will be revealed.

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54. Precision Cleaning of Biomaterials by a Solvent Free Technique

[experimental based study, require two students**]**

Cleaning of surgical devices and biomaterials requires the removal of all foreign materials. Because of infection risks associated with the reuse of certain medical instruments, such as endoscopes, effective cleaning is essential. Current methods for

cleaning rely on hand or machine washing with aqueous detergents, alcohols, or enzymatic solutions. Subsequently, sterilization is required using standard methods, including gamma-irradiation, ethylene oxide gas (ETO), hydrogen peroxide, liquid chemicals, or steam sterilization. These methods may have a detrimental effect and alter the characteristics of the surfaces of certain biomaterials. In addition, there are safety and health concerns for using chemicals such as ETO, glutaraldehyde, and hydrogen peroxide.

Polymeric biomaterials such as ultra high molecular weight polyethylene (UHMWPE) play an increasingly important role in the biomedical field. As with all materials, any polymeric biomaterial used for surgery or implantation must be sterilized prior to use. A critical objective of any sterilization process is destruction of bacteria without damaging the surface of the device, or compromising either its bulk material strength or its biocompatibility. New processes that can clean and sterilize at moderate to low temperatures continue to be developed.

Moreover, precision cleaning is required for thorough removal of oil residue retained on the surface of surgical devices and fine biomaterials fabricated from metal or ceramics. Current cleaning processes while are not efficient for entire cleaning of medical devices are also associated with consumption of large amount of organic solvents and surfactants provoking an environmental concern.

Dense CO2 is being evaluated as an alternative, chemically-benign technology for simultaneously cleaning and sterilizing certain biomaterials [1]. Its chemical inertness, non-toxicity, and low critical temperature (31.1ºC) make CO2 an especially attractive option for cleaning and removing bacteria, endotoxins, and other debris from surgical instruments and orthopedic implants [3].

The aim of this study is to assess the potential of dense gas CO2 for cleaning the surface of various surgical devices and biomaterials manufactured by Australian Surgical Design and Manufacturing (ASDM) Company. Cleaning and sterilization with CO_2 depends on many parameters such as temperature, pressure, moisture content, and treatment time [2, 3]. The effect of these variables on the removal of oil and other contaminant residues will be evaluated to determine the optimum conditions. The effect of process variables on the bulk material properties of polymeric biomaterials, adhesives and packaging materials will be assessed. The tensile strength and lap shear strength of the material will therefore be measured.

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