SCHOOL OF CHEMISTRY

HONOURS PROJECTS

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INTRODUCTION

This booklet is intended to provide an overview of the research activities within the School of Chemistry and to give you an indication of the Honours projects that are being offered. For students exploring projects for the Masters in Green Chemistry and Sustainable Technology, or for CHM2990 and CHM3990 undergraduate units, this booklet will help you find academics that may offer projects that interest you. You should contact the respective unit coordinators for enrolment information.

Current third year students are eligible to do Chemistry Honours (Clayton) provided that they fulfil the entry requirements and that a supervisor is available. You can find all of the requirements at https://www.monash.edu/science/current-students/science-honours.

You are encouraged to study the projects in this booklet and to speak with the research supervisors. This research project makes up 75% of the final mark for the Honours year, with the other 25% from the coursework component which runs in first semester. Students will be allocated to supervisors and projects on the basis of their third-year results and their preferred projects. Great care is taken to ensure that all students are treated equitably and that where possible they are allocated to the area and supervisor of their choice.

All Honours candidates must discuss prospective projects with at least four supervisors before choosing their preferred project. They should then select at least three potential supervisors and projects in order of preference. The application forms – an on-line Honours entry form *via* the Faculty of Science and a project nomination form from the School of Chemistry – are both available through the School of Chemistry Honours web page.
https://www.monash.edu/science/schools/chemistry/current-students/honours

Please note that the project descriptions are quite short, and more comprehensive details can be obtained when speaking to supervisors. Academics are listed alongside their “Enterprise Themes” which will give you an idea of the “big picture” research themes with which some of their projects align.

☼ Green Chemistry
(suitable for students in Masters in Green Chemistry and Sustainable Technology)

❤ Chem4Health

✇ Clean Energy

🍐 Smart Food

We look forward to seeing you in the Honours course next year. Please contact me if you have any questions about the Honours year, I’m always happy to chat about the course in more detail.

Assoc. Prof. David Turner
Honours Coordinator, School of Chemistry
Room 123, 19 Rainforest Walk (Building 19)
9905 6293
david.turner@monash.edu

Associate Professor Dominic Agyei

Food Chemistry • Proteins • Bioactive Compounds

dominic.agyei@monash.edu Room 227, Building 86 (Green Chemical Futures)
https://research.monash.edu/en/persons/dominic-agyei

My research centres on the use of various bio-based techniques and *in silico* tools to study the presence and mechanism behind the activities and functional properties of food bioactives and ingredients. The following undergraduate and Honours project topics are available, so please contact me to discuss more if you are interested.

1. Anti-Glycoxidative Properties of Native Plants

Glycoxidation—the combined action of glycation and oxidative stress—contributes to the development of chronic diseases like diabetes, Alzheimer's and neurodegeneration. Bioactive compounds such as especially polyphenols and flavonoids in plants have demonstrated the capacity to inhibit glycoxidative pathways by scavenging reactive carbonyl on proteins, as well as oxygen species. This project explores the anti-glycoxidative potential of selected native plants using *in silico* tools and *in vitro* glycation models. It aims to identify plant-derived inhibitors that prevent the formation of advanced glycation end products (AGEs). The expected outcome is the discovery of functional food ingredients that mitigate glycoxidative stress, promoting healthier diets and adding value to underutilized indigenous plants.

2. Protein-Nanofibrils from Fish By-Products: Preparation, Self-Assembly and Bioactive Properties

In Australia, fish processing generates substantial protein-rich by-products with untapped potential. These can be transformed into protein nanofibrils (PNFs), which exhibit unique structural and bioactive properties. However, the methods of preparation strongly the yield, structure, morphology and functionality. This project investigates the effects of different physical and enzymatic treatments on the preparation and self-assembly of PNFs derived from fish by-products. Objectives include optimizing processing conditions to enhance fibril yield and stability, self-assembly behaviour, and potential to be used as biomaterial for the encapsulation of high value compounds. The project aims to develop high-value PNF-based ingredients for use in nutraceuticals and functional foods, supporting sustainable valorisation of seafood waste streams.

3. Synthesis and Bioactive Properties of Peptide-Lipid Conjugates for Oxidative Stress Control

Oxidative stress is implicated in aging and many non-communicable diseases. Peptides with antioxidant activity can be enhanced through conjugation with bioactive lipids, improving their stability, bioavailability, and cellular uptake. This project focuses on the synthesis of peptide-lipid conjugates using enzymatic and chemical (Fmoc) methods, evaluating their antioxidant properties through in vitro assays and cellular models. Key objectives include identifying optimal conjugation site, and conjugate structures and assessing their efficacy as antioxidant compounds. The expected outcome is the development of multifunctional peptide-lipid complexes for application in functional foods or therapeutic formulations targeting oxidative stress-related health conditions.

Professor Phil Andrews

Organometallic • Main Group • Anti-microbial Resistance

✉ phil.andrews@monash.edu Room 121N, Building 23 (17 Rainforest Walk)
https://research.monash.edu/en/persons/philip-andrews

1. Combating multi-drug resistant bacteria with metal complexes (Bi *vs* Fe *vs* Ga)

In tackling the continued growth in multi-resistant bacteria and the increasing rate of antibiotic resistance, this project focuses on the development of bismuth(III) and gallium(III) compounds which show high activities against common and resistant strains of bacteria (eg MRSA, VRE). **Read more**: *Chem. Eur. J.*, 2020, doi.org/10.1002/chem.202000562

2. Development of new bismuth and gallium based anti-Leishmanial drugs *(with Dr Lukasz Kedzierski, Peter Doherty Institute, University of Melbourne)*

Leishmaniasis is a parasitic infection prevalent in the developing world. Current frontline drugs are based on Sb(V) compounds which show severe side-effects and for which resistance has begun to appear. This project focuses on developing and testing new bismuth and gallium compounds as more active and less toxic alternatives. **Read more**: *Eur. J. Med. Chem.*, 2020, doi.org/10.1016/j.ejmech.2019.111895

3. Developing new antimicrobial materials and coatings *(with Dr. Warren Batchelor, Chemical Engineering; Prof. Laurence Meagher, Monash Institute of Medical Engineering)*

This project investigates the formation of novel bismuth(III) complexes which have high antimicrobial activity and their incorporation into natural and synthetic polymers and materials. The antimicrobial activities of the new materials and their potential as 'clean surfaces' will be assessed. **Read more**: *Chem. Eur. J.*, 2018, **24**, 1 – 13. DOI: 10.1002/chem.201801803

4. Targeting Novel Chiral Heterobimetallic Main Group Complexes *(with Dr. Victoria Blair)*

This project involves the design, synthesis and full characterization of novel chiral hetero-di-anionic and hetero-bimetallic complexes of alkali metal, and d or p-block elements (eg. Zn, Cu, Al, Ga, In, Sn, Sb), and subsequent examination of their reactivity and selectivity in asymmetric synthesis and in the formation of unusually substituted heterocycles. Requires inert atmosphere handling techniques. **Read more**: *Organometallics*, 2018, **37**, 1225–1228. DOI: 10.1021/acs.organomet.8b00047

5. Heterobimetallic Compounds, Cages and Nanoparticles for Radiation Sensitisation *(with Dr. Kristof Zarschler, Radionuclide Theranostics, Helmholtz Zentrum Dresden-Rossendorf)*

Radiation therapy (RT) is a common form of cancer treatment, however the resistance of tumour cells to RT is a serious concern. One way to enhance damage to tumour cells is to employ radio-sensitisers. These are molecules, cages or nanoparticles which can increase the radio-sensitivity of tumour cells and therefore the effectiveness of the treatment. This project will explore the design and development of mixed heavy metal compounds and an assessment of their potential as radio-sensitisers for tumour cell depletion. **Background reading**: *Trends in Pharmacological Sciences*, 2018, **39**, 24-48.

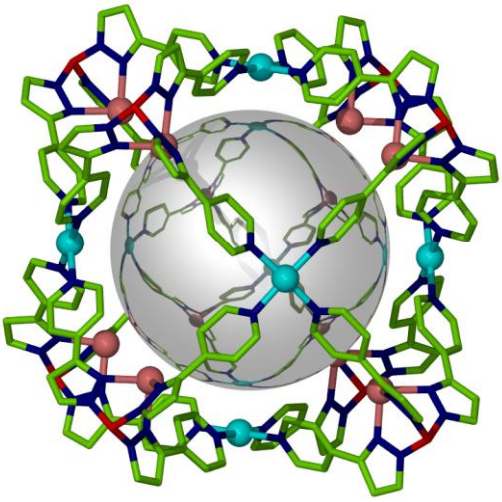
Professor Stuart Batten

Coordination Chemistry • MOFs • Crystallography

stuart.batten@monash.edu
http://stuartbatten.net
Room 121, Building 19 (19 Rainforest Walk)

Coordination Polymers and Supramolecules

We are designing and making coordination polymers (sometimes also known as metal-organic frameworks, or MOFs) and supramolecular species for a variety of interesting applications, including adsorption of gases such as hydrogen (for hydrogen fuelled cars) and carbon dioxide (greenhouse gas capture), long or short range magnetic ordering, molecular switching (for information storage or molecular sensing), and as new materials for molecular separations. We are pursuing a number of approaches to this, including:



- New classes of bridging ligands in which the bridging length can be controlled by the presence or nature of e.g. group I or II metals (*Chem. Commun.*, 2009, 5579).
- Large (3 nm in diameter) spherical supramolecules (or 'nanoballs') (*Angew. Chem. Int. Ed.* 2009, **48**, 2549 & 8919; *ChemPlusChem* 2012, **77**, 616) which show a large variety of properties. For example, they can switch between two magnetic spin states. The change may be induced by change in temperature or irradiation of light. The molecular packing also creates cavities within the solid state, and thus the crystals will readily absorb solvent vapours, hydrogen, and CO_2. Finally, the nanoballs also show catalytic activity.
- Incorporation of amine groups into porous MOFs in order to increase the selectivity of CO_2 sorption over other gases, such as N_2. These amine groups also provide sites for further reactivity after assembly of the MOF to tailor the material for specific molecular capture and separation processes.
- Porous MOFs for the chromatographic separation of molecules based on size, chirality or other chemical features. Surprisingly little work has been done in this field, and we are currently exploring this potential in depth (*Chem. Commun.* 2014, **50**, 3735).

Chemistry of Small Cyano Anions

We have been investigating the chemistry of small cyano anions (*Chem. Commun.* 2011, **47**, 10189). They have shown some remarkable chemistry, including the synthesis of a large range of transition metal and/or lanthanoid clusters which may have applications as single molecule magnets, interesting new coordination polymers and discrete complexes showing unusual packing motifs and ligand binding modes, new hydrogen bonding solid state networks, nucleophilic addition of alcohols and amines across the nitrile groups to give new anion families, and the production of ionic liquids containing either the free anions or even metal complexes of the anions. The versatility and range of applications of these simple anions is unprecedented.

Associate Professor Toby Bell

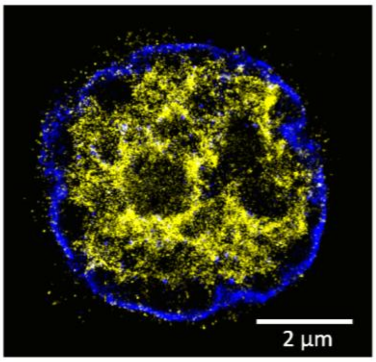
Fluorescence • Super-Resolution Imaging • Lasers

toby.bell@monash.edu
www.super-resolution.org.au
Room G32C, Building 23 South (17 Rainforest Walk)
@Bell_Fluorescence

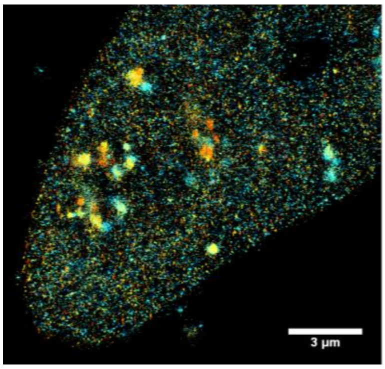
In the Bell Fluorescence Lab, we develop and apply advanced fluorescence techniques to address major research questions in multidisciplinary contexts. We operate at the ultimate level of single (bio)molecules, to perform super-resolution microscopy and see inside the diffraction limit of light. This enables us to make discoveries from within the sub-cellular milieu. All of our projects make use of our bespoke, home-built instruments and we collaborate widely across Monash, especially with the Monash Biomedicine Discovery Institute.

Ultra-resolution microscopy of epi-genetic modifications in the cell nucleus

Epi-genetic modifications to chromatin play a critical role in gene regulation and expression and are central to cell differentiation and immunological memory. We have developed new tools – ultra-resolution microscopy – capable of mapping individual histone modifications throughout an entire cell nucleus. Projects in this area will involve mapping histone modifications of known function (e.g. repressive/active with respect to gene expression) to investigate the role of spatial distribution, and visualising and characterising higher order chromatin conformations and clusters or regions with dense epi-genetic modifications. A range of cell lines can be studied including pluripotent cells and T cells. Image is of the nuclear envelope (blue) and the active histone mark H3K4me3 (yellow) in a T cell.



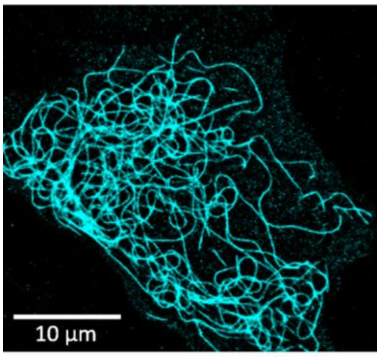
Visualising the host-virus interface



Viruses have developed sophisticated means for hijacking cellular systems for their own needs, in particular the cellular replication machinery for the production of viral proteins. A critical and not well understood aspect at the host-virus interface is how viruses supress the cellular innate immune response. Current projects in this area focus on rabies and Hendra viruses and include: how rabies virus P proteins remodel the microtubule network by 'bundling' microtubules, how this leads to interferon antagonism, investigating the role of P protein interaction with centrioles, determining where within the nucleolus Hendra M protein localises to, how M protein suppresses ribosomal RNA synthesis, and how M protein interacts with the cell's DNA damage response mechanism. Image is of a single cell nucleus with M protein 'puncta' located within nucleoli.

Discovering sub-cellular effects of anti-cancer drugs

Many current chemotherapeutic drugs have been in use for some decades with good effect. However, off-target side effects can occur leading to sub-optimal outcomes and the mechanisms causing these are not fully understood. Super and ultra-resolution imaging methods can now shed light on what effects drug molecules have at the sub-cellular level. Projects include effects of drugs such as colcemid, paclitaxel, and nocodazole, on various organelles and structures including microtubules, mitochondria and the microtubule network. The image shows aberrant curvature of microtubules in human cancer cells treated with sub-clinical levels of colcemid, a derivative of the anti-mitotic drug colchicine. Ultimately, this research could lead to improved treatment regimens and outcomes.

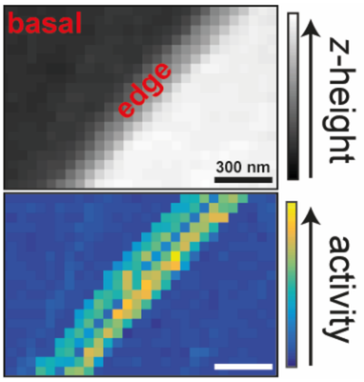


Dr Cameron Bentley

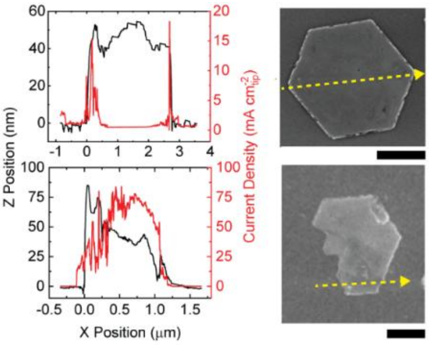
Electrochemistry • Nanochemistry • Materials Chemistry

✉ cameron.bentley@monash.edu Room G24, Building 19 (19 Rainforest Walk)
https://research.monash.edu/en/persons/cameron-bentley

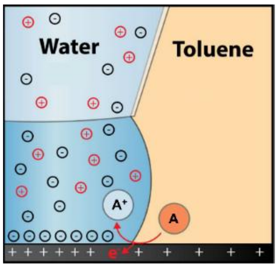
My research centres on the use of glass nanopipettes to "see" the nanoscale active sites of electrodes during operation, through high-resolution *electrochemical microscopy*. Relating electrochemical activity on this scale to the underlying electrode surface structure guides the design/synthesis of the "next-generation" of materials with higher activity, improved stability, longer cycle life etc.



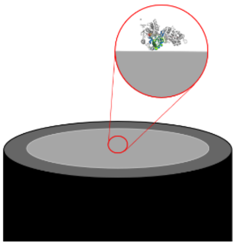
(1) Nanoscale reaction imaging of electrodes for alkaline water splitting. Electrochemical water-splitting is recognised to be one of the most promising approaches to store renewable energy in the form of hydrogen fuel. Commercially feasible water electrolysis requires the use of highly stable and active electrodes, known as electrocatalysts, to overcome the high energy barrier(s) associated with water-splitting. Identifying and characterising the active sites of electrocatalysts highly challenging but is very important to rationally design and engineer new electrodes for alkaline water splitting. In this project, the *Honours Candidate* will develop new nanoscale electrochemistry techniques (based on the use of a novel gel-based nanoscale probe) to probe the catalytic active sites of earth-abundant transition metal-based water splitting electrodes.



(2) Single nanoparticle electrochemistry. Over the past three decades, the whole of science has been impacted massively by the revolution in nanoscience. For example, nanoparticles (NPs) have found many applications in electrochemistry, such as the noble metal (*e.g.*, Pt) electrocatalysts used in fuel cells or electrolysers. With the widespread uptake of NPs in electrochemistry and beyond, there is a great demand for techniques that can answer the fundamental question: what is the relationship between structure and/or composition, and electrochemical activity at the *single particle* level? In this project, the *Honours Candidate* will address this important question by probing the structure–activity of individual noble metal NPs supported on electrode support surfaces.



(3) Multi-phase electrochemistry at the nanoscale. Coupled electron- and phase-transfer reactions are fundamentally important in many areas of modern electrochemical science, *e.g.*, electrodeposition of metals from solvated metal ions, metal corrosion in mixed solvents, cation desolvation and intercalation in lithium-ion batteries, and multiphasic photocatalytic systems *etc.* These types of reactions are typically characterised by the partial or complete replacement of the local solvent environment around the species (*e.g.*, ions) of interest. Despite their great importance, such processes are difficult to study, hindering fundamental understanding and limiting our capability to design new applications around such phenomena. In this project, the *Honours Candidate* will develop new nanoscale electrochemistry techniques to study coupled electron- and phase-transfer reactions, using the electrocatalytic oxidation of water-insoluble environmental pollutants (*e.g.*, long-chain alcohols such as dodecane) at the water|toluene|electrode three-phase interface as a model system.

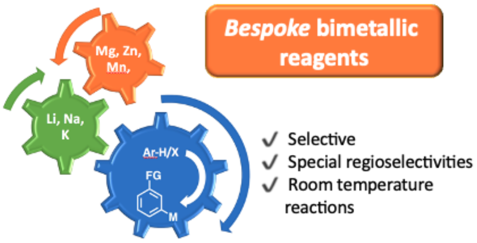


(4) Nanoscale protein film voltammetry. In the field of bioelectrochemistry, protein film voltammetry (*i.e.* the electrochemical analysis of thin films of proteins on an electrode surface) is often used for fundamental understandings of biological electron transfer and/or catalysis with wide reaching applications. The electrochemistry of metalloproteins is primarily investigated at the macroscale and is hindered by non-ideal responses (thought to arise from kinetic and thermodynamic dispersions), as well as complex electrode constructions and challenges of reproducibility. In this project, the *Honours Candidate* will use nanoscale electrochemistry to gather spatially resolved data for protein-modified electrodes (*e.g.*, CjX183 or laccase on carbon electrodes) and will investigate the origins of the non-ideal behaviour observed in traditional macroscale protein film voltammetry measurements.

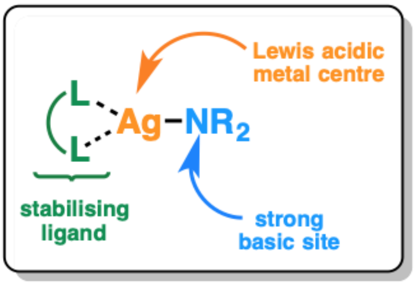
Dr Victoria Blair

Organometallic • Catalysis • Main Group

✉ victoria.blair@monash.edu
Room 111, Building 23 North (17 Rainforest Walk)
https://research.monash.edu/en/persons/victoria-blair

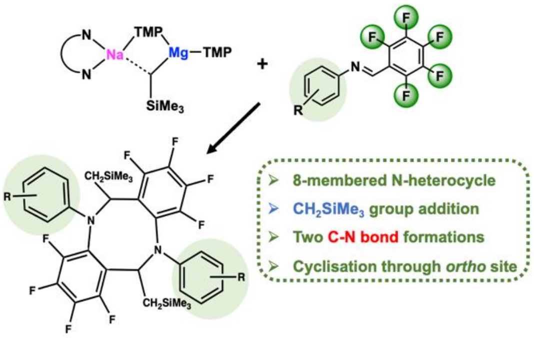


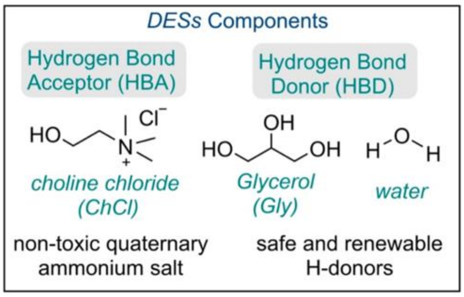
Bespoke Bimetallics: By combing the reactivity of two metal components within the one system we can make a range of bespoke bimetallic bases that have better reactivity, regioselectivity and atom economy than either of the individual mono-metallic components alone. The unique chemical cooperativity that exists allows the direct C-Mg bond formation, of various aromatic substrates offering new pathways for building molecular scaffolds applicable to the pharmaceutical, material and agrochemical industries.



Active Metal Catalyst Design: Of the Group 13 coinage metals studied as potential metal-catalyst systems silver is often overlooked due to its relatively moderate Lewis acidity, ease of reduction and photosensitivity. In our group we have been designing light stable Silver(I)amido pre-catalysts that are active in a range of hydrofunctionalisation reactions. By tailoring both the amido and stabilising ligands attached to the silver metal centre a diverse range of Ag(I) amide complexes can be synthesised which offer unique reactivity profiles yet to be explored. *see Chem. Euro. J.*, **2020**, *26*, 4947

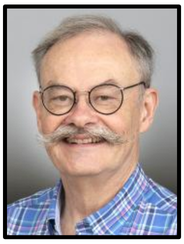
Bimetallics in hydrodefluorination: 20% of pharmaceuticals and 30% of agrochemicals synthesised today contain at least one C-F bond. Both building and removing them from molecules is a synthetic challenge – partly due to the relative chemically inert C-F bond. Our group are researching the use of bimetallic reagents (Mg/Na) to effectively remove F via C-F activation of a range of fluorinated substrates, creating new C-C, C-N or C-P bonds in their place. This methodology has uncovered some interesting and unexpected organic cyclic products!





Deep Eutectic Solvents (DES) in Organometallics: Advancing polar organometallic chemistry away from traditional volatile organic compounds (VOCs) and into more sustainable, environmentally friendly alternative reaction media is central to the green chemistry ethos of '*benign by design*'. DESs are room temperature liquids composed of a salt and a hydrogen bond donor molecule. They are cheap, non-toxic, biodegradable and can be fine-tuned for specific applications. Extending DESs to polar organometallic chemistry, in particular, traditionally air and moisture sensitive metal-mediated reactions will establish a qualitative shift in the way organometallic chemistry is designed and conducted.

Professor Alan Chaffee



Carbon • CO_2 Capture • Materials Chemistry

alan.chaffee@monash.edu Room 223, Building 23 North (17 Rainforest Walk)
https://research.monash.edu/en/persons/alan-chaffee

My group undertakes applied chemistry research on topics that are, in some way, related to biomass and fossil resource utilization. For example, new approaches to the preparation of industrial chemicals, specialty liquid fuels (eg, jet fuel), road bitumen, coke for steel making, and specialist high surface area active carbons are being developed so as to minimize energy losses and CO_2 emissions. We also investigate the capture of CO_2 emissions by adsorption and, once captured, its transformation back into useful products by heterogeneous catalysis. In doing so, innovative new materials such as mesoporous silicas, metal organic frameworks (MOFs) and ionic liquids (ILs) are employed as adsorbents, catalysts and/or solvents. These novel materials are often sourced from other research groups within the School. Molecular modeling tools are also frequently applied in these studies, so that experiment and theory inform each other.

Turning Carbon Dioxide into Fuel

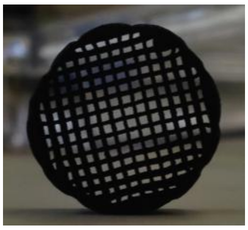
Waste CO_2, when combined with 'renewable H_2' (eg, from photovoltaic water splitting) over appropriate catalysts, leads to hydrocarbon products (methane and higher hydrocarbons, formaldehyde, methanol) which can be directly used as fuel or chemical feedstocks. We are thermally transforming metal organic framework (MOF) precursors to produce nanoparticulate catalysts of varying metal cluster size, supported on carbonaceous ribbons that seek to provide exceptionally high reaction rates and selectivity to these products.

Capturing Carbon Dioxide from Air

Prior work in the group has identified amine-based adsorbents that have the ability to reversibly capture and release CO_2 at concentrations (~15 wt%) and temperatures typical of the flue gas from power stations. Another approach to controlling CO_2 in the atmosphere could be to adsorb it directly from air at atmospheric concentration (~400 ppm). This project will prepare and evaluate new adsorbent formulations for this purpose involving high surface area mesoporous silica (such as SBA-15) as a support material.

Environmental Applications of Active Carbon Monoliths

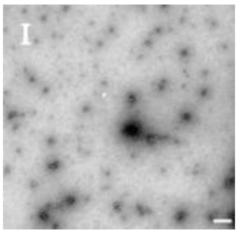
The group has recently developed a new form of monolithic carbon, derived from brown coal, that provides for efficient gas and liquid contact with low pressure drop. These materials have exceptional surface areas and, therefore, multiple potential applications as adsorbents, catalysts, electrodes, etc. Their inherent electrically conductive means that they can, in principal, be very efficiently regenerated by ohmic heating. Projects are available that investigate their performance for the removal of pollutants from gas phase (e.g., NO_x) or from liquid phase (e.g., heavy metal) streams, their regenerability, as well as optimization of fabrication methods.



Active Carbon Monolith

Quantum Dot Medicine (Collaboration with Assoc. Prof. Lisa Martin)

In recent work we have demonstrated that carbon quantum dots (CQDs), prepared from brown coal, can mitigate against the types of protein aggregation that are associated with Alzheimer's disease and Type 2 diabetes. This project will prepare a series of CQDs with varied surface functionality with a view to determining how varied chemical composition effects aggregation rates.



CQDs prevention of fibrilisation

Professor Philip Chan

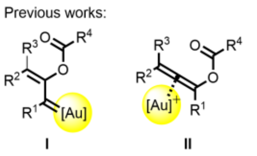
Catalysis • Organic Synthesis • Photoredox

phil.chan@monash.edu
Room 243A, Building 23 South (17 Rainforest Walk)
https://research.monash.edu/en/persons/philp-wai-hong-chan

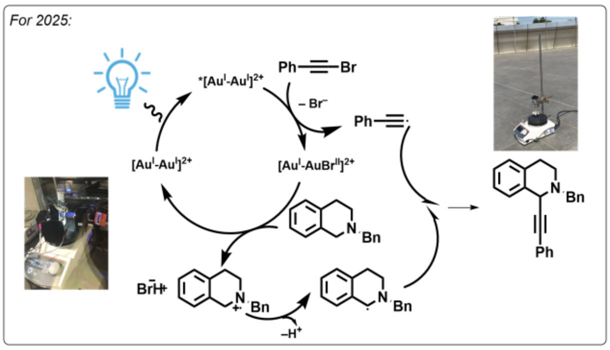
We are an organic chemistry group focused on the discovery and understanding of new and sustainable reactions through the power of homogeneous catalysis and their application to the synthesis of bioactive natural products and functional materials.

Homogeneous transition metal catalysis, photoredox catalysis and organocatalysis: new strategies for natural products synthesis and drug discovery

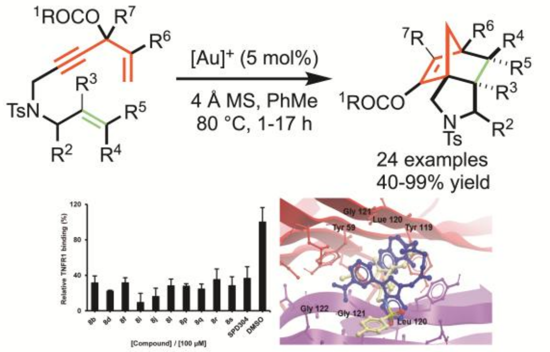
Research in our group is focused on three main areas. The first is homogeneous transition metal catalysis, one of the most powerful and stereoselective synthetic tools in the chemist's armory for the assembly of complex molecules from readily accessible precursors in a single step. In this field of catalysis, we will explore the novel reactivities of the vinyl gold carbenoid species **I** as well as those of the allenylgold intermediate **II** developed by our group in chemical synthesis.



Selected examples from our group: 1) *Angew. Chem. Int. Ed.* **2008**, *47*, 1138; 2) *Angew. Chem. Int. Ed.* **2010**, *49*, 4619; 3) *J. Am. Chem. Soc.* **2011**, *133*, 15248; 4) *J. Am. Chem. Soc.* **2012**, *134*, 7344; 5) *J. Am. Chem. Soc.* **2012**, *134*, 10811; 6) *J. Am. Chem. Soc.* **2013**, *135*, 7926; 7) *J. Am. Chem. Soc.* **2015**, *137*, 6350; 8) *Chem. Eur. J.* **2015**, *21*, 9111; 9) *Angew. Chem. Int. Ed.* **2018**, 10.1002/anie.2018-09376.

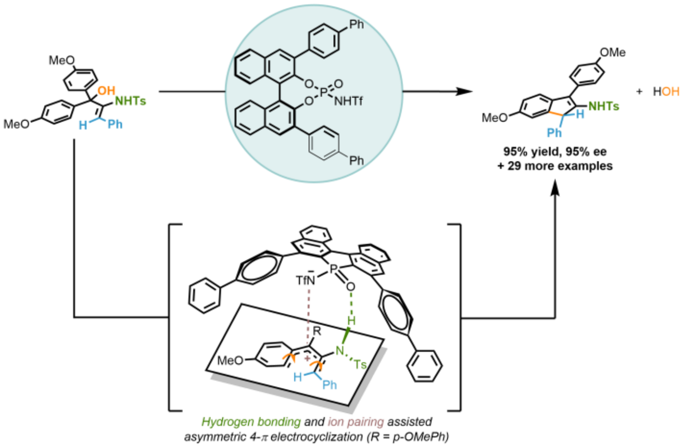


A second area of catalysis research we will focus on is the recent new discoveries from our lab in photoredox catalysis driven by either a metal or organic dye photocatalyst in the presence of a light source, which is currently a hot topic in research. The goal will be to realise new reactivities, develop new catalysts along the way and provide mechanistic insights into these novel synthetic technologies. Several Honours projects that explore this new area of catalysis are available, such as the 4-CzPN-mediated α-aminoalkylation of azomethine imines by α-silylamines under blue LED light. **Key references:** see references in the Figure and our recent review: León Rojas, A. F.; Kyne, S. H.; Chan, P. W. H. *Acc. Chem. Res.* **2023**, *56*, 1406.



biologically potent TNF-α-TNFR1 binding antagonists
(Susanti, D.; Liu, L.-J.; Rao, W.; Lin, S.; Ma, D.-L.; Leung, C.-H.; Chan, P. W. H. *Chem. Eur. J.* **2015**, *21*, 9111)

The third area of catalysis pursued in the group and one of the most powerful catalytic methods to emerge over the last two decades to rapidly achieve molecular complexity in an enantioselective manner from readily accessible precursors is organocatalysis. Our interest in the organocatalytic reaction chemistry of π-rich alcohols is driven by the ease of substrate preparation providing the possibility to introduce a wide variety of substituents. Added to this is the potential formation of water as the only byproduct that makes it a highly attractive environmentally sustainable and atom-economical approach. A recent example of this strategy is a seminal work by us revealing the first chiral Brønsted acid catalysed dehydrative Nazarov-type dehydrative electrocyclisation of aryl- and 2-thiophenyl-β-amino-2-en-1-ols to 1*H*-indenes and 4*H*-cyclopenta[*b*]thiophenes. **Key references:** see references in the Figure and our review: Ayers, B. J.; Chan, P. W. H. *Synlett* **2015**, 1305.



Professor Perran Cook

Water Chemistry • Nitrogen • Coastlines

perran.cook@monash.edu Room G25A, Building 19 (19 Rainforest Walk)
https://research.monash.edu/en/persons/perran-cook

Sand sediments dominate our coastline, yet we have little understanding of how this environment emits greenhouse gases.

Methane production in permeable sediments driven by plan metabolites

Methane is a potent greenhouse gas that is rapidly increasing the atmosphere. To manage methane emissions, we need to better understand sources and sinks of this gas. Typically, methane production in marine sediments is thought to be negligible due to methanogens being outcompeted by sulfate reducing bacteria. However, our recent work has shown high emissions of methane in Port Phillip Bay, and that plant metabolites such as dimethyl sulfide, choline and methyl amines may be important sources. This is potentially very important, because it has been proposed that seaweed farming could be used to absorb CO_2, yest little is known about its methane production potential. This project will investigate the role that plant metabolites play in methane production in coastal sediments, including the effect of species and growth conditions on this.

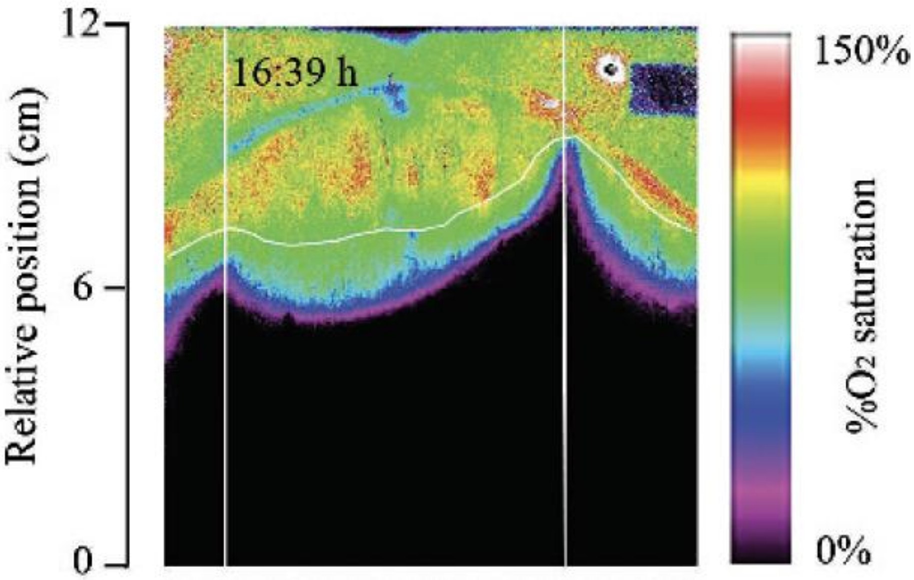


Figure shows oxygen distribution within a sand ripple. Organisms within this environment must cope with rapid shifts in oxygen concentrations. Surprisingly, this environment has the potential to produce large amounts of methane.

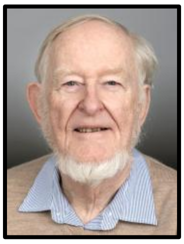
Denitrification pathways

Denitrification is a key reaction in the environment because it removes excess bioavailable nitrogen. Nitrous oxide is a key intermediate in the process and is a powerful greenhouse gas.

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

There a number of pathways and organisms that can mediate denitrification including bacteria, fungi and chemical processes. By analysing the stable isotopes of N and O in N_2O we can gain insights into the processes driving denitrification. Our recent research has discovered that chemo denitrification may be a more important denitrification pathway in coastal systems. This project will examine isotope ratios in N_2O to better understand denitrification pathways taking place in coastal systems and nitrogen rich groundwater.

Emeritus Prof. Glen Deacon



Rare Earths • Organometallic • Coordination Chemistry

glen.deacon@monash.edu
Room 136C, Building 19 (19 Rainforest Walk)
https://research.monash.edu/en/persons/glen-deacon

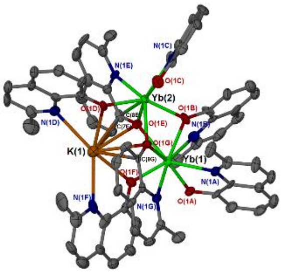
Emeritus Prof. Glen Deacon is available as a co-supervisor on the projects below (with the primary supervisor given in each case). If interested, please chat to both supervisors.

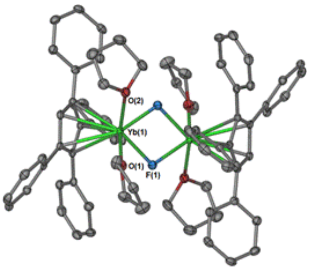
Rare earth elements (Group 3-Sc, Y, La and the lanthanoids Ce - Lu)

Rare earths are currently seen as the strategic materials of the 21st century with considerable international concern over the Chinese domination of the supply of separated elements. Our group provides fundamental knowledge to underpin industrial developments in the area. **Australia has abundant rare earth resources which have been mainly neglected** despite their widespread uses, e.g. ceramic supports for exhaust emission catalysts, alloy magnets in all car engines, and catalysts for artificial rubber production. Potential applications include green corrosion inhibitors (below). Their metal-organic chemistry is a major new frontier and is generating great excitement, for example in the discovery of new oxidation states. We are particularly interested in high reactivity rare earth organometallics (Ln-C), organoamides (Ln-NR_2) and aryloxides (Ln-OAr), and have developed unique synthetic methods to obtain them. Features of these compounds include low coordination numbers and extraordinary reactivity including C-F bond activation, the most resistant carbon-element bond. To prepare and structurally characterize the compounds represents a major challenge. Some specific projects follow:

1. **New Approaches to Metal-Based Syntheses** (with Prof. Peter Junk (JCU) and Dr Victoria Blair)
2. **Carbon-fluorine activation with reactive rare earth complexes** (with Dr Victoria Blair and Prof. Peter Junk)
3. **Heterobimetallic complexes and pseudo solid state synthesis** (with Prof. Peter Junk (JCU) and A/Prof. David Turner)
4. **Green Corrosion Inhibitors** (with Prof. Peter Junk (JCU), A/Prof. David Turner and Prof. Maria Forsyth (Deakin University))
5. **New Materials Derived from Small Cyano Anions** (with Prof. Stuart Batten)

Novel recent structures





Techniques

Inert Atmosphere handling; X-ray crystallography including Synchrotron use. X-ray powder diffraction; IR, UV-Vis, NMR spectroscopy, Mass spectrometry Pseudo solid state synthesis, solvothermal synthesis

Some recent papers

Angew. Chem. Int. Ed., 2009, **48**, 1117-1121; Chem. *Eur. J.*, 2009, **15**, 5503-5519; *Chem. Commun*., 2010, **46**, 5076-5078 ; *Chem. Comm.*, 2012, **48**, 124-126; *J. Inorg. Biochem.*, 2012, **115**, 226-239; *Chem. Eur. J.*, 2013, **19**, 1410-1420; *Organometallics*, 2013, **32**, 1370-1378; *Chem. Eur. J*., 2014, **20**, 4426-4438; *Inorg. Chem.*, 2014, **53**, 2528-2534; *Chem. Commun*., 2014, **50,** 10655-10657*; Eur. J. Inorg. Chem*., 2015, 1484-1489; *Chem.Eur.J*. 2016, **22**, 160-173; *Chem. Eur. J.*, 2017, **23**, 2084-2102; *Angew. Chem. Int. Ed*., 2017, **56**, 8486-8489; *Coord. Chem. Rev*. 2020, **415**, 213232, 1-23; *Dalton Transx.*2020, **49**, 7701-7707; *Chem. Eur. J*., 2022, **28**, e202103865 (1 - 11): *Chem. Commun*. 2022, **58**, 4344-4347.

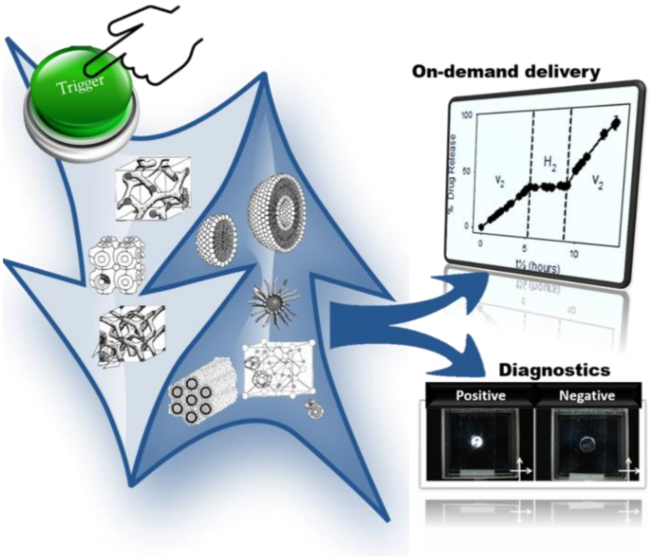
Dr Khay Fong

Microplastics • Lipids • Green Chemistry

khay.fong@monash.edu
https://research.monash.edu/en/persons/khay-fong
Room 119, Building 23 (17 Rainforest Walk)

Our research group **manipulates the dynamic spontaneous assembly of lipids** for use as on-demand drug delivery systems and diagnostic materials, and **quantifies environmental microplastics** to contribute to the global conversation about this generation's pollution problem.

Below is a snapshot of our ongoing projects if you see anything of interest, we can discuss your potential honours project on one of these topics further – please don't hesitate to contact me on the details above!



Directing self-assembly

Lipids self-assemble into a variety of nanomaterials when exposed to aqueous conditions. These materials have unique optical and diffusion properties based on their nanostructure. We look at how we can deliberately manipulate their assembly for biopharmaceutical and environmental applications.

Projects in this theme involve formulation, synthesis, colloidal and nanoscale characterisation and the utilisation of scattering techniques at large national facilities such as the Australian Synchrotron and the Australian Nuclear Science and Technology Organisation (NSW).

We're currently looking at:

1. How our native biomacromolecules and our microbiome effect their use **as drug delivery systems.**
2. The **formulation and delivery** of poorly water-soluble drugs and biologics.
3. Incorporation of colorimetric molecules for the detection of environmental pollutants.

Environmental microplastics

Plastic pollution represents one of the most pressing environmental challenges of our time. What were once revolutionary materials designed for durability have become persistent pollutants that fragment into microplastics throughout our oceans and ecosystems.

We collaborate with international partners and NGOs to design citizen science expeditions and provide them with data to help with their advocacy. Back in the laboratory, we employ advanced analytical techniques including FTIR spectroscopy coupled with artificial intelligence to characterise plastic pollutants at the molecular level.

Our approach goes beyond traditional environmental monitoring. We translate scientific findings into actionable insights that inform community decision-making and contribute to evidence-based policy discussions on plastic pollution mitigation. This creates a powerful feedback loop between rigorous analytical chemistry and real-world environmental solutions.

Research opportunities span multiple disciplines:

- Advanced analytical and environmental chemistry techniques
- Human health impact assessment of microplastic exposure
- Science communication and community engagement methods
- International collaborative research experiences

Students joining our group will develop expertise in cutting-edge analytical methods while gaining experience in interdisciplinary research that bridges laboratory science with community-based environmental action. This work offers the opportunity to contribute meaningful solutions to one of the world's most urgent environmental challenges.

Associate Professor Alison Funston

Nanoscience • Nanoparticles • Exciton Science

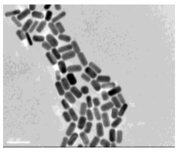
✉ alison.funston@monash.edu
Room G32B, Building 23 South (17 Rainforest Walk)
https://funstongroup.monash.edu/

Research Area – Nanoscience

Towards functional super-nanostructures (nanoparticle 'machines')!

When matter is divided into tiny particles, that is, into crystals of nanometer sizes (1 nm = 1×10^{-9} m), its properties change. Very tiny spheres containing 1000 gold atoms are red. The colour of tiny spheres of semiconductor materials only a few nanometers in diameter can be tuned across the visible region by changing their size. This effect is due to quantum confinement and the spheres are called quantum dots (QDs). The colours of nanoparticles can be controlled by:

Changing the size or shape of the crystal
Changing the environment of the crystal
Bringing two or more nanocrystals into close proximity



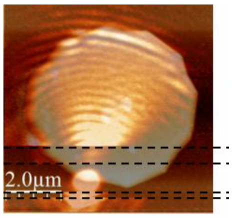
The nanocrystals have potential applications in energy harvesting for solar energy, nanoscale energy transfer, sensing, and medicine (drug delivery, cancer therapies). We research ways to manipulate the way light energy is absorbed, transported and transformed in advanced nanoscale materials for:

- Nanoparticle machines/functional nanostructures
- Solar energy conversion
- Energy-efficient lighting and displays
- Security labelling and optical sensor platforms

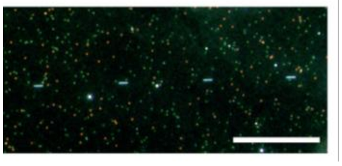
Australian Research Council Centre of Excellence in exciton science

Our research involves synthesis, DNA-based self-assembly and investigation of the optical properties of nanocrystal systems. We investigate the mechanism of growth of nanocrystals, making use of electron microscopy (TEM and SEM). We use advanced spectroscopy and microscopy techniques to measure the optical properties of ***single nanoparticles*** and ***single nanoparticle superstructures***.

Potential honours projects include:

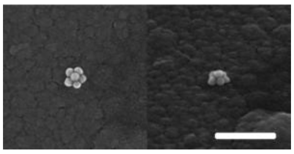


Capturing Light and Manipulating Transport through Nanoscale Structures: This is important for solar cells and solar energy harvesting. Projects include energy or electron transfer between nanocrystals, across interfaces and in self-assembled films.



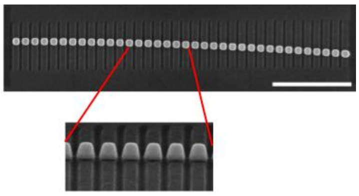
Changing the Colour of Nanoparticles - Nanoparticle Coupling: Assemblies of nanocrystals have optimal characteristics for many applications. This project aims to make, understand and use these.

Perovskite Particles – Halide Diffusion: Perovskites are a new class of materials which have shown great promise in solar cells and as sensors. These applications are affected by the halide composition of the crystal. This project aims to understand halide diffusion at the interface of perovskite micro- and nanocrystals.



Nanoparticles and Nanowires as Nanoscale Optical Fibres: Nanowires are able to transport energy below the diffraction limit of light. This project will investigate how the three-dimensional shape of the nanowire changes the efficiency of the energy transport.

Synthesis of Nanoparticles: Silicon nanoparticles are a low-cost, low-toxicity potential alternative to traditional nanoparticle materials which utilize heavy atoms such as cadmium. This project aims to synthesise silicon quantum dots, which emit blue light, and larger particles.



Dr Felipe García

Mechanochemistry • Main Group • Mitochondria

felipe.garcia@monash.edu
Room 124, Building 23 North (17 Rainforest Walk)
https://research.monash.edu/en/persons/felipe-garcia

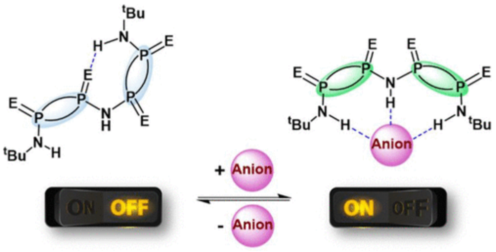
We focus on the synthesis of a wide range of main group compounds and transition metal complexes to be used as building blocks for materials with technological and biological significance. Our primary interest lies in developing new, straightforward, and well-defined synthetic strategies for systematically assembling these compounds, many of which have been scarcely explored but hold significant potential for future applications in materials science, biology, and catalysis. For further details email: felipe.garcia@monash.edu.

Mechanochemistry for main group synthesis and catalysis.

Traditional chemical thinking, rooted in Aristotle's idea that *'compounds do not react unless fluid or dissolved,'* has long upheld the assumption that solvents are essential for molecular synthesis. While solvents facilitate reactions and product purification, their widespread use is increasingly recognized as unsustainable. In response, mechanochemistry has emerged as a powerful solvent-free alternative.

This project aims to mechanochemically produce a diverse range of metal complexes and explore their application in solvent-free catalysis and small molecule activation. Representative reference: *Chem. Sci.*, **2023**, *14*, 12477-12483.

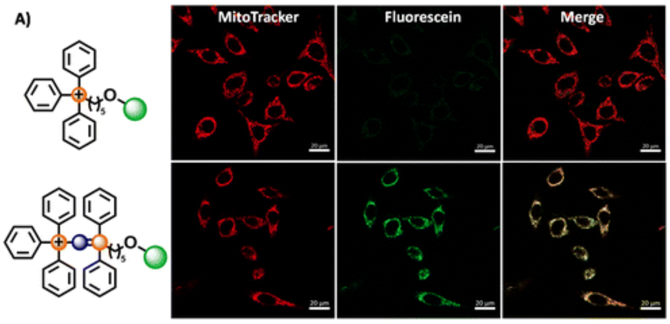
Fully inorganic molecular machines and sensors



Artificial molecular machines have been a focal point in chemistry for over two decades. Traditional molecular machinery, such as rotaxanes, rotors, and switches, largely relies on organic compounds for structure and function. However, the potential of main group elements, particularly from the p-block, remains relatively untapped in this area.

This project aims to produce PN molecular building blocks for the assembly of fully inorganic and hybrid organic-inorganic molecular machines, with a focus on their implementation in molecular sensing. Representative reference: *J. Am. Chem. Soc.* **2023**, 145, *23*, 12475–12486

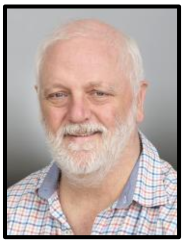
Fully Enhanced Mitochondrial Accumulation for Improved Therapeutics



Mitochondrial targeting is a promising strategy for treating metabolic, degenerative, and hyperproliferative diseases, as mitochondria play crucial roles in essential cellular functions. Triphenylphosphonium (TPP+) moieties, the current 'gold standard,' have been widely employed as mitochondrial targeting vectors for various molecular cargos. Recently, further optimisation of the TPP+ platform has gained attention to enhance mitochondrial therapies, although its core structure remains largely unchanged.

This aims to produce conventional (TPP^+ based) and non-conventional (PN^+ based) frameworks to be used as novel mitochondrial delivery vectors. Representative reference: *Chem. Sci.*, **2023**, *14*, 4126-4133

Associate Professor Mike Grace



Water Chemistry • Ecology • Analytical Chemistry

✉ michael.grace@monash.edu Room G25C, Building 19 (19 Rainforest Walk)
🌐 https://research.monash.edu/en/persons/michael-grace

These projects can be modified to suit the interests of the student – from physical, analytical and/or environmental chemistry and biogeochemistry through to aquatic and microbial ecology.

1/ Are pharmaceuticals threatening key aquatic ecosystem processes?

Awareness of the effects of common pharmaceuticals on organisms (insects, fish) living in streams and lakes has slowly but definitively emerged over the last decade. Despite their prevalence in urban waterways, there has been almost no published research on how these pharmaceuticals can affect rates of fundamental ecosystem processes. Work in our group has shown that some of these chemicals can have dramatic effects. This project will use novel pharmaceutical diffusing substrates and bioassay techniques to investigate effects of common drugs like antibiotics, mood modifiers, painkillers and antihistamines on a range of fundamental ecosystem processes including photosynthesis, respiration, biomass accrual and denitrification in urban waterways.

2/ Emerging Organic Contaminant effects in porous sediments e.g. Port Phillip Bay

Pharmaceuticals, personal care products (including Triclosan) and other organic chemicals including herbicides and pesticides are constantly being discharged into Port Phillip Bay from the Western Treatment plant and tributaries such as the Yarra River and Mordialloc Creek. This project will examine the impacts of such chemicals on near shore, sandy environments from the bay. The focus will be on assessing how environmentally relevant concentrations of some of these chemicals alter rates of organic carbon decomposition (respiration) and nutrient cycling. LC-MS/MS will be used to measure the concentrations of the target organics in the tributaries and flow-through reactors (pictured) will be used as experimental mesocosms.

3/ A biogeochemistry project based on your interests

I'm very happy to co-design an Honours project with you based on any specific interests (e.g. sites, pharmaceuticals/other contaminants, types of studies etc) you have.

Dr Joel Hooper

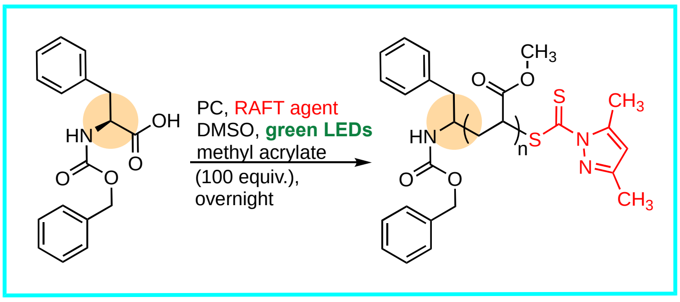
Organic Chemistry • Cellulose • Peptides

joel.hooper@monash.edu Room 242, Building 23 South (17 Rainforest Walk)
https://research.monash.edu/en/persons/joel-hooper

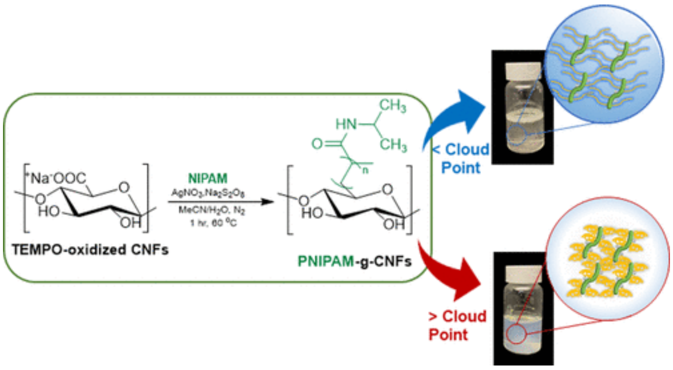
Our group is focused on the development of novel catalytic reactions, and their application to the synthesis of small molecules and materials.

Radical decarboxylation for polymer synthesis and materials science

The radical decarboxylation of carboxylic acids is a powerful method to generate carbon-centred radicals. We are applying this approach to the synthesis of highly functionalised RAFT polymers, thermoresponsive cellulose materials and functionalised graphene materials.



Sustainable chemistry for cellulose materials

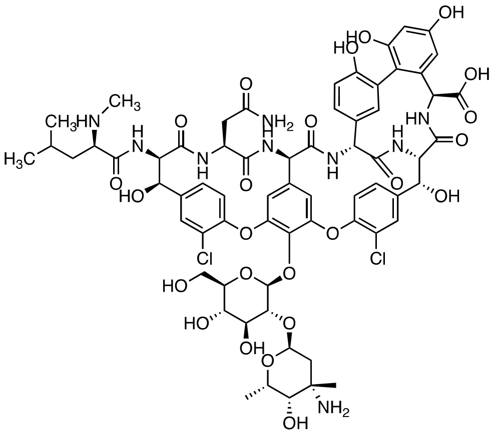


Cellulose is the most abundant polymer on earth, and an invaluable material for sustainable materials and chemical production. We are developing green catalytic processes to convert cellulose into functional and commercially valuable materials for the biotechnology, mining and materials industries. And we aim to do it all in water.

This project is in collaboration with Prof Gil Garnier in Chemical Engineering and the BioPRIA research instate.

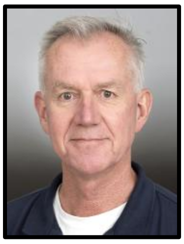
Unnatural amino acids in peptide-based antibiotics

Ribosomally synthesised and post-translationally modified peptides (RiPPs) are a class of peptide-based natural products that have a wide range of biological functions, including antimicrobial activity. We are interested in the synthesis of unnatural amino acids as substrates for enzymatic post-translational modification. This involves the synthesis of novel compounds and their isotopically labelled analogues, and testing in collaboration with Prof Max Cryle in Monash Biochemistry.



Representative publications: Hayne, Hooper, Henderson *Chem. Commun*, **2023**, 9860; Mendoza, Garnier, Hooper *Macromolecules*, **2023,** 56, 3497; Ayuruni, Hooper, *JACS Au, **2022**, 2, 169.*

Professor Cameron Jones



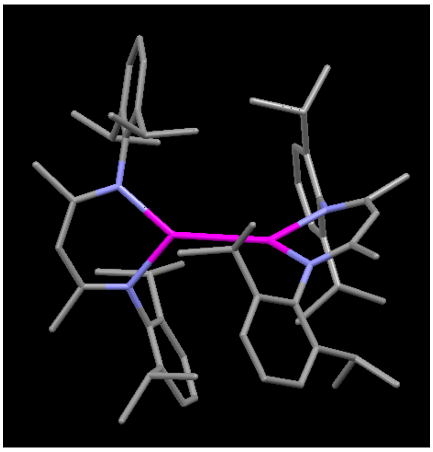
Organometallic • Synthetic Chemistry • Catalysis

cameron.jones@monash.edu Room 110, Building 23 North (17 Rainforest Walk)
www.monash.edu/science/research-groups/chemistry/jonesgroup @Jones_Research

Modern Main Group Chemistry

In the past 10 years remarkable progress has been made in the chemistry of very low oxidation state and low coordination number s- and p-block compounds. It is now possible to prepare and investigate the fascinating reactivity of compounds that were thought incapable of existence until a few years ago. The fundamental and applied aspects of this area are rapidly expanding in the Jones group (see group website for further details). Representative examples of the many potential Honours projects that are available within this exciting area are as follows:

(i) Stabilisation and application of complexes of Group 2 metals in the +1 oxidation state.

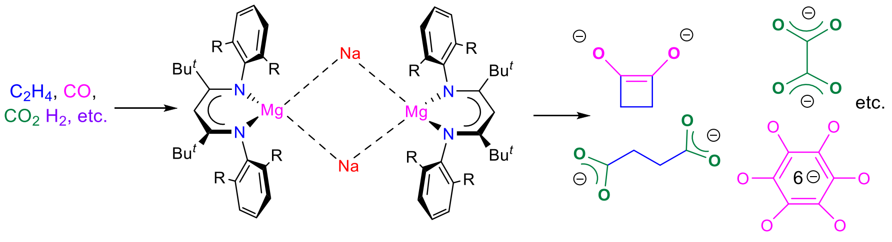


It has previously been only possible to prepare compounds containing the Group 2 metals (Be, Mg or Ca) with the metal in the +2 oxidation state. We have reversed this situation with the landmark preparation of the first thermally stable compounds to contain Mg-Mg bonds (*e.g.*, see picture). The formal oxidation state of the magnesium centres in these compounds is, therefore, +1. As a result, these species are highly reducing, a situation which has lent them to use, in our laboratory, as specialist reagents in organic and organometallic synthetic methodologies. You will further explore this potential, in addition to examining the possibility of preparing the first dimeric calcium(I) compounds. Furthermore, you will examine the use of such systems (and magnesium(I) compounds) for the reductive transformation of normally inert small molecules (*e.g.*, CO, N_2, H_2, C_2H_4 and CO_2) into value added organic products. In this respect, the group 2 metal systems can be seen as soluble models to study the mechanisms of important industrial processes that normally need expensive and toxic transition metal catalysts to proceed, *e.g.*, Fischer-Tropsch, Haber-Bosch, hydroformylation etc.

See (i) *Science*, 2007, **318**, 1754; (ii) *Angew. Chem. Int. Ed.*, 2023, **62**, e202308347; (iii) *Angew. Chem. Int. Ed.*, 2021, **60**, 630; (iv) *J. Am. Chem. Soc.*, 2019, **141**, 8764; (v) *Angew. Chem. Int. Ed.*, 2019, **58**, 11459.

(ii) Accessing magnesium(0) compounds using mechanochemistry (with Dr. Felipe Garcia)

Very recently, we have extended the low oxidation state chemistry of magnesium to the 0 oxidation state. In this joint project, similar compounds will be sustainably prepared by reduction of magnesium(II) precursors with sodium metal using mechanochemical techniques in the absence of solvents. the potential for the magnesium(0) compounds to undergo redox (0/+2) catalysis with gaseous small molecules (e.g. CO_2, CO, H_2, N_2 etc.) to give value added organic products will then be explored. In the project you will gain skills in organometallic synthesis and mechanochemistry.



See: (i) *Angew. Chem. Int. Ed.*, 2025, **64**, e202500264; (ii) *Commun. Chem.*, 2020, **3**, 159.

Dr Kamila Kochan

Spectroscopy • Imaging • Anti-microbial Resistance

kamila.kochan@monash.edu Room G20, Building 23 South (17 Rainforest Walk)
https://research.monash.edu/en/persons/kamila-kochan

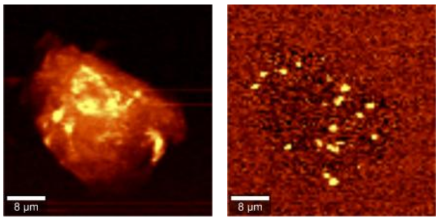
Research Overview

My group focuses on applying cutting-edge vibrational spectroscopy techniques to address medical and clinical challenges. These include nanoscale methods like AFM-IR imaging and advanced Raman techniques, alongside more established approaches such as Infrared (IR) spectroscopy. By integrating advanced AI-driven chemometric analysis, we aim to extract detailed molecular insights from biological materials like tissues, cells, bacteria, and single virions.

We offer a variety of research projects suitable for Honours students, which can be tailored to your specific interests.

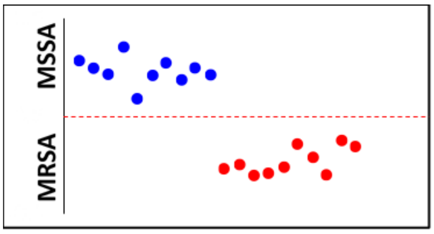
Key Research Areas

Antimicrobial Resistance (AMR)

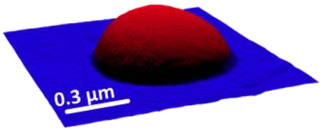


Raman imaging of infected cells

AMR represents a critical global health threat, with resistant bacterial strains developing and spreading rapidly. Projections suggest AMR could become the leading cause of death by 2050, largely due to the overuse and misuse of antibiotics in humans, animals, and agriculture. While the molecular mechanisms driving resistance remain poorly understood, our research aims to close this gap by studying the chemical changes that underlie resistance to key antibiotics, including quinolones, glycopeptides, and β-lactams. Additionally, diagnostic methods for detecting AMR remain slow and inefficient, leading to delays in appropriate treatment. By utilizing advanced vibrational spectroscopy techniques, such as Raman and AFM-IR, combined with AI-based analysis, we explore both the mechanisms of resistance and the development of faster, more reliable diagnostic tools, such as portable ATR-FTIR devices.



- ***Development of Rapid Diagnostic Tools for 12 Global Priority Pathogens***
  We are developing a rapid diagnostic test based on ATR-FTIR combined with machine learning algorithms to quickly and accurately detect antibiotic resistance in 12 global priority pathogens. This approach could significantly reduce the time needed to identify resistant strains and contribute to the global fight with the AMR crisis.
- ***Nanoscale Imaging of Bacteria***



AFM-IR imaging of MRSA

Using advanced techniques like AFM-IR, we investigate bacterial resistance mechanisms at the nanoscale level, focusing on how bacteria respond to antibiotics and how combinatory or suppressive drug interactions work. This research seeks to uncover new insights into resistance mechanisms and guide innovative treatment strategies.

Bacteriophage Research

Phages, which target and destroy bacteria, represent a potential alternative to antibiotics in fighting resistant strains. Our research explores how bacteriophages interact with bacterial cells, using nanoscale imaging and vibrational spectroscopy to uncover the molecular mechanisms of phage action. We aim to understand how phages overcome bacterial defences and how they can be used in combination with antibiotics to enhance treatment efficacy.

Women's Health: Studies of Birth Injuries

We are applying vibrational spectroscopy to investigate the molecular changes in tissues and cells affected by birth injuries. This project seeks to identify biomarkers for early tissue damage, helping to better understand the healing process and improve outcomes for maternal health. Through this research, we aim to contribute to the development of more effective therapies for birth-related injuries.

Professor Tanja Junkers

Polymers • Automation • Digital Chemistry

tanja.junkers@monash.edu Room 220A, Building 23 North (17 Rainforest Walk)
www.polymatter.net

The Polymer Reaction Design group (www.polymatter.net) strives for the development of new materials via state-of-the-art polymer synthesis methods. From fundamentals and kinetics of polymerizations to the design of new polymer reaction pathways, all elemental steps are addressed and custom-made materials are constructed.

PRD
POLYMER REACTION DESIGN

From traditional chemistry to digital synthetic chemistry

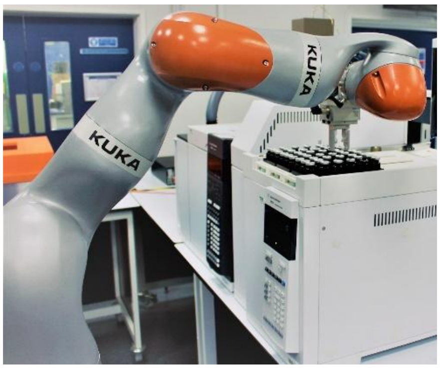
In our group we offer many different projects, ranging from traditional synthetic chemistry over polymer engineering to kinetic and mechanistic studies of polymerization. We are mainly interested in:

- **Bridging synthetic and natural polymers**

We use methods of controlled polymerization to synthesise so called sequence-controlled oligomers. These oligomers resemble classical polymers in their backbone structure, but carry the same depth of information in sequence information as a peptide. The aim is to synthesise such oligomers and test them towards their efficiency in biomedical application, i.e. cell adhesion, antimicrobial properties, etc.
Suitable for: Students with strong interest in wet chemistry and advanced modern polymer chemistry.

- **Automation of polymerization**

Automation is the future of chemical synthesis, we strongly believe in this. To automate our processes, we use continuous flow chemistry methods and laboratory robotics. With these high-throughput tools we can rapidly screen reactions with our benchtop NMR, HPLC, FTIR or DLS monitors. The aim is to optimize reactions, and to provide high quality materials for testing. In this way we can screen reactions in few days that conventionally would take months to carry out. This includes synthesis of bioderived and biodegradable polymers.
Suitable for: Students with strong interest in modern polymer chemistry, and who like to play with technical setups, robots and instrumentation.



- **Developing tools for digital synthetic chemistry**

After automation comes data processing. Based on data acquisition, data mining, and cloud collaboration with other laboratories, we want to transform chemistry into a domain that produces ‘big data’. With that at hand, we work with data scientists to use machine learning on every possible level in the synthesis process. Be it in prediction of reactions, analyzing existing data, correlating physical features of materials. Yet, we don’t just want to understand correlations, we want to use them directly in synthesis. Think of a reactor that has access to all previous data via the internet from other laboratories, and that then can independently carry out the desired reaction by itself. This is where we want to get to.
Suitable for: Students with strong interest to combine data science with synthetic chemistry. Knowledge of how to use Python is advantageous.

Professor David Lupton

Reaction Discovery • Organic Synthesis • Catalysis

david.lupton@monash.edu
http://users.monash.edu.au/~dwlupton/index.html
Room 238, Building 23 South (17 Rainforest Walk)
@LuptonChemistry

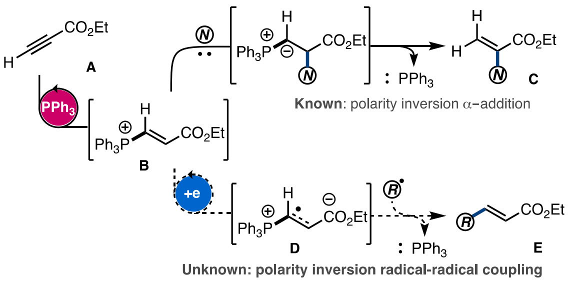
Our group is interesting in the science of:

- **The Discovery of New Chemical Reactions** (*see Project A*)
- **The Development of New Synthetic Strategies** (*see Project B*) *and*
- **The Synthesis of Complex Molecules designed for Function** (*see Project C*)

For more details about our projects arrange a chat with David.

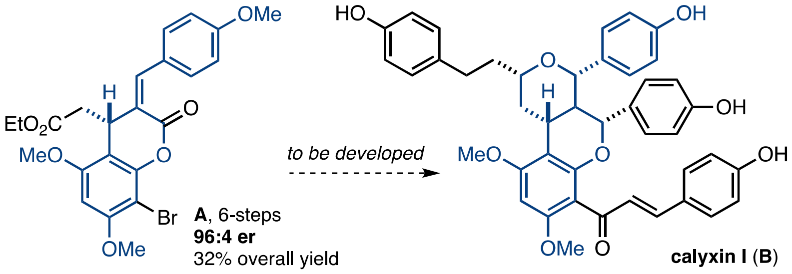
Project A*:* Can polarity changes allow radical reactions?

Organocatalysis with alkynes (**A**) and triphenyl phosphine gives the polarity inverted species **B** which can couple with nucleophiles to give product **C**. Recently we commenced studies examining the single electron reduction of **B** to give **D**. These studies have enabled a novel radical addition to give **E**. *Studies in this project are focused on learning just how general this new reactivity pattern is.*



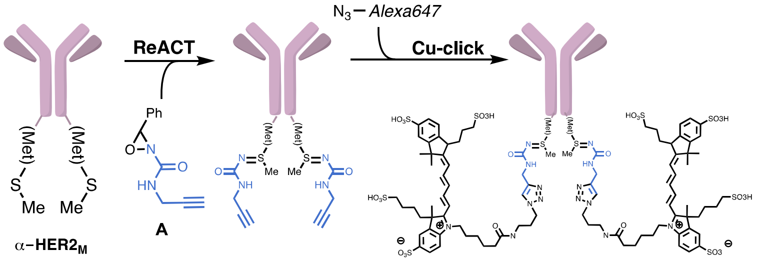
Project B: Enantioselective synthesis to calyxin I

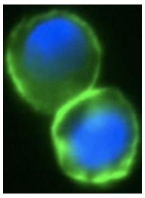
Earlier studies in our group have developed a simple route to lactone **A**. In this project we will develop a synthetic strategy to convert this material through to calyxin I (**A**). This molecule has undeveloped bioactivity and is yet to made by chemical synthesis.



Project C: Bioconjugation at methionine

Chemical probes that allow bioconjugation are usefull in chemical biology. Recently we prepared the methionine labelling **A** and developed an antibiody tagged fluorophore selective for cancer cells. *Studies this year are focused on developing a new generation of such probes that are easier to make, more robust and more flexible.*





Dr Shahnaz Mansouri

Food Chemistry • Education • Food Processes

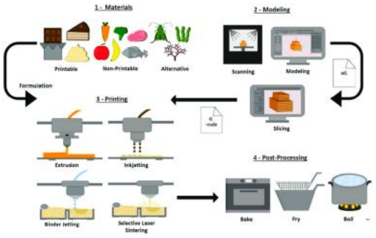
shahnaz.mansouri@monash.edu
Room G25B, Building 19 (19 Rainforest Walk)
https://research.monash.edu/en/persons/shahnaz-mansouri

The following information will give you some ideas about the types of research I am undertaking with my research partners. If you have any further queries, please do not hesitate to contact me.

Food Science, Process, Chemistry

Food 3D Printing

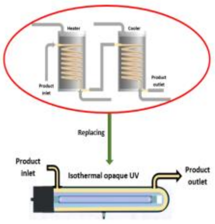
The personalising food request is growing dramatically. It has stimulated a period of innovation and investigation by developing techniques to customise functional foods' texture, flavour and nutritional contents. In this situation, three-dimensional (3D) printing technology is developing quickly to create complex edible shapes, simultaneously enabling alteration of food texture and nutritional content required by specific diets and covering wide nutrition requests.



UV Applications in Food and Beverage

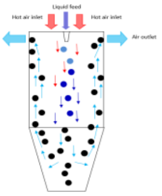
UV technology has been successfully used in various food and beverage industries to treat incoming water, syrups, clean-in-place water, filter systems, wastewater, and surface packaging. However, the direct application in beverages, juices, and milk is still under research.

In this project, we will apply Ultra-fast isothermal pasteurisation of opaque beverages using microcapillary membranes irradiated with UV light to replace the heating process for juices.



Spray Drying Process

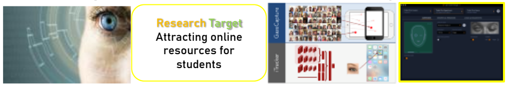
The spray Drying technique is one of the best pharmaceutical and food product drying processes, preferred methods for the production of powders from aqueous (and/or organic-aqueous) solutions or suspensions.



Educational Research

Eyes-Tracker Device and using Gaze-Capture by Eye Movements on Developing Virtual Education

This research aims to show how eye-tracking technology can be employed to develop online teaching resources and enhance classroom engagement skills by collecting data from wearable eye-tracker.

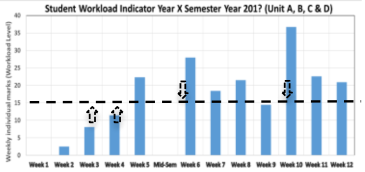


The target is focused on investigating text density through slides by aiming to look at included spacing, text size, and use of images by designing the platform in advance.

"Give me a pause, please!"
Student Weekly Workload Evaluation

Assessment tasks contribute to students' workload. Many students report that they are overloaded. Some students report that they cannot finish all assessments on time, especially in particular weeks across the semester.

- Has the workload balanced across the semester?
- Can we predict student workload?
- Can we help students to have less overload?
- Can we have a better understanding of the assignments due?
- Providing better assignment timelines will engage students to perform better with less pressure.



Associate Professor Lisa Martin

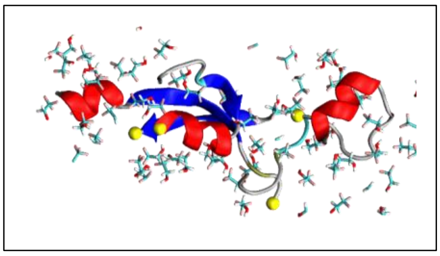
Peptides • Biochemistry • Medicinal Chemistry

lisa.martin@monash.edu
Room 157, Building 23 South (17 Rainforest Walk)
https://research.monash.edu/en/persons/lisa-martin

This page will give you an idea of some of the broad research projects in my group, so if you are interested or want more details, email me and we can arrange a time to discuss these project areas.

Bioinspired Chemistry: Many of the global challenges facing us are in biomedical science; however, these problems need an understanding and knowledge of basic molecular and electronic properties. The Martin group draws on these analytical tools for projects in medicine and biology.

1. Is Alzheimers Disease linked to an aberrant antimicrobial peptide? (with Prof. Ajay Panwar, IITB)



A number of neurological diseases are linked to protein or peptide aggregation, such as, Alzheimer's Disease (AD). In fact, ~70% of all late-onset dementia cases are due to AD and with an aging population in Australia, intense research is therefore required to find better therapeutic approaches. Although there are several treatments available for AD, these can only manage the disease and offer no reversal. Currently there is no cure.

Here, we study the favourable properties of the Uperin family of antimicrobial peptides produced via dorsal secretions of the Australian Toadlet, to probe the fundamental molecular basis of peptide self-assembly. An understanding of the self-assembly process and drivers of peptide aggregation will direct future treatments for amyloid diseases.

Three projects are available and uses a combination of experimental and *in silico* simulation methods to explore the secondary structural transitions that Uperin, a frog peptide undergoes when transitioning from a soluble (random coil) peptide into an amyloid (β-sheet-rich) aggregates. These projects include:

(i) Uncovering the of molecular transitions in amyloid formation – the role of the C-terminus;

(ii) Revealing the mechanistic link between antimicrobial and amyloid forming properties;

(iii) Designing novel antimicrobial peptides to inform therapeutics.

2. The Evolution and Impact of Steroid Hormones: From Marsupials to Adrenal Cancers

Steroid hormones are necessary for a wide range of metabolic functions; salt balance; metabolic processes and the biological synthesis of cholesterol, androgens (male hormones) and oestrogens (female hormones). For species to survive these essential hormones have evolved dramatically. For example, as amphibians transitioned from the sea to land, there was a need to evolve a way of retaining salt, which although in high abundance in sea water, needed to be regulated by the kidneys on land. Most steroid hormones are synthesised in a pathway which uses redox active metalloproteins to chemically modify steroids for specific functions. These subtle chemical modifications that impact on the function of the hormone can vary across species. There are also links to malfunction of these hormones and this can lead to adrenal cancer, prostate cancer and breast and ovarian cancers.

Some Aussie species; Emu, Platypus, Wallaby

Two projects are available:

(i) Collection of samples (faeces, serum, tissue) from unique Australian species to compare the evolution of steroid hormones in Australia (for example, compare the tammar wallaby (a marsupial); echidna (a monotreme) with lungfish (ancient fish with both gills and lungs) using liquid chromatography coupled with mass spectrometry.

(ii) Structural analysis of protein/enzymes responsible for steroid hormone biosynthesis (cytochrome P450s) to understand the protein-protein interactions that regulate steroid production. X-ray crystal structures | AI predictive (AlphaFold) 3D structural models and Molecular Dynamics will be used.

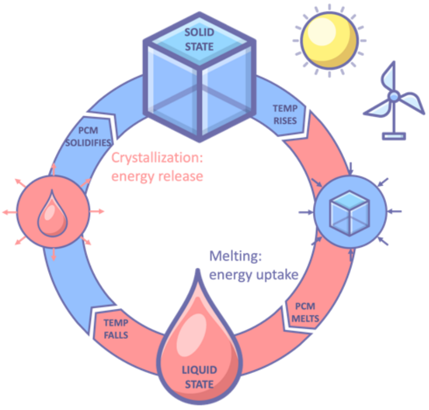
Dr Karolina Matuszek

Energy Storage • Electrolytes for Batteries • CO_2 Capture

karolina.matuszek@monash.edu Room 331, Building 86 (Green Chemical Futures)
https://research.monash.edu/en/persons/karolina-matuszek

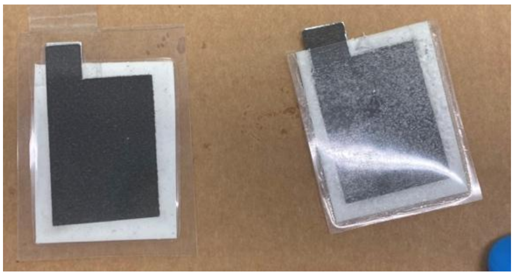
My research interests revolve around materials discovery and design for various energy storage applications. My primary objective is to develop a cost-effective technology capable of storing large quantities of renewable energy reliably and durably. If you are interested in materials design and physical chemistry - I am offering Honours projects in three different areas:

The Carnot Battery – the Future of Renewables (with Prof. D. MacFarlane or A/Prof. R. Tabor)



Intermittency of renewable energy sources can be overcome with efficient energy storage technologies, where thermal energy storage (TES) is one of the options. TES can be achieved in many ways, such as using phase change materials (PCMs). PCMs are classified as materials in which heat is absorbed when the material undergoes a phase transition, usually melting, and the heat can be released upon crystallization or solidification. The amount of energy needed to melt the material, the heat of fusion (ΔH_f), is one of the primary properties of PCMs, while its melting point determines the application temperature range (have a look at my recent paper in Chem.Rev 2023 for more detail). If you chose this project, you will be working on the design and synthesis of new intermediate temperature range PCMs (T_m: 100-220 °C) that can be applied in the Carnot Battery technology. This "battery" allows storage of electricity in the form of heat and then regeneration of the electricity. This project includes also study of the materials using differential scanning calorimetry (DSC), single crystal X-Ray and/or XRD (potentially synchrotron, Monash X-Ray platform and ANSTO), Raman, IR etc. Nature 2024 RSC Sus. 2023, Mat. Adv. 2023.

Electrolyte design and characterisation for Lithium and Aluminium batteries



Around 15 million Li-ion batteries are required to transition the global transport sector to renewable energy. Simultaneously, approximately 60 million batteries are needed for electricity generation and grid storage via renewable sources. However, there are insufficient resources to meet this demand for lithium batteries. On the other hand, aluminium, which is significantly cheaper (2.8 AU\$/kg) compared to lithium (~40 AU\$/kg) and more abundant, presents an interesting and worthwhile alternative to consider. Currently, aluminium battery technology is in its infancy but is growing rapidly. This project aims to develop a feasible proof-of-concept Al-ion battery pack, which can demonstrate its grid storage application. Our work in this space includes the design and characterisation of new electrolytes including ionic liquids, liquid coordination complexes, deep eutectic solvents etc.

Green materials for CO_2 capture (with Prof. Paul Webley from *Chem. Eng.*)

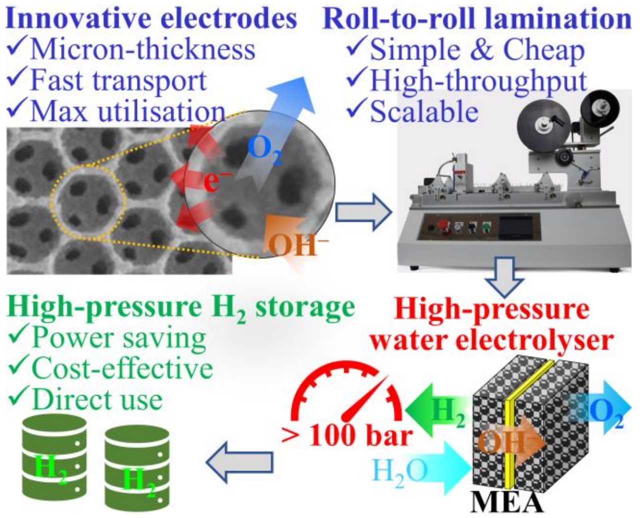
CO_2 capture technology, along with renewable energy storage, can play a vital role in the sustainable global energy economy. The existing technology that utilizes alkanolamines is highly energy-consuming and costly. Current research is focused on the development of new absorbents with high CO_2 absorption capacity that do not require high temperatures for regeneration. In collaboration with Prof. Webley, we aim to design and develop new materials, such as ionic liquids, eutectics and deep eutectic solvents. This project will involve materials synthesis, characterization, and CO_2 capture measurements.

Dr Tam Nguyen

Electrochemistry • Green Hydrogen • Redox Flow Batteries

tam.nguyen2@monash.edu
Room 330, Building 86 (Green Chemical Futures)
https://research.monash.edu/en/persons/tam-nguyen

Scalable high-performance electrolytic hydrogen generator

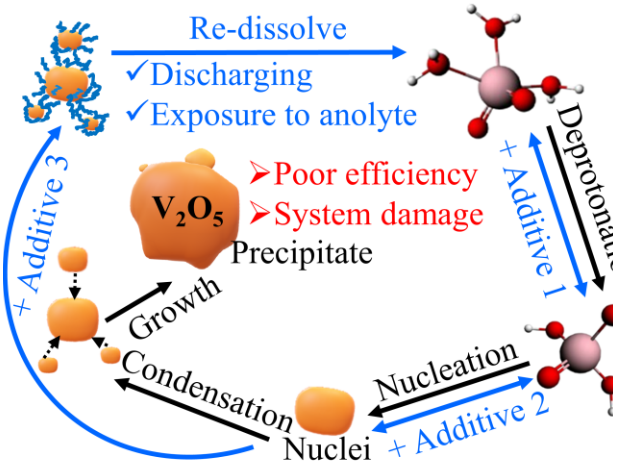


Roll-to-roll fabrication of electrolyser components for high-pressure green hydrogen production.

Advancement and application of technologies for green hydrogen generation from renewables is of key strategic importance to Australia's future energy security and economic growth. Implementation of the National Hydrogen Strategy requires effective means of H_2 production, such as by renewable-powered water electrolysis (WE) – the most effective of the sustainable methods for hydrogen generation at scale. Currently limiting the industrial use of WE are the high cost and insufficient efficiency of the electrolysers, both originating from imperfections in the electrode-electrolyte designs. Additional significant costs are associated with the compression of H_2 for storage, which can be alleviated by operating an electrolyser at high pressure ($P \geq 100$ bar).

To address these issues, our group aims to develop a roll-to-roll lamination process for high-throughput production of membrane-electrode assemblies based on micron-thick electrodes with advanced architecture for energy-efficient high-pressure water electrolysis. The project is being carried out in collaboration with our key industry partner, Energys Australia Pty Ltd.

High performance electrolyte for the vanadium redox flow battery



Design of advanced vanadium redox flow battery electrolyte

Vanadium batteries present a highly-scalable, sustainable solution for storage of renewable electricity, but the technology needs to be improved for robust and efficient operation in the warm Australian climate. This project aims to design and extensively test new high-performance electrolyte compositions with advanced thermal stabilising additives for safe long-term battery operation at 60 °C. New knowledge in materials science and electrochemistry will be generated. The core outcome of the project is a sustainable large-scale energy storage technology ready for immediate application in Australia. This will support the transition of the Australian energy sector to renewables and provide businesses with distributed energy storage solutions.

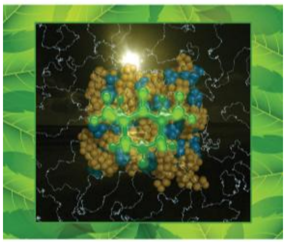
Professor Katya Pas

Computational • Theoretical • Machine Learning

katya.pas@monash.edu
https://mccg.erc.monash.edu/
Room 126, Building 86 (Green Chemical Futures)

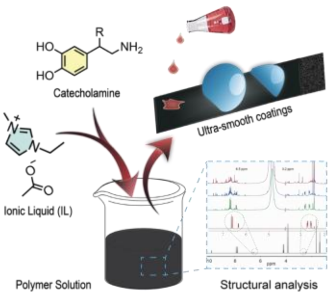
This document will give you an idea of the type of research we are undertaking within my group, Monash Research Computational Chemistry Group. In our research, we apply computational chemistry methods to a range of chemical problems. If you have any further queries, please do not hesitate to contact me (details above).

Projects on Organic redox flow batteries



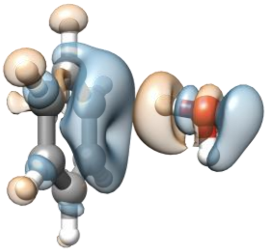
Recently we have discovered significantly increased stability of nitroxide radicals in select ionic liquids, allowing us to control their redox chemistry. Through a careful tailoring of ionic liquids to each nitroxide radical we have managed to successfully test a radical redox flow battery that can now compete with Li-ion batteries. In this project, the student will design ionic liquids based on nitroxide radicals and predict their oxidation and reduction potentials.

Projects on polymerisation of catecholamines (with Dr Sophie Crouch & Prof. Benny Freeman, UT at Austin)



Polydopamine (PDA) is one of the most intriguing biomimetic polymers produced by a rapid polymerization of a neurotransmitter called dopamine. PDA possesses strong adhesive and antimicrobial properties. The structure of PDA had been unknown for decades due to its poor solubility in all organic media until our group discovered a designer solvent that can easily it. Recently we have identified the polymerization mechanism of dopamine in these designer solvents and established chemical components of PDA responsible for its black colour. The student will study polymerization mechanisms of catecholamines, a broad class of neurotransmitters including adrenalin and serotonin. The student may also choose to characterize electrochemical and/or antibacterial properties of polymerised products using experimental and/or theoretical techniques.

AI Projects on Chemical Reactivity and Molecular Crystals (with Dr Peter Halat & Prof. Philip Chan, Monash)



There are several projects on offer in the group in one of the fastest growing field, physics-driven AI technologies. In our group we have developed a new approach to solve the Schrödinger's equation (aka the wave equation) using the most defining descriptor for a molecule – its electron density. Our physics-driven AI code can now predict physicochemical properties of molecules such as atomisation energies and interaction energies with accuracy rivaling Density Functional Theory. We are interested in expanding the existing code to learn kinetics and thermodynamics of chemical reactions for a fast-tracked design of novel catalysts and study many-body effects to predict crystal structures and lattice energies of organic molecular crystals.

AI Projects on Binding Affinity (with Prof. Ralf Hoffmann, Leipzig University)

G-protein coupled receptors (GPCRs) represent a very diverse group of receptors responsible for an array of common disorders from anxiety to diabetes. Due to the multitude of GPCRs, the development of highly potent drugs for a specific receptor is challenging. Coupled with the average cost associated with bringing a successful drug to the market, the recent trend in the drug design area is to repurpose the already approved drugs for other disorders. Since the drugs were already deemed as safe for human consumption, repurposing leads to significant cost savings. We have adopted our physics-driven AI code (described above) to successfully predict binding affinity of peptides to receptors on Gramm-positive and Gramm-negative bacteria. We are interested in expanding this code to study binding affinity of already approved drugs to GPCRs.

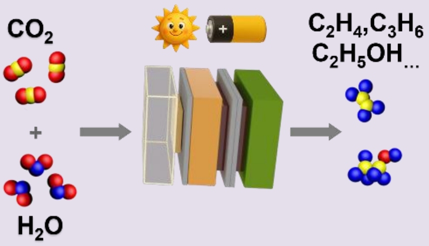
Dr Hangjuan Ren

Electrochemistry • Catalysis • Reaction Pathways

✉ hangjuan.ren@monash.edu
Room 222, Building 86 (Green Chemical Futures)
https://research.monash.edu/en/persons/hangjuan-ren

1. Turning CO_2 into Treasure

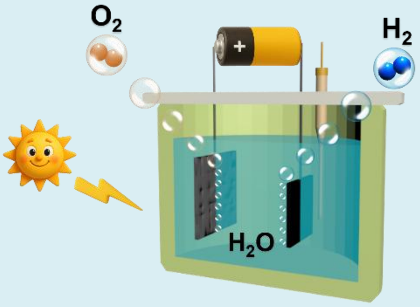
How can we transform a climate problem into a valuable resource? Our group develops electrocatalytic and photoelectrocatalytic systems that convert waste carbon dioxide (CO_2) into fuels and high-value chemicals, such as carbon monoxide (CO), methane (CH_4), ethylene (C_2H_4), and alcohols. We focus on:



- Designing selective and robust catalysts for multicarbon product formation
- Investigating the role of active sites, surfaces, and nanostructures
- Exploring solar-assisted CO_2 reduction to enhance energy efficiency

2. Green Hydrogen Production

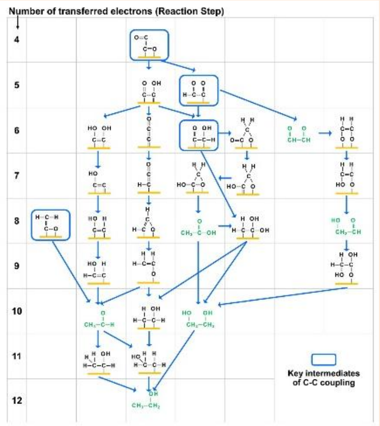
Hydrogen is widely regarded as the fuel of the future, but its long-term impact depends on how sustainably it can be produced. Our team develops advanced water-splitting systems that generate hydrogen using electricity and/or sunlight, with zero carbon emissions. We are actively working on:



- Electrolysis systems with advanced electrode materials and engineered interfaces
- Photoelectrochemical water splitting, integrating light-harvesting and catalysis
- Exploration of hybrid devices for solar-to-fuel conversion

3. Tracking Reaction Pathways in Real-Time

To develop more effective catalysts, it is essential to gain a detailed understanding of their behaviour under actual reaction conditions — not just before or after the process, but as the reaction unfolds. Our group employs a suite of advanced in-situ and operando characterisation techniques to probe catalytic systems in real time. These tools — including *operando* mass spectrometry, *in-situ* Raman spectroscopy, and *in-situ* X-ray absorption spectroscopy — allow us to track reaction intermediates and uncover detailed reaction pathways.



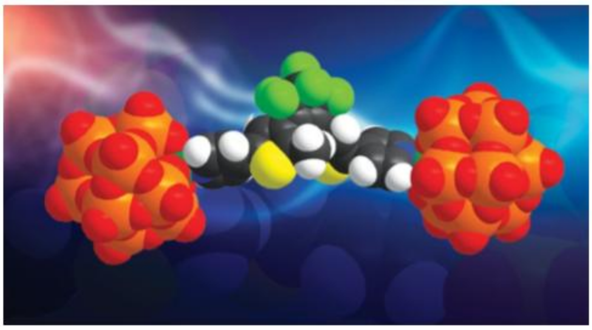
Key publications: *Nature Catalysis*, 5, 1169–1179 (2022), *Advanced Materials*, 31, 1807204 (2019)

Dr Chris Ritchie

Photochemistry • Fluorescence • Coordination Chemistry

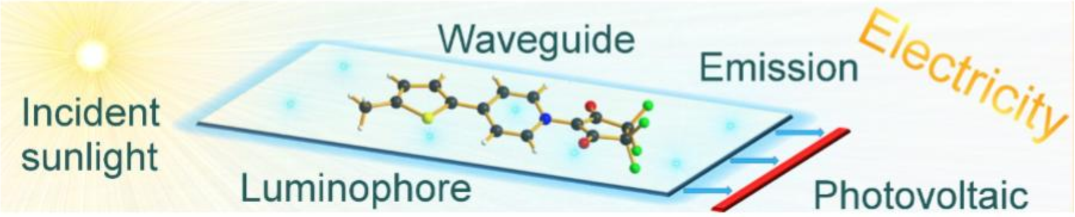
chris.ritchie@monash.edu
Room 253, Building 23 South (17 Rainforest Walk)
https://research.monash.edu/en/persons/chris-ritchie

Project 1 - Molecular Componentry for Photochromic, Photocatalytic and Electrochromic Materials



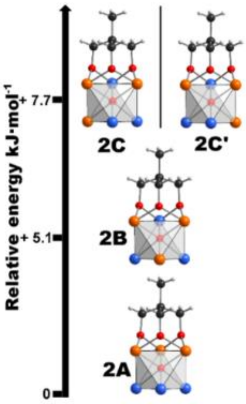
The design and synthesis of novel organically functionalised molecular metal oxides will be the core component of this project. In unpublished work, we have revealed that the combination of polyoxometalates and diarylethenes using coordination chemistry results in molecular assemblies with significantly altered photochemical properties. A suitable candidate will have an interest in both inorganic and organic synthetic chemistry (benchtop and inert atmosphere), photochemistry and materials science. This project will involve collaborations with colleagues in Germany and Australia.

Project 2 – Highly Fluorescent Pyridinium Betaines for Luminescent Solar Concentrators and Sensors



Recently, we discovered that a selection of pyridinium betaines that display near unity photoluminescent quantum yields and significant emission Stokes shifts. These properties in combination with their thermal stability and minimal aggregation induced luminescence quenching make them suitable candidates for utility in Luminescent Solar Concentrators. Expansion of the compound library has resulted in our identification of structural modifications that result in the activation of sensing capabilities. A suitable candidate will prefer organic synthesis, materials chemistry and the potential for interactions with industry partners. See (J. Xu, B. Zhang, M. Jansen, L. Goerigk, W. W. H. Wong, C. Ritchie, Angew. Chem. Int. Ed. 2017, 56, 13882) for more details.

Project 3 – Microwave-assisted Synthesis of Heteropolyoxometallates and Nanoparticle Self-assembly



Over the course of the last four years we have developed microwave-assisted methodologies for the preparation of heteropolyoxometalates. Throughout this study we noted that the substitution patterns of the metal ions within molybdovanadates could be rationalized. We have since expanded upon this fundamental synthetic study to include the preparation of atom transfer radical polymerisation macroinitiators from which we can assemble pH responsive nanoparticles. A suitable candidate will have an interest in inorganic and organic synthetic chemistry, spectroscopy and materials science. See (S. Spillane, R. Sharma, A. Zavras, R. Mulder, C. A. Ohlin, L. Goerigk, R. A. J. O'Hair, C. Ritchie, Angew. Chem. Int. Ed. 2017, 56, 8568) for further details.

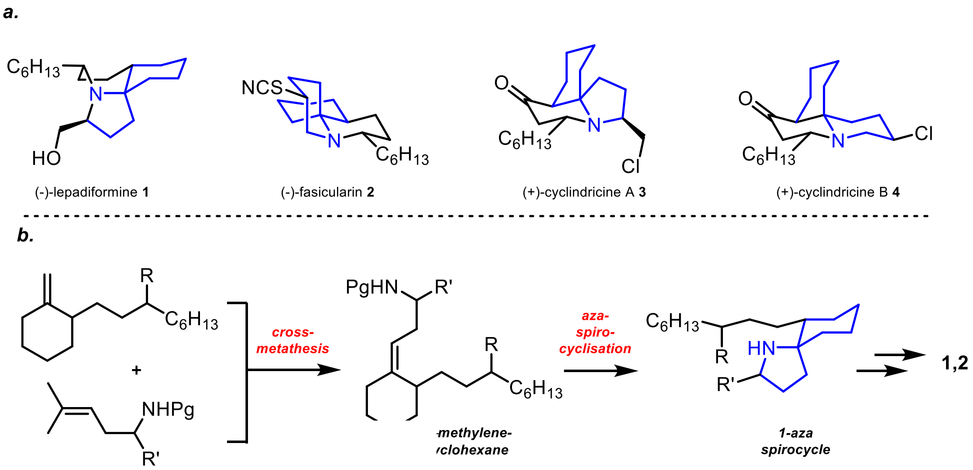
Professor Andrea Robinson

Catalysis • Peptides • Medicinal Chemistry

andrea.robinson@monash.edu
http://andrearobinsongroup.com
Room 114C, Building 19 (19 Rainforest Walk)

Catalysis

Our group has a long-standing interest in catalysis, particularly when it is applied to asymmetric synthesis, natural products and peptidomimetics. We are currently interested in the synthesis of new ligands and catalysts, developing efficient tandem catalytic processes for green organic transformations and industrial feedstocks, solid supported catalysts and the application of catalysis to bioactive targets and natural products. The development of new catalysts to perform catalysis in water are of particular interest. Recent targets are shown below (*a*) with synthetic strategy (*b*).



Peptides and Cyclic peptides

Peptides have contributed enormously to the modern pharmaceutical industry and their market is growing nearly *twice* as fast as other agents due to an increased number of therapeutic targets and improved delivery methodologies. Green approaches to conduct solid phase peptide synthesis is needed to meet sustainable and market need. Our group are actively pursuing new strategies in this area.

Nature uses cyclisation to protect peptide backbones from proteolytic cleavage. Unstable cystine bridges can be replaced with non-proteinaceous dicarba linkages. Using tandem catalytic sequences and specially designed non-proteinaceous amino acids, we have developed a way to control the formation of multiple dicarba-bridges. We have several projects examining the preparation of carbocyclic derivatives of naturally occurring cystine containing molecules, including biologically active peptide neurotoxins, cyclotides and somatostatin derivatives. Additionally, we have an interest in the design of new peptides for use in radiopharmaeutical applications. Structural characterisation of new peptidomimetics is performed in collaboration with research teams across Australia.

Insulin superfamily

One important class of disulfide containing peptides is the insulin super family, which includes, insulin, relaxin and a number of insulin-like growth factors (IGFs). These peptides are involved in important biological functions such as glucose metabolism and parturition where several disulfide bonds are formed but whose specific function in the resultant biological function remains unknown. Recently we have made significant progress in understanding insulin's mode of action at its receptor but there is still a lot to uncover! This is important for the design of non-peptidic analogues for the treatment of diabetes.

Analgesic conotoxins

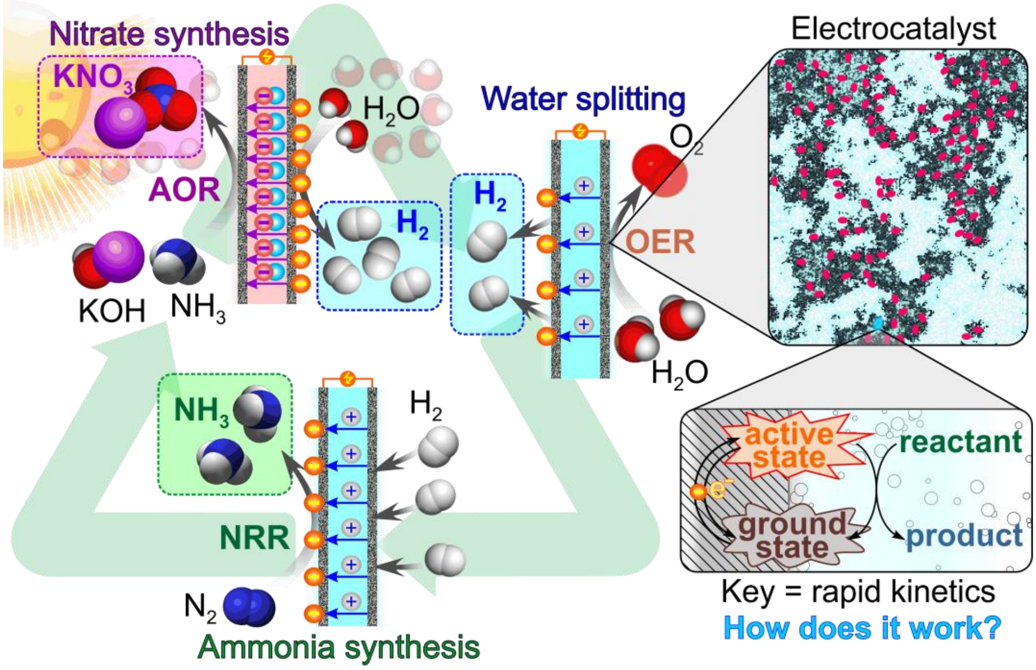
We are also examining the preparation of carbocyclic derivatives of marine derived conotoxin molecules. These natural products exhibit potent analgesic activity yet their mode of action is currently unknown. Projects in the area aim to identify potent and selective analogues for the treatment of chronic pain and uncover their mode of action.

Associate Professor Alexandr (Sasha) Simonov

Electrochemistry • Catalysis • Green Energy

alexandr.simonov@monash.edu Room 329, Building 86 (Green Chemical Futures)
https://research.monash.edu/en/persons/alexandr-simonov

We discover and design new materials and devices that harvest and convert renewable energy into green chemicals and fuels, and investigate mechanisms of relevant reactions using a broad arsenal of cutting-edge techniques. Our perfectly equipped laboratories are located in Green Chemical Futures building. Our researchers and students are provided with access to high-end research facilities and specialised equipment for the fabrication and characterisation of materials, including that available at the Monash X-ray platform, Monash Centre for Electron Microscopy, Melbourne Centre for Nanofabrication, Australian Synchrotron and Australian Centre for Neutron Scattering. We actively engage with the Australian and German energy companies, and broadly collaborate with other academic groups globally. In 2021, we have established a **spin-out company Jupiter Ionics Pty Ltd.** to commercialise the green ammonia synthesis technology developed in our laboratory.



Honours projects available in the group will suit candidates interested in physical chemistry, both inorganic and organic chemistry, materials science and renewable energy technologies – fields that underpin the new Australian energy and sustainable chemistry sectors. At the heart of the technologies we develop are the renewable-powered **electrochemical reactions**, *i.e.* chemical processes driven directly by electricity. This allows for the conversion of renewables into green energy carriers and important commodity chemicals, like hydrogen, ammonia and fertilisers, in a more energy efficient manner than with traditional methods and under close-to-ambient conditions. Our students are trained to use state-of-the-art electrochemical, materials synthesis, analytical and device fabrication facilities, and apply this equipment and their knowledge to solve real-life problems.

Honours projects in the group are very flexible and diverse, so we can fit it to match your specific interests. One can focus on the development and investigation of new types of catalytic materials for new advanced modes of water electrolysis. Another might explore the effects of the device geometry on the kinetics and selectivity of ammonia oxidation into a ready-to-go fertiliser solution. Alternatively, you can analyse the effects of the organic electrolyte composition on the effectiveness of dinitrogen reduction to ammonia. Or you can come up with your own idea that fits our expertise.

Some of our papers: Nature 2022; Science 2021; Joule 2020; Adv Materials 2020; Nature Catalysis 2019.

Professor Rico Tabor

Surfactants • Sustainability • Nanomaterials

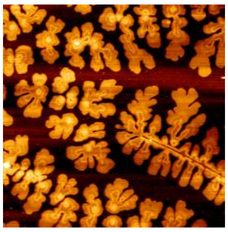
✉ rico.tabor@monash.edu
https://www.ricotabor.com
Room G24B, Building 19 (19 Rainforest Walk)

The chemistry of sustainable, functional colloids, surfactants, and nanomaterials

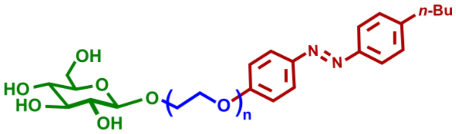
We are researching a range of topics in fundamental and applied colloid chemistry, including:

- New surfactants and emulsifiers for use in agriculture, formulation and personal care.
- Responsive colloids and nanomaterials that change their properties due to an internal or external stimulus such as pH, light or magnetic/electric fields.
- Nanomaterial design for functional colloidal systems – controlled surface chemistry, sensing substrates, capsules, liquid crystals, *etc*.

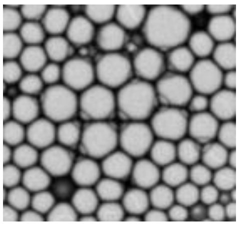
Some examples of possible projects are provided below. Projects can involve synthesis, analysis, visits to ***large-scale facilities****, e.g. the Australian Synchrotron and OPAL reactor, Lucas Heights, NSW. Much of our research involves* ***working with industry partners****.*



Metal-capturing surfactants and emulsions (with Prof. Kellie Tuck) **-** The interaction between metals and surfactants is crucial to solvent extraction (one of the main processes used to capture valuable metals from ores), but also emerging fields of environmental remediation and ion flotation. Using sustainable resources, your project will design and make new surfactants capable of gathering metal ions for recycling electronic waste.



Controlling liquids with light - Controlling liquid interfaces is central in designing tailored emulsions, foams and coating systems for fluid handling in printing, diagnostics and nanotechnology. Using a range of recently synthesised light-sensitive surfactants (and potentially new molecules that you design and synthesise), you will create new droplet and bubble systems that can be manipulated using light.



Encapsulating actives for beauty (with Varden Process Pty Ltd) - Capsules on the micron scale offer a unique way to protect and transport chemicals. By filling these tiny environments with actives for skincare + beauty, more effective formulations with greater shelf life and lower waste can be developed. Develop the next generation of formulations with truly biodegradable capsules that produce zero microplastics.

Better barriers for compostable packaging (with Varden Process Pty Ltd) - Single-use plastic is a cancer on modern society, choking the oceans and turning unsustainable fossil fuel into toxic waste. Current compostable alternatives are designed to sneak past regulations rather than authentically biodegrading at the end of their life. Help to produce the next generation of *truly* compostable packaging that protects products, leaves no toxic traces, and permanently removes single-use plastic from our trolleys.

Design your own project! If you have an interest in colloids, nanomaterials or physical forces, then talk to us about what you'd like to study. From biodegradable detergents to the best way to formulate sunscreen, we research all things soft, squishy and self-assembling.

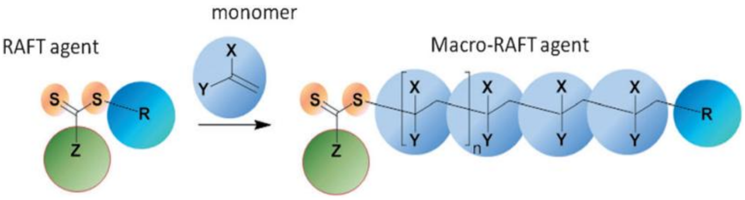
Professor San Thang AC

Polymers • Nanomaterials • Separations

✉ san.thang@monash.edu Room 252, Building 23 South (17 Rainforest Walk)
https://research.monash.edu/en/persons/san-thang

Our group's research interests is to advance the **R**eversible **A**ddition-**F**ragmentation Chain **T**ransfer (**RAFT**) polymerization, a process discovered in 1998 by *Moad, Rizzardo and Thang*. The RAFT process has the potential to become the method *par excellence* with its versatility, effectiveness and industrial friendliness for the production of a wide range of specialty polymers of well-defined architectures.

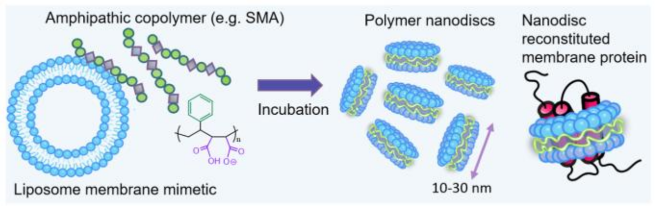
Reversible Addition-Fragmentation Chain Transfer (RAFT) Process



Macromolecules, **1998**, 31, 5559-5562. *Aust. J. Chem.*, **2005**, *58*, 379-410. *Aust. J. Chem.*, **2006**, *59*, 669-692. *Aust. J. Chem.*, **2009**, *62*, 1402-1472. *Aust. J. Chem.*, **2012**, *65*, 985-1076.

Fluorescent polymer nanodiscs: synthesis, characterisation and its membrane proteins extraction efficiency

(Joint project supervision with A/Prof Lisa Martin)

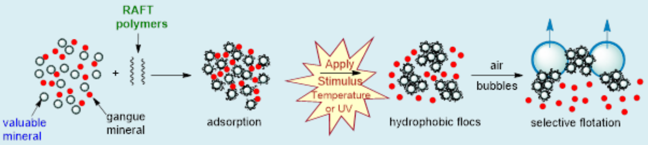


Membrane proteins (MPs) reside within the protective layers encasing and compartmentalising biological cells, otherwise known as phospholipid bilayers. Although MPs are critical to biological processes making them predominant targets for drugs, their structures are underrepresented in the protein database due to inherent difficulties involved in their biophysical characterisation while at the same time retaining their structural integrity. This project will involve the synthesis of fluorescent polymer nanodisc materials by RAFT to harness membrane proteins, and using fluorescence to assess fundamental physical polymer nanodisc properties and functional MPs extraction efficiency.

Ref: *Chemistry – A European Journal* **2021**, *27*, 12922-12939

Smart RAFT polymers design and synthesis for beneficiation of minerals

(Supported by the ARC Centre of Excellence for Enabling Eco-Efficient Beneficiation of Minerals)

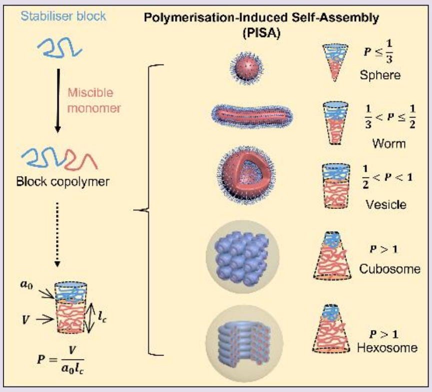


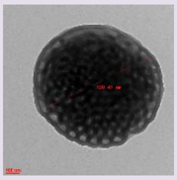
To address the increasing complexity of mineralogy, new reagents for minerals processing are highly sought after, hence the need to develop materials (small molecules and RAFT polymers) for improving its selectivity and functionality with some additional new tricks would be desirable. We welcome a highly motivated research student to join our group to undertake this ARC CoE project on the design and synthesis of smart materials by RAFT for improving selectivity, specificity and stimuli-responsive properties so that valuable minerals (e.g., Cu, Au, Pt, rare earth elements) can be efficiently recovered and gangue minerals can be easily dewatered and removed.

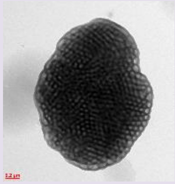
Polymer Cubosomes and Hexasomes – A New Generation of Triggered Degradable Mesoporous Colloidal Particles

Our recent published work on the RAFT polymerisation-induced self-assembly (RAFT PISA) system has led to the realisation of a new generation of triggered degradable mesoporous colloidal particles (polymer cubosomes and/or hexasomes) with great potentials as smart templating scaffold, platform delivery vehicles for drugs and proteins. This is an exceptional research opportunity to be part of our team to further develop this fascination work on the aspects of its synthesis, optimisation and mechanism study.

Ref: *ACS Nano* **2021**, *15*, 4688-4698; *Chem. Sci.*, **2022**, *13*, 4192-4224







Professor Kellie Tuck

Molecular Sensors • Surfactants • Medicinal Chemistry

kellie.tuck@monash.edu Room 250, Building 17 South (17 Rainforest Walk)
https://www.monash.edu/science/schools/chemistry/research-groups/tuckgroup

MOLECULAR SENSING TECHNOLOGIES

Luminescence-based systems for environmental monitoring and toxic chemicals

Chemosensors are molecules that produce a measurable response on binding or sensing the analyte of interest (Fig. 1). We are currently interested in their use for the detection of environmental pollutants and toxic chemicals. We have a number of projects in this area.

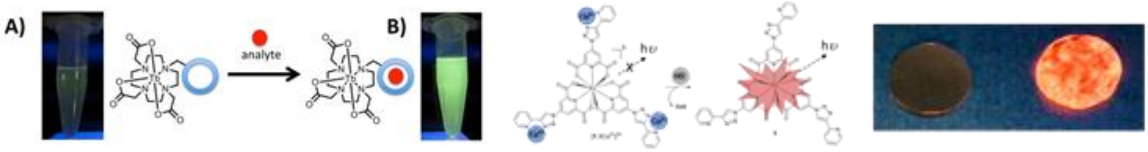


Figure 1. Example of the luminescent output of a chemosensor in the A) absence of analyte. B) presence of analyte. C) Lanthanide-based sensor for the detection of hydrogen sulfide.

Project collaborations with A/Prof. David Turner (Monash Chem.), Dr Victor Cadarso (Monash Eng.), Prof. Mike Ward (UWarwick), Prof. Bert Kersting (ULeipzig), DSTG.

Recent publication: Mini, P., Springer, M. A., Grace, M. R., Dennison, G. H. & Tuck, K. L., Chemical Communications, **2020**, 56, 5605.

Theranostic nanomedicine (project with Dr Maggie Aulsebrook (Monash Biomedical Imaging)

Theranostic agents enable the diagnosis of a disease with a radiolabeled drug, and subsequent treatment with another radiolabeled drug, both within the same molecule. They are commonly used for the treatment of cancers. This project will involve the synthesis and design of ligands for the radionuclide, binding studies with the non-radioactive isotope, and if time permits radiolabeling experiments at MBI.

Recent publication: Kubeil, M., Martínez, I. I. S., Bachmann, M., Kopka, K., Tuck, K. L. & Stephan, H., Pharmaceuticals, **2022**, 15, 27.

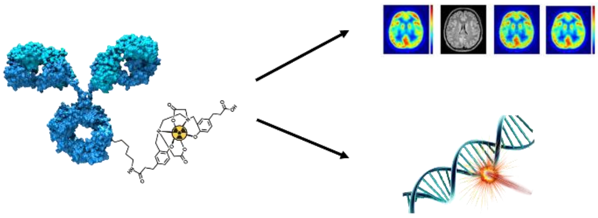


Figure 2. Example of a radiolabeled agent, that has the potential to be used for imaging and treatment.

NOVEL SURFACTANTS

The synthesis and analysis of surfactants from renewable plant-based feedstocks (project with Prof. Rico Tabor (Monash Chem)

Surfactants are amphiphilic molecules that have commonplace in personal care, formulation and agriculture. Understanding their various micellar geometries is key to their controlling their self-assembly properties (Fig. 3). Many surfactants are derived from petroleum-based feedstocks, we are investigating the use of plant-based feedstocks as they are a sustainable and renewable resource. This project is a collaborative project between the Tabor and Tuck groups.

Recent publications: Butler, C. S. G., Giles, L. W., Sokolova, A. V., De Campo, L., Tabor, R. F. & Tuck, K. L., Langmuir, **2022**, 38, 7522, Kelleppan, V. T., King, J. P., Butler, C. S. G., Williams, A. P., Tuck, K. L. & Tabor, R. F., Advances in Colloid and Interface Science, **2021**, 297, 102528.

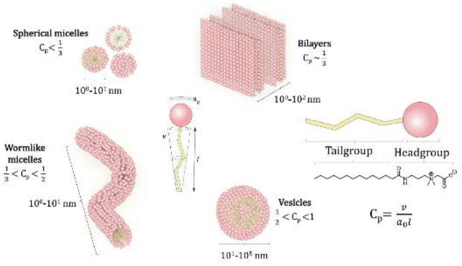


Figure 3. Diagram showing the various micellar geometries of surfactants.

Associate Professor David Turner

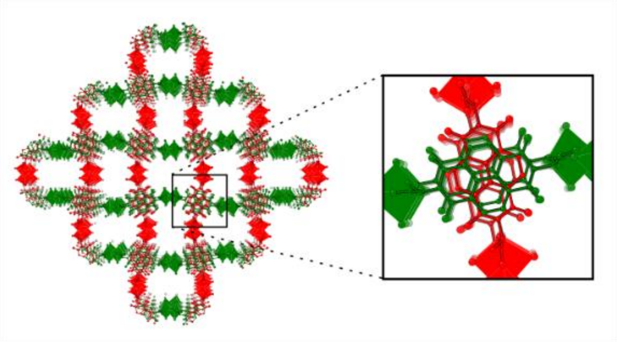
Coordination Chemistry • Supramolecular • Sensing

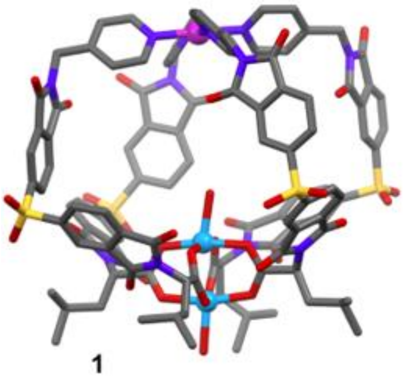
david.turner@monash.edu
Room 123, Building 19 (19 Rainforest Walk)
https://research.monash.edu/en/persons/david-turner

All research projects in my group are concerned with aspects of coordination chemistry and supramolecular chemistry. Our research primarily aims to design coordination compounds that contain holes or pores into which we can insert guest molecules. These are either polymeric, crystalline materials that resemble nano-scale scaffolding, or soluble coordination cages. In both cases, we aim to make compounds that will be able to selectively store, sense or separate small molecules.

All projects involve, to varying extents, (i) the synthesis of organic ligands that will be able to bridge between metal atoms to construct the framework and which will possess additional sites for supramolecular interactions, (ii) synthesis of coordination polymers and/or coordination cages, (iii) structural characterization by X-ray crystallography (typically involving the Australian Synchrotron) and (iv) analysis of the physical properties of the materials for separation/storage/sensing where appropriate. The focus of the project is very flexible to your preferred aspects (from lots of synthesis to dozens of crystal structures) and I'm always happy to tailor projects towards individual preferences.
Current project areas include (but are not limited to):

- **Chiral coordination cages**
  Discrete cages are broadly studied for their catalytic behavior and ability to trap guests in their internal space. We are also exploring fundamental aspects of these cages, including their ability to swap ligands in solution (followed in real-time), how their stability relates to the ligands that are used, whether we can incorporate multiple functionalities around the exterior of the cage, and how to incorporate fluorescent groups into the ligands. Our aim is to introduce complexity into cages that spontaneously assemble through multiple parts, such as including multiple different metals or ligands in a predictable manner.
- **Chiral coordination polymers for separation**
  Using quite simple bis- or tris-amino acid ligands, we have been able to construct several coordination polymers that are able to provide resolution of racemic mixtures in small-scale liquid chromatographic experiments.
- **Crystal engineering**
  We are always interested in exactly how molecules interact within crystals and have a number of projects that are primarily crystallographic, exploring unusual interactions and motifs.





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Left: A chiral coordination polymer used for resolution of racemates (Boer et al., Chem. Eur. J., 2014). Right: A recent cage complex containing multiple metals that self-assembles (Thoonen et al., Angew. Chem. Int. Ed., 2025).

Associate Professor Drasko Vidovic

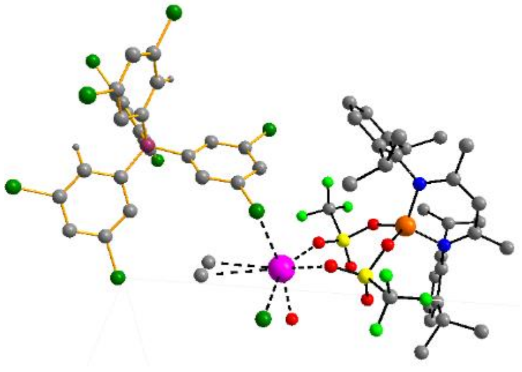
Catalysis • Organometallic • Synthesis

drasko.vidovic@monash.edu Room G24, Building 19 (19 Rainforest Walk)
https://research.monash.edu/en/persons/drasko-vidovic

Catalysis is the main research theme in our group. We are developing green and sustainable catalysts that are capable of performing a variety of organic transformations.

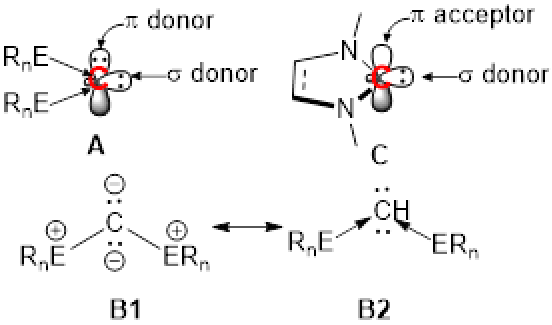
Lewis acid catalysis

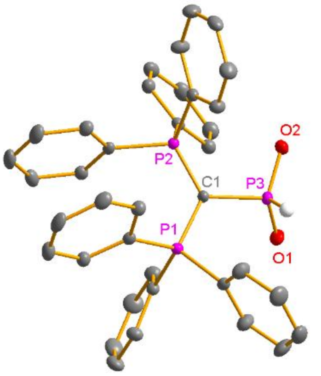
In the last decade or so, there have been numerous reports demonstrating that the field of Lewis acid (LA) catalysis was (in)adverently affected with the presence and consequent activity of hidden Brønsted acids (HBAs). This is predominantly due to improper synthesis, identification and use of Lewis acids as well as the lack of various control experiments that are crucial for eliminating HBA activity. Our research group is developing well-defined and well-characterised Lewis acids based on aluminium as it is the most abundant metal in the Earth's crust. Thus far, we have prepared several aluminium-based complexes (see the insert) that showed remarkable catalytic activity regarding a variety of Diels-Alder cycloadditions (*Dalton Trans.* **2017**, 46, 753. *Chem. Eur. J.* **2015**, 21, 11344). In fact, we have recently discovered that one of our catalytic systems is capable of polymerizing cyclic dienophiles which could be considered as functionalized polyolefins (*Chem. Sci.* **2024,** *15* (2), 639). The preparation of functionalized polyolefins, in general, is very difficult as ill-defined and low-molecular weight materials are normally prepared, while our procedure offers to drastically change that. Therefore, the aims of this project include further exploration of our catalytic systems with respect to several other organic transformations such as borylations, Michael additions, transfer hydrogenations etc. Also, we would like to further explore the synthesis of functional polyolefins in order to determine all their properties.



Carbones – Exceptionally electron rich ligands

Carbones represent a class of carbon-based compounds whose central carbon atom is formally in a zero-oxidation state. The central carbon atom is also predicted to contain two lone pairs (**A**, see below), regardless of which mesomeric form (**B1** vs **B2**, below) is most appropriate to describe these molecules. As a result, these molecules are considered as both σ and π bases i.e. σ and π electron donors (**C**). This particular electronic property means that carbone species are significantly different compared to the well-established carbene and phosphine compounds as these molecules are commonly viewed as donors with ability to act as π acids i.e. π electron acceptors. Our efforts in this research, among other achievements, led to the preparation of first examples of phosphenium di- and tri-cations (*Angew. Chem., Int. Ed.* **2013,** *52* (11), 3132 and *Chem. Commun.* **2016,** *52* (63), 9789). Very recently, we disclosed the synthesis and preliminary reactivity (i.e. phosphonylation) of carbone-stabilised parent dioxophosphorane (**D**; *J. Am. Chem. Soc.* **2022,** *144* (16), 7357).[19k] Currently, we are aiming to expand the chemistry of carbone molecules to Group 14 elements with a focus on electron deficient silicon compounds. In addition, we are interested in the development of, for example, Grubbs-like catalyst for olefin metathesis that would contain a carbone ligand.





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Professor Bayden Wood

Spectroscopy • Surfactants • Medicinal Chemistry

bayden.wood@monash.edu
Room G24A, Building 19 (19 Rainforest Walk)
https://research.monash.edu/en/persons/bayden-wood

Biospectroscopy, an emerging field within the spectroscopic examination of biological tissues or body fluids, bridges the physical sciences with advanced computational analysis to uncover insights into biological processes. This interdisciplinary approach is advancing our understanding of the structure and activity of biological molecules, placing it at the forefront of cutting-edge research in chemistry and biology.

Development of a UV/Visible Spectrometer Coupled with Machine Learning for Rapid Malaria Diagnosis

Malaria remains a significant global health challenge, particularly in resource-limited settings where access to advanced diagnostic tools is often unavailable. This project focuses on the development of a simple and cost-effective UV/visible spectrometer integrated with machine learning algorithms to diagnose malaria with high accuracy. The spectrometer analyzes the optical properties of blood samples, detecting subtle spectral changes associated with the presence of malaria parasites. Machine learning models are then applied to classify the samples, enhancing the sensitivity and specificity of the diagnostic process. This innovative approach has the potential to provide a rapid, portable, and affordable diagnostic solution, making it particularly valuable for remote regions. Through this project, students will gain hands-on experience in spectroscopy, data analysis, and machine learning, contributing to the development of accessible technologies for global health.

Multimodal Imaging Reveals New Insights into Ancient Egyptian Embalming Practices

Multimodal imaging techniques are transforming our understanding of ancient Egyptian embalming practices by enabling detailed analysis of mummified remains with established provenance. By integrating advanced methods such as biospectroscopy, synchrotron imaging, and second-harmonic generation microscopy, researchers can non-destructively examine the molecular composition, structure, and preservation of embalming materials and tissues. These techniques have uncovered the use of innovative recipes, including calcium-based compounds, animal-derived collagen, and antimicrobial agents, challenging long-held assumptions about the universal use of natron. Spectral archaeology further enhances this analysis, revealing the interplay between local resources, cultural practices, and environmental conditions in shaping embalming methods. This multidisciplinary approach not only deepens our knowledge of ancient technologies but also highlights the sophistication and adaptability of the ancient Egyptians in preserving the human body for eternity.

Dr Tomohiro Yasukawa

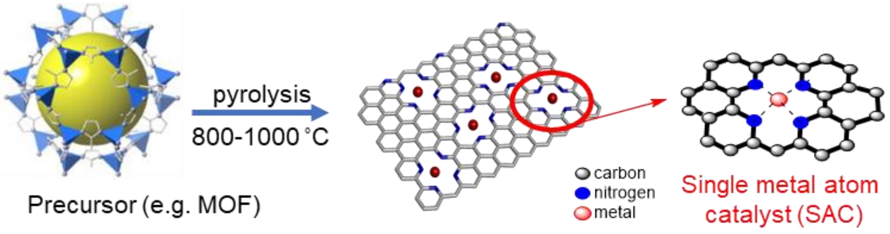
Catalysis • Electrochemistry • Organic Synthesis

tomohiro.yasukawa@monash.edu Room 171, Building 23 South (17 Rainforest Walk)
https://research.monash.edu/en/persons/tomohiro-yasukawa

Our laboratory develops novel synthetic methods using heterogeneous catalysts. We aim to develop green and sustainable organic reactions by combining knowledge of organic chemistry, inorganic chemistry, electrochemistry and flow chemistry. Below are three key concepts from our laboratory. If you have any further queries, please do not hesitate to contact me (details above).

Single-atom catalysts (SACs)

Catalysts can be classified into homogeneous and heterogeneous catalysts. Heterogeneous catalysts can be easily recovered and reused but have disadvantages such as low activity and a lack of uniformity in the structure of active species. Single-atom catalysts (SACs) are heterogeneous catalysts that have a localized single metal active site created by strong metal-support interactions, and they are attracting attention as an approach that maximizes the atom utilization efficiency of metal resources. SACs have the advantages of both homogeneous and heterogeneous catalysts. We are particularly interested in the catalytic activity of SACs supported on nitrogen-doped carbon. We believe that SACs with their unique structure, which is uniform and cannot be reproduced by metal complexes, will be useful for the development of next-generation organic reactions.

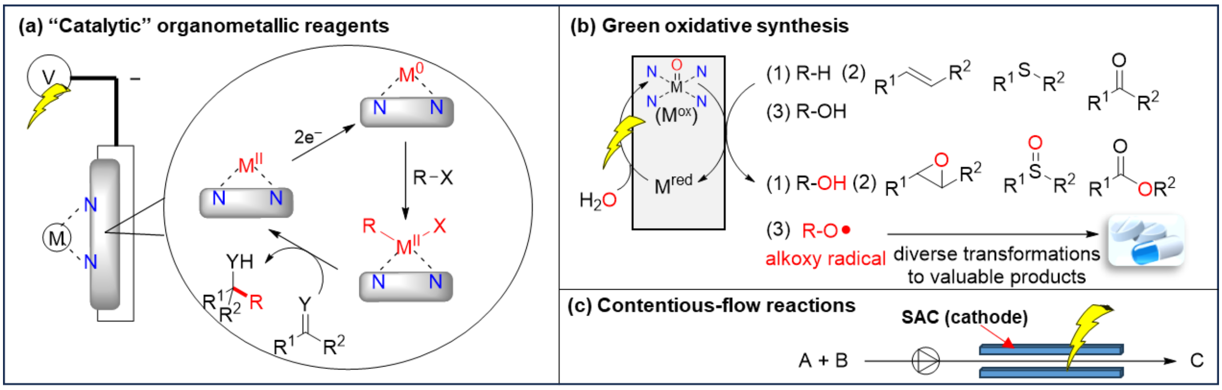


Electrochemical synthesis

Electrochemical synthesis uses electrical energy to drive chemical reactions, offering a cleaner alternative to traditional methods using harmful chemicals. Electrochemical organic synthesis often uses an electrode that is mainly responsible for mediating the transfer of electrons to substrates. We are developing an approach by adding a “catalyst” function to electrodes using single-atom catalysts (SACs).

One of our focuses is to develop reductive reactions driven by electrochemically generated low-valent metal species on SAC-immobilized electrodes. Organometallic reagents such as Grignard reagent are very useful but produce equivalent amounts of metal waste. If the metal can be immobilised on an electrode and the metal(0) species can be regenerated by electrochemical reduction, a “catalytic” reaction is possible (Fig. a).

We also focus on novel electrooxidation that emulates enzymatic mechanisms, forming high-valent metal-oxo species directly on the SAC-electrode and thereby enabling environmentally benign organic synthesis (Fig. b).

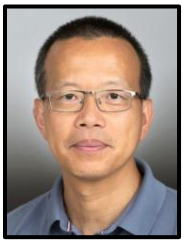


Continuous-flow synthesis

We aim to apply our electrochemical reactions to continuous-flow systems (Fig. c), where starting materials flow through a small reactor to produce products. This method is gaining attention because it is safer, more efficient, and scalable than traditional batch reactions.

Key References: *J. Am. Chem. Soc.* 2023, *145*, 11939.

Associate Professor Jie Zhang



Catalysis • Electrochemistry • Machine Learning

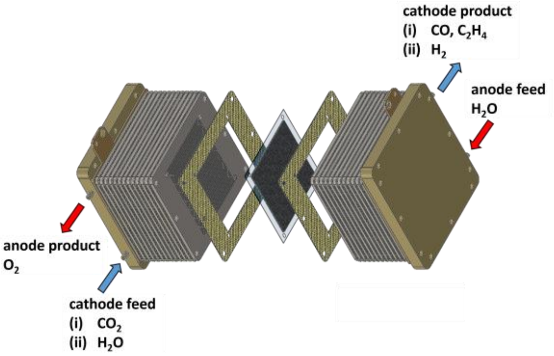
jie.zhang@monash.edu
Room 145, Building 23 South (17 Rainforest Walk)
https://research.monash.edu/en/persons/jie-zhang

Our research focuses on: 1. Developing advanced electrolyzers for small molecule activation to generate value-added chemicals, and 2. Applying artificial intelligence in electrochemistry.

We currently have two available projects in these areas:

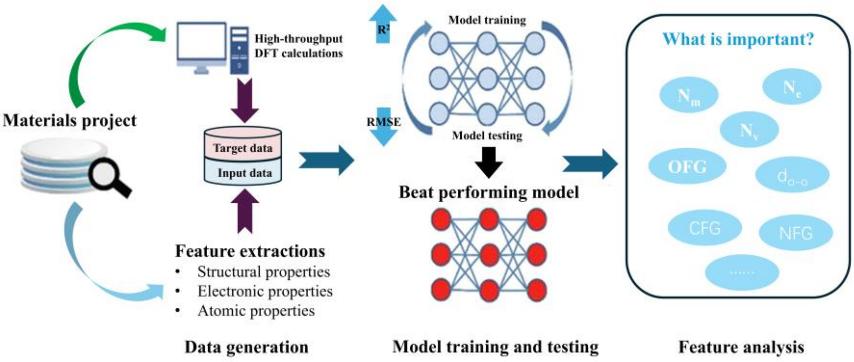
Project 1: Advanced zero-gap CO_2/water electrolyzers

Electrolyzers store electricity in the chemical bonds of small molecules, which can then be used as fuels (e.g., H_2, methanol) or as feedstocks (e.g., CO, ethylene) for chemical processes. This project involves the preparation of individual electrolyzer components, including ionomer, membrane, catalyst synthesis, gas-diffusion electrode, and flow-field plate design and fabrication, along with materials characterization, cell assembly and testing, and the identification and quantification of electrolysis products. By systematically optimizing the design and integration of these components, this work aims to improve electrolyzer efficiency, selectivity, and long-term stability under industrially relevant conditions. Some of our recent work related to this project can be found in References 1-3.



Project 2: Data-driven catalyst design via machine learning and meta-analysis

In this project, we will develop a unified, large-scale approach to mechanistic studies in electrocatalysis by combining systematic meta-analysis with modern machine learning (ML) techniques. The reactions of interest include CO_2 reduction, oxygen reduction and evolution, and hydrogen oxidation and evolution. We will: (i) automatically extract quantitative and qualitative data from figures, tables, and supplementary files in the lieterature; (ii) organize these datasets into a well-annotated knowledge graph; and (iii) deploy interpretable ML models, such as Gaussian process regression with SHAP attribution and graph neural networks, to uncover hidden structure-property-performance relationships that are often overlooked in conventional single-study approaches. The resulting data repository and predictive frameworks will enable hypothesis-free interrogation of catalyst descriptors and generate decision rules to guide rational catalyst design. By replacing subjective, trial-and-error mechanistic claims with statistically robust, cross-domain evidence, this project aims to establish a new standard for evidence-based discovery in electrocatalysis and accelerate the transition from empirical optimization to principle-guided innovation. Some of our recent work related to this project can be found in References 4 and 5.



If you are interested in these projects and would like to know more details, please feel free to talk to me directly. More information on my research can be found at **https://scholar.google.com.au/citations?user=_W3sW9IAAAAJ&hl=en**

References:

(1) Yu, H.; Wu, H.; Chow, Y. L.; Wang, J.; Zhang, J. *Energy Environ. Sci.* 2024, *17*, 5336-5364. (2) Wu, H.; Yu, H.; Chow, Y. L.; Webley, P. A.; Zhang, J. *Adv. Mater.* 2024, *36*, 2403217. (3) Li, L.; Chen, J.; Mosali, V. S. S.; Liang, Y.; Bond, A.; Gu, Q.; Zhang, J. *Angewandte Chemie* 2022. (4) Zhu, D.; Wu, H.-W.; Fong, W.-K.; Tabor, R. F.; Zhang, J. *Angew. Chem. Inter. Ed.* 2025, e202500145. (5) Zhu, D.; Wu, H.-W.; Wang, X.; Zhang, J. *Adv. Mater.* 2025, *37*, DOI: 10.1002/adma.202510752.