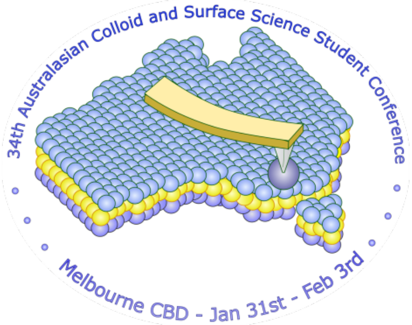
34th AUSTRALASIAN COLLOID AND SURFACE SCIENCE STUDENT CONFERENCE



Abstract Booklet

The relationship between interfacial tension and contact angle in three phase systems

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The transfer of a solid particle between two immiscible phases depends on several factors, with the particle surface wettability by these two liquids being one of them. The spreading of a liquid on a solid surface is a measure of the wettability (by a given liquid) of this solid. The wettability can be expressed as the contact angle (θ). A hydrophobic solid surface will have a low contact angle for a non-aqueous liquid as the affinity for the non-aqueous liquid is stronger than for water.

To investigate how the kinetics of droplet spreading and the resulting contact angle depends on the interfacial tension of a given non-aqueous liquid, a series of static (captive drop) and dynamic (collisions of a single rising droplet with the solid interface observed by a high-speed camera) contact angle measurements were conducted and compared for a model hydrophobic solid surface and various non-aqueous liquids. In addition, for dynamic measurements, spreading kinetics were investigated to see how quickly quasi-equilibrium is achieved.

These experiments are the first step in the determination of the effect of surface hydrophobicity on solid particle transfer between two immiscible liquids.

Green microcapsules made from chitosan emulsions

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Development of microcapsules from Pickering emulsions is an emerging field in interfacial science, with the attractive ability to provide controlled release of encapsulated molecules. These microcapsules use particles to stabilise emulsion interfaces, which can be then reinforced to improve stability and functionalised to improve responsiveness to external stimuli.[1] Chitosan is a polyglucosamine biopolymer which has demonstrated suitable properties of emulsification and capsule formation. It is cationic in solution at neutral and acidic pH due to its large population of amine groups, allowing for a range of unique possibilities not seen in other biopolymers.[2] Chitosan is known to be responsive to changes in pH and salt concentration. Polymer chains can also be crosslinked to form larger structures, although the application of these to chitosan-based emulsions has yet to be well studied.[3]

Our work has focused on how the influence of additives to chitosan emulsions affects their size and stability, along with their ability to be converted into microcapsules. Different aqueous conditions have been explored to fully understand their effect on emulsion size and stability and a range of ideal conditions has been confirmed, enabling facile access to emulsions with diameters as small as 12 μm. Additives including crosslinkers glutaraldehyde, tripolyphosphate and trisodium citrate have shown the ability to form capsules capable of withstanding air drying with varied shell chemistries and dosages. We anticipate that these capsules will have a range of possible applications, including in agriculture, pharmaceuticals and food production.

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Commercially extracted plant protein isolates: Does more soluble proteins mean stronger gels?

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The increasing global demand for a more sustainable and stable food supply has been driving the growth of the plant protein market. The comparatively less intensive production method for plant proteins is one of the major driving forces for the consumer market. Plant-based meat products are dominated by soy-based products, due to having reported superior gelation abilities compared to other plant proteins like pea proteins. Soy protein, however, contain higher amount of anti-nutritional components and are a common allergen. Pea proteins have been gaining popularity as a soy alternative but have reported to have weaker gelation abilities[1].

Plant proteins can form texturised products by going through gelation, which is induced by heating and cooling of the proteins. Research efforts suggest that the gelation strength, which determines the final product texture, is highly dependent on the soluble protein content, as the first step of gelation involves the denaturation of the soluble protein. These denatured proteins then interact with each other to form aggregates which can eventually form a network structure[2-3]. Commercially extracted proteins consist of large amounts of denatured proteins as these plant proteins are most commonly extracted through isoelectric precipitation and spray drying[4]. The extraction process is done at relatively high temperatures which irreversibly denatures the proteins. This in turn results in commercial proteins having high amounts of insoluble proteins, which have often to be reported to exhibit low gelation abilities. Technological advancements in the protein extraction method however have since helped increase the protein solubility of commercial plant proteins.

In this project, commercial pea proteins that are extracted with different production methods are compared against each other to investigate how the solubility of plant proteins can affect the gelation behaviour of these proteins. By using methods such as rotational rheology, nano-differential scanning calorimetry, size exclusion chromatography as well as circular dichroism, it was found that although commercial extraction process can affect the protein solubility (by as much as 4x), it did not result in higher gelation strength. This shows that contrary to previous research, the main driving force for protein gelation is not soluble protein denaturation but instead protein aggregate interaction.

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Investigating Reversible Assemblies of Janus Particles

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Colloidal self-assembly is a powerful strategy for developing technologies where nano- or micro-scale particles self-organise into structures with emergent properties[1,2]. One particular type of particles of interest is asymmetric colloids known as Janus particles. The anisotropic nature of these particles introduces directionality in particle-particle interactions[3] and for amphiphilic particles these interactions are dominated by the hydrophobic attraction[4]. However, further study is needed to better understand the dynamics of these interactions, and how they are influenced when Janus particles are suspended in a microfluidic channel with continuous flow.

In the present work, we study the dynamics and assemblies of Janus particles inside a sheath-flow microfluidic channel. We use polystyrene and silicon spheres as our base particles to create amphiphilic Janus particles with sizes visible using optical microscopy (4-10 μm). Amphilphilic nature is created by depositing gold on these spheres prior to functionalisation with thiol groups. Our sheath-flow microfluidic channel is tested using COMSOL with the computational fluid dynamics module before fabricating them using soft lithography. We characterise particle-particle interactions by their orientation as a function of position through the microfluidic channel, and our latest results and analysis of these experiments will be presented.

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Pickering Emulsion Droplet Sizing using Low Field Nuclear Magnetic Resonance

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Pickering emulsions are a well-established subset of emulsions which are stabilised by coating the dispersed phase with a steric barrier that prevents droplet coalescence. These are used widely within the food industry where they are subject to a range of processes such as drying and freeze-thawing depending on their application. Ensuring emulsion stability throughout such processes is essential for maintaining the quality of the product. In this work, we present the first use of low field NMR to size Pickering oil in water (o/w) emulsions of esters in water using silica nanoparticles as an emulsifying agent. The droplet sizes obtained are demonstrated to be of similar magnitude to those obtained using optical microscopy. The stability of emulsions after both removal of the aqueous phase (creating 'Dry Emulsions') and after freeze-thawing was investigated. Dry emulsion stability was observed to be correlated with increasing molecular mass of the oil phase, whilst none of the emulsions generated in this work indicated stability under freeze-thawing. Analysis of the NMR spin-lattice relaxation time constants (T_1) of the dry emulsions facilitated the assignment of two unique relaxation environments for both the oil and water species, providing insight into microscopic emulsion structure.

Design of a High-Frequency Liquid Metal Droplet Generator

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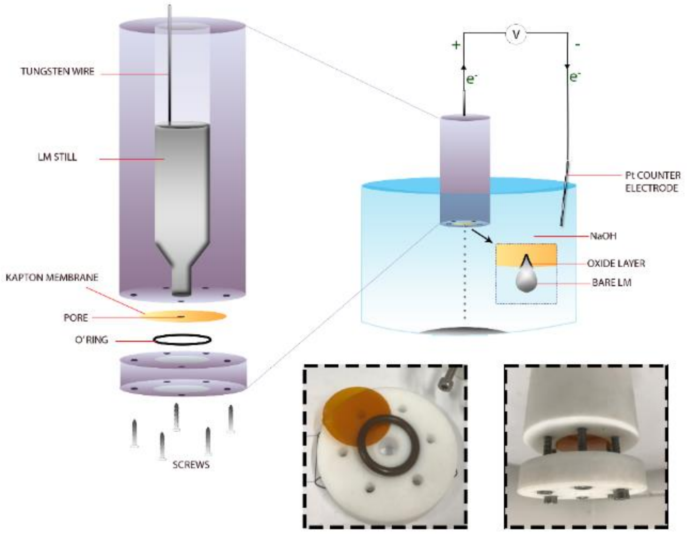
Liquid metal (LM) droplets with outstanding properties and responsive features are seen as promising candidates for a wide range of emerging technologies, while automatic generation of LM droplets with precise control over their size and morphology remains challenging. In this study, we have designed a high-frequency LM droplet generator by manipulating the electrohydrodynamic behaviour of LMs. Specifically, the oxide layer on the LM surface are controlled through applying different electric potentials and thereby varies the surface tension of the LMs, which results in rapid generation of homogeneous LM droplets with different size distributions. The size of the LM droplets generated can be ranged from 40 to 200 microns, with a low energy input (< 0.75 V vs Ag/AgCl). More impressively, these droplets can be stabilized in large scale with presence of surfactants, rendering them promising for the further application in the field of biomedicine, catalysis, and soft robots.



Explaining the slippery, liquid-like behaviour of nanothin grafted layers

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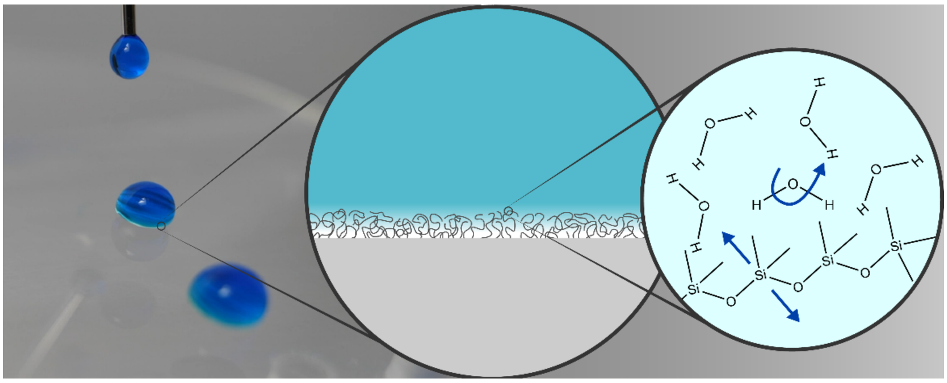
It is becoming accepted that liquid molecules retain some of their macroscopic 'liquid-like' properties when they are covalently tethered to solid surfaces. instance, tethered silicone oil (PDMS) possesses low roll-off angles[1] and anti-icing,[2] -biofouling,[3] and -scaling[4] properties – similar to a liquid film – despite the PDMS layer being < 5 nm thick and incapable of flow.[1,2] These slippery covalently attached liquid surfaces (SCALS) possess the benefits of lubricated surfaces, but cannot be depleted. Curiously, the thickness and roughness of SCALS do not predict or explain their performance; Rather, their efficacy is attributed to the *liquid-like mobility* of the tethered chains.[1,2] However, there is no direct evidence to support this mobility hypothesis,[2] and physicochemical characterisation of such layers is poor, raising the fascinating question: *what does it mean to be liquid-like?*



We are seeking to answer this slippery question, conclusively and quantitatively. Here we will document our efforts thus far, starting with a thorough characterisation of a variety of relevant SCALS, before moving onto an investigation of their mobility at key length-scales.

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High Throughput Screening of Hen Egg White Lysozyme in Ionic Liquid-Water Solutions

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A proteins solvent environment is key to its stability due to the influence the environment has on protein aggregation and folding. For many proteins, aqueous buffer solutions do not provide the optimum solvent environment and so alternative solvents are required for protein stability. The use of ionic liquid-water mixtures has been shown to manipulate these protein properties, with certain ion combinations and concentrations greatly increasing protein stability or activity. These changes are based on the interactions occurring within the solution between protein-water, protein-ionic liquid and protein-protein. However, there is currently no working understanding of the relationship between ionic liquid (IL) structure and its effect on a protein making investigations of IL-protein systems a trial-and-error activity. To expedite this, our research presents 137 IL-water mixtures with 10 unique cations and 10 unique anions at 4 different concentrations to investigate the effect of IL structure and concentration on the model protein hen egg white lysozyme. It was found that the specific ion effects of a single ions structure are not consistent across ion pairs. Several trends were found at low IL concentrations, for example a hydroxyl group or the increased alkyl chain length of the cation reduced the size of lysozyme. It was also found that these trends were inconsistent across concentrations and highly specific to the ion series. The study of specific ion effects has shown great promise in relation to solvent effects on protein stability, however with the inclusion of ILs in this field it becomes necessary to incorporate a model of analysis that includes the ion pair and how combinations of ions affect a protein in solution.

Probing the expression and adhesion of glycans involved in *Helicobacter pylori* infection using atomic force microscopy

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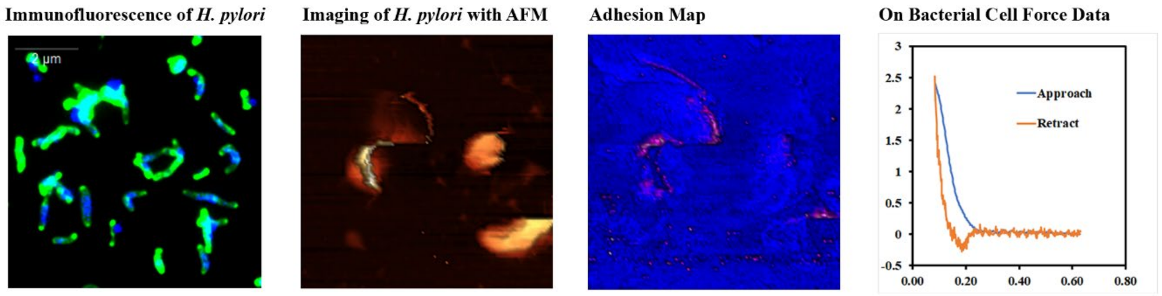
Helicobacter pylori (*H. pylori*) is a gram-negative bacteria that infects approximately half the human population and has an unusual infective niche of the human stomach. Colonisation with *H. pylori* results in gastritis, which can lead to gastric cancer, causing *H. pylori* to be classified as a group 1 carcinogen by the WHO. Current treatment for *H. pylori* involves triple or quadruple antibiotic therapy, but antibiotic resistance is becoming increasingly prevalent. *H. pylori* has been found to express a group of carbohydrate blood group antigens, known as the Lewis system antigens, as a part of its outer membrane lipopolysaccharide (LPS), which is thought to assist immune evasion. The *H. pylori* LPS has also been found to play a role in adhesion to host cells in conjunction with several bacterial adhesion proteins. The structural diversity and variation of the *H. pylori* LPS presents a challenge in establishing an accurate structure-function relationship between the *H. pylori* LPS and an infected host. Further study into the expression and role of carbohydrate antigens in *H. pylori* infection and adhesion can shed new light on the molecular interactions of this bacterium and may lead to new drug and vaccination targets. This study examines the carbohydrate expression profiles of *H. pylori* reference strains using monoclonal antibodies (mAbs) and lectins, identifying interaction between two carbohydrate-targeting mAbs and *H. pylori* strains SS1 and 26695. Both reference strains of *H. pylori* also interacted with multiple lectins, allowing for further inspection of these interactions using atomic force microscopy (AFM). The AFM method permits the visualisation and measurement of lectin-bacteria and antibody-bacteria interactions on a nanoscale. The selected mAb and lectin displayed an increased adhesive force over the surface of the curved *H. pylori* rods in comparison to the background on AFM scans **(Figure 1).** Further study will examine how carbohydrate binding proteins can affect the interaction between *H. pylori* and human gastric adenocarcinoma cells.


Immunofluorescence of *H. pylori*

Imaging of *H. pylori* with AFM

Adhesion Map

On Bacterial Cell Force Data

Figure 1. Example immunofluorescence, AFM topography images, adhesion maps and force curves (left to right) for interaction of a lectin with glycans on *H. pylori*.

Quantifying the effects of clay on dewatering in mineral tailings

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Clay and clay minerals are commonly found in mineral ore-bodies and increasingly show negative impacts in processing operations. The amount of clay usually varies with location across the ore body. This not only causes poor performance but large and often unpredictable process variabilities. As such, the presence of clay in the ore negatively impacts most unit operations, including comminution, concentrating (i.e. flotation), separations, dewatering and tailings management.

The main issue with clays is their high aspect ratio, which causes a low density in particulate aggregates (large occluded volume) and higher suspension viscosities at any given solids concentration. As a result, achieving low moisture content tailings is made difficult, leading to higher water use per tonne of ore and a larger and less geotechnically stable tailings storage volume (Chryss (2017)). In this study, the effect of clay in mineral tailings was explored and quantified using a comprehensive dewaterability analysis (de Kretser, Usher et al. (2001)) as well as shear rheology measurements. A range of tailings were simulated using a combination of fine calcium carbonate (D[3,2] of 6.6 um) and varying proportions of kaolinite (D[3,2]of 1.9 um). The dewatering properties of these simulated tailings were measured and then used in models of thickening and filtration (Usher and Scales (2005)), (Stickland, de Kretser et al. (2006)). This combination of experimental characterisation and modelling allowed changes in clay addition to be systematically quantified in terms of dewatering throughput and moisture content.

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Computational study of liquid-bridge induced particle agglomeration

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Abstract

In daily life, liquid-liquid-solid systems are increasingly becoming prevalent and have a wide range of potential applications. Here, a particular type of system, known as capillary suspensions, is made up of small volumes of an immiscible secondary liquid added to a bulk liquid that contains solid particles[1]. This secondary fluid can create a liquid bridge between the solid particles that generates attractive forces at the micro-scale. This can cause particle agglomeration and substantially modify the suspension rheology at the macro-scale.

Although there is extensive experimental research on particle agglomeration, the real-time non-invasive dynamic behaviour of primary particles smaller than roughly 10 μm is difficult to image. Therefore, numerical simulations of particle agglomeration in multiphase flows are now widely used to provide insight into particle agglomeration behaviour. Here, we couple two discrete particle methods, Smoothed Particle Hydrodynamics (SPH) and Discrete Element Method (DEM), to model the continuous fluid dynamics, the fluid-particle drag and the particle-particle interactions, with an analytical expression used for the capillary bridging force due to the secondary fluid. Compared with traditional computational fluid dynamics (CFD) method, the SPH method has the advantage of utilizing a Lagrangian meshless technique, which makes detecting the interface between fluids and solids simple, avoiding the complications of tracking the interface location and reducing the computational time and cost.

To our knowledge, this novel SPH-DEM approach is utilized for the first time to examine liquid-bridge induced particle agglomeration. The influence of different important parameters, namely shear rate and the secondary fluid surface tension, on particle agglomeration and suspension rheology has been investigated. This investigation has the potential to provide engineering guidance for optimizing dewatering processes.

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In situ formation of covalent/ionic conetwork hydrogels for biomedical applications

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Hydrogels with self-healing properties, good mechanical properties, and stretchability are of enormous importance in tissue engineering, cell delivery, drug delivery, and wound healing applications. Hydrogels made from oppositely charged polyelectrolytes (PE hydrogels) are formed by multistep polymerization or moulding and are, therefore, not injectable. The addition of a strong charged PE to an oppositely charged PE leads to precipitation due to charge neutralization and dehydration. Herein we have developed injectable hydrogel systems containing covalent linkages and ion pairs. Sequential nucleophilic substitution reaction at the backbone of tertiary amine functional macromolecules such as poly(2-dimethyl aminoethyl)methacrylate (PDMA), poly(2-dimethyl aminoethyl)methacrylate-*block*-poly(N-isopropyl acrylamide) (PDMA-*b*-PNIPAM), dextran, poly(vinyl alcohol) with activated halide-terminated PEG in presence of strong negatively charged polyelectrolyte leads to the formation of different hydrogels with modulated mechanical properties and degradation. In situ formation of covalent linkages ($^{+}$N-C) facilitates the formation of ion pairs in the presence of a negatively charged polyelectrolyte. The covalent/ionic hydrogels are hemocompatible, injectable and show sustained release of a representative drug, methotrexate, compared to that from purely covalent hydrogels. The hydrogel obtained by the PDMA-*b*-PNIPAM polymer and halide-terminated PEG, in presence of polyelectrolyte, exhibits temperature/pH-responsive behaviour. This strategy is useful to obtain varieties of hydrogels with predetermined ionic fraction with improved overall properties for biomedical applications.

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Development of Liquid Metal Alloy based catalysts for the reduction of Carbon dioxide into Carbon

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For poster consideration

The utilization of carbon dioxide from the greenhouse gases to create value added products, offers an excellent opportunity to tackle the problem of global warming. However, this conversion is mostly limited to liquid and gaseous fuels as the performance of the catalyst decreases with time, due to coking in the case of solid products. Liquid metal catalysts consisting of cerium have been found to be excellent candidate for use in electrolytic process converting carbon dioxide into carbon [1]. The unique properties of the metal oxide interfaces/skins, that liquid metal alloys form with the surrounding environments provide an active site for catalysis. The elimination of the impact of the van der Waals forces between the by-products and the interface prevents the adherence and thus makes the liquid metal catalysts resistant to the deactivation via coking [2]. This study aims to synthesize, characterize and study the fundamental reaction chemistry of the interfaces, that different liquid metal-based alloys form with the electrolytes. The study can provide useful insights that may help to upscale the process for industrial use.

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Formation and release of anthocyanins from protein-coated alginate hydrogel beads

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Anthocyanins are natural water-soluble phenolic compounds found in various flowers, vegetables, and fruits which produce bright colours such as red, purple, and blue. Anthocyanins have a number of potential benefits for human health including antidiabetic, antimicrobial and anti-inflammatory properties; anti-obesity effects and cardiovascular disease prevention [1]. Unfortunately, the stability and colour of these pigments are influenced by external factors such as pH, light, temperature. In order to overcome stability issues and to increase the oral bioavailability and biological efficiency of anthocyanins, microencapsulation technology can be used to address formulation challenges. Alginate is a natural polysaccharide commonly used to form polymeric hydrogels to encapsulate bioactive for pharmaceutical and biomedical applications. However, the alginate hydrogel network exhibits a low density due to having a highly porous structure resulting in the rapid release of the entrapped substance [2]. Studies have shown that polysaccharide coatings and protein incorporation can improve the encapsulation efficiency of bioactive compounds and prolong release of encapsulants [1, 2].

Alginate hydrogel beads containing an anthocyanin rich bilberry extract were formed using the external gelation method, whereby an alginate solution containing the extract is extruded dropwise into a calcium chloride solution. Hydrogel beads 4.7mm in diameter were produced containing an extract concentration of 0.5 wt%. To attempt to retard anthocyanin diffusion from the beads, a beta-lactoglobulin (BLG) protein coating was applied. Electrophoretic mobility studies showed surface-charge reversal upon exposure to proteins, suggesting successful adsorption of BLG to the hydrogel surface. The effect of a BLG protein coating on the hydrogel was examined through anthocyanin release studies conducted using UV-Vis spectroscopy. A 15 % decrease in anthocyanin release was observed when a protein-coating was applied, suggesting that appropriately selected protein coatings can indeed inhibit the release of encapsulated anthocyanins from calcium-alginate hydrogels.

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Investigating Grass Pollen Allergen-Lipid Membrane Interactions in the Development of Thunderstorm Asthma

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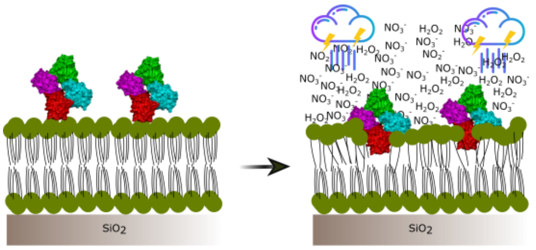
Epidemic thunderstorm asthma (ETSA) refers to a sudden upsurge in the number of asthma cases due to a high concentration of grass pollen allergens coupled with thunderstorms. *In-vitro* studies have shown that the respiratory distress of ETSA may be triggered due to the interactions of pollen protein allergens with epithelial cells (A549) present in the human lower airways (alveoli). Cellular changes trigger spatial reorganization of microtubules and decrease in cell compressibility coincided with the release of inflammatory agents. However, the physicochemical mechanism behind allergen-epithelial bilayer interactions in determining the interaction-mediated pathophysiological outcomes is unknown. We therefore investigate these interactions along with the role of reactive oxygen nitrogen species (RONS) originating from the atmospheric plasma-activated water (PAW).

In this talk, we demonstrate a model system consisting of solid-supported 1-palmitoyl-2-oleoyl-sn-glycero-3-phosphocholine (POPC) lipid bilayer mimicking phospholipid epithelium. It was allowed to interact with the allergen proteins including WFL and Lol p 1 derived from *Wisteria* seeds and ryegrass pollens, respectively, and the measurements were conducted at various relevant temperatures and pH conditions. The examination of PAW-treated allergens showed an uptake of RONS from the aqueous environment, aggregation, as well as strong adsorption onto the POPC bilayer, implying structural alterations. Furthermore, neutron reflectometry (NR) measurements revealed the insertion/penetration of allergens into the upper leaflet of the lipid bilayer, uncovering a mechanism of membrane destabilization. Interestingly, allergens treated with water at similar pH to PAW resulted in negligible or no loss in membrane integrity. These findings indicate the role of PAW in enhancing the allergenicity of pollen allergens, which can be envisaged to induce downstream respiratory effects. The data obtained from these experiments complement *in-vitro* cell studies and enable the development of effective therapeutic interventions for the treatment of ETSA.



Hyper-phosphorylation induces structural alterations and exacerbates the cytotoxicity of alpha-synuclein in Parkinson’s Disease pathogenicity

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Alpha-synuclein (α-syn) is an intrinsically disordered protein (IDP) that is known to misfold and aggregate in Parkinson’s Disease (PD). A dramatic increase in the phosphorylation of α-syn has been established in PD pathogenicity, but its effect on structure and cytotoxicity is still controversial. We phosphorylated α-syn using an *in vitro* kinase assay. Using high-resolution mass spectrometry we observed multi-serine phosphorylation at S42, S87 and S129 with Polo Like Kinase 2 (PLK2) and at S87 and S129 with G Protein Coupled Receptor Kinase 4 (GRK4). TEM analysis showed distinct alpha-synuclein strain formation post phosphorylation. Significant structural alterations and peak shift due to phophorylation were confirmed using Nuclear Magnetic Resonance (NMR). The phosphorylated α-syn formed SDS resistant higher molecular weight species. It accelerated the aggregation kinetics of monomeric α-syn and enhanced the nucleation capacity of the strain. The p-α-syn species were cytotoxic as assessed in SH-SY5Y cells, suggesting diverse pathways of multi-serine phosphorylation induced pathology. Based on these findings, we performed stereotaxic administration of multi-serine phosphorylated α-syn strain aggregates into the Substantia nigra (SN) region of the rat brain. This resulted in altered course of pathology spread indicating enhanced spread of the phosphorylated species. Significant increase in dopaminergic neuronal death was observed using phosphorylated α-syn. The proteomic results from high resolution mass spectrometry demonstrate the overall changes in the SN of the rat brain and provide a concrete evidence for phosphorylation in α-syn induced pathology.

Measuring the structures and adsorption behaviour of surfactant/polymer complexes at the oil/water interface

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Mixed stabilisers are ubiquitous in industrial applications, as carefully selected mixtures of polymers and surfactants offer unique advantages over a single surfactant system. In personal care products specifically, combining anionic and non-ionic surfactants in conjunction with polymers and salts provides not only colloidal stabilisation but also rheological control. The adsorption of polymer/surfactant (PS) complexes to interfaces is key to the delivery of hydrophobes in many products; their structures are formed from a balance of synergistic effects and antagonistic effects. This project seeks to improve the selection of polymers and surfactants for emulsion formulation, derive fundamental rules for formulating with these materials, and permit industry to source surfactants in a more environmentally sustainable fashion.

In this work, we look at the effect of salt on complexation between a homologous series of alkyl ether sulfate surfactants (SC_nES) and selected polymers (Guar & JR-30M), studying how salt changes the interactions with a model oil layer (PDMS). Using a combination of quartz crystal microbalance with dissipation (QCM-D) and neutron reflection (NR) measurements, we are able to investigate adsorption of each surfactant and polymer of interest on the oil mimic, yielding structural and compositional information regarding surfactant-polymer complexes at the oil/water interface. We see that at low-moderate salt concentrations, increasing the salt concentration increases the amount of complex adsorbed on PDMS. On the other hand, at high salt concentration, the adsorbed complex amount is reduced, potentially due to charge screening effects that hinder complex formation.

We will discuss how these experiments provide knowledge that permits us to tune the properties of PS complexes, influencing the colloidal and fluid properties within oil/water interfaces.

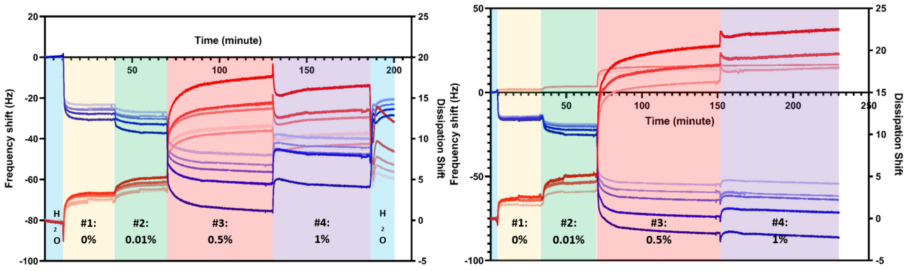

Figure 1: Frequency and dissipation shifts of 1% w $SC_{12}ES$/0.05% w Guar system (Left) and 1% w $SC_{12}ES$/0.05% w JR-30M system (Right) with varied NaCl concentrations

The effect of varying the stabilising agent on selenium nanoparticles to combat antimicrobial resistance

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Antimicrobial resistance (AMR) complicates bacterial infection treatment resulting in simultaneous use of multiple antibiotics, extended courses of antibiotic therapy, and prolonged hospitalisations. Unlike antibiotics, antimicrobial peptides (AMPs) and inorganic NPs can combat pathogens with minimal or delayed AMR development. AMPs are a class of short chained peptides that are a promising alternative to antibiotics. Selenium is an essential human trace element, thus selenium nanoparticles (Se NPs) are more likely to have a favourable safety profile than metallic and non-nutritious nanoparticles. Se NPs and AMPs are both known to have multifunctional antimicrobial properties and we hypothesise that the combination of Se NPs with specific AMPs can produce conjugates with superior antibacterial characteristics while minimising the potential for AMR development.

We have demonstrated that spherical Se NPs stabilised with polyvinyl alcohol (PVA-Se NPs) and electrostatically coated with the AMP ε-poly-L-lysine (ε-PL) significantly delayed the onset of resistance in selected Gram-positive and Gram-negative bacterial strains.[1] However, little is known about how the loading density of peptides on the Se NPs influences their physicochemical and antibacterial properties. To explore this, we investigated the effects of changing the stabilising agent on the characteristics of the spherical Se NPs. We fabricated spherical Se NPs stabilised with sodium alginate (Alg-Se NPs) and electrostatically coated with ε-PL. The size, shape, surface charge of the Alg-Se NPs and the amount of ε-PL physically adsorbed onto them were determined and compared to the current PVA-Se NPs. The Alg-Se NPs adsorbed a larger amount of peptide resulting in a significantly higher positive surface charge than for the PVA-Se NPs. This indicates that the Se NPs with different characteristics can be successfully fabricated by varying the stabilising agent, allowing for specific Se NP-AMPs to be developed for use against different bacterial strains.

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High Pressure Dewatering Rolls Mk-II: A novel dewatering technology for mineral tailings

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The mining industry produces a large amount of mineral tailings with the potential to cause significant environmental and social impacts in the occurrence of tailings storage facility failures. Dewatering tailings before storage using thickening is the industry standard, but for tailings with fine particles, thickening operation alone cannot generally reduce the tailings water content to a geotechnically safe level. Thus, high pressure filtration is now being considered by many mining companies to both decrease water use in the industry and provide safer tailings storage.

Figure 1: High Pressure Dewatering Rolls (HPDR) Mk-II

Plate-and-frame filters are commonly used in many industries for high pressure filtration applications. However, this technique can have high capital and operating costs since they are batch processes requiring considerable ancillary equipment and infrastructure, have fixed plate separation and therefore limited versatility for changing feed types, and can suffer cloth fouling and wear, requiring regular washing and eventual changeout. A novel solid-liquid separation device developed at the University of Melbourne, called High Pressure Dewatering Rolls (HPDR) (Scales et al., 2017, Scales et al., 2018) has the potential to overcome these issues. An initial Mk-I prototype was trialled using a range of compressible industrial suspensions (Höfgen et al., 2019) and achieved comparable cake solids concentrations to conventional high pressure filters. The Mk-II HPDR prototype, presented here, is designed and manufactured specifically for mineral tailings to overcome the Mk-I's limitations via a higher effective filtration area and increased finer particle filtration. This work presents an overview of the HPDR Mk-II design and demonstrates its performance using copper tailings.

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A Machine Learning Approach to Contact Angle Analysis

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Wetting is a fundamental property of interest when creating novel materials or fluids. Analysing surface wetting properties using sessile drop contact angles is a simple process but can take up to 20 min per sample[1] due to many points of human input and slow drop fitting methods. Contact angle measurements are increasingly used by researchers from a diverse range of fields, however, current techniques require human input which introduces a significant source of variability in measurements.[2-3] The research presented aims to create a new approach to sessile drop contact angle analysis employing machine learning, thereby increasing the speed, accuracy, and autonomy of this important measurement. The model is trained on a large data set of synthetic drop images created by solving the Young-Laplace equation, and outputs a predicted contact angle. Current work has been restricted to the analysis of high contact angle (>100°) drops resting on opaque surfaces but the resulting model is of a comparable accuracy to the Bashforth-Adams Young-Laplace fit at a greatly enhanced speed when tested on a synthetic data set. The model's effectiveness will be benchmarked against existing methods using a data set of experimental systems and will be made freely available and open source. This method of contact angle analysis will make efficient and reliable wetting analysis accessible to the wider academic community, allowing for higher quality investigation into surface wetting properties across a wide range of applications.

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Structural forces dominate drainage in micellar thin films

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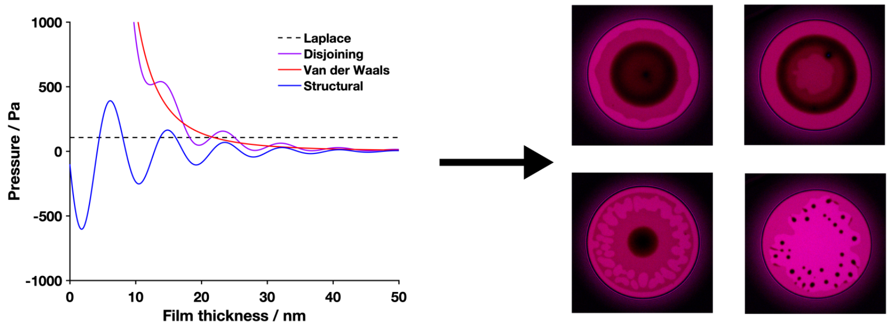
As a bubble in a fluid medium approaches a wall, the thickness of the intervening fluid layer decreases until it is much thinner than the objects on either side, establishing what is known as a fluid thin film. The dynamics of such films are controlled by various forces including hydrodynamic force from fluid flow, capillary forces arising from bubble surface tension, and surface forces across the intervening fluid layer. Classical DLVO theory is sufficient for understanding homogeneous, Newtonian fluids, such as water. However, in many real-world scenarios, thin fluid films are composed of complex fluids that contain polymers, particles, or surfactant micelles.[1] In these cases, non-DLVO contributions[2] arise and can dominate thin films, resulting in unique and unpredicted behaviour.

Here, we study the drainage behaviour of thin films comprising sodium dodecyl sulfate (SDS) micelles between an air bubble and mica using a custom-built two-colour interferometry apparatus to obtain sub-diffraction limit film profiles. We find that significant structural forces are observed due to layering of micelles upon confinement within a fluid thin film. This leads to stratified drainage behaviour with preferred separations arising that correspond to multiples of the layer thickness. As drainage proceeds, multiple novel thin film instabilities are observed, as shown in the figure below.



We are able to map these instabilities across SDS concentration and interaction velocity, providing insight into the interplay between structural forces and hydrodynamic conditions. In addition, we calculate film volume as a function of time using empirical data and find counter-intuitive trends across a range of conditions. Theoretical modelling is attempted using the Stokes-Reynolds-Young-Laplace (SRYL) model. We find that late-stage drainage profiles and kinetics cannot be predicted using this contemporary theory. These results and insights have broad implications for colloidal materials containing complex fluid thin films, including many foodstuffs, biological systems, and surface coatings.[1]

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Stability and characterization of oil-in-water emulsions with xanthate surfactants

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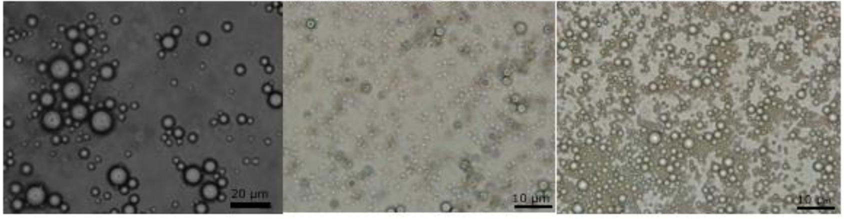
The creaming rate, droplet size distribution, and oil separation of kerosene-in-water emulsions formed with potassium amyl xanthate (PAX), potassium vitamin E ethyl xanthate (VitE-Ethyl), and potassium vitamin E PEG400 xanthate (VitE-PEG400) were investigated. Understanding the stability and properties of the emulsions is crucial for industrial applications. In particular, such emulsions may be an effective way of delivering oil to copper-containing minerals to aid in froth flotation. It was discovered that the kerosene emulsion with the VitE-PEG400 was the most stable while the droplet size distribution of the emulsion with the vitamin E ethyl xanthate was the smallest. The zeta potential of the kerosene emulsion with the VitE-PEG400 xanthate was also the most negative supporting the results from the creaming rate and oil separation.

The pH of the emulsion is different from the pH of the starting aqueous solution. The pH of the kerosene emulsions formed with PAX ranges from 7.18 to 7.79 when the starting aqueous solution was either acidic, neutral, or alkaline. It is also interesting to note that the droplet size distributions, creaming rates, and oil separations of these emulsions are similar. This indicates that there is an equilibrium pH range for the kerosene emulsion with potassium amyl xanthate.

Furthermore, the study on the hydrophilic-lipophilic balance (HLB) of common emulsifiers shows that the application of a single indicator such as HLB for the emulsifying properties of surfactants is not effective. A similar observation was reported by other researchers[1]. However, our study indicated that the emulsifying properties of surfactants are significantly influenced by the molecular weight and specific chemical properties of the head group and hydrophobic chain group of the surfactants. It was observed that surfactants with different head groups and hydrophobic chain groups exhibit different emulsifying properties even with a similar HLB.



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Formation of particulate lipid lyotropic liquid crystalline nanocarriers using a microfluidic platform

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Non-lamellar lyotropic liquid crystal nanoparticles (LLCNPs) are gaining significant interest in the fields of drug delivery and nanomedicine. Traditional, top-down formulation strategies for LLCNPs are typically low-throughput, can lack controllability and reproducibility in the particle size distribution, and may be unsuitable for loading more fragile therapeutics. The development of a controllable, reproducible, scalable, and high-throughput strategy is urgently needed.

In this work, Monoolein (MO)-based LLCNPs with various stabilizers (F127, F108, and Tween 80) and phytantriol (PT)-F127 cubosomes were produced at various flow conditions via a bottom-up method using a microfluidic platform. This simple enabling strategy was used to formulate LLCNPs with lower polydispersity compared to the traditional top-down homogenization method. Significantly, particle size could be quantitatively controlled by varying the overall flow-rate; a scaling law was identified between nanoparticle mean size and the total flow rate (Q) of mean size~Q^(-0.15) for MO cubosomes and mean size~Q^(-0.19) for PT cubosomes (at a fixed flow rate ratio). Effective size control was achieved for a range of cubosome formulations involving different lipids and stabilizers. The formulation of stable, drug-loaded cubosomes with high encapsulation efficiency using this method was exemplified using calcein as a model drug. This work will further promote the utilisation of LLCNPs in nanomedicine and facilitate their clinical translation.

The role of the solvent in specific ion effects: PNIPAM brushes in non-aqueous electrolytes

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Stimulus-responsive polymers can uniquely alter their conformation as a function of external factors.[1,2] One such polymer is the thermoresponsive poly(*N*-isopropylacrylamide) (PNIPAM), which, when end-tethered to a substrate at sufficiently high grafting densities, forms a brush that undergoes a phase transition from well- to poorly-solvated over a broad temperature range.[2] These smart coatings modify interfacial properties such as surface charge, film thickness, wettability, and adhesion, thereby improving the deployment of the underlying material in otherwise challenging media.

The phase transition of polymer brushes can be moderated to higher or lower temperatures by altering the effective solvent quality, such as the inclusion of ions. These resultant phenomena are known as specific ion effects (SIE), whereby the observed effect is dependent on ion identity rather than mere concentration or valence.[3,4] To date, no all-inclusive theory regarding SIE exists; however, as natural environments are composed of complex mixtures of aqueous and non-aqueous electrolytes, understanding the interplay of ions and solvent identity is imperative for real-world applications. To probe the role of the solvent in SIE, we investigate changes in the behaviour of a PNIPAM brush in mixed dimethyl sulfoxide (DMSO)/aqueous electrolytes. Due to its membrane penetration abilities, DMSO is frequently used as a cryoprotectant and a drug delivery vehicle. Neutron reflectometry (ANSTO; *Platypus*) and ellipsometry measurements revealed a complex relationship between solvent composition and the structure and film thickness of a PNIPAM brush, illustrating that the behaviour of PNIPAM is modified when DMSO is introduced to the system. By examining the subtle changes in polymer brush conformation in mixed non-aqueous/aqueous electrolytes, we aim to elucidate the dominant drivers behind SIE and move towards developing a predictive theory.

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Selective flocculation of hematite and silica for fine particle flotation

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Recovery of valuable ultrafine minerals in a cost-effective manner remains a serious issue in mineral processing given the increased entrainment of gangue minerals and therefore, reduction in concentrate grade. Minerals within the particle size range of 50-150 μm can be successfully recovered by flotation due to effective particle-bubble collision, whereas valuable particles less than 50 μm tend to get carried away by the fluid streamlines around the air bubbles.[1] Despite the challenges, low-grade ores are ground finer to liberate valuables and hence, techniques such as selective flocculation are of growing interest. The overall aim is to selectively flocculate the valuables and make the flocs hydrophobic so they can be recovered by froth flotation. In this study, commercial polymers are utilised in selectively flocculating 0.77 μm hematite (with isoelectric point pH 9.5) and 0.84 μm silica (with isoelectric point below pH 2). Increasing the size of these fines by forming aggregates using high molecular weight flocculants aid with particle-bubble attachment and allows for quick and effective recovery.

The role of high molecular weight anionic and cationic polyacrylamide-based flocculants with a range of charge densities is studied to determine the minimum dosage and selectivity in the presence of 0.01 M KCl using turbidity measurements. It is important that the oppositely charged fine minerals are firstly well dispersed before carrying out selective aggregation, which is why a dispersant is used. Anionic dispersant, sodium hexametaphosphate is used which in turn affects the surface charges of hematite and is analysed using zeta potential measurements. The difference in the surface charges of the minerals in combination with charged flocculants aid selectivity. Single mineral flocculation of iron oxide using anionic flocculants and silica using cationic flocculants have shown that the dosage required decreases as charge density of polymer increases.

The aggregation is carried out in a controlled manner in a stirred reactor designed to imitate shear conditions within a flotation cell and the selectivity is observed for different polymers. Selectivity of the polymers towards the minerals are examined by plotting adsorption isotherms using Total Organic Carbon (TOC) analyser. Future work involves making these aggregates hydrophobic using charged collectors and investigating the flotation behaviours via contact-angle measurements.

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Nonaqueous electrolytes in one- and two-dimensions

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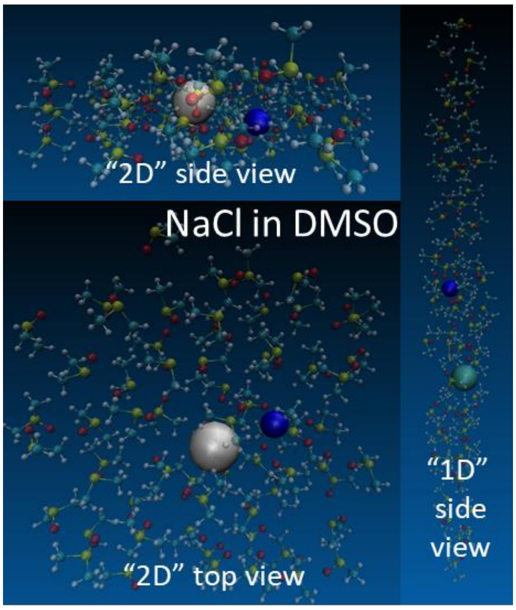
Electrolytes are essential for our daily lives. They regulate our daily functions (*e.g.,* heart beat), allow batteries to function and are used in water treatment.[1] However, the ion structure at a interfaces is still not fully understood. This is important in both 2D interfaces,[2] and 1D electrolytes, such as those occurring in ion channels,[3] which allow (or exclude) ion transport, and desalination of a solvent through a membrane.[4] Given their broad importance and the predominance of aqueous data, it seems imperative to understand these phenomena more generally, allowing for greater utility and adaptability for in broader purposes. Here, ion solvation in one- and two-dimensions has been investigated, in both aqueous and nonaqueous electrolytes.



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Effect of membrane composition on the lipid packing and solute permeability of synthetic cells

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This project is part of efforts to build a propagating minimal synthetic cell. A core feature of this synthetic cell is the presence of enzymes required to grow the membrane (Figure 1). For a high yield of phospholipid synthesis and subsequent membrane growth to occur, an external feedstock of nutrients is required.[1] The growing membrane could have a range of different lipid compositions depending on gene expression levels, but it is not yet understood how this range of lipid compositions could impact membrane permeability. Improving the permeability of membranes of mixed lipid composition to the nutrients required for phospholipid synthesis, some of which are largely impermeable, will help ensure that membrane growth and subsequent division can successfully occur.

Electrical impendence spectroscopy and a shrink-swell assay were used to monitor lipid packing and the permeability of bilayers composed of a mixture of lipids. We found that vesicles composed of a blend of POPC and POPG were permeable to sugars such as glycerol but impermeable to larger species such as sucrose. We also found that these membranes were largely impermeable to a range of solutes including AMP, ATP and NaCl, likely owing to their charged nature or size. Cataloguing the permeability of blended membranes to solutes such as these helps us to tune gene expression levels to improve bilayer permeability to nutrients that are vital to the function of the synthetic cell.

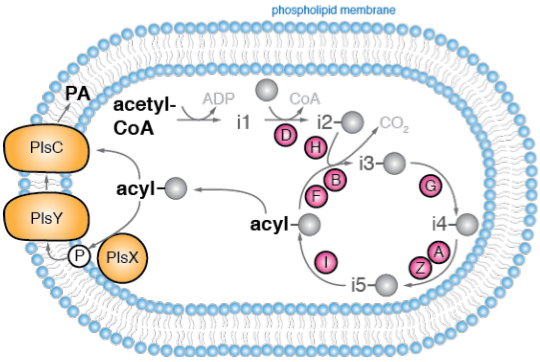

Figure 1. Schematic showing the initial phospholipid synthesis pathway. Enzymes are shown in orange (Pls) and pink (Fab). Acyl-carrier protein is shown in grey. Intermediates are labeled i#. Courtesy Kuruma, Y., Rogers, B., Wang, A., HFSP grant.

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Modelling the Size and Structure of Fractal-like Aggregates under Shear by Computational Fluid Dynamics-Discrete Element Method

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The control of dispersion, aggregation, and restructuring of fine particles is important for mineral processing as particle characteristics (e.g., size, structure, density, shape) affect product grade and recovery, and process efficiency[1]. Aggregation of fine valuable mineral particles can enable their collection by froth flotation. Aggregate size and structure are usually controlled by altering the pH, adding surface modifiers or salts, flocculation with polymers, or applying shear forces to the suspension[2]. Even though almost all unit operations inevitably result in shear flow, their effect on aggregate characteristics is not fully understood due to difficulties in observing aggregate behaviour over short time scales at the microscopic level. Computer simulations are an excellent tool to study particle and aggregate dynamics as they enable observation of particles and aggregates in suspensions without interference[1].

In this work, Computational Fluid Dynamics coupled with Discrete Element Method have been applied to investigate the effect of shear on particle aggregation and aggregate fragmentation accounting for particle-particle (surface, contact and collision forces) and particle-fluid interactions (hydrodynamic forces). At steady-state, the aggregate size distribution closely matches the experimental size distribution[1]. The steady-state structural characteristics (fractal dimension, average size, size distribution) of the aggregates during particle aggregation and aggregate fragmentation are quantified. Simulations are in excellent agreement with the theoretical[3] shear-induced aggregation rate at low shear rates, where aggregation is dominant. In addition, the effect of aggregate characteristics on the aggregation and breakage rate under various shear rates will be discussed. Higher shear rate leads to faster particle aggregation and aggregate breakage and lower aggregate fractal dimension, indicating a more open, fractal-like structure, consistent with Kushimoto et al.[1]

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Uncovering the Microbial Death Force: Adhesion Forces of Bacteria and Fungi on Nanostructures Antimicrobial Surfaces via Single Cell Microscopy.

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Antimicrobial resistance is a silent pandemic sweeping the globe. For the past 100 years, antibiotic drugs have prevented infections and diseases caused by fungal and bacterial species. The development of nanotextured surfaces, inspired by naturally occurring nanofeatures, have been used as a mechanism for contact-based killing. When microbes interact with these surfaces, the membrane is penetrated, causing cell lysis leading to the inability to reproduce and therefore cellular death. Although these surfaces show inherent antimicrobial activity, one aspect remains hotly debated: what are the underlying forces and bio-physical properties that govern mechano-responsive antimicrobial action? The process of mechano-microbiocidal interactions involves three main factors - adhesion of the cell, elasticity of the cell's membrane, and the force required to irreversibly damage (puncture) the cell force. Each of these factors were investigated to understand the relationship with the mechano-microbiocidal in both bacterial and fungal cells. Specifically, a suite of atomic force microscopic techniques were employed to probe the adhesive behaviour of two bacterial species, *Pseudomonas aeruginosa* and Methicillin-resistant *Staphylococcus aureus* (MRSA), and two fungal species, *Candida albicans* and *Cryptococcus neoformans* at a variety of nanostructured titanium interfaces (solid, spikes, and wires). Single-cell force spectroscopy and high-resolution nanomechanical measurements provided an insight into the biological interface of nanostructured materials and shed some light towards the mechano-bactericidal mechanism and the attachment-kill forces which govern these phenomena. This investigation aids in the improvement of the surface properties to increase the antimicrobial characteristics of implant materials and medical equipment to prevent the transference of hospital acquired infections.

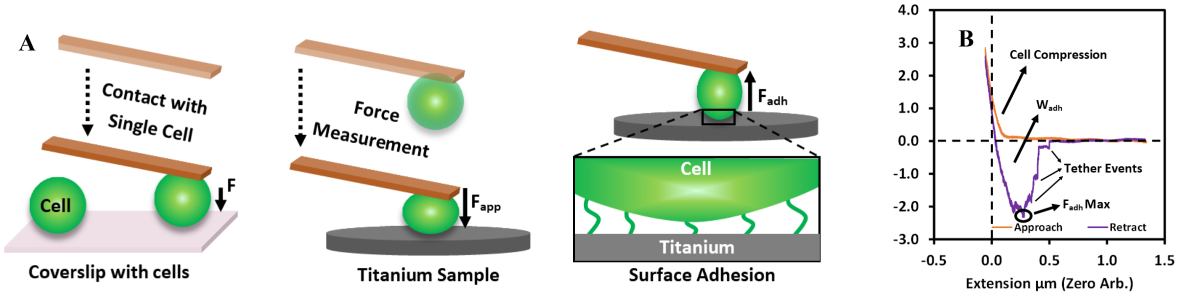

Figure 1. A) the progression of cell on the cantilever interacting with titanium surface. B) Force curve indicating the points of interest post surface-to-cell interaction

Direct observation of bacterial production of hierarchical cellulose nanofiber mesh structures

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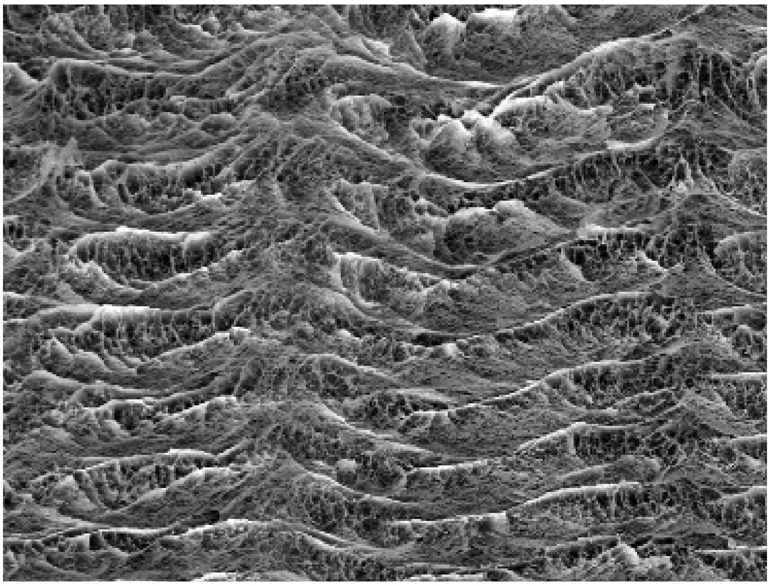
Acetobacter bacteria produce 3D cellulose biofilms with incredibly low solid densities via fermentation. Electron and confocal microscopy imaging of the fibrous meshes indicates complex multilayer structures form and can vary significantly depending on fermentation conditions. However, no direct observations of full biofilm formation have been carried out to explain how the complex structures form. A holistic model of bacterial cellulose structure formation is needed to enable direct engineering of these structures during fermentation. Here, we used Light Sheet Fluorescent Microscopy to visualize and track three-dimensional bacterial motion, and with it the trajectories of every nanofiber's growth, during fermentation. Engineering of the fiber mesh structure is carried out using changes in the growth medium rheology that can dramatically alter the structure's packing density.



Tuning the nanostructure and surface charge of lipid-based non-lamellar nanoparticles using choline ionic liquids

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The structure-function relationship of lyotropic liquid crystalline nanoparticles (LCNPs) is of fundamental interest for their development as sustained release delivery systems[1]. Ionic Liquids (ILs) are tailorable solvents, some of which can be used as designer solvents for LCNPs[2]. We employed synchrotron small angle X ray scattering (SAXS) and zeta potential measurements to investigate the nanostructure and surface charge of phytantriol (PHY)-based LCNPs doped with 12 choline based ionic liquids. Most ILs preserved the diamond cubic ($Q^D{}_2$) structure of phytantriol. Cubosomes with a primitive nanostructure ($Q^P{}_2$) were also obtained. The phase behaviour of the particles depended on the structure of the anions, and the IL's concentration. Moreover, positively charged cubosomes were obtained in PHY:IL samples prepared in 20 mM acetate buffers. The charge of the particles depended on the IL's concentration and the pH of the solution. This study validates the efficiency of using biocompatible ILs as tailorable solvents for the preparation of responsive LCNP systems.

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Elucidating the effect of the protein corona on the interactions between nanoparticles and brain cells

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Nanoparticle-based therapeutics show promise for the treatment of neurodegenerative diseases due to their ability to deliver drugs across the blood-brain barrier (BBB) 1. Upon entering biological fluids, nanoparticles are coated with proteins, forming an outer layer known as the "Protein corona, PC" which determines their *in vivo* behaviour and fate 2. Recent reports suggest that systemically-injected nanoparticles form a serum-derived PC, which is then partially shed as the particles cross the BBB into the brain where they acquire an additional cerebrospinal fluid (CSF)-derived PC 3. At present, there is little information on the impact such PC changes have on the development of nanoparticles for neurodegeneration therapies.

This project investigates how PCs derived from different biological fluids influence the downstream interactions nanoparticles have with brain cells. Herein, polymeric PLGA nanoparticles (with and without PEGylation) were synthesized and exposed to various biological fluids: foetal bovine serum (FBS), rat serum (RS), and rat CSF. Each of the PCs formed on the nanoparticles were characterised and the interactions between the particles were evaluated against a brain cell panel: microglia, astrocytes, and neurons.

We found that PCs formed rapidly on particles, and increased in size over 12 h. As expected, PCs were less prominent on PEGylated NPs due to the anti-fouling nature of PEG. LC/MS analysis showed variations in PC compositions were mostly the result of the different biological fluids used. Flow cytometry and confocal microscopy showed PEGylation reduced the uptake of polymeric nanoparticles by brain cells. Nanoparticle uptake was the most efficient in microglia, while the lowest internalisation was observed in astrocytes. Under all conditions tested, the presence of PCs enhanced nanoparticle uptake, but this varied depending on the biological fluid Interestingly, PLGA particles reduced the viability of neurons, however, the presence of PC on these particles then alleviated this cytotoxicity. We are now investigating the effect the nanoparticle PCs have on brain cell immune responses (i.e., pro- and anti-inflammatory).

Overall, our results currently suggest that biological fluid effects nanoparticle-brain cell interactions *in vitro*. This critical information can inform the development of nanoparticle-based therapies for neurodegeneration, including the design of *in vitro* and *in vivo* studies.

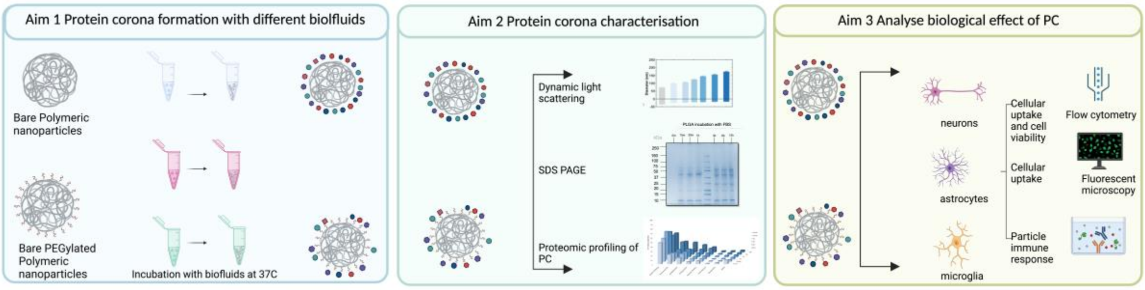

Figure 1: Experimental workflow **1:** Protein corona (PC) formation on PEGylated and non-PEGylated polymeric NPs exposed to FBS, rat serum, or rat CSF. **2:** Characterisation of PCs. **3:** The effect PCs have on the interactions between nanoparticles and different brain cell types (e.g., safety, uptake, and immune response).

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Fluorescent Carbon Nanodot Doped Smart Hydrogels

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Hydrogels, composed of three dimensional hydrophilic polymer networks withholding large amounts of water inside, have been widely used in biomedical areas, including wound healing, drug delivery, tissue regeneration, etc[1]. Natural hydrogels, such as sodium alginate based hydrogels, possessing similar properties to the characteristics of the native extracellular matrix, have excellent biocompatibility, tuneable biodegradability, minimally invasive, high permeability to oxygen and nutrient, and easy manipulation[2]. However, the monotonous function and poor mechanical strength of this type of hydrogels fail the need for real-time and long-duration biomedical treatments, for instance, in chronic wounds[3]. Doping of nanomaterials with advanced physical and chemical properties into the hydrogel network can potentially overcome the hurdles[4].

Carbon nanodots (C-dots) are a new type of nanocarbon materials. Possessing excellent photophysical properties, such as stable photoluminescence (PL) and tuneable emission wavelength. Additionally, recent studies show that C-dots have good biocompatibility and low cytotoxicity, indicating great application potential in the biomedical area[5]. In this work, we introduce C-dots into the sodium alginate (SA) hydrogel system and investigate how the doping of C-dots impacts SA-based hydrogel formation and properties. Specially, the gelation time, morphology and photoluminescence of the C-dot/SA hydrogels are studied. In addition, the responsiveness of the C-dot/SA hydrogels to the environmental conditions, such as pH and oxygen radical ions, are tested. The results indicate that formed C-dots/SA hybrid hydrogels have promising potential as smart hydrogels for biological applications.

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Moisture Sorption and Transport within Australian Native Fruits in Preservation

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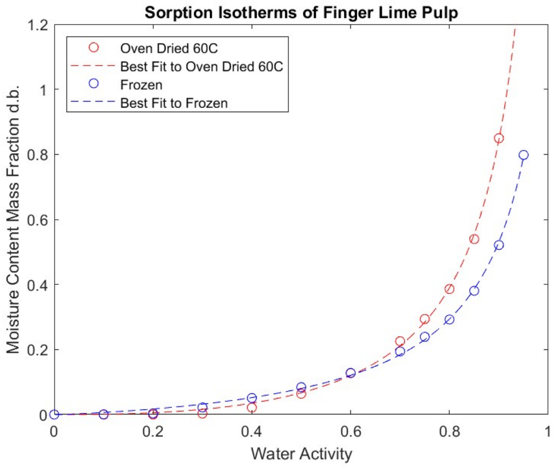
Australia’s food production is being challenged by population growth and increased drought. One way to manage these challenges may lie in Australian native food crops, which have unique sensory and nutritional properties while being well-adapted to Australian climate and soil and in which there is emerging a local industry and global interest.[1] A barrier to the industry’s growth, however, is the knowledge gap regarding best practice to maximise the retention of quality attributes over the course of preservative processes, particularly those processes which manipulate food moisture. Essential to overcoming this obstacle is a rigorous understanding of the dynamics of water within and at the interface of the fruits with their process environment, as well as how this affects other quality values. In this work Dynamic Vapour Sorption (DVS) has been used to produce sorption isotherms describing the water at the fruit surface at a range of humidities. This not only informs the shelf-stable moisture contents, but through the fitting of isotherm models, yields parameters that describe the sorption moisture layer between the surface of the fruits and their environment. By coupling the parameters so obtained for finger limes, Kakadu plums, riberries, and muntries preserved in a range of conditions to the nutritional and structural changes that occur because of this processing, larger-scale processes can be designed that more effectively preserve these fruits with minimal quality loss.



Finger Lime	mg Vitamin C/100 g fruit, dry basis
Frozen	213
Oven Dried (60°C, 18h)	130

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Improving the recovery of valuable fine copper minerals by flocculation/flotation

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Copper is an important industrial metal that is essential to guarantee the supply of future renewable and clean energy[1]. Most of the current copper sources are located in low-grade deposits that need to be ground into smaller particles, generating a high quantity of fine materials[2]. However, the conventional flotation process used to recover these minerals is ineffective for treating fine particles (<20 µm), resulting in a loss of valuable fines recovery and selectivity[3,4]. The purpose of this work is to use the flocculation/flotation approach to increase the size of valuable copper particles (chalcopyrite) until a range where they can be collected by conventional flotation (typically 50 to 150 µm). In the present system, chalcopyrite was chosen as the copper source, and quartz as the gangue mineral. The first part of the project is to investigate aggregation of fine chalcopyrite particles using commercial polyacrylamide polymers of different charge densities and molecular weights. The different charge (anionic or cationic) is used to control selectivity in aggregating chalcopyrite and quartz. Then, the chalcopyrite aggregates were made hydrophobic by adding Potassium Amyl Xanthate (PAX) as an appropriate collector. The efficiency of the reagents was evaluated based on the minimum dosage required for a clear supernatant on individual mineral flocculation and their selectivity on the mixed minerals system.

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Studying Drop Adhesion with different Polymer-surfactant Coatings using Microfluidics and AFM

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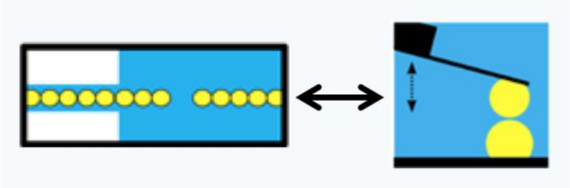
Emulsions used in formulated products commonly have surface-active coatings which help impart function. Often, these surface-active coatings result in attractive or adhesive interactions between emulsion droplets, but prevent coalescence. This can lead to an emulsion at different states of aggregation or even gelling, providing an additional pathway to provide function in a product. The surface-active coatings are often multi-component mixtures where attributing the relative importance of different components to the adhesive interactions between drops can become a laborious and lengthy processes using traditional surface force measurement methods. In this work, we have used a novel 3D printed microfluidic device to explore the adhesive interactions between drops over a large parameter space of mixtures of different polymer-surfactant species. We also use AFM to study a subset of these systems in more detail.

Microfluidic drop adhesion measurements allow us to qualitatively study drop-drop adhesive interactions in a high throughput context. Building on previous designs developed in our group[1], we have developed a new design that has three main sections – drop generation, drop collision and drop chain formation, to be able to form a drop chain structure that is sensitive to the drop interactions rather than hydrodynamic forces. With this method, we measure the chain size and build a drop size distribution. Initial microfluidic results suggest that our device can generate reproducible results and is able to identify interesting trends. This presentation will discuss the effect of dilution, the effect of surfactant mixtures with different types and ratios, and the effect of different polymers, on the adhesive behaviours. The drop-drop AFM technique[2] allows us to gain more information of the adhesion forces – for example its magnitude and force range, under different conditions including equilibrium and dynamic interactions, different contact times, and different loading forces.



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Dye Anchoring Modes of Ru-based N719 dye investigated using FTIR and ARXPS.

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Immobilization of dye on semiconductor substrate deposited on a conductive glass combinedly make the working electrode. The way the dye anchors on to the titania substrate directly influences the charge injection from the dye molecule to the conduction band of the semiconductor. Thus, dye anchoring plays an important role in determining the cell efficiency and extensively influences the cell stability. This makes the investigation of the characterization of the dye complex adsorption on the titania substrate very crucial as it will help in exploration of the sensitization phenomenon and to optimize their quantum yield.

The present work aims to re-investigate extensively studied Ru-based dye, N719 using FT-IR and Angle resolved XPS, to set up a methodology and further apply it in investigating the anchoring in other dyes. FTIR helps in identifying the change in the structure of dye molecule upon adsorption revealing information about the anchoring modes. ARXPS on the other hand helps in determining the depth profile of the dye adsorbed on to the titania. ARXPS being a non-destructive technique is based on simple principle of tilting the sample to increase the sample surface sensitivity [1].

The ageing of dye sensitized solar cell has adverse impact on the cell performance of which one of the crucial factors is change in the dye structure. To understanding how the dye attaches on to the titania substrate and how the dye anchoring changes with ageing give insight into how the change in dye structure with ageing is affecting the cell efficiency and what functional groups are more prone to get affected under stress.

FTIR result suggested, the role of TBA^+ is deprotonation of the carboxylic group hence, COO^- anchors to titania via multiple modes, i.e., bidentate chelating and ester bonds. However, the changes in feature of NCS suggested the partial involvement of thiocyanate ligand in the dye attachment. In addition, the depth profile obtained from ARXPS suggested the dye adsorption mostly concentrated onto the surface than depth with COO^- at the depth and NCS+S just above Ru with Ru at the depth of 0.7 λ.

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Deposition Behaviour of Polydopamine coated Silica Particles in Microfluidic Channel

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Transportation of composite particles is essential for a number of applications in catalysis, drug delivery, food enhancement, etc. During the transportation process, one of the critical concerns is particle deposition onto the surfaces, which can have beneficial or adverse effects based on the purpose of the process. Therefore, it is crucial to understand why, how, and where composite particles deposit in a system. In recent years, silica particles coated with polydopamine have been an excellent candidate for advanced engineering coating, drug delivery for cancer therapy, and image sensing in recent research due to their optical, paramagnetic properties, conductivity, reactivity, biocompatibility.[1] Despite the extensive deposition studies of polymeric and silica particles, current literature lacks a comprehensive understanding of the deposition process of polydopamine-coated silica particles, as the surface properties can be significantly different compared to their homogeneous counterparts.

The current work modifies an existing Brownian Dynamics simulation model coupled with advection to account for the retarded van der Waals, electrostatic interactions present in the system to predict the deposition behaviour of composite particles. The adequacy of the simulation model was further validated by comparing the predicted deposition kinetics with the experimental measurements utilising the advancement of the recently developed Resonance Imaging Microscopic (RIM) technique to observe the deposition of colloids in real time under flow in a microfluidic channel. The results indicate that the presence of colloidal forces, diffusion and advection have a strong impact into the adsorption of the particles onto the surface in dynamic flow conditions.

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Encapsulated ultra-short AMPs in cubic phase lipid nanoparticles fighting against bacteria

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According to the World Health Organisation (WHO), antibiotic resistance is one of the biggest threats for global health today[1]. A slowdown in discovery rates for new antibiotics has prompted research on alternative delivery vehicles such as nanocarriers (NCs) or colloidal nanoparticles. NCs are an attractive approach for targeted drug delivery due to many advantages over free drugs[2], such as improvement in intracellular penetration and protection of the drug from premature degradation[3]. Lipid nanocarriers of cubic symmetry (cubosomes) display good biocompatibility, can be formulated using a wide array of lipids and can load hydrophilic, hydrophobic, and amphiphilic drugs due to their unique amphiphilic nanostructure.

Compared to conventional antibiotics, antimicrobial peptides (AMPs) appear to induce a lower rate of acquired resistance in bacteria making them ideal potential new antibiotic candidates[4]. Additionally, ultra-short peptide sequences derived from AMPs are appealing because of their short amino acid sequences which could lower production costs and remove toxicities that may come from the parent sequence[5]. Thus, encapsulation of AMPs, and associated ultra-short peptides, may alleviate a major issue with these potential antibiotics, which is their physical and chemical stability, particularly *in vivo*. Herein, we have encapsulated the AMP indolicidin along with its ultra-short peptide fragments RW5 and priscilicidin within cubosomes. We have demonstrated the associated changes to the internal structure, particle size and surface charge of these cubosomes. We observed that the presence of AMPs disrupts the cubic structure at high concentrations of peptide, the presence of salt helps retain a cubic structure and the addition of highly curved lipid (DOPE) pushes the cubic phase to lower curvature.[1] Encapsulation was shown to significantly enhance the antibiotic activity of indolicidin particularly against gram-negative bacteria.

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Colloidal synthesis of photoactive p-type spinel copper gallate nanocrystals

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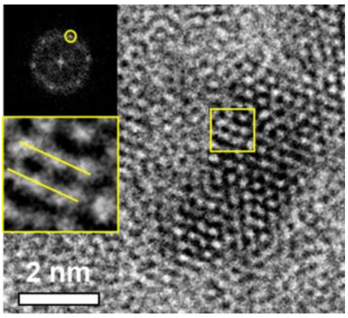
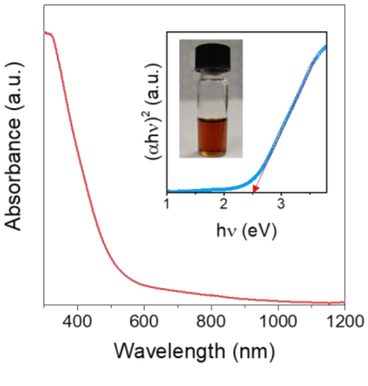
Metal oxide semiconductors are becoming an essential component for various devices and applications. This is primarily due to their unique optical, electrical and catalytic properties as well as their chemical and thermal stability. While binary metal oxides have been the primary focus for research, recently ternary metal oxides have begun to garner more and more attention. This is due to the enhanced properties provided by a more complex stoichiometry, and also to the possibility of modifying these properties through controlling the cation stoichiometry within the material itself. Due to the additional cation site it is also possible to co-dope the material, which allows for additional control over how the materials properties.

Currently, metal oxides produced for use in devices (solar cells, LCDs etc…) are mainly produced via physical deposition methods such as sputtering, electron beam evaporation and atomic layer deposition (ALD). While these methods do allow for highly crystalline films with good optical and electrical properties to be produced, they are also highly energy intensive and require high temperature and vacuum environments.



In this work[1] we present a method for the synthesis of copper gallate ($CuGa_2O_4$) nanocrystals (NCs) using a colloidal heat-up reaction. These particles were found to have an average size of 3.7nm and showed strong p-type characteristics. While computational studies showed a predicted bandgap of 3eV, surface defectivity was found to contribute to a narrowing of the band gap, with experimental values of ≈2.5eV confirming this. Modulation of the cation stoichiometry showed that these NCs can be synthesised in Cu-deficient environments while still maintaining the same crystal phase. The NCs were also found to be photoactive under visible (blue) light illumination while maintaining a stable photocurrent.



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Microplastic Particles' Surface Properties probed by CP-AFM

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Microplastic (**MP**) particles pose a risk to the health of organisms and environment. In the past MP was classified only by polymer type, shape and size. This had led to different results in systematic studies on the effects of MP to cells and organisms. In a recent study we untangled these contradictory effects and proposed that the environmental fate and toxicity of MP particles is dominated by their surface properties.[1]

However, once exposed to the environment biomolecules and other natural organic matter adsorb to the surface and form the so-called eco-corona. This adsorptive layer changes the surface properties. Hence, their interaction behaviour is different from pristine particles. Upon eco-corona formation a pronounced increase of long-range repulsive interactions occurs. These force distance characteristics follow the polymer brush model by Alexander and de Gennes (**AdG**) and allow for a quantitative description of the eco-corona.[2] Our results show that concepts of fundamental polymer physics, like the AdG model, help understanding more complex systems like biomolecules adsorbed to surfaces, i.e., the eco-corona. Furthermore, the foundation of the eco-corona interacting like a polymer brush with its surrounding may help understand MP particle-cell interactions, transport and aggregation in the environment.

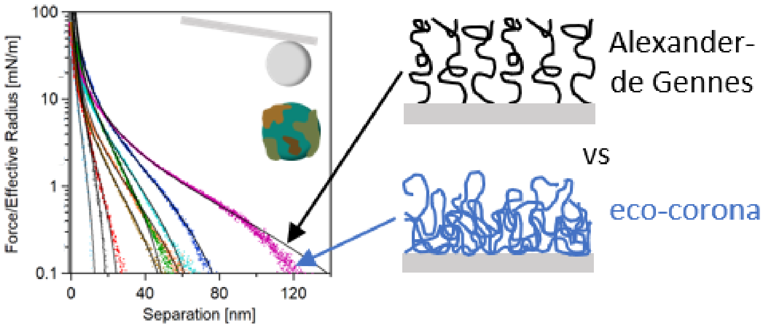

Figure. *Interaction forces of the eco-corona quantitatively follow polymer brush theory of Alexander-de Gennes although its structure is different from one another as outlined right.*

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Optimizing surfactant templating of yttria-stabilized zirconia aerogels for high-temperature applications

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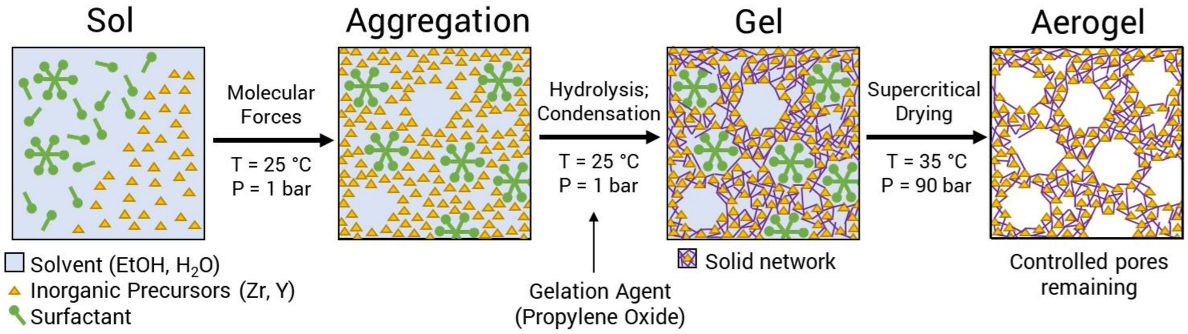
Aerogels, unique, mesoporous materials with extreme material properties including high specific surface area, low density, and low thermal conductivity, are advantageous for applications including catalysis, drug delivery and sorption media. The low thermal conductivity and high surface area of aerogels makes them useful as thermal management systems. However, aerogel pore collapse and subsequent surface area decrease following exposure to high temperatures must be mitigated to allow aerogels to be effectively used in thermal management applications. Surfactant templates can influence the pore structure of aerogels, increasing surface area and reducing pore collapse following high-temperature exposure.

This work investigated the cationic surfactant cetrimonium bromide (CTAB), the anionic surfactant sodium dodecyl sulfate (SDS), and the nonionic surfactant Pluronic® P-123 as surfactant templates in yttria-stabilized zirconia (YSZ) aerogels. It was determined that the addition of SDS and P-123 increased the surface area and pore volume of as-dried aerogels; however, the impact of SDS and P-123 surfactant templates on the surface area and pore volume of aerogels exposed to temperatures up to 1100°C was negligible, potentially due to low concentrations of surfactant and the removal of the surfactant following high-temperature exposure. In contrast, the addition of CTAB increased the surface area and pore volume of as-dried aerogels and aerogels exposed to 600°C and 1000°C. By utilizing surfactant templates, it was anticipated that surface area reduction and pore collapse following high-temperature exposure would be mitigated, increasing the effectiveness of YSZ aerogels when used in high-temperature applications.



Tunable Two Dimensional -SnOx-Based Memristor by Octanol-SnOx Interactions

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As an important electronic element with digital and analogue resistive switching, memristors can process and store information for neuromorphic computing, in-memory computing, logic/circuit applications and non-volatile memory[1]. The metal oxides have been considered as a compatible candidate for memristors because of their resistive switching characteristics[1]. Two-dimensional (2D) metal oxides with controllable thickness can reduce the leakage and operation current, improving the device performance. Among many metal oxide materials, tin oxide is of particular interest due to its multiple oxidation states (i.e., SnO_2, Sn_2O_3, Sn_3O_4 and SnO), which has the potential for advanced memeristors[2-3].

In this work, we show that by simply depositing octanol onto the surface, a 2 nm-thickness 2D SnO_x-composed two-terminal device with constant resistance was switched into a memristor SnO_x device with tuneable hysteresis region. The interactions between octanol and SnO_x have been investigated by surface characterisation techniques, such as X-ray photoelectron spectroscopy, indicating the change in bonding and bandgap in SnO_x. Also, the composed SnO_x-based two-terminal device is responsive to the amount of octanol on the surface and environmental light exposure, which illustrates its capability in sensing applications.

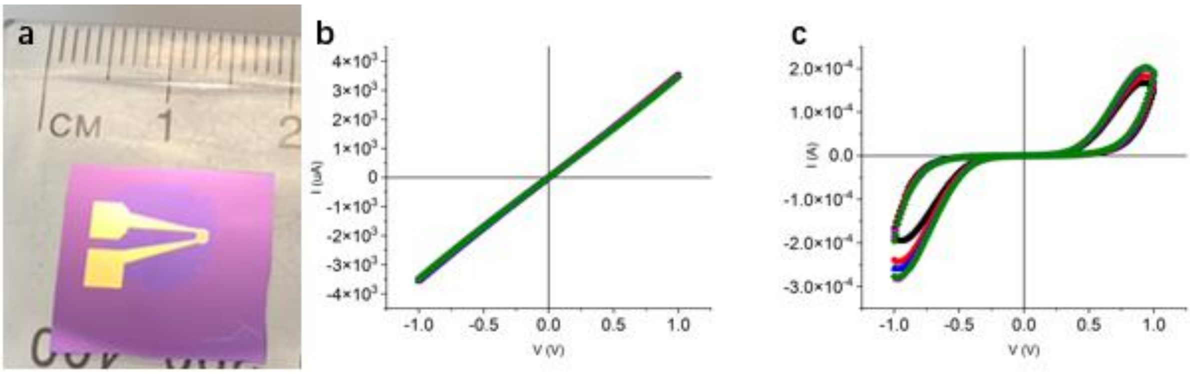

Figure 1: Two-dimensional SnO_x based two-terminal device. (a) an optical image of the fabricated device. I-V curves of the device (b) before and (c) after applying octanol on the surface of SnO_x.

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Paclitaxel-loaded cubosome lipid nanocarriers stabilised with pH and hydrogen peroxide-responsive steric stabilisers as drug delivery vehicles

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Introduction: Effects are being made to develop 'intelligent' nanocarriers, such as cubosomes, liposomes and hexosomes, by synthesizing and using stimuli responsive materials. The reason is that tumour sites have low pH value[1], and high H_2O_2 concentration when compared with normal cells and healthy tissues[2]. Nanoparticles that respond to pH and H_2O_2 stimuli could provide improved delivery of anti-cancer drugs into cancer cells with a controlled rate[3].

Purpose: We synthesized two novel amphiphilic block copolymers (ABCs) containing responsive groups to stabilize monoolein-based cubosomes (MO-Cubs) loaded with paclitaxel (PTX). Our hypothesis is that these ABCs will act as steric stabilizers to make cubosomes and provide pH and/or H2O2 responsiveness for enhanced PTX delivery to tumour sites.

Results: High throughput small angle X-ray scattering studies demonstrated that the synthesized ABCs could simultaneously stabilize cubosomes and provide internal particle nanostructure responsiveness to changes of H2O2 concentration and pH. The particle size of all samples was less than 300nm. The PDI of them was around 0.25. The encapsulation efficiency of them was in the range of 50-65%. Additionally, in drug release study, cubosomes presented a desirable sustained release behaviour (Figure 1). And in vitro cytotoxicity study indicated that these nanoparticles could inhibit the proliferation of AGS and L929 cancer cells in a concentration-dependent manner.

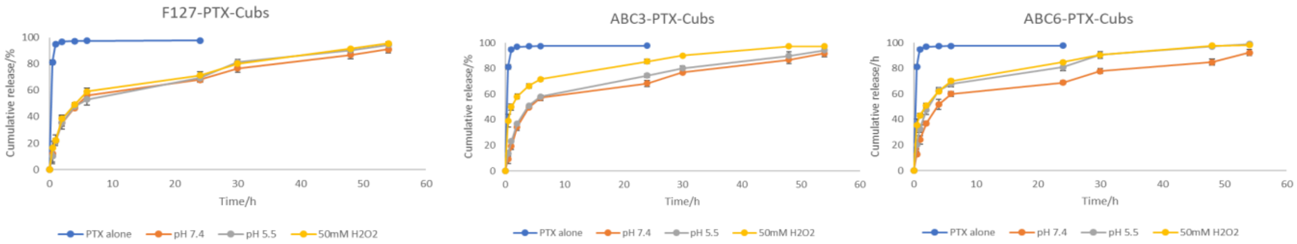

Figure 1: In vitro drug release of PTX-loaded nanoparticles in pH 5.5, pH 7.4 and 50 mM H_2O_2.

Conclusion: In this work, "intelligent" MO-Cubs had been successfully synthesized. The results showed that these cubosomes have desirable particle size, high drug loading capacity, excellent mesophase changes under different conditions, sustained release characteristics, high inhibitory effect to the proliferation of AGS and L929 cancer cells. MO-Cubs as described in this study may be useful as drug delivery carriers for the treatment of cancers.

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Developing Encapsulin Protein Nanocages into a Modular Vaccine Platform

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Protein nanoparticles represent a promising platform for vaccine applications due to biocompatibility, storage stability, rapid and cost-effective production, and the capacity to display a repetitive array of antigens on their surface, enhancing immunogenicity.[1] Encapsulins are an emerging class of protein nanoparticles found in nature that self-assemble from identical protein subunits into cage-like structures with different icosahedral architectures and size[2,3]. They have demonstrated early promise as a safe vaccine platform and have been shown to elicit both humoral and cellular immune responses in vivo. Furthermore, the outer and inner surfaces of encapsulins can be readily engineered to display and/or package peptide/proteins, thus representing an adaptable scaffold for the rational design of modular vaccines with multiple antigen modalities.

Herein, I will present an in-depth characterisation of encapsulin self-assembly and physical stability. Moreover, I will show a set of functionalisation strategies for the modular attachment of antigens to the outer surface of nanocages (e.g., enzymatic-, electrostatic-, and tag-mediated). This includes our use of SpyTag-SpyCatcher coupling, in which encapsulin subunits were modified to contain the SpyCatcher protein. Spectroscopy, electron microscopy, and polyacrylamide gel electrophoresis revealed its incorporation did not significantly alter encapsulin’s architecture. Moreover, SpyTagged antigens implicated in Alzheimer’s Disease (AD) successfully bound to encapsulin’s exterior, creating a proof-of-concept vaccine against AD. Future work will focus on understanding the stability and in vivo bio-nano interactions of encapsulin vaccines and evaluate their capacity to induce functional immune responses in mouse models.

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A novel approach to observing interfacial structuring of ionic liquids

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Ionic liquids have been investigated as potential replacements for molecular solvents due to their particular properties and customisability.[1] Despite their merits, common application of ionic liquids remains inaccessible due to their often unpredictable effects.[2] Recent work has investigated a homologous series of ionic liquids, $[C_{2n+2}C_1im][NTf_2]$ (Fig 1. a, $n = 0\text{-}5$) for their effect on reaction outcome when performing a bimolecular nucleophilic substitution (S_N2) process, finding a clear relationship between structure and dynamics in solution.[3]

Given the influence of alkyl tail length on the self-organisation behaviours in these ionic liquid systems, it was of interest to find a technique that may effectively observe the surface adsorption of the salt components. Total Internal Reflection (TIR) Raman spectroscopy (Fig 1. b) is a non-invasive technique which uses a high intensity laser to probe short distances from a surface and return characteristic signals of the species present in short acquisition times (<1 minute).[4] In this work, we present the first example of electro-responsive TIR-Raman spectroscopy to induce and monitor *in-situ* the formation of adsorbed thin films, allowing differentiation of surface behaviours in a homologous series of ionic liquids.

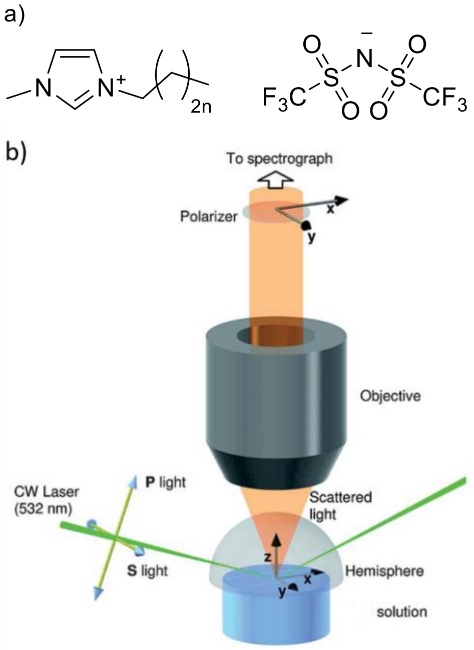

Figure 1. a) The $[C_{2n+2}C_1im][NTf_2]$ homologous series of ionic liquids. **b)** Representative diagram of a standard TIR-Raman spectroscopy configuration showing the sample, collection optics and incident light (including the directions of electric field vectors for incident and scattered light).[5]

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Investigation of the porosity of Victorian Western Volcanic Plain basalts as a Martian regolith simulant

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The Orion spacecraft launched on 16th November 2022 by the Space Launch System rocket is part of NASA's Artemis programs first mission, Artemis I. This begins a series of missions that will return humans to the Moon and prepare space exploration for the next giant leap, a crewed mission to Mars. Water is a vital recourse for both survival and fuel. To reduce the launch and landing mass for crewed missions, and to explore Mars, *In Situ* Resource Utilisation (ISRU) of Martian assets, particularly water[1], is critical.

We are developing a Martian regolith simulant from Australian natural resources to investigate methods of extracting water. Two basalts have been sourced from Victoria's Western Volcanic Plains: one from Holcim's Manor quarry and one from Holcim's Werribee quarry. Water uptake was measured gravimetrically by equilibrating the basalts in sealed containers in equilibrium with saturated salt solutions of known relative humidity. Surface area was estimated by measuring Brunauer, Emmett and Teller (BET) isotherms.

At all relative humidity levels, the Manor basalt absorbed more moisture than the Werribee sample. At relative humidity close to 100%, the weight of both samples increased by over 2.8%. The Manor sample's BET surface area was found to be 9.686 ± 0.009 m^2/g, which was greater than the surface area of the Werribee sample at 6.357 ± 0.008 m^2/g. Manor's greater surface area could be due to a greater porosity which could explain the greater uptake of water. Small Angle Neutron Scattering (SANS) is being used to investigate the porosity of the basalts by determining the volume and number of open and closed pores[3], and preliminary results will be presented.

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The influence of Tween emulsifier structure on the interfacial crystallisation of glycerol monostearate – a single interface study

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Emulsions are stable dispersions of tiny droplets of one immiscible liquid within another, made possible by chemicals called emulsifiers. Traditional emulsifiers are either low molecular weight surfactants or macromolecular species such as proteins, and polysaccharides, and can adsorb at oil-water interface. Despite their established effectiveness, there is a growing shift in the food industry towards the replacement of synthetic emulsifiers with natural, and more sustainable. The most appealing candidates are colloidal particles. Lipid crystals are a class of colloid particles that confer stability in many everyday food emulsions including milk, cream, or butter. Monoglycerides are indigenous to many oils and can also be added to alter the stability and texture of food products. Monoglycerides are inherently amphiphilic molecules and can adsorb at oil-water interfaces. Monoglyceride crystallisation occurring specifically at the oil-water interface is of particular interest, as emulsion stability can be enhanced through a Pickering-like mechanism upon formation of a crystalline film at the interface. Alternatively, emulsion can be compromised through the protrusion of interfacial lipid crystals into adjacent dispersed oil droplets to form partially coalesced globules.

The structure of other emulsifiers, and specifically the degree of unsaturation is reported to influence the crystallisation of oil in dispersed and continuous emulsion systems. However, determination of the interfacial composition and any potential influence on the crystal formation and structure at the interface is not possible in emulsion studies. In this research, we have employed a novel combination of profile analysis tensiometry (PAT) and small and wide-angle X-ray scattering (SAXS/WAXS) to elucidate the role of two Tween emulsifiers (saturated Tween 80 and unsaturated Tween 60) on the crystallisation of glycerol monostearate at the isolated oil-water interface. SAXS/WAXS was performed on capillaries containing single oil-water interfaces which enabled the examination of crystal concentration and structure in the interfacial region compared to bulk oil. The interfacial activity of crystals and the effect of surfactants was also assessed using PAT by monitoring the kinetics of interfacial tension in response to temperature changes. The PAT results confirmed the hypothesis that Tween 80 interfered with glycerol monostearate crystallisation the most, compared to Tween 60, impacting the temperature at which interfacial crystallisation occurred.

Functionalisation of lubricin and its aptamer in an electrochemical biosensor

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Hormonal issues like infertility have severe negative consequences like social isolation, depression, poor self-esteem, personal harm as well as domestic abuse in extreme cases. While there are assisted reproductive technologies available to treat infertility, it still has a low success rate and high cost of treatment [1]. Not just infertility, but other disorders that are caused due to hormonal imbalance require patients to regularly monitor their hormones levels via blood check-ups. This can be an invasive, painful, time consuming and expensive procedure for patients.

Using a rapid self-assembly sensing interface amendable to methods of mass production, this research aims to demonstrate the ability to detect and quantify fertility hormones (estradiol, progesterone, luteinising, follicle stimulating) in a small volume of blood, using a test format strip reminiscent of a blood glucose test.

The detection of hormones at picomolar levels will be achieved through a new transduction mechanism based on the impact of hormone interactions on the molecular dynamic motion of an aptamer cross-linked lubricin anti-fouling brush.

The signal generation of an electrochemical biosensor for detecting hormones from complex matrices could be interrupted due to biofouling. Hence, lubricin, a surface-active glycoprotein that is capable of self-assembling on surfaces and providing lubricant and antifouling properties on a range of materials is used [2].

However, due to LUB brush's size selective transport properties, large sized macromolecules like luteinising or follicle stimulating hormones cannot pass through it but small molecules like estradiol can. Hence a unique bi-functional aptamer containing recognition elements for both the lubricin, and the target analyte will be developed using lubricin as a tether.

A suitable aptamer is identified by Systematic Evolution of Ligands by Exponential Enrichment (SELEX). This process enriches aptamer sequences that fold into a unique 3D (three dimensional) structure to bind with the target [3]. Here, the SELEX process will be used to raise an aptamer against lubricin. This setup ensures the retention of LUB's antifouling properties and the aptamer's wide target binding affinities.

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Phenylalanine Amyloid Formation and Structure, Identifying Molecular Targets for Treating Phenylketonuria

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Phenylketonuria (PKU) is an inherited error of metabolism that prevents the metabolism of phenylalanine leading to insoluble aggregates in body tissues. These toxic deposits cause a number of neurological and developmental issues. During last 20 years convincing evidence has been published that the toxicity of these phenylalanine aggregates is due to their amyloid structure (Packman, 2003). Amyloids are the molecular hallmark of neurodegenerative and systematic diseases such as Alzheimer’s and FSA (familial systematic amyloidosis), however the toxic culprit in these diseases is debated. In diseases including Alzheimer’s and Parkinson’s there is a consensus suggesting that small amyloid (or non-amyloid) oligomers are the toxic species and mature amyloid fibrils are non-toxic aggregation end-products (Cline *et al.*, 2018).

My research has shown novel understanding of the molecular assembly mechanisms and kinetics of Phe self-assembly, and has led to the discovery of an oligomeric intermediate species of Phe before the formation of fibrils. Initial evidence suggests that, as with Alzheimer's and Parkinson's the oligomeric species maybe more toxic than the mature amyloids, this could lead to new approaches in treating PKU targeting the smaller oligomers instead of large amyloid structures.

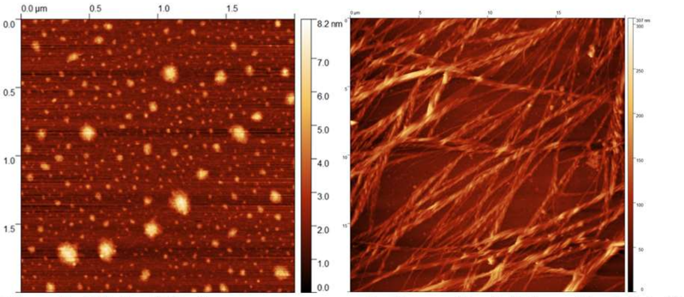

Figure 1: Effects of Starting monomer concentration on Phe Self Assembly- left is 10 mg/mL starting concentration of Phe leading to small oligomer aggregates, Right is 30 mg/mL starting concentration of Phe leading to large fibrils and ribbons.

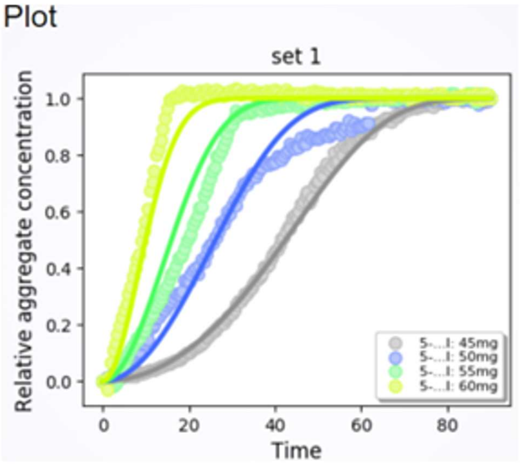

Figure 2: AmyloFit graph of Phe aggregation kinetics over time at various concentrations.

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Probing the Interactions of Metal Nanomaterials with Synthetic Cell Membranes

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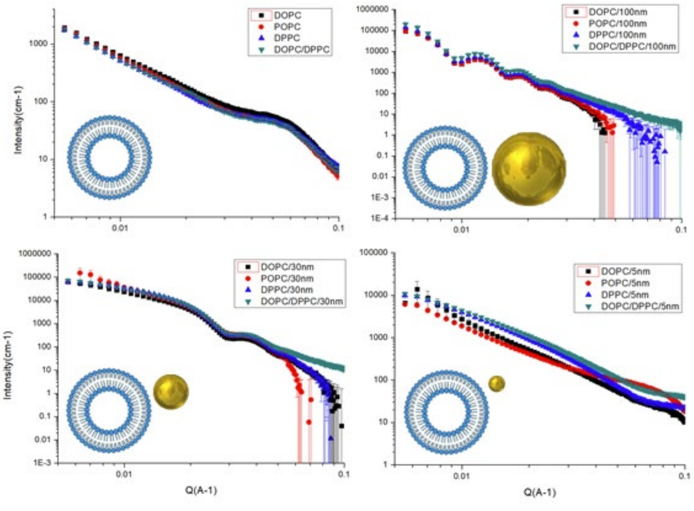
Various nanomaterials, including gold nanoparticles, have been investigated for use in a wide range of bio-medical applications, the success of which is dependent on their ability to interact with, alter, or traverse the outer membrane of a cell. However, the complexity of these systems means that it is currently difficult to determine what effect a nanomaterial will have on biological functions without direct testing, something which is also made difficult due to the complexity of the systems. This causes challenges in the process of developing new nanomedicines, which has slowed the optimisation and real-world utilisation of these treatments, and has also led to concerns regarding possible unforeseen impacts caused by the growing use of nanotechnologies in other industries.

Model membranes have been studied comprehensively as a way to mitigate the aforementioned issue of complexity. By mimicking a simplified in vivo cellular membrane composed of only one or two phospholipids, more specific information can be gleaned. These structures have widely been accepted as appropriate models for various biological materials such as viral particles, extracellular vesicles, and most relevantly, cells.

In our studies, we investigate the fundamental interactions of nanomaterials with a synthetic cell membrane. This will allow a more complete understanding of the structure-behavior relationship of nanomaterials in biological applications. This information will better inform the design of theragnostic nano particulates, specifically citrate-capped AuNPs which are perhaps the most widely available form of gold nanoparticle. Particle size is known to be one of the most important factors impacting a nanoparticles function, here we study the interactions between citrate capped AuNPs of a range of different sizes (2nm-100nm) and DOPC model membrane systems (supported lipid bilayers [SLBs] and small unilamellar vesicles [SUVs]) to better understand the role size plays in membrane interactions. This has been done through a mix of atomic force microscopy (AFM) and small angle x-ray scattering (SAXS).



Combining Black Phosphorous and Deep Eutectic Solvents for Antimicrobial Gels

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The rise of antimicrobial resistance among pathogenic bacterial and fungal cells has been declared one of the top 10 global public health threats by the World Health Organisation.[1] Recently, low-dimensional materials, including black phosphorous (BP), have emerged as promising antimicrobial agents. Previous studies have demonstrated that few-layer and 2D black phosphorus (BP) nanoflakes when applied as a surface coating, have a high effectiveness against a wide range of pathogenic microbial cells, whilst showing low toxicity towards mammalian cells.[2] One limitation facing BP as a surface coating is the rapid degradation under ambient conditions. To address this concern, BP nanoflakes were suspended into a green, non-toxic eutectic gel. The deep eutectic solvents choline chloride and glycerol (ChCl-Gly) was combined with cellulose and dehydrated. The eutectic gel was able to delay the degradation of the BP nanoflakes, with the BP-gel still showing high antimicrobial activity. After one month of storage, BP-gel was still able to achieve over 80% cell death against the bacteria methicillin-resistant *Staphylococcus aureus* and *Pseudomonas aeruginosa*, as well as the fungi *Candida albicans*. The combination of eutectic gel and few-layer BP nanoflakes provides a promising, practical pathway for implementing low-dimensional materials as next-generation antimicrobial treatments.

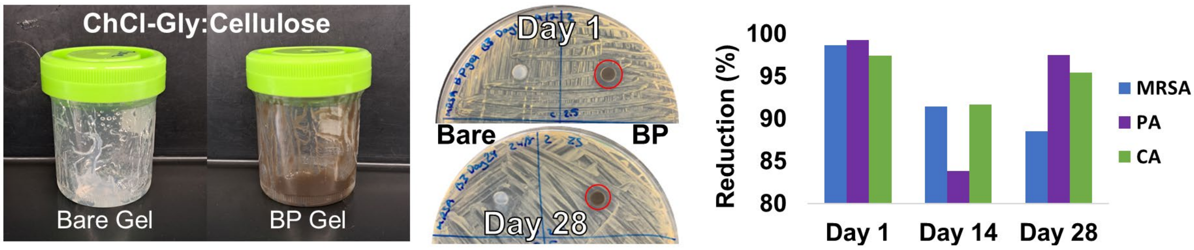

Figure: Left) DES gel both without (bare) and with BP nanoflakes. Middle) Zone of inhibition tests for the gels after 1 day of storage and 28 days of storage against MRSA. The red circle indicates the regions with no microbial growth. Right) Percentage of cell colony forming units (CFU) reduction after 1 day, 14 days and 28 days of storage.

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A new method of AFM based nanolithography using frequency enhanced electrochemical pressure solution etching

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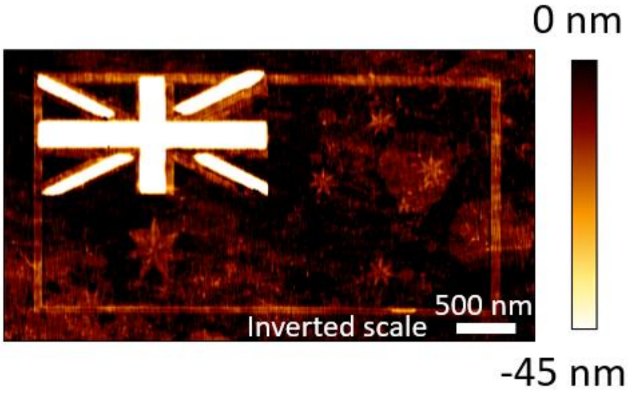
We report a new method of direct-write nanolithography that is able to rapidly etch silica surfaces under a scanning AFM probe in tapping mode (TM). In this lithography technique, silica surfaces are etched using a recently described electro-chemo-mechanical phenomenon of frequency enhanced electrochemical pressure solution (FEEPS)[1]. In FEEPS, the tapping of the AFM tip generates oscillations of the Stern potential at the silica-water interface that can accelerate the silica dissolution kinetics by more than 5-6 orders of magnitude when surface resonance states are achieved; i.e. when the oscillation frequency is in phase with the dynamics of interfacial chemical reaction steps. By scanning silica surfaces in TM, silica is selectively dissolved below the tapping tip as it is scanned. The FEEPS accelerated silica dissolution rates can generate etched features with depths of more than 60 nm in a single AFM tip pass. The rate of etching can be controlled easily by varying the scanning rate or by modulating the tapping frequency. This fine control over the silica etching process and because material is removed (dissolved) rather than displaced as with nanoscratching, the FEEPS process lends itself to grey scale nanolithography which is demonstrated.



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Colloidal Liquid Metal Nanodroplets

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Liquid metals (LMs) are an emerging class of solvent metal with potential applications in catalysis, biomedicine, and stretchable electronics.[1] However, to achieve their full potential in many applications, functionalising the already available base nanodroplets is required.[2] This research focusses on producing colloidal materials within LM solvents - a unique colloid system which produces "hard" intermetallic nanoparticles (NPs) within a droplet of LM (see Figure 1). The formation of such NP encapsulated LM systems is not trivial, and the fundamental behaviour of metal colloids within LMs are underexplored. In this work, we explore the synthesis, morphology, and dynamics of nanoparticle formation within a variety of LM solvents. Affectively, these systems exist due to intermetallic formation, this can be clearly represented in various phase diagrams depending on the material of choice. For example with the Ga-Cu alloy, the phase diagram for this system states that there is a intermetallic that forms Ga_2Cu at around 249°C.[3] But in order to form such system, the temperature needs to be above the melting point of the intermetallic and not that of the bulk metal. This ensures a homogenous mixture is achieved, and NP formation is optimised. Our carefully controlled synthetic methods produce colloidal LM nanodroplets with large surface area and functionalised metal NPs suspended in solution, this can lead into great opportunities in future research with understanding metal-metal bonding, electronic properties, etc, and in-turn use in various applications.

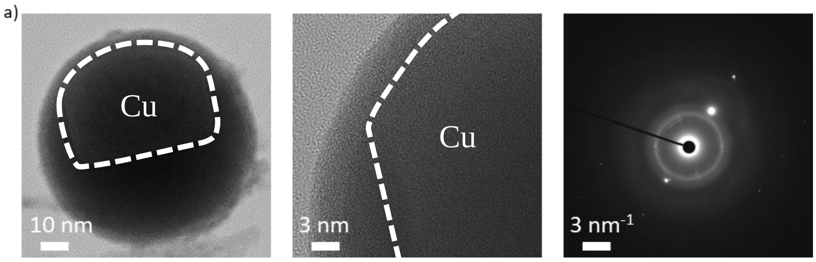

Figure 1: A bright field TEM image of 5wt% CuGa with a zoomed in image and a diffraction pattern confirming crystallinity

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Effect of hot press on the properties of nanocomposite sheet based on cellulose nanofibre and lignin particle

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Nanocomposite sheets based on cellulose nanofibre (CNF) and lignin macro or nanoparticle (LMP or LNP) were prepared via spray deposition technique[1]. The sheets were then pressed at 150°C for 15 minutes, and their properties before and after the process were compared. Water vapour permeability of the sheets was improved by hot press up to nearly 50%, apparently because of more densely packed structure as well as lignin particles. Their water contact angle (WCA) was also affected: the sheets after hot press showed a bigger WCA than the ones before the process (Fig. 1), but the effect on the samples including LNPs was smaller than the others. Surface roughness evaluation suggests that hot press made the surface flatter and the surface roughness is a key factor in determining WCA of the sheets. Following Wenzel's equation[2], the flatter surface should always bring a bigger WCA for our sheets whose the contact angle is smaller than 90°, but in fact some samples with a rougher surface showed a bigger WCA. These results indicate that the morphology of lignin particles and their hydrophobicity might also play an important role in determining WCA.

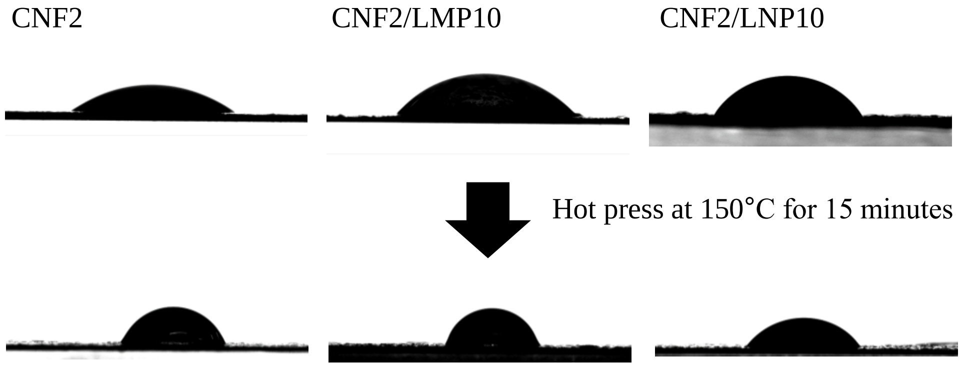

Fig. 1 Water droplet images on the nanocomposite sheets

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Investigating the Solvation Forces Within Room Temperature Liquid Metal Systems

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Liquid metals (LMs) are emerging as an interesting class of solvent, which have found application in 2D materials synthesis, energy storage media, and biological applications, among others. The definition of LMs is broad, however, in general they are metals which remain fluidic at temperatures below 500°C. Room temperature liquid metals (RTLMs), such as gallium, tin, and indium, and their eutectic alloys, are a subset of these metals, which remain liquid ≤60°C, and have recently gained wide scientific and industrial attention. Many of the applications of RTLMs exploit the atomically thin oxidation layer present at the air-liquid metal interface, or the fluidic nature of the metal. Of particular interest is gallium in its atomic state, as well as the LM-based alloys EGaIn (Ga-In eutectic) and fields alloy (Sn-In-Bi). However, almost nothing is known about the structural arrangements of the metal atoms within a LM at or near interfaces. In this work, RTLM nanoparticles (NPs) of roughly uniform size were produced using a top-down ultra-sonication and isolation method, developed in house for gallium, EGaIn, and fields metal. The resulting RTLM were deposited on 2D silicon wafer and clean of synthetic solvent, creating a sub-monolayer of RTLM NPs for nanoscale investigation. The nanoparticles of 3 LMs, Eutectic-Gallium-Indium (EGaIn), Gallium (Ga) and Bismuth-Tin-Indium (Fields), were then characterised using Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), Dynamic Light Scattering (DLS) and Tunnelling Electron Microscopy (TEM). Surprisingly, AFM force measurements revealed distinct nanostructural arrangements of the metal ions below the oxide surface, which are well structured and surprisingly regular. Here, this work will show for the first time the heterogenous nanostructure of a LM-air interfacial system with atomic resolution.

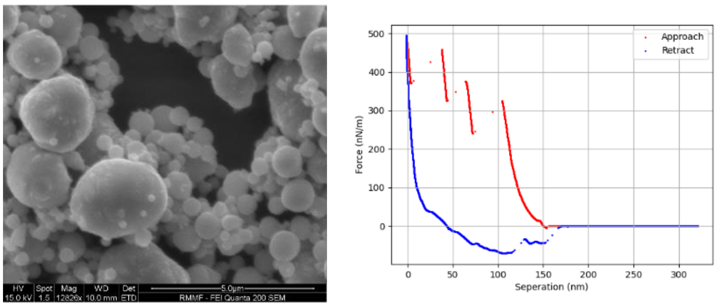

Figure 1. (Left) SEM Image of an EGaIn particle cluster on a silicon wafer. **(Right)** AFM separation vs force curve for a single force measurement of an EGaIn particle. The red and blue curves represent the tip approach and retract respectively, with the gaps in the red curve indicating a "puncture" event.

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Slippery Surfaces Enhance Water Collection Efficiency

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Hydrophobic coatings are known to induce efficient dropwise condensation, that is during condensation they facilitate the easy shedding of water droplets from surfaces due to relatively low contact angle hysteresis.[1] Hydrophilic coatings, on the other hand, induce the nucleation of droplets at much higher densities, and have lower nucleation barriers, yet typically display higher hysteresis,[2] which leads to transitions into film-wise condensation with reduced heat transfer and condensation efficiency.[3] Slippery covalently attached hydrophilic coatings of polyethylene glycol with ultra-low contact angle hysteresis have recently emerged, and have been shown to induce dropwise condensation with superior heat transfer, unlocking new potential for use in atmospheric water capture applications.[4] In this work, we compare condensing droplet growth behaviour and the water collection performance of two slippery coatings, one hydrophobic (based on PDMS) and one hydrophilic (PEO), both with low contact angle hysteresis (6°). Contrary to expectations, we show that similar water collection rates are observed on the two surfaces. We identify an important synergy between intrinsic wettability and hysteresis, and show how hysteresis ultimately determines the total water volume collected.

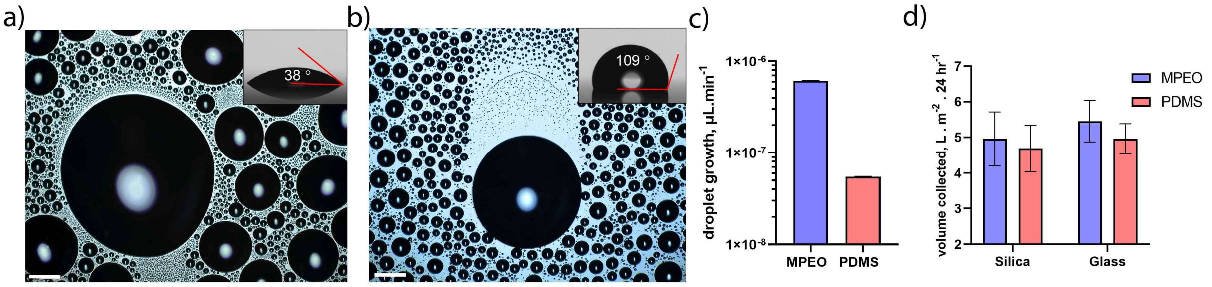

Figure 1. Water droplets being shed during condensation on silicon wafers coated with a PEGylated (a), and PDMS (b) nano-thin layer, with insets depicting static contact angle. Individual droplet growth rates are an order of magnitude difference larger on the MPEO surface relative to the PDMS (c), however total water volume collected is comparable after 5 hours of analysis (d).

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Adsorptive Smectite Clays as a Novel Therapy Against Obesity

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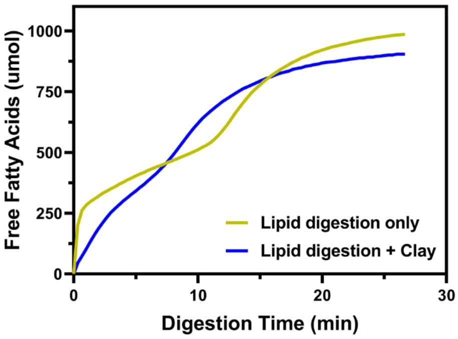
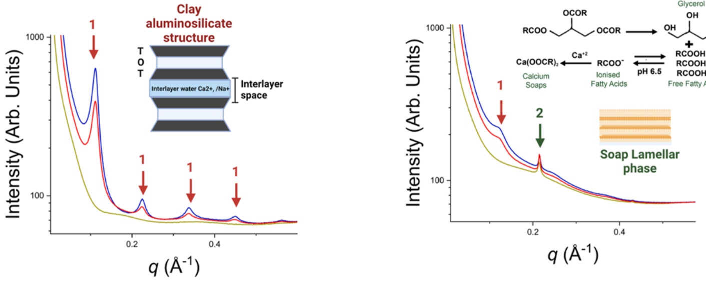
Adsorptive biomaterials, such as smectite clays, have been recently shown to be effective in improving metabolic outcomes of health through their promising anti-obesity properties. [1] The aluminosilicate clay structure acts on the lipid digestion pathway by **(i)** disrupting the lipid-in-water interface integral to enzymatic hydrolysis, **(ii)** physically adsorbing lipids and lipolytic products, and **(iii)** adsorbing lipase to inhibit binding with co-lipase for functionality.

We have shown that smectite clays can reduce the amount of free fatty acids released by 8.2% after 30 min of in vitro simulated lipid digestion (**Fig. A**). When examining the formation of self-assembled liquid crystalline structures during digestion using synchrotron small angle x-ray scattering (sSAXS), we observed a lamellar peak for the clay in digesting conditions (**Fig. B**). Previous studies have confirmed the identity of these peaks as calcium soaps formed when ionised free fatty acids electrostatically interact with calcium ions in the media. [2] The SAXS profiles also indicated a reduction in interlayer spacing from 5.64 nm prior to digestion to 5.11 nm post-digestion. Further characterisation using transmission electron spectroscopy (TEM) confirmed the decrease in interlayer spacing after digestion. Scanning electron microscopic (SEM) images of the clay particles showed that prior to digestion, clay particles formed 10-15 um spherical aggregates, however after digestion, the aggregates were small, 5-10 um, disordered aggregates with no distinct morphology. It is likely that the adsorption of lipids has disrupted the electrostatic stacking of clay platelets, resulting in disordered clay particles which can also be noted from the broadening of the clay lamellar peak in the post-digestion SAXS profile. The administration of the clay to a rat model of obesity resulted in a reduction in cumulative weight gain over 21 days and improvements in blood triglyceride, as well as high-density lipoproteins (HDL) cholesterol. Future longitudinal animal studies are required to assess the efficacy of smectite clays for improving metabolic outcomes in patients with obesity.

(A) In vitro lipid digestion



(B) Formation of lamellar structures



Pre-digestion **Post-digestion**

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Stability and characterization of oil-in-water emulsions with xanthate surfactants

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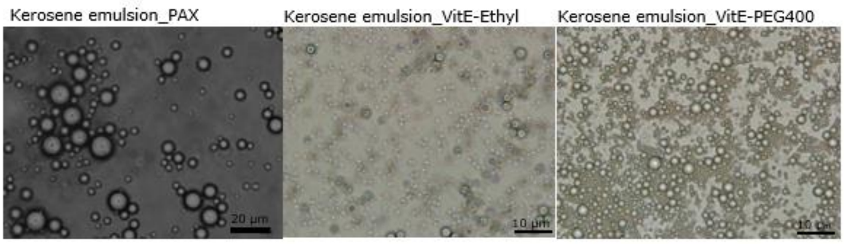
The creaming rate, droplet size distribution, and oil separation of kerosene-in-water emulsions formed with potassium amyl xanthate (PAX), potassium vitamin E ethyl xanthate (VitE-Ethyl), and potassium vitamin E PEG400 xanthate (VitE-PEG400) were investigated. Understanding the stability and properties of the emulsions is crucial for industrial applications. In particular, such emulsions may be an effective way of delivering oil to copper-containing minerals to aid in froth flotation. It was discovered that the kerosene emulsion with the VitE-PEG400 was the most stable while the droplet size distribution of the emulsion with the vitamin E ethyl xanthate was the smallest. The zeta potential of the kerosene emulsion with the VitE-PEG400 xanthate was also the most negative supporting the results from the creaming rate and oil separation.

The pH of the emulsion is different from the pH of the starting aqueous solution. The pH of the kerosene emulsions formed with PAX ranges from 7.18 to 7.79 when the starting aqueous solution was either acidic, neutral, or alkaline. It is also interesting to note that the droplet size distributions, creaming rates, and oil separations of these emulsions are similar. This indicates that there is an equilibrium pH range for the kerosene emulsion with potassium amyl xanthate.

Furthermore, the study on the hydrophilic-lipophilic balance (HLB) of common emulsifiers shows that the application of a single indicator such as HLB for the emulsifying properties of surfactants is not effective. A similar observation was reported by other researchers[1]. However, our study indicated that the emulsifying properties of surfactants are significantly influenced by the molecular weight and specific chemical properties of the head group and hydrophobic chain group of the surfactants. It was observed that surfactants with different head groups and hydrophobic chain groups exhibit different emulsifying properties even with a similar HLB.



Kerosene emulsion_PAX Kerosene emulsion_VitE-Ethyl Kerosene emulsion_VitE-PEG400

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Characterising and predicting talc floatability in copper ore flotation

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Rising global demand for copper has necessitated the efficient recovery of a large amount of copper from low-grade copper ore deposits. However, low-grade copper ore deposits are often closely associated with hydrophobic gangue minerals like talc ($Mg_3Si_4O_{10}(OH)_2$), making selective flotation of the copper minerals more difficult. Talc frequently appears in flotation concentrates due to its natural floatability, lowering concentrate grades and posing challenges for subsequent metallurgical operations.

The current approach for dealing with talc in flotation in the mining industries involves identifying the presence of talc prior to the mineral processing of the copper ores, and then employing an appropriate operation technique and reagents to depress it from floating. This method is effective for detecting the presence of talc in copper ore systems, but it does not necessarily indicate whether the talc will be highly floatable in a flotation system. Improving this approach in the mining industry requires identifying the morphology of talc responsible for its high floatability in copper ore flotation. The mining industry can increase plant profitability by utilising the floatability of talc to recover high-grade copper with minimal energy and cost.

In this study, it is proposed to use advance XRD techniques in conjunction with SEM techniques and other experiments to quantify the morphology of talc in a complex copper ore. The floatability of talc in copper ore flotation would be predicted using Partial Least Square Regression (PLSR) method. An additional aim is to link the morphology of talc in complex copper ore systems to their flotation performance in a quantitative manner. The work further looks at the economic performance and benefit of predicting talc floatability in the mineral processing of copper ore.

Generation and characterization of core-shell microparticle containing water core for biomedical purposes

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Core-shell microparticles have emerged as promising devices for biomedical purposes, including regenerative medicine, tissue engineering, and targeted delivery of therapeutic agents. The essential step in producing such a unique-structured microparticle is forming a droplet template. Herein, we present a facile technique to produce a surfactant-free core-shell droplet with a water core using a flow-focusing microfluidic device. The solid microparticles were obtained by polymerizing the droplet's polymeric shell of trimethylolpropane trimethacrylate (TMPTMA). The microfluidic technique enabled precise adjustment of the core and the shell geometries by the flow rates of the components. Optimized single core-shell microparticles had a core and a shell radius of about 30 µm and 60 µm, respectively. In the next step, we studied experimentally and analytically the behavior of resultant microparticles under thermal and mechanical loads (Figure 1). Three different microparticles with the ratios of the shell thickness to the outer radius $T_{\mathrm{Shell}}/R_{\mathrm{Core-Shell}}$ of 0.37, 0.41, and 0.46 were investigated, respectively. The compression test results revealed that the resistance of microparticles to deformation and rupture increases by increasing $T_{\mathrm{Shell}}/R_{\mathrm{Core-Shell}}$. The critical rupture displacement of the microparticles scales directly with $T_{\mathrm{Shell}}/R_{\mathrm{Core-Shell}}$. The results implied that microparticles' average critical rupture temperatures are independent of $T_{\mathrm{Shell}}/R_{\mathrm{Core-Shell}}$, and all rupture at about 113 °C. Microparticles' thermal and compression behaviors were then evaluated using the existing analytical models. The results indicated that the predicted behaviors of the microparticles agree well with the experimental data. Water- TMPTMA core-shell microparticles showed considerable thermal and mechanical stability critical for biomedical applications such as bioreactor and bone and cartilage tissue engineering. In the following, we validate the application of the particles as a bioreactor by encapsulating DNA and performing PCR experiments. For this purpose, we use DNA extracted from fecal samples of a healthy individual. We demonstrate the capacity of the particles loaded with DNA for monitoring fecal pollution in water using the human-specific faecal DNA marker.

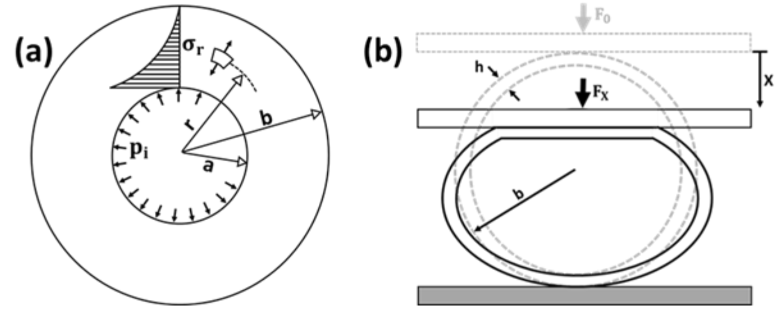

Figure1. Configuration of core-shell particle representing (a) internal pressure causing by heating and (b) deformation as it compressed.

Behavior of citrate-capped ultrasmall gold nanoparticles on a supported lipid bilayer interface at atomic resolution

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Nanomaterials, have the ability to revolutionize current biomedical and biological research in regards to the development of novel therapies, with applications ranging from drug delivery, diagnostics to controlling specific biological process. Current research is aimed at specific tasks such as enhancing cellular uptake of a material whilst keeping functionality. However the specific interactions that govern interactions between nanomaterials and biological systems, in particular cellular membranes, remains vaguely understood and under-characterized. This study provides detailed insights into the molecular mechanisms that govern the fundamental interactions between one of the most commonly used nanoparticles and model phospholipid bilayers. Using a combination of atomic force microscopy (AFM) and molecular dynamics (MD) simulations (Figure 1), the precise mechanisms by which citrate-capped 5 nm gold nanoparticles (AuNP) interact with supported lipid bilayers (SLBs) of pure fluid (DOPC) and pure gel-phase (DPPC) phospholipids are elucidated. On fluid phase DOPC membranes, the AuNP are adsorbed and get progressively internalized as the citrate capping of the AuNP is "shed" or disassociated by the surrounding lipids. The AuNPs also interact with DPPC membranes, where they partially embedded into the outer leaflet, locally disturbing the lipid organization. In both systems the AuNP cause systematic perturbations throughout the bilayer. AFM shows that the lateral diffusion of the particles is several orders of magnitudes lower that that of the lipid molecules, which creates some temporary scarring of the membrane surface. These results reveal how functionalized AuNPs interact with differing biological membranes, with mechanisms that could also have cooperative membrane effects with other molecules.

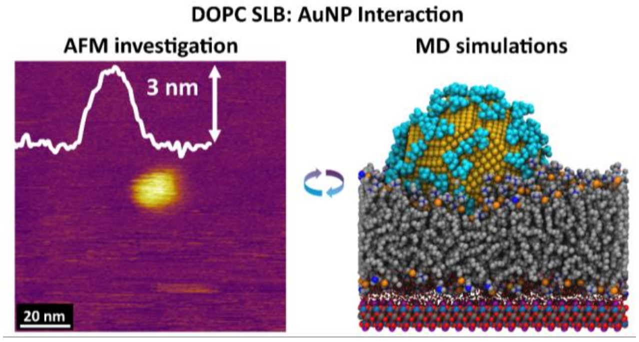

Figure 1. AFM (left) and MD simulations (right) of AuNP-SLB interaction.

Protein-Gold Nanoparticle Interactions & Protein Corona Formation

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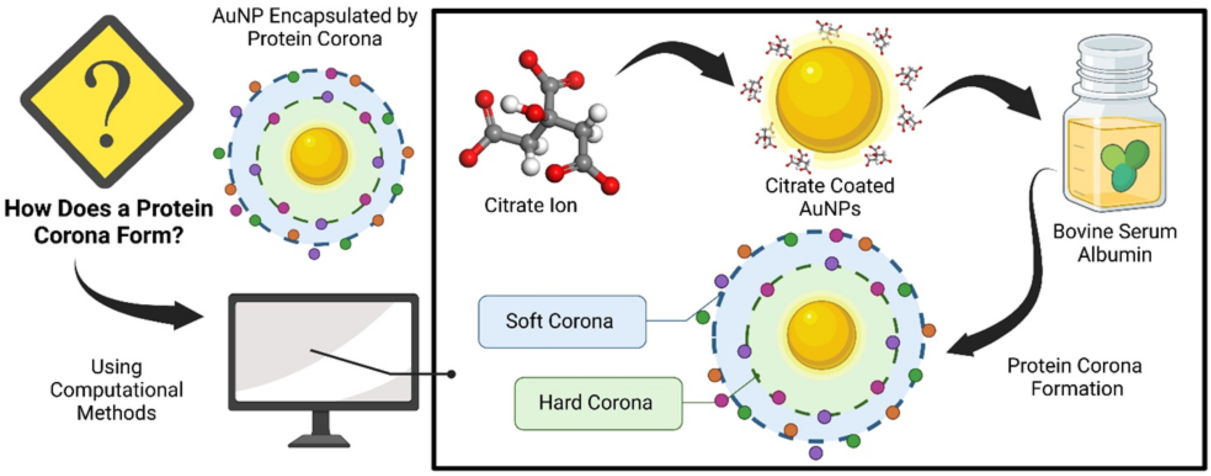
Understanding and controlling protein-nanoparticle interactions is important for improvements to biomedicines, however the complex mechanism of protein encapsulation of nanoparticles (NPs) and resulting protein corona (PC) formation are poorly understood. This project intends to develop a fundamental understanding of the molecular interactions of gold nanoparticles (AuNPs) with a biologically relevant protein using computational methods[1, 2]. We will observe the interactions of citrate stabilised gold nanoparticles with bovine serum albumin (BSA), to investigate any potential exchange of citrate ions with protein residues, along with the dynamics of the interactions.

The aims for this project are to create a model of a AuNP-BSA system, and examine the adsorption dynamics, which will allow us to make predictions using the ideal model. These aims will be addressed by determining certain criteria, including the adsorption of a single protein onto AuNPs, PC formation, and exchange dynamics between BSA and citrate capped AuNPs. The simulations to be conducted will provide a deeper understanding of the nature, adsorption mechanism and dynamics of AuNP-BSA interactions.



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How ionic liquid composition and structure affect micelle morphology

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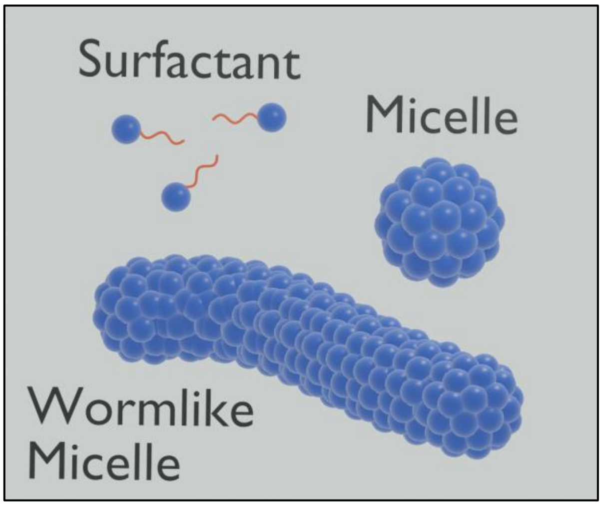
A common method of making viscoelastic, wormlike micellar systems in water is to combine a cationic surfactant with a salt featuring a strongly bonding or hydrotropic counterion, such as sodium salicylate. Despite their inherent high ionic strength and evidence for cylindrical or worm-like micelles, viscoelastic micellar systems have yet to be reliably observed in ionic liquid solvents.

In this work, micellar structures of a series of alkyltrimethylammonium and alkylpyridinium salicylate surfactants were examined by small-angle neutron scattering (SANS) and rheoSANS in the protic ionic liquids ethylammonium nitrate (EAN), ethanolammonium nitrate (EtAN), ethanolammonium formate (EtAF), their mixtures, and aqueous solutions.

Results reveal the conditions under which wormlike micelles form and elucidates how solvent structural features such as ionic strength, H-bond connectivity and the inherent liquid amphiphilic nanostructure, as well as applied shear, affect micelle morphology. In turn, learning about these subtleties provides a greater understanding of how amphiphilic self-assembly occurs in neoteric solvents, allowing for more directed design of such systems for a variety of applications.



This is the title of my research presentation

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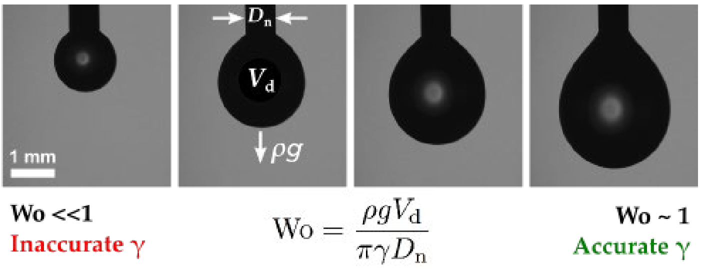

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Liquid Metal Colloids as a Novel Phase Change Material

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Gallium, a liquid metal and its alloy counterparts are one of the most preferred thermal candidates due to their highly stable and non-toxic nature.[1] This study aims to understand the thermal properties of various gallium-based alloys such as Ga-Cu, Ga-Ag, Ga-Bi, Ga-Zn and Ga-Ni. We investigate the phase change phenomenon of the intermetallic compounds within the gallium-based alloys by subjecting them to various temperatures and cycles of heating and cooling. Initial investigation of the Ga-Cu nanoparticles using Differential Scanning Calorimetry (DSC) curves reveals the melting and freezing of gallium at temperatures of ~31 °C and ~44 °C, respectively (**Figure 1a**). The DSC curve also indicates a sharp liquid-liquid phase transition at an onset temperature of 223 °C with an endothermic dip at ~280 °C, suggesting the melting of the intermetallic $CuGa_2$ with the liquid alloy. Upon cooling, the Ga-Cu nanoparticles undergo crystallization at various temperatures between 175 °C and 275 °C, depending on the size of the nanoparticles. Supercooling causes differences in the areas associated with the endothermic (enthalpy of fusion) and exothermic (enthalpy of crystallization) signals. Furthermore, X-Ray Diffraction (XRD) data from **Figure 1b** shows the intermetallic ($CuGa_2$) presence at different phases within the liquid Ga-Cu.

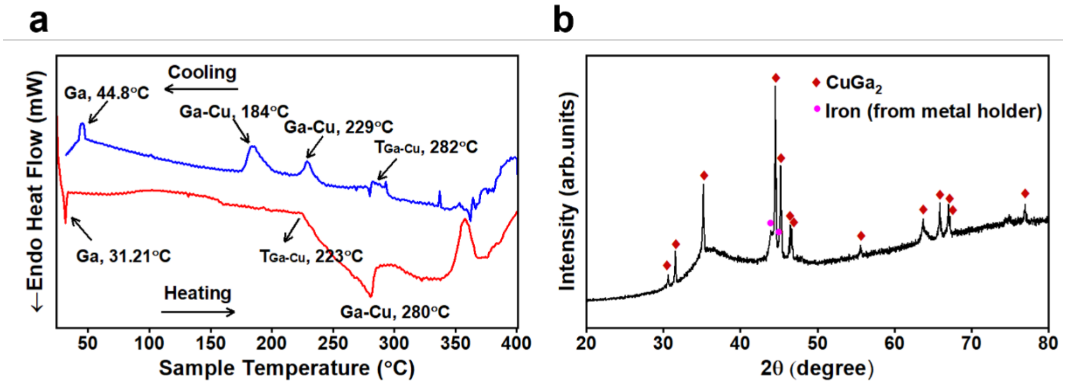

Figure 1: Analysis of Ga-Cu alloy (a) DSC curves of Ga-Cu (95 -5 %). Starting at 25 °C, the temperature was raised to 400 °C followed by a cooling cycle to 25 °C. Temperature scan rate: 10 °C/min (b) XRD OF Ga-Cu nanoparticles dried in vacuum at room temperature.

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Stimuli-responsive colloids for sustainable chemistry

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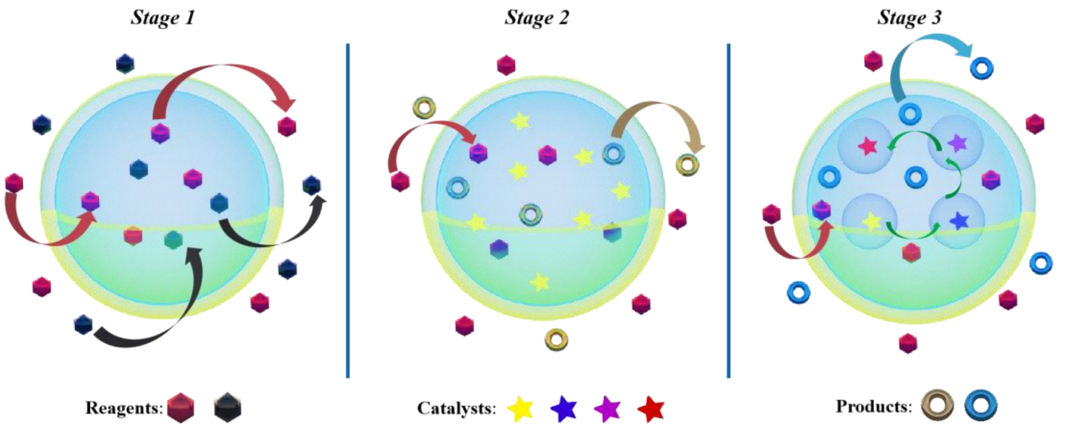
The recent years have seen considerable efforts in constructing artificial cells to mimic living cells' functions, behaviour and architectures. Developments in artificial cells expand our understanding of biology, and form a bases for development of bio-inspired systems and devices that could be useful in clinical and industrial settings[1]. Generally, transmembrane mass transportation, as an essential process of molecular exchange between cells, plays a critical role in metabolism. Consequently, the mimics of cell membrane with a tuneable cut-off threshold of permeation, provide advanced functionality to artificial cell systems. Such systems might be useful in increasing of our knowledge of the origin of life.

Herein, we will design an artificial microcapsule, water in oil in water (W/O/W) double emulsions produced by a microfluidic platform, whose oil shells includes stimuli-responsive materials. These materials could change the pore's size, polarity and zeta potential of the membrane under stimuli (temperature, pH, light) to control diffusion of different molecules through the membrane in designed order. Furthermore, microcapsules with a stimuli-responsive materials membrane could function as microreactors and allow us to perform cascade reactions regulated by control of transmembrane transport.



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Enzyme-Responsive Nanostructure as Smart Delivery Systems in Biomedical Applications

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Synthetic self-assembling peptides (SAP) are valuable hierarchical materials for biomedical applications because of their intrinsic characteristics namely their biocompatibility, the potential of modifying their biological functions, high chemical, and biological diversity, high selectivity, and bottom-up fabrication [1,2]. Here, we designed a smart delivery system for proteins and vectors that provide temporally controlled release of small molecules and proteins. To reach this goal, we designed SAPs containing a cleavable sequence for Tobacco Etch Virus protease (TEV), one of biotechnology's most used proteases. The sequence of these SAPs were optimized to spontaneously form thermodynamically stable supramolecular nanostructures at physiological pH (7.4). We found that with sequence and condition optimisation, we could reach different kinds of nanostructured for delivering different kinds of therapeutic agents. The optimized sequences of the peptide were synthesized using routine solid-phase peptide synthesis. To characterize the prepared SAPs nanostructures, the samples were tested through Fourier Transform Infrared Spectroscopy (FT-IR), Circular Dichroism (CD), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), and Zeta potential assay. Based on the results, this will allow researchers to exploit and circumvent current limitations in delivering therapeutic agents in vivo, through controlled delivery and distribution of them, while shielding them from the host inflammatory response.

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Specific ion effects in amino acid functionalised brushes

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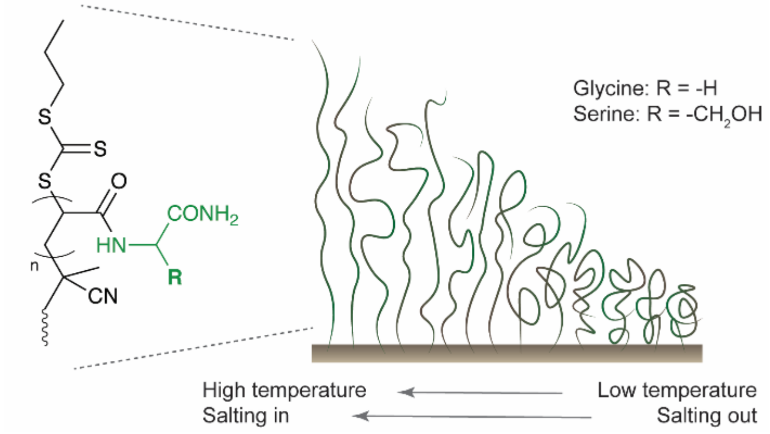
It has long been known that the influence of dissolved ions on protein conformation and function depends not just on the concentration of ions, but also on their identity.[1] Understanding the molecular origin of these specific ion effects in proteins remains challenging, partly due to the structural complexity of proteins and the broad range of amino acids which may have varying interactions with ions. Such an understanding would have profound applications across a broad range of scientific fields, ranging from the control of protein stability for biological applications, to the rational design of biomaterials which exhibit the desired conformation and functionality in native electrolyte environments.

We are using amino acid functionalised polymer brushes as a simple platform[2] to isolate and understand the ion specific trends which occur with a number of different amino acids. Brushes composed of derivatives of the amino acids glycine and serine will be synthesised via surface-initiated RAFT polymerisation, with dry coatings characterised via ellipsometry and water contact angle measurements. Subsequent analysis via neutron reflectometry and ellipsometry will probe the ion specificity of the brushes via the modulation of structural and solvation characteristics as well as the thermoresponse of the brush in aqueous solutions of anions spanning the Hofmeister series. Initial results will be presented.



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Temporal analysis of hMSCs under electrical stimulation with AFM

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Human mesenchymal stem cells (hMSCs) have great potential for tissue engineering application due to their multipotent differentiation ability, but with limitation of time-consuming using current method. Electrical stimulation can induce stem cell to differentiate into many pathways (bone, muscle, etc) efficiently, without exogenous growth factors,[1] but the mechanism by which this occurs is unclear. We hypothesise that electrical stimulation may influence cytoskeletal structure, which is a known factor for differentiation[2]. Hence, we used Atomic Force Microscopy (AFM) in this project to monitor the structural and mechanical properties of these cells throughout the period of stimulation.[3] This will provide information on the cell mechano-transduction pathway, which will further enhance the use of electrical stimulation on stem cells for tissue engineering.

After 1h electrical stimulation (0.5V, 1Hz, 100ms), the cytoskeleton reorganizes. (**Fig.1**) The filipodia of the cells gradually disappeared, meaning the adhesion of cells edge decreased. Post stimulation, less cells can be observed, possibly due to detachments (decreased adhesion). Stimulated cells presented more elongated structure. **(Fig.2).** In conclusion, this project applied electrical stimulation with various parameter on stem cells to affect their fate. The change of cytoskeleton structure, mechanical properties as well as the focal adhesion were clearly observed, which will further affect the differentiation of stem cell.

A data analysis program has been created to preciously model Young's Modulus (YM) to provide detailed intracellular stiffness characterisation. The peak on YM distribution histogram shifts as a function of stimulation time, which will be used to correlate with gene expression.

In conclusion, this project applied electrical stimulation with various parameter on stem cells to affect their fate. The change of cytoskeleton structure, mechanical properties as well as the focal adhesion were clearly observed, which will further affect stem cell fate.

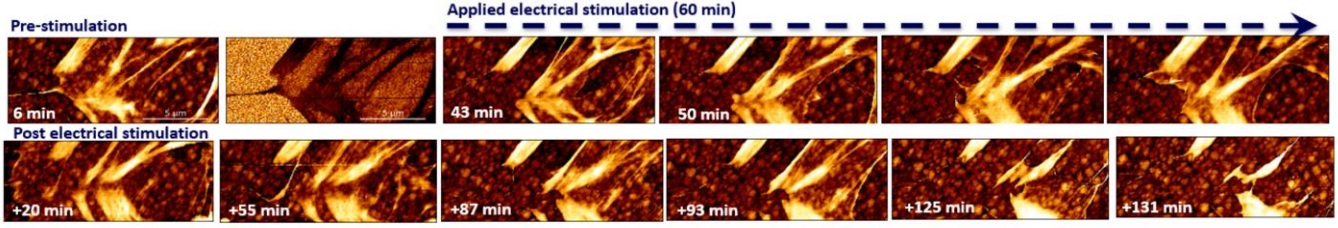

Figure 1: AFM images of cell before (top row) and after (bottom row) stimulation.

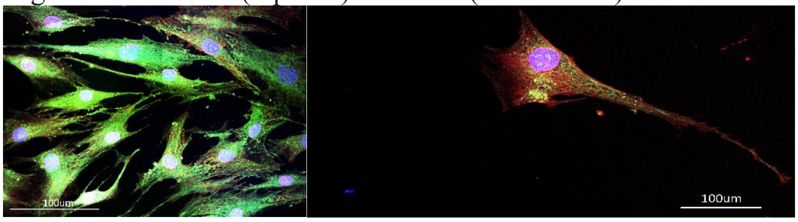

Figure 2: Confocal microscopy images of cell without (left) and with (right) stimulation. Blue, green, red represents nuclei, actin, vinculin respectively.

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Hydrogen nuclear spin conversion catalysis at interfaces

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Of the various potential transport vectors, liquid hydrogen (LH_2) has emerged as a viable option for the large-scale international export of low-carbon energy [1]. Efficient hydrogen liquefaction processes, however, necessitate the highly exothermic conversion between ortho-H_2 and para-H_2 nuclear spin isomers (see Fig. 1 below), wherein the two nuclear spin vectors are aligned parallel or antiparallel, respectively. Under ambient conditions so-called normal hydrogen (n-H_2) comprises 75% ortho-H_2 and 25% para-H_2 at equilibrium; upon cooling to 20.3 K, however, LH_2 comprises nearly 100% para-H_2 at equilibrium, necessitating significant ortho-to-para conversion upon liquefaction. As the direct interconversion of ortho and para spin isomers is forbidden by quantum mechanical selection rules, ortho-to-para conversion must take place via external stimuli. Such processes are facilitated by the integration of spin conversion catalyst materials into the liquefaction process, which provide both active interfaces to facilitate ortho-to-para transitions, and a heat sink via which to extract the significant (525 kJ/kg) energy released upon conversion. Despite their importance and ubiquity across hydrogen liquefaction processes, detailed knowledge of the surface dynamics and spin conversion mechanisms which take place within these materials remain largely unexplored. Accordingly, this talk will provide an introduction to the phenomenon of hydrogen spin conversion catalysis, and detail some of the analytical tools which may be employed to test emerging materials for such applications.

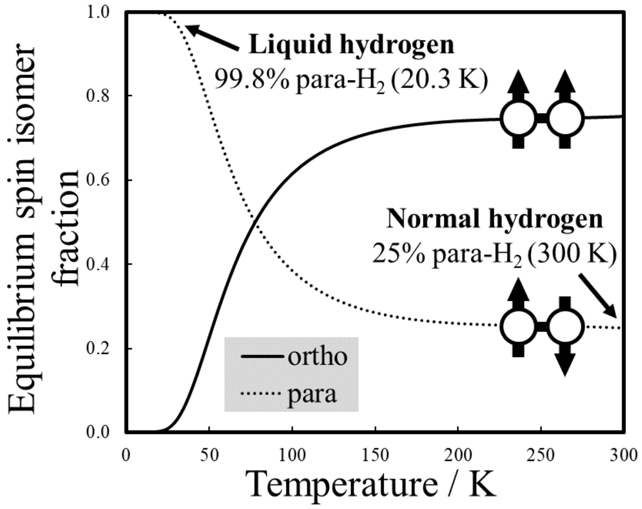

Fig 1. Equilibrium ortho- and para-H_2 spin isomer fractions as a function of temperature.

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Effect of Bacterial-Surface Interactions on Antimicrobial Resistance

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Antimicrobial Resistance (AMR) occurs when pathogenic microorganisms evolve mechanisms to protect them from antimicrobials. Overuse and misuse of antimicrobials such as antibiotics has led to rapid development in AMR worldwide. While developing new and effective antimicrobial agents (e.g. antimicrobial peptides, chemical modification of existing antibiotics) is one of the solutions to address AMR, there is also a need to prevent the spread of resistance and development of new resistant strains.

Considering bacteria are ubiquitous on surfaces, human contact with surfaces (e.g. frequently touched surfaces in hospitals) is a main mechanism for the spread of pathogenic microorganisms and infection. Antifouling and antimicrobial coatings represent one such preventative strategy for AMR by minimizing the spread of infection via human contact with surfaces. Such coatings have potential to limit population growth of resistant bacteria and minimize use of antibiotics due to lower infection rates.

Even though considerable research has been undertaken to evaluate how pathogenic bacteria develop resistance to antibiotics or antimicrobial agents, to our knowledge no research has been reported on investigating the role of surface-attached bacteria (as opposed to planktonic, free-swimming bacteria), including their physicochemical interactions and mechanisms of adhesion, on AMR. Furthermore, with the emergence of antifouling/antimicrobial coatings as a preventative strategy, it is important to assess the bacterial exposure to different coating materials and chemistries in order to determine their effects and impact on AMR.

Herein, we intend to develop a bacterial resistance culture model with novel incorporation of material surfaces/coatings to investigate the effect of surface-attached bacteria versus planktonic bacteria on resistant development. In this model, the pathogenic bacteria, *Staphylococcus aureus* and *Escherichia coli*, will be exposed to different concentrations of antibiotics; penicillin-streptomycin and gentamicin for several subculture cycles. The change in minimum inhibitory concentration (MIC) over subculture cycles is then measured to determine the development of AMR. Importantly, the model will allow for investigation of AMR in response to bacterial interactions and adhesion on various surface materials and chemistries present in the culture media. The fundamental knowledge gained from the project will assist in understanding the role of bacterial-surface interactions and adhesion on AMR and potentially lead to application of antifouling and antimicrobial coatings for infection prevention and control, which is critical for combating the global burden of antibiotic resistance in AMR.

Challenges associated with *in situ* small angle scattering methods for semi-solid casein gel investigations

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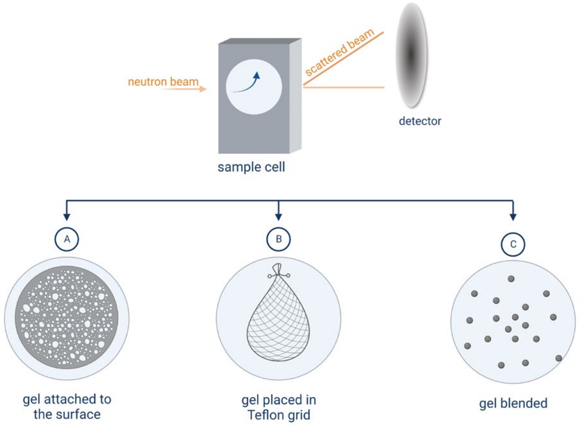
The weak interaction between neutrons and matter allows neutrons to penetrate materials easily and as a result, it is feasible to use complex sample environments for *in situ* studies[1]. On the other hand, to investigate a large casein gel particle during digestion, the gel should be under the neutron beam within a 1 mm cell maximum in order to avoid a phenomenon called ‘multiple scattering’.

This study examined options for in situ analysis of a gel structure during digestion: (A) attaching the gel structure to the surface of the sample cell or holding it within a mesh while passing digestive enzymes through, (B) trapping the gel in a Teflon grid, or (C) blending the gel particles. It was determined that blending gels and utilising a flow setup is the optimal method for ensuring that the internal structure of gel particles does not change significantly between the 1 nm and 20 µm length scale[2].



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Insists into the Structure of Thermotropic Liquid Crystals

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Thermotropic liquid crystals are a group of pure molecules that experience liquid crystal phases at specific temperatures without the aid of a solvent[1]. Liquid crystals are important due to their properties likened to both solid and liquid phases, such as electrochemically behaving as a solid but flowing like a liquid. These properties are utilised through applications in digital screens in the form of LCDs[2], and biological and chemical sensors[3,4]. For these liquid crystal systems, the structure is incredibly important. As such, we have conducted powder diffraction experiments to determine the structure of the crystalline state which thermally leads into the liquid crystal state, in an effort to gain insights into this structure. This research will be furthered through the use of molecular dynamics simulations. Eventually, we plan to use Fluctuation X-ray Scattering (FXS)[5], in particular using the novel Pair-Angle Distribution Function (PADF) method[6,7], which will provide novel insights into the liquid crystal structure.

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Structured biolayer emulsion: Biocatalysis in compartmentalised droplets

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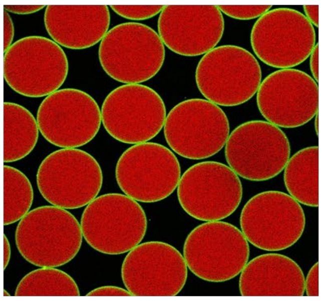
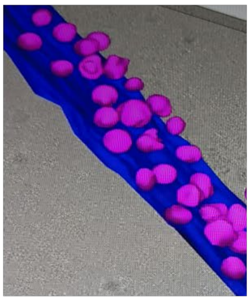
A novel hierarchical oil-in-water type emulsion, termed structured biolayer emulsion (SBE), was for the first time, assembled from virus-like particle (VLP) nanocages using a surface-active protein layer as the supporting matrix. Utilising a co-assembly strategy via microfluidics, ultra-stable SBEs can be constructed using various compounds as the dispersed phase, including hydrocarbons, fluorocarbons and organic solvents. Transmission electron microscopy and tomography examinations revealed an ordered monolayer arrangement of VLPs surrounds the protein-bound emulsion droplets. This very unique ultra-structure emulsion possesses discreate micro-compartments for segregating and holding diverse guest molecules, which enables broad application potential, especially in bio-catalysis. By encapsulating enzymes in VLPs, we have demonstrated SBEs serving as micro-reactors to carry out biocatalytic transformations involving hydrophobic substrates or products. With the VLPs positioned at Oil/Water interface, enzymes within VLP lumen remain in an aqueous environment, this configuration helps conserving enzyme activity by minimising the enzyme exposure to detrimental substances such as organic solvents, while it also ensures the accessibility of enzymes is not compromised, owing to the permeable nature of VLP shells. Two model enzymatic reactions conducted further confirmed accessibility of enzymes to the substrates were not hindered regardless of substrate being dispersed in the oil or the water phase. This approach to biocatalysis provides great potential in research and manufacturing of pharmaceuticals, flavours, and fragrances. With more advanced multi-enzymes configuration designs, it can be imagined mimicking eukaryotic organelles towards rapid multi-enzyme pathway testing and optimisation.

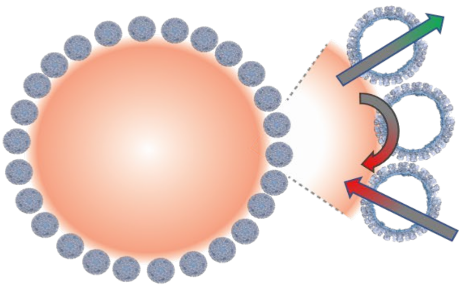
Stable droplets



Ultrastructure



Biocatalytic interface



Improving flotation of fine valuable lithium minerals through the formation of small hydrophobic flocs

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Due to the fast-paced evolution of electronic devices and new energy vehicles, the consumption of lithium has skyrocketed[1]. The primary and most reliable Li resource for industrial applications is spodumene[2]. Most commonly, flotation is used to separate spodumene from other minerals including feldspar, quartz, and mica[3]. However, spodumene, feldspar, and quartz are all silicate minerals with similar surface properties[1]. We investigate selective flotation of spodumene over feldspar and quartz. Spodumene can be floated using anionic collectors even though there is electrostatic repulsion between the negatively charged spodumene surface and the anionic collector[4]. The flotation of spodumene using an anionic collector is improved by the use of a metal ion activator,[4] to facilitate adsorption of fatty acid collectors[5]. For example, as a result of Ca(II) ions being used in the combination of sodium oleate (NaOL) and in some cases other collectors the recovery of spodumene improves[6]. As well, metal ions can facilitate the flotation of feldspar and quartz together; however, there is insufficient research on metal ions' effects on these gangue minerals[4]. Consequently, it is necessary to explore the influence of metal ions not only on spodumene, but also on feldspar and quartz so as to optimize separation. Fine spodumene particles are difficult to recover via flotation because they do not attach efficiently to bubbles. The recovery of fine particles which have been aggregated (flocculated) to about 100 μm size is expected to improve their recovery. In mineral processing, polyacrylamide (PAM) has been widely used as a polymer flocculant[7]. The purpose of this study is to determine whether one mineral, specifically spoduemene, can be selectively flocculated from feldspar and quartz using conventional and commercial PAM polymers.

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Floatation depression of graphite in the presence of biopolymers: A combined bubble-risning, AFM and QCM-D study

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Polysaccharides have shown a significant utility over synthetic polymers in mineral flotation processes due to their abundance and biodegradability. We hypothesize that the collision and bouncing of sub-millimeter gas bubbles with a hydrophobic model surface (graphite) is significantly affected by guar gum (GG) and the morphology of GG networks at the solid-liquid interface. A high-speed video microscope was used to monitor the effect of adsorbed GG on wetting film drainage time and bubble-graphite attachment. The adsorption of GG on graphite and the morphology of adsorbed layer were monitored using a quartz crystal microbalance with dissipation (QCM-D) and an atomic force microscope (AFM) respectively. It is shown that GG adsorbed from a 10 ppm polymer solution can significantly prolong the wetting film drainage time by an order of magnitude and the final receding contact angle is reduced by approximately 60 deg. Upon adsorption from a solution of the higher concentration, polymers attain interconnected and continuous arrangements at the liquid-solid interface (40-60% surface coverage). However, isolated and sparsely distributed chains (~8% surface coverage) are observed if adsorption takes place from a solution of a low concentration, i.e. 1 ppm GG solution. The observations of the bubble-surface encounter, both prior to and after film rupture, provide strong indications on the importance and effectiveness of the varying coverages of polymer layer on the recovery of minerals in flotation.

Physical properties of fluorescent high-pressure high-temperature (HPHT) nanodiamond thin films

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Nanodiamonds are of interest in many material studies due to their unique mechanical, chemical and optical properties, with possible applications from quantum sensing[1] to photocatalysis.[2] Three key advantages of nanodiamonds over bulk diamond is that particles have: (1) a high surface-to-volume ratio; (2) can be integrated with other materials; and (3) are very cost-effective. A key prerequisite for many potential applications is the ability to deposit homogenous layers of nanodiamond particles with close control over layer thickness (ideally down to monolayer coverage), porosity and particle orientation (relative to each other and the diamond lattice). Yet to date, very few of these processes have been developed. Those processes that have been developed focus on the use of detonation nanodiamonds, which cannot generally be used for quantum sensing applications. High-pressure high-temperature nanodiamonds (HPHT) are biocompatible, chemically inert, and have an ability to host so-called fluorescent colour centres. Our most recent study suggests that bare fluorescent HPHT particles are a very promising tool for the study of biological systems *in-vitro* and *in-vito*.[3]

Thin films made from fluorescent HPHT nanodiamonds could be an interesting platform for several applications including biosensing and imaging across the nano- and microscale. In this work we aim to explore the spin-coating of nanodiamond-polymer composites for the fabrication of nanodiamond films with controlled thickness and porosity by systematically varying the concentration of polyvinylpyrrolidone (PVP). Both nanodiamond-polymer composite thin films and pure nanodiamond thin films will be investigated. The latter will be created by annealing-induced decomposition of the polymer matrix.

The HPHT suspensions are characterised using ultra-small and small-angle neutron scattering and dynamic light scattering to understand their properties in suspension. Thin films are characterised using bright-field microscopy and profilometry. Electron microscopy and scattering techniques will be used to analyse the relative particle positions and orientation inside layers. We will present these results and discuss the future directions of this project.

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Fundamental Understanding of Electrode-Electrolyte Interfaces of Batteries: Deciphering Ion Specificity in Complex Electrolytes

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Recently, energy storage systems gained high attention for energy sustainability and among them, Li-ion batteries are a promising system of electrical energy storage with high energy density [1-4]. Providing low-cost battery storage systems for renewable energy will enable better exploitation of renewable energy. However, the challenge for rechargeable Li-ion batteries development is the ability to design low-cost Li-ion batteries with high electrolyte conductivity and fast charge / discharge of electrodes [2]. Deep understanding of the natural interfaces of electrolyte-electrodes and their reactions will help to overcome such challenges and lead to intrinsic improvements of Li-ion batteries [3,4]. Deciphering ion specificity in complex electrolytes will be the main aim of this project. The understanding of ions' interactions with cathodes and anodes in electrolyte solutions will contribute to identifying a suitable electrolyte solution for Li-ion batteries.

Study of the surface structure of liquid electrolytes (e.g., propylene carbonate (PC) dissolved in Li salt) provides a better description of electrolyte solution for li-ion batteries and a better understanding of the electrode-electrolyte interaction. A non-destructive method is needed to investigate the surface structure of the materials used. Neutral impact collision ion scattering spectroscopy (NICISS) will be applied to examine the structure and surface of different electrolyte solutions. This technique will allow us to study how ions interact with electrolyte solutions and electrodes (cathodes and anodes), which will provide information on suitable electrolyte solutions for improving Li-ion batteries.

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Magnetoelectric Polymer Composites Functionality in Liquids.

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The Magnetoelectric (ME) effect in ME polymer composites is a product of a cross-interaction between two separate constituent phases: a magnetostrictive and piezoelectric phase. When a magnetic field is applied to an ME polymer composite, a strain will be induced within the magnetostrictive material (e.g. the metal alloy, Metglas), which then transfers to the piezoelectric material (e.g. PVDF polymer) via mechanical coupling of the two materials. The strain exerted on the piezoelectric material induces electrical polarization to generate an output voltage.

The ME effect provides transformative technological devices, enabling the generation and control of electrical fields using magnetism and vice versa. This operating principle of ME polymer composites does not necessitate the use of electrical connections or wires and thus ME polymer composites are envisaged for use as “wireless” or contactless electrode devices. For example, their use in implantable electrode devices or neural prosthetics to deliver remotely activated, electrical stimulation at the electrode-tissue interface via an applied magnetic field. To date most studies on ME composites have been done under ambient conditions (i.e. in air). Furthermore, to our knowledge, the ME effect has yet to be measured in liquids and hence our research aims to understand the ME properties and effects in liquid environments.

PVDF polymer and Metglas were used as the piezoelectric and magnetostrictive components, respectively, for the fabrication of ME laminated composites. To enable measurements in liquid, the ME laminated composites were placed in a solution filled tube (Figure 1 (B)) that was positioned within a ME measurement setup consisting of an electromagnet and hemholtz coil to apply DC and AC magnetic fields whilst measuring the output voltage from the ME laminated using a lock-in amplifier. Significantly, the PVDF/Metglas laminated composites produced output voltages around 50 mV (with a high ME coefficient) and in doing so demonstrated for the first time the operation of ME devices in liquid. In addition, the study identified the critical need for insulation of the PVDF/metglas due to rapid corrosion of the metglas and ensuing failure of the device in liquid (Figure 1 (A). However, some types of insulation were found to have a deleterious effect on the ME output voltage. Several types of insulation were therefore evaluated, including Varnish and Paraylene C that were the most optimal for both protecting the device and preserving the ME properties/output voltage. Further measurements were done to investigate the effect of different solutions, salt concentration and pH. In summary, the feasible operation and advances in our understanding of ME polymer composites in liquids represents a significant leap in the field of ME composites. This paves the way for their translation into electrode devices that introduce novel “wireless” capabilities for electrochemical sensing and implantable electrodes/neural prosthetics and other diverse applications operating in liquid environments.

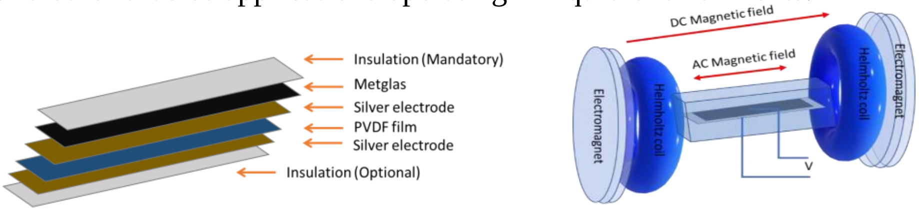

Figure 1 (A) Schematic of PVDF/Metglas ME laminate structure for operation n liquids. (B) Schematic view of the bulk system for ME voltage measurement in liquids.

Peptide adsorption on hydrophobic surface

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Peptide surfactants are novel (and often stimulus-responsive) molecules that can alter the properties of air-water and oil-water interface[1]. Significant research exists on their ability to influence the formation of foams and emulsions, but less has been published on their use as targeted adsorbates for metal and mineral surfaces. There is potential for these surfactants to act as surface modifiers in applications such as mineral flotation, but to prove efficacy (both in terms of adsorption strength and adsorption selectivity) there is a requirement for detailed study of their adsorption behaviour onto solid surfaces from solution. This study examined peptides with specific molecular weights and functional group chemistry to adsorb on a model hydrophobic surface using a surface-sensitive technique - quartz crystal microbalance with dissipation monitoring (QCM-D). Adsorption of peptides was observed with QCM sensor frequency change being detected (which is directly proportional to mass of the adsorbed layer). Contact angle measurements were performed using the captive bubble method to investigate the changes in the wettability of the surface.

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The Movement of Air Bubbles in High-solid content slurry

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In the construction industry, concrete slurry is a main raw material that consists of cement, sand, aggregates of different sizes, as well as water and air. Air exists in the concrete slurry in the form of bubbles of different sizes. Small air bubbles (typically around 100 µm in diameter) are desirable since they can not only enhance the mobility of cement slurry during the mixing and pumping processes but also improve the mechanical properties of concrete by offering extra space for the expansion of frozen water to mitigate the freezing damage. Therefore, the retaining of air bubbles within the concrete is essential. However, it is undesired that large bubbles of several millimeters or even centimeters are trapped on the fresh slurry-formwork interface since it could create surface voids (Figure 1) after the demoulding process of concrete, which has an impact on the appearance of the construction. The compressive strength and durability of concrete might also be reduced. Consequently, it is a critical issue in the concrete industry that requires engineering solutions.

The wettability of the solid surface has a straightforward relationship with the attachment of bubbles. Improving the wettability of the solid surface could prevent the attachment of bubbles on the surface via the hydrophobic force. So, the poly acrylic acid was grafted on the substrate to create a slippery hydration layer to improve the movability and detachment of bubbles on the surface since it is a hydrophilic polyanionic brush. After the characterization of the modified surface and lubrication test of bubbles, the modified substrate was applied as the pre-casting mould of the mimic concrete slurry system. However, in the high solid content system, the effect of air bubble lubrication on the solid surface was strongly inhibited by the surrounding particles since bubbles are required to overcome the gravitational force applied by particles. Unless extra energy is applied to bubbles, the single injected bubble would stay on the surface.

Therefore, initial hypotheses were proved that the simple fabrication of polymer brush on the surface of the mould is insufficient to eliminate the trapped bubbles, and a vibration plate is proposed as a new hypothesis for the development of the project to allow trapped bubbles to float up.

Figure 1. Surface voids on the surface of the wall