Centre for **Sustainable & Circular** Technologies

MONASH University

UNIVERSITY OF BATH

Bath Monash Global PhD Programme in Sustainable & Circular Technologies

Project Title:	Emulsions stabilized by Cellulose & Sugar-based Stabilizers
Supervisors at Bath:	Prof Karen Edler (lead); Dr Antoine Buchard
Supervisors at Monash:	Dr Rico Tabor; Prof Gil Garnier
Home Institution:	University of Bath
Indicative period at Host Institution:	2.5 years at Bath; 12 months at Monash with exact dates to be confirmed

Project Summary

Emulsions are key to many consumer goods including foods, personal care and cleaning products, and are used in applications such as the delivery of drugs and agrochemical active compounds. Recently, Pickering emulsions, where adsorbed particles stabilise the oil-water interface, are gaining attention due to their improved stability, (potential for slow release) and lack of irritancy (e.g. on skin).[1] Naturally derived, biodegradable particles are desirable for this application to reduce end-of-life environmental impact, and can potentially act as functional units that can enhance the properties of the emulsion (e.g. for drug binding and release). Combinations of soluble biopolymer and biopolymer nano/microparticles offer opportunities for the development of renewably derived and biodegradable emulsion systems and also formation of robust capsule systems due to charge complexation, entanglement or hydrogen bonding at the oil-water interface.[2] Cellulose nanoparticles (both crystalline and fibrillar) can be sustainably produced from renewable resources such as waste plant biomass or recycled paper, or bio- synthesised by bacteria, while biodegradable polymeric amphiphiles can be synthesised from plant-derived sugars and fatty acid precursors. Active species can be incorporated within the emulsion droplets (either oil in water or water in oil) or via electrostatic or covalent binding to the particles/polymers.

In this project we aim to study emulsions stabilized by cellulose nanofibrils, surface functionalized via straightforward reactions (e.g. using glycidyl based reagents) to vary charge sign and density, and hydrophobicity/philicity of the fibril surface. This will provide a tool-kit of particulate stabilisers which can be tuned to interact specifically with polymeric amphiphiles to vary the properties of the Pickering emulsion particle layer, altering permeability, thickness and strength, thus changing the encapsulation properties of the emulsion. Encapsulated species such as natural insect repellants (e.g. citriodiol) and sunscreens will be tested for extended release. Functionalised particles can also provide multiple functionality to the emulsion by allowing binding of other active species for multiple or extended release applications. Initially vegetable oils such as sunflower or jojoba will be used but we will also consider novel solvents such as deep eutectic solvents, which in our preliminary studies show excellent preservation of anti-oxidant species and biologically derived material (proteins, peptides, etc).

The student will be based in Bath, and they will initially work with Prof Edler and Dr Buchard on cellulose fibril stabilized oil or DES-in water emulsions will be prepared, and interactions between sugar-fatty acid polymers and the cellulose fibrils will be studied using SAXS, SANS, rheology, and confocal microscopy. During their year in Monash, supervised by Dr Tabor, they will use atomic force microscopy to determine the mechanical properties of encased oil droplets and how this relates to their release.[3] Synchrotron SAXS will be utilized to determine shell porosity and thickness, and the relationship between shell structure and emulsion droplet

release properties. Cross-linking and composite inorganic-cellulose shell chemistries will be explored to further tailor the emulsions into capsules, offering new opportunities for controlled and stimulus-responsive release of valuable cargoes.[3-4]

1. Calabrese, V.; Courtenay, J. C.; Edler, K. J.; Scott, J. L., Pickering emulsions stabilized by naturally derived or biodegradable particles. *Curr. Op. Green Sus. Chem.* **2018,** *12*, 83-90.
2. Calabrese, V.; da Silva, M. A.; Schmitt, J.; Hossain, K. M. Z.; Scott, J. L.; Edler, K. J., Charge-driven interfacial gelation of cellulose nanofibrils across the water/oil interface. *Soft Matter* **2019**, DOI: 10.1039/C9SM01551E.
3. Meaney, S. P.; Follink, B.; Tabor, R. F., Synthesis, Characterization, and Applications of Polymer–Silica Core–Shell Microparticle Capsules. *ACS Applied Materials & Interfaces* **2018,** *10* (49), 43068-43079.
4. Ali, M.; Meaney, S. P.; Abedin, M. J.; Holt, P.; Majumder, M.; Tabor, R. F., Graphene oxide–silica hybrid capsules for sustained fragrance release. *J. Colloid Interface Sci.* **2019,** *552*, 528-539.

Features of the programme

- PhD researchers will be registered at both institutions and will be awarded a joint PhD degree.
- PhD researchers will be jointly supervised by academics from both Monash and Bath Universities.
- All PhD researchers in the joint programme will also undertake a bespoke advanced training plan covering a range of topics focusing on sustainability.
- Applicants can apply to either Monash University or the University of Bath as their nominated home institution.
- PhD researchers will undertake a period of no less than 12 months at the partner institution.
- Up to four scholarships/studentships will be offered. Additional and suitably qualified applicants who can access a scholarship/studentship from other sources will be also considered. Evidence of funding must be provided.
- The scholarships/studentships include:
  - a *full tuition fee sponsorship* provided by Monash or Bath for the course duration (up to a maximum 42 months). Note, however, that studentships for Bath-based projects will provide cover for UK/EU tuition fees ONLY.
  - *a living allowance (stipend)* provided by Monash or Bath Universities.

Note: Overseas Student Health Cover (OSHC) must be paid by the student, unless covered by the university.

How to apply

You MUST express interest for three projects in order of preference. Please submit your application at the Home institution of your preferred project ('Home' institution details can be found in the project summary). However, please note that you are applying for a joint PhD programme and applications will be processed as such.

The deadline to submit applications is 23rd February 2020

Monash University

Expressions of interest (EoI) can be lodged through https://www.monash.edu/science/bath-monash-program. The EoI should provide the following information:

CV including details of citizenship, your Official Academic Transcripts, key to grades/grading scale of your transcripts, evidence of English language proficiency (IELTS or TOEFL, for full requirements see: https://www.monash.edu/graduate-research/faqs-and-resources/content/chapter-two/2-2), and two referees and contact details (optional). You must provide a link to these documents in Section 8 using Google Drive (Instructions in Section 8).

University of Bath

Please submit your application through the following link: https://www.csct.ac.uk/bath-monash-global-phd-programme/

Please make sure to mention in the "finance" section of your application that you are applying for funding through the joint Bath/Monash PhD programme for your specified projects.

In the "research interests" section of your application, please name the three projects you are interested in and rank them in order of preference. Please also include the names of the Bath lead supervisors. Please make sure to mention in the "finance" section of your application that you are applying for funding through the joint Bath/Monash PhD programme for your specified projects.

In the "research interests" section of your application, please name up to three projects you are interested in and rank them in order of preference. Please also include the names of the Bath lead supervisors.