

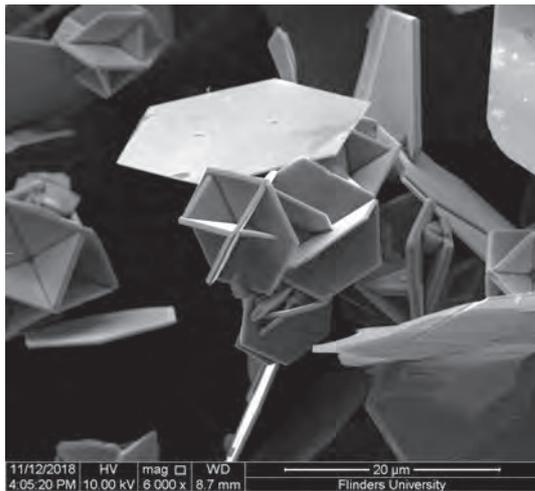
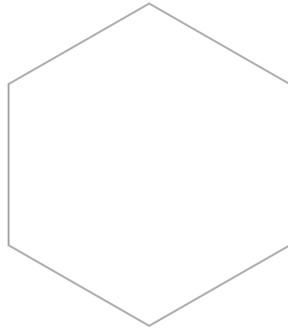


**Flinders**  
UNIVERSITY

Institute for  
**Nanoscale  
Science &  
Technology**

**ANNUAL REPORT 2019**





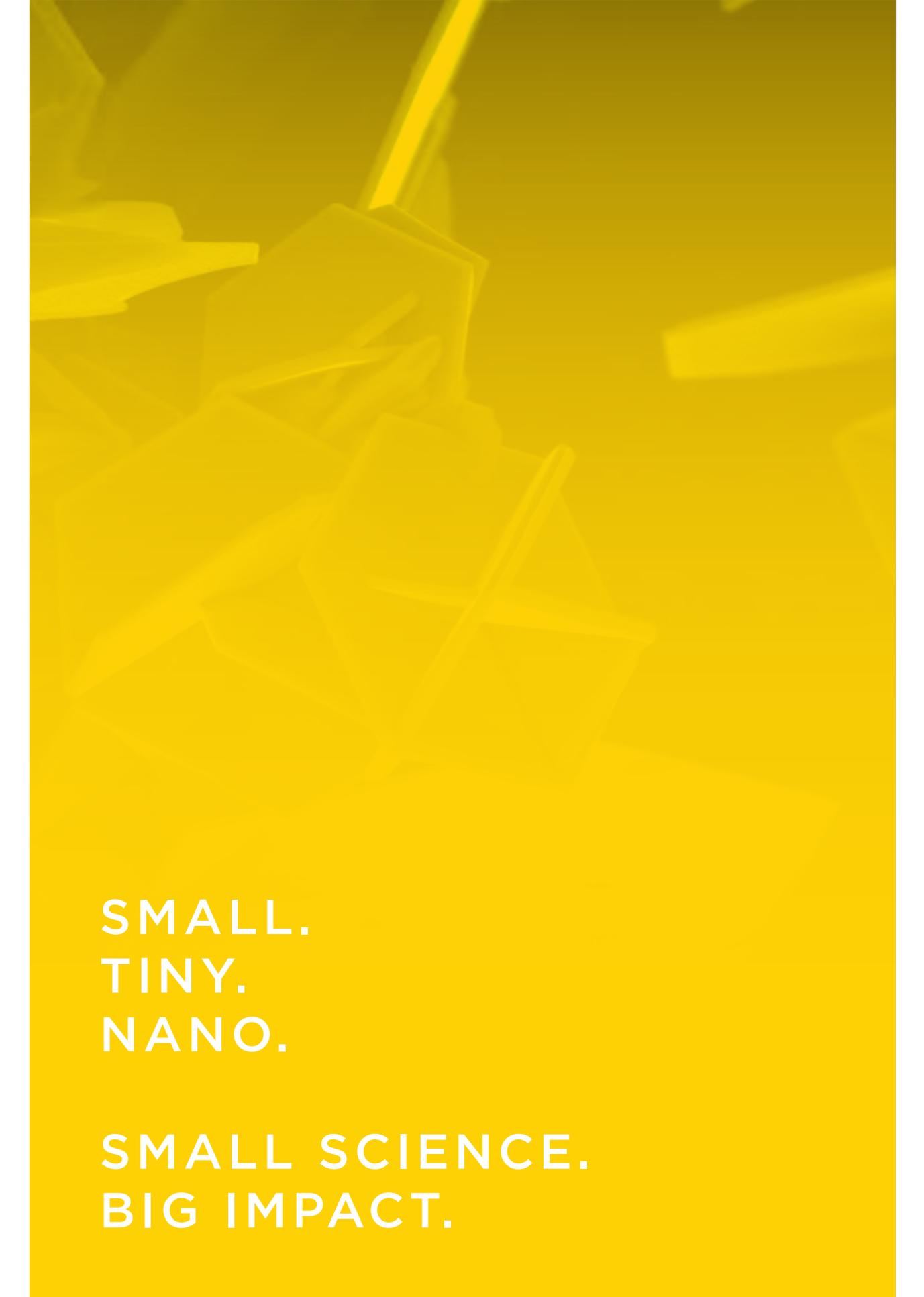
The Scientific Image of the Year Competition was awarded to Mr Zhen He (PhD candidate supervised by Professor Sarah Harmer). The 2019 winner was selected by an expert judging panel, including Monique Russell from Blend Creative Design Agency and Emeritus Professor Ian Gibbins.





# INSTITUTE FOR NANOSCALE SCIENCE + TECHNOLOGY **ANNUAL REPORT 2019**

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SMALL.  
TINY.  
NANO.

SMALL SCIENCE.  
BIG IMPACT.

## DAVID LEWIS

### DIRECTOR

Following last year's elevation from Centre to Institute, 2019 been a little less frantic but just as productive with 100 papers in high-quality journals, continued grant success and an expansion of our international focus.

After much behind the scenes work, the Flinders Microscopy and Microanalysis Facility led by Professor Sarah Harmer launched in 2019. The focus has been the physical consolidation of our internationally leading surface science capability into a freshly renovated, purpose-built location in the Sir Eric Neal Building. This move was also in preparation for the arrival of our new flagship photoemission electron microscopy in late 2020. This facility and the resources provided through the continuing strong support from our Deputy Vice-Chancellor (Research), Professor Rob Saint and the Vice President and Executive Dean (Science and Engineering), Professor Alistair Rendell, will become a focal point for the Institute.

2019 saw the launch of the Biofilm Research and Innovation Consortium led by Associate Professor Sophie Leterme, with a focus on understanding and controlling biofilm formation on surfaces. This initiative involves several of our Research Leaders due to the importance of surface chemistry and structure on the initial biofilm formation. This consortium provides a real opportunity for novel coatings chemistry and nanoscale structures to control the formation of biofilms. Additionally, this grouping provides an excellent forum to engage with companies to better understand their challenges. To date projects facilitated by the consortium include antimicrobial nanoparticle coatings for evaporative cooler pads and novel coatings to prevent biological growth in seawater.

I would like to single out some highlights during 2019 and these are:

- Following her promotion to Professor, Sarah Hamer is now the first female Physics Professor in the history of Flinders University. An impressive and well-deserved achievement.
- Youhong Tang was also promoted to Professor and Justin Chalker to Associate Professor this year, recognising their international research profiles and contributions to Flinders University and the wider community.
- Professors Colin Raston and Youhong Tang are significant contributors to the ARC Training Centre for Green Chemistry in Manufacturing, administered by Monash University (\$3.6M, 2019 - 2023)
- Two patents from Associate Professor Justin Chalker's laboratory were purchased by Clean Earth Technology, with a long-term research collaboration agreement valued at \$260,000 per annum
- Associate Professor Justin Chalker being awarded an ARC Special Research Initiative Grant for PFAS remediation (approximately \$650,000)
- Three ARC Discovery grants were awarded to Professor Colin Raston (two grants totalling \$1.1M) and Associate Professor Justin Chalker (\$410K).



The Institute continues to expand our strategic partnerships with major international organizations and we are now working with Max Planck Institute for Polymers, Germany, Chalmers University of Technology, Sweden and INSA-Lyon, France. This year Elliott Jew interned at ENSTA Bretagne, France and Jesse Daughtry spent 6 months at our long-term partner, the National Institute for Material Science, Japan.

PhD candidate Mohammed Khorsand (supervised by Professor Youhong Tang) was awarded the Best Higher Degree by Research Student Publication for his paper entitled Simulation of high-output and lightweight sliding-mode triboelectric nanogenerators. Congratulations Mohammed for yet again demonstrating the impact being made by the Institute.

One of our founding Board members, Don Bursill is stepping down to "retire properly" - according to his wife. I would like to thank Don for his never-ending enthusiasm and support for all that the Institute is trying to achieve.

Julie Cairney, CEO of Microscopy Australia and Professor at the University of Sydney joined our Advisory Board this year. Along with her "day job" as a materials scientist, Julie brings a wealth of technical and management experience to our Board

Judy Halliday, Director: Science, Technology and Commercialisation, Department of Innovation and Skills, SA Government will join our Advisory Board in 2020. Judy has more than 25 years' executive experience in technology commercialization, entrepreneurship and innovation as an inventor, founder, investor, academic and industry professional. I look forward to welcoming Judy to our Board.

I would lastly like to acknowledge the contribution made to our Institute by Nathan O'Brien, Research Support Officer over the last two years. Nathan left the Institute in December 2019 to pursue a career in STEM teaching in country SA. Nathan made a significant contribution to previous editions of the Institute's annual report and annual conference but also marketing and social media. I am sure you will all join me in wishing Nathan all the best and we look forward to a stream of talented students from his school.

2020 will be the 10th year of operations for the Institute and although some of the celebrations we had planned may now have to be "virtual"; research and the development of industry partnerships continue in what I anticipate will be another good year for the Institute.

## ADVISORY BOARD

The Institute Advisory Board consists of renowned professors and industry experts. The board meet once a year to review, advise and guide the institutes activities.



**Professor Don Bursill**  
Water Industry expert and Former Chief Scientist for South Australia.



**Professor Julie Cairney**  
Materials Characterisation, School of Aerospace, Mechanical and Mechatronic Engineering and CEO Microscopy Australia



**Professor Paul Mulvaney**  
Nanotechnology leader based at Bio21, University of Melbourne.



**Mr Len Piro**  
Former Executive Director at the Department of State Development, South Australia.



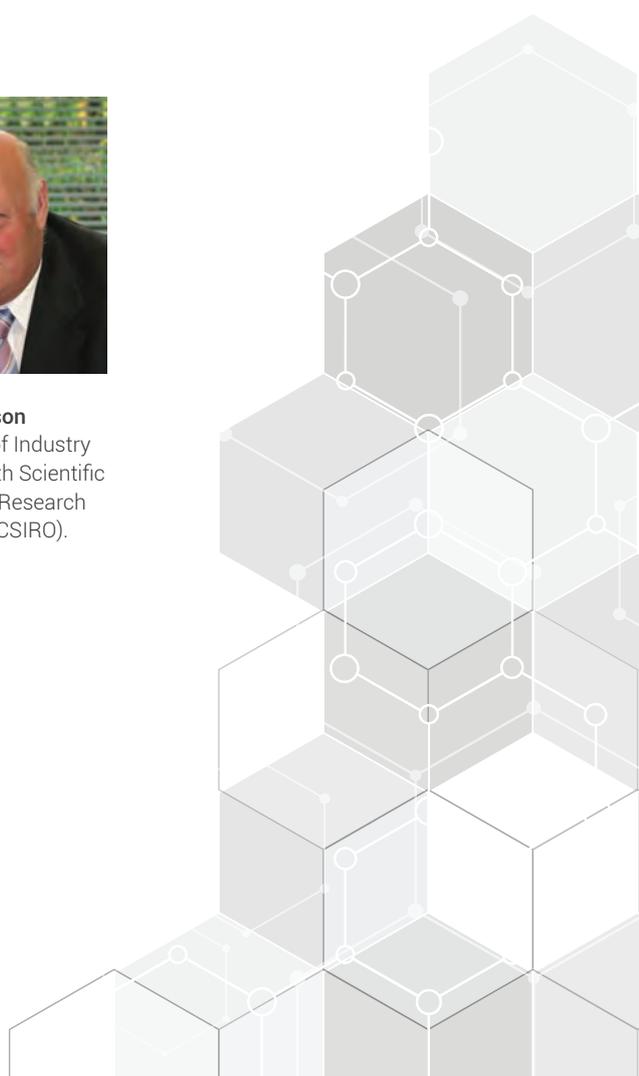
**Professor Kohei Uosaki**  
Director of Global Research Centre for Environment and Energy based on Nanomaterials (GREEN) at National Institute for Materials Science, Japan.

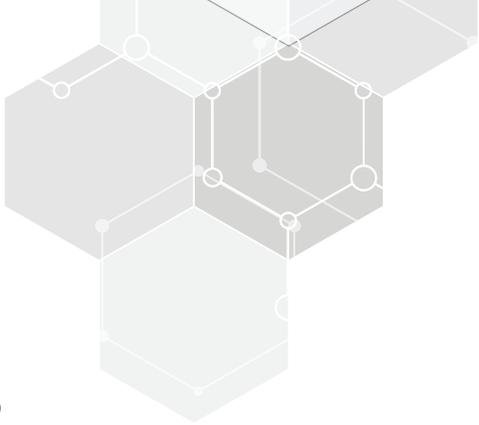


**Professor Robert Saint**  
Deputy Vice Chancellor (Research) Flinders University and expert in genetics.



**Dr Greg Simpson**  
Deputy Chief of Industry Commonwealth Scientific and Industrial Research Organisation (CSIRO).





## INSTITUTE MEMBERS

### Research Leaders

Professor Gunther Andersson  
Professor Mats Andersson  
A/Professor Justin Chalker  
Professor Sarah Harmer  
A/Professor Martin Johnston  
A/Professor Ingo Köper  
A/Professor Sophie Leterme  
Professor David Lewis  
Professor Jim Mitchell  
Professor Jamie Quinton  
Professor Colin Raston  
A/Professor Youhong Tang

### Research Staff

Dr Munkhbayar Batmunkh  
Dr Jonathon Campbell  
Dr Ashley Connolly  
Dr Sait Elmas  
Dr Louisa Esdaile  
Dr Chris Gibson  
Schannon Hamence  
Dr Christopher Hassam  
Dr Wei Han  
Dr Mahnaz Dadkhah Jazi  
Dr Martyn Jevric  
Dr Darryl Jones  
Dr Daniel Mangos  
Cheylan McKinley  
Dr Rebecca Norman  
Dr Raihan Rumman  
Dr Javad Tavakoli  
Dr Kasturi Vimalanathan  
Dr Yanting Yin  
Jinjian Wu  
Xinyi Zhang

### PhD Students

Ahmed Hussein Al-Antaki  
Lisa Alcock  
Thaar Alharbi  
Firas Andari  
Alex Ashenden  
Jonas Mattiasson Bjuggren  
Belinda Bleeze  
Liam Brownlie

Jessica Carlson-Jones  
Clarence Chuah  
Emily Crawley  
Jesse Daughtry  
Bradley Donnelly  
David Doughty  
Liam Howard-Fabretto  
Renzo Fenati  
Jody Fisher  
Melanie Fuller  
Joshua Gethardt  
Tom Grace  
David Harvey  
Alex Hayes  
Zhen He  
Aghil Igder  
Matt Hisee  
Tamar Jamieson  
Elliott Jew  
Matt Jellicoe  
Nikita Joseph  
Emma Kent  
Mohammad Khorsand  
Guler Kocak  
Renata Kucera  
Anand Kumar  
Sian La Vars  
Nicholas Lundquist  
Xuan Luo  
Oskar Majewski  
Maximillian Mann  
Todd Markham  
Jake Marshall  
Stefan Martino  
Rowan McDonough  
Muthuraman Namasivayam  
Xun (Caroline) Pan  
Jessica Penrose  
Spencer Petticrew  
Zoe Pettifer  
Jessica Phillips  
Scott Pye  
Connor Retallick  
Nahideh Salehifar  
Yuya Samura  
Danielle Saunders

Natalya Schmerl  
Kym Scroggie  
Altaf Shamsaldeen  
Alexander Sibley  
Ruby Sims  
Gaurav Singhai  
Eko Kornelius Sitepu  
Tim Solheim  
Jordan Spangler  
Kaili Stacey  
Daniel Suhendro  
Jade Taylor  
Alfreds Tikoalu  
James Tsoukalas  
Elise Tuuri  
Ruben Wheeler  
Michael Wilson  
Max Worthington  
Xinyi Zhang

### Masters Students

Sunita Guatam Adhikari  
Mayisha Ahmedullah  
Gabriella Anggelia Essi Christian  
Israa Hussain  
Tao Peng

### Honours Students

Brodie Parrott  
Nathan Garner  
Bradley Kirk  
Nicola Papazis  
Niki Romeo  
Aoife Rutley  
April Van Der Kamp



### Awarding of the PEEM to Flinders University

The powerful microscope – the only one of its kind in Australia – will be acquired by the newly established Flinders Microscopy and Microanalysis facility at the University's Bedford Park main campus, south of Adelaide. The PEEM's spectro-microscopic technique combines high lateral resolution parallel imaging with photoemission spectroscopic analysis for the chemical composition of material surfaces.

### ERA Celebrations

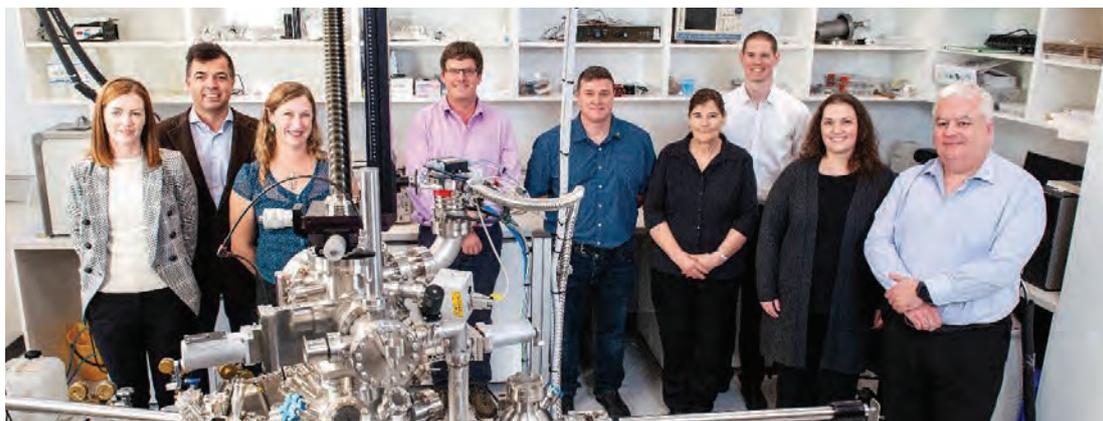
To celebrate the Institute exemplar contribution to Flinders University's 2018 ERA evaluation an afternoon tea was held on Thursday 2 May 2019. Attended by Institute members, Research and Development Services staff, Vice President Alistair Rendell and Deputy Vice-Chancellor Research Professor Robert Saint.

Flinders University ERA 5 ranking in 2012 and 2015 were consolidated into 2018, with ERA 5's in Nanotechnology, Materials Engineering, Physical Chemistry and Condensed Matter Physics.

Deputy Vice-Chancellor Research Professor Robert Saint praised Flinders researchers for their commitment to making a positive difference through high quality research. He congratulated all our dedicated researchers, and especially those who have moved up the four-digit specific research field rankings and are working at levels which are equal to or better than the rest of the world. These results reflect our leadership in innovation and ground-breaking research that extends beyond our campuses to engage business, industry and the community.



Elliott Jew (PhD candidate supervised by Professor David Lewis) visited Brest, France to work with ENSTA Bretagne and Thales Group as part of a Nicholas Baudin Internship. Elliott is conducting research on using adhesive bonds rather than welding in ships and submarines. His project was entitled Correlation of interfacial changes during seawater exposure of adhesively bonded structures.



### Opening of Flinders Microscopy and Microanalysis

This newly formed facility is a collaboration between the College of Science and Engineering and Flinders College of Medicine and Public Health. The facility's Director is Research Leader Professor Sarah Harmer and brings together a team of multidisciplinary instrument leaders and highly skilled technical staff will be on hand. The Flinders Microscopy and Microanalysis Facility will support vital development of nanomaterials, photovoltaics, corrosion, 3D metal printing prototypes and minerals processing. Part funded by the latest \$12.6 million federal government's National Collaborative Research Infrastructure Strategy (NCRIS) and an Australian Research Council Linkage Infrastructure, Equipment and Facilities (LIEF) grant.

All the equipment that makes up the Flinders Microscopy and Microanalysis (FMMA) is open to Australian and visiting scientists and researchers, and industry users ranging from medical research and advanced manufacturing, with applications spanning geology, agriculture and materials science. A list of the instruments and full capabilities can be found at [www.flinders.edu.au/microscopy](http://www.flinders.edu.au/microscopy) or email [microscopy@flinders.edu.au](mailto:microscopy@flinders.edu.au) for further information and bookings.



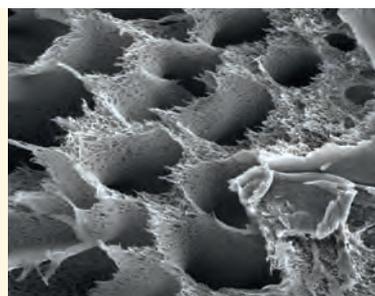
### Chief Scientist Institute visit – 29 August 2019

The Institute was privileged to have a visit by the Chief Scientist for South Australia Professor Caroline McMillen on Thursday 29 August 2019. Professor McMillen gave a presentation on the "State of Science" as part of her process on developing a discussion paper 'The State of Science, Research and Innovation Discussion Paper'.

Professor McMillen also generously spent time with four of the Institute's PhD students, listening to their short presentation, sharing her advice and answering their questions. These students were Xuo Luo and Zoe Pettifer, Ruby Sims and Max Worthington.

As part of the Institute's annual Scientific Image of the Year Competition, a People's Choice Award, sponsored by the Office of Communication, Marketing, and Engagement, Flinders University was run for the first time. With over 140 votes received the winning image was entitled Nano Beehives submitted by Mr. Aghil Igder (PhD candidate supervised by Professor Colin Raston).

The winning People's Choice vote was cast by Ms. Maya Roberts, Senior Grants Officer, Research and Development Support.





**Brittany Scholarship – SA Government**

Research Leader Sophie Leterme was awarded \$10,512 to travel to France allowing her to strengthen the relationship between South Australia and Brittany.



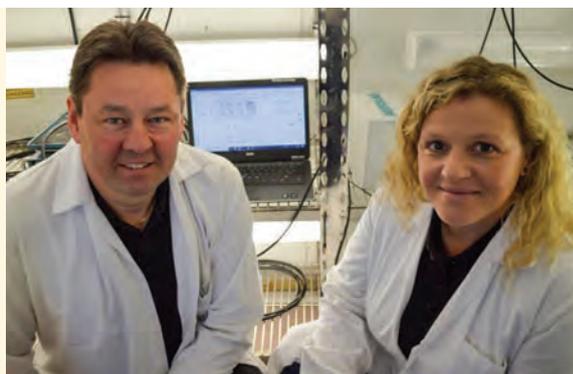
**International Women's Day Lab Coat Challenge**

On May 8 2019, to celebrate women in STEMM, Chief Scientist for South Australia, Professor Caroline McMillen, joined the Lab Coat Challenge on the Flinders University Plaza which featured over 300 staff and students wearing their lab coats, among them several Institute members.

The challenge was hosted by the Flinders STEM: Women Branching Out. The group provided the Lab Coat cake made by Carly Schramm, PhD student in College of Science and Engineering (left), which was enjoyed by all participants.

**Defence Innovation Partnership Grant**

Research Leaders Professor Mats Andersson and Associate Professor Sophie Leterme received a \$150,000 SA Government grant to develop and test new state-of-the-art coatings to prevent the growth of bio-contaminants. The Defence Innovation Partnership grant, with partners at ASC, Defence and the UniSA, will focus on delivering electrically conducting carbon-based coatings to prevent the growth of unwanted organisms on marine surfaces.



**Ninth Annual Conference**

The Institute's Annual Conference was held at the Tonsley Innovation Precinct on June 18 2019 with this year conference sponsored by SciTek.

The conference was opened by Professor Rob Saint, Deputy Vice Chancellor (Research). A packed program included Julie Cairney, CEO Microscopy Australia, Sally McArthur, Professor of Biomedical Engineering Swinburne University and CSIRO Research+ Science Leader in Biomedical Manufacturing and Steve Wessling, Executive Director, South Australian Health & Medical Research Institute.

A focussed professional development activity by senior PhD institute members was provided to challenge less experienced members to develop their pitch and entrepreneurial skills. The winning teams were awarded prizes for their successful pitch in a simulated "shark-tank" environment.



PhD candidate Mohammed Khorsand has been awarded the Best Higher Degree by Research Student Publication for his paper Simulation of high-output and lightweight sliding-mode triboelectric nanogenerators.



Research Leader Associate Professor Ingo Koper visited NANOTEC Thailand, the country's national nanotechnology research centre, as part of the Institutes ongoing collaborations with this premier research organisation.



Research Leader Professor Youhong Tang was part of the launch of the China-Australia Intergovernmental Scientific and Technological Cooperation Project.



**Summary of Major Grant Awarded**

Flinders University was successful in securing eight new Australian Research Council Discovery Projects – total funding \$3.83 million over the next three years. Three of these grants were awarded to Institute Research Leaders.

Research Leader Professor Colin Raston will lead two projects to bring revolutionary new materials processing closer to industrial production. The vortex fluidic device, capable of partially 'unboiling an egg' and cutting carbon nanotubes – the "strongest material available" – will be used in both new Discovery Projects, to commence in 2020. One project will fabricate new forms of carbon, which include using electric and magnetic fields to control their properties. The other Discovery Project will use the vortex fluidic device to build pharmaceutical molecules that eliminate the formation of waste and avoid the use of toxic reagents.

Ground-breaking research will see Research Leader Associate Professor Justin Chalker secure funding to explore new strategies in recycling, additive manufacturing, and sustainable mining. The Chalker Research Lab is progressing field trials and commercial translation of polymers made from industrial waste products such as sulfur. These materials have shown great potential as recycled rubber, plastics and glass, with valuable applications in environmental remediation.



#### The 4<sup>th</sup> International Conference on Aggregation Induced Emission

On January 22, 2019, during the winter in the northern hemisphere, the southern hemisphere was in warm summer. We crossed half of the earth to gather in Adelaide, Australia, a beautiful city on the southern edge of the Australian mainland to open an academic collision, exchange and exploration journey. The 4th International Conference on Aggregation-Induced Emission of Materials, Mechanisms and Applications (AIE-4) successfully opened at Flinders University, Adelaide, South Australia. The AIE-4 conference focused on the latest developments in the field of AIEgen research through conference reports, invitation reports, oral reports and poster presentations, focusing on breakthroughs and new challenges of AIE molecular design, synthesis and application related developments. The AIE conference was jointly organized by Flinders University, Hong Kong University of Science and Technology and South China University of Technology. Professor Youhong Tang, Professor Qin Anjun and Professor Tang Benzhong were the chairmen.



2019 has been another successful year for PhD completions with eleven students awarded their PhD

**PhD - HASSAM, Christopher Lee**

Supervisors: CAMPBELL, J; \*LEWIS, D  
High-concentration nanofluids prepared from functionalised silica nanoparticles: synthesis optimisation and investigation of rheological properties

**PhD - DOUGHTY, David James**

Supervisors: PERKINS, M; \*JOHNSTON, M  
Mechanistic and Forensic Understanding of Clandestine Synthesis of Amphetamine Type Stimulants (ATS) from Benzaldehyde(s)

**PhD - MAJEWSKI, Oskar**

Supervisors: QUINTON, J; \*LEWIS, D  
A Theoretical and Experimental Investigation of a Photochromic RAFT Agent and the Photoiniferter Effect

**PhD - SIBLEY, Alexander James**

Supervisors: ANDERSSON, G; \*QUINTON, J  
A Study of Chemical and Plasma Deposition of Organosilane Thin Films

**PhD - YIN, Yanting**

Supervisors: LEWIS, D; \*ANDERSSON, G  
Investigation of Interfaces Formed of High Workfunction Metal Oxides with Conjugated Polymers

**PhD - AYOB, Muhammad Taqiyuddin Mawardi**

Supervisors: \*LEWIS, D  
Development of Silver-doped Phosphate Glasses for Radio Photoluminescence Glass Dosimeter

**PhD - CARLSON-JONES, Jessica Alice Pillay**

Supervisors: SPECK, P; \*MITCHELL, J; ROGERS, G; SMITH, R; MARTIN, J  
The Microbial Ecology of the Paediatric Oral Microbiome in Healthy and Sleep Disorder Breathers

**PhD - MATTIASSON BJUGGREN, Carl Jonas Mikael**

Supervisors: LEWIS, D; \*ANDERSSON, M  
Synthesis of naphthalene diimide structures for application in polymer solar cells

**PhD - SOLHEIM, Timothy Samuel Elling**

Supervisors: PERKINS, M; \*RASTON, C  
Understanding the vortex fluidic device through the development of a theoretical model and the application of neutron techniques

**PhD - SIMS, Ruby Alice**

Supervisors: HARMER-BASELL, S; \*QUINTON, J  
The Self-assembly of Organosilane Films on Aluminium Oxide and their Application to Si-Al Composite Materials for 3D Printing

**PhD - ALCOCK, Lisa Jane**

Supervisors: PERKINS, M; \*CHALKER, J  
Chemical tools for detecting cysteine sulfenic acid

\* Designates primary supervisor.



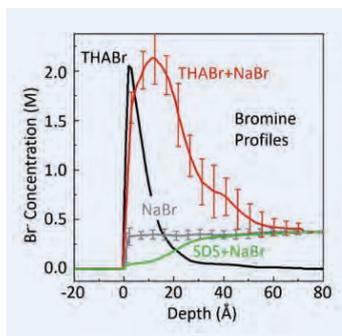
# RESEARCH LEADERS



## PROFESSOR GUNTHER ANDERSSON

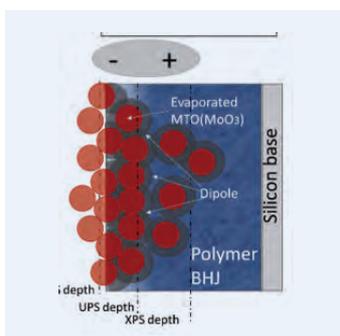
The Andersson lab focusses on surfaces and interfaces, specifically clusters on surfaces, liquid surfaces and polymer interfaces. The lab has methods and equipment available and can investigate surfaces under ultra-high voltage conditions to liquid surfaces with finite vapour pressure. The latter capability allows analysing surfaces relevant for atmospheric research.

Gunther joined Flinders University in 2007 after working in Germany, where he developed a specialised technique- Neutral Impact Collision Ion Scattering Spectroscopy (NICISS).



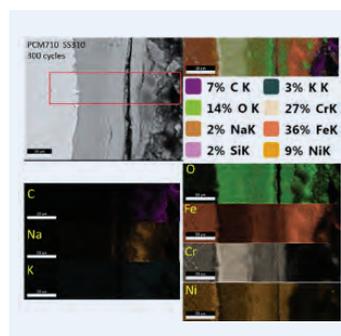
### Bromine surface reactivity

The reaction of  $\text{Cl}_2$  with  $\text{Br}^-$  to form  $\text{Cl}^-$  strongly depends on the concentration of  $\text{Br}^-$  in the surface near region. The addition of the cationic surfactant tetrahexylammonium ( $\text{THA}^+$ ) bromide increases the  $\text{Br}^-$  presence in the surface near region and the addition of the anionic surfactant sodium dodecyl sulfate ( $\text{DS}^-$ ) decreases the  $\text{Br}^-$  presence. These different interfacial  $\text{Br}^-$  propensities correlate with previously measured gas-liquid reactivities: gaseous  $\text{Cl}_2$  readily reacts with  $\text{Br}^-$  ions in the presence of  $\text{THA}^+$  but drops 70-fold in the presence of  $\text{DS}^-$ ; demonstrating that surfactant headgroup charge controls the reactivity of  $\text{Br}^-$  through changes in its depth profile.



### Increased charge transfer with molybdenum trioxide

$\text{MoO}_3$  is used as anode buffer layer in organic solar cells due to its capability to extract electrons and inject holes from the active layer. We have shown that evaporation of the  $\text{MoO}_3$  causes a unusually strong dipole to form at the interface between the active layer and the  $\text{MoO}_3$ . The strength increases with increasing thickness of the  $\text{MoO}_3$  layer and saturates at 2.2 eV and thickness of 3nm. The formation of this strong dipole makes the material suitable for facilitating the charge transfer between materials.



### Degradation of alloys in solar thermal arrays

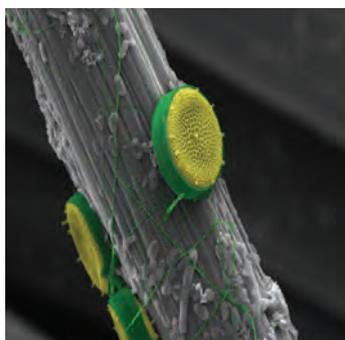
The degradation of alloys used for containment for high-temperature phase change materials (PCM) is critical to advancing our understanding of solar thermal arrays. The formation of interface, such as  $\text{Cr}_2\text{O}_3$  passivation front and corroded Fe layers can be studied with a combination of microscopy and spectroscopy methods. A wide choice of both PCMs and alloys can be studied and down-selected for optimizing solar thermal containment, which can assist to enhance solar thermal system design. Pre-treating such alloy surface coating can be further performed and studied using comprehensive characterisations.



## PROFESSOR MATS ANDERSSON

The Andersson lab research interests include organic chemistry, polymer synthesis, the structure – property relationship, conjugated materials, morphology characterisation, polymer nanoparticles, polymer electronics, polymer solar cells, polymers for insulation of high voltage cables, and antifouling coatings.

Mats joined Flinders University and the Institute in 2017, as a Matthew Flinders Fellow. With strong links to Europe Mats, is also an affiliate professor at Chalmers University of Technology, Sweden, where he held the Chair in Polymer Chemistry 2007 to 2015.



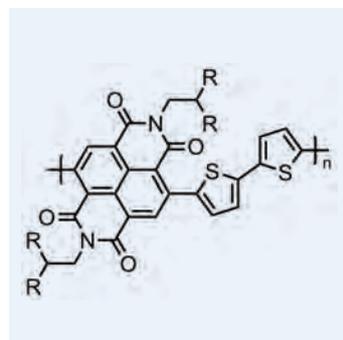
### Antifouling coatings for ships

The hull of a ship is a perfect home for marine species such as algae and barnacles. This fouling can slow down ships, increase fuel consumption, and reduce ship durability. Our research focuses on taking up copper in seawater and managing its release to eliminate fouling.



### Printed polymer solar cells

Plastic solar cells are a type of photovoltaic that uses conjugated polymers, for light absorption and charge transport to produce electricity from sunlight by the photovoltaic effect. The focus of our research is to deliver polymer solar cells on a flexible plastic surface with an emphasis on environmentally friendly, efficient fabrication process.



### Designing and synthesising conjugated polymers

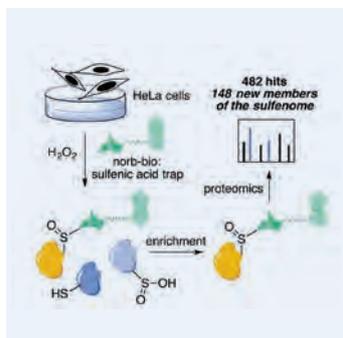
Conjugated polymers are organic macromolecules that are characterized by a backbone chain of alternating double- and single-bonds. We are modifying and developing new electron accepting polymers to use on polymer solar cells.



## ASSOCIATE PROFESSOR JUSTIN CHALKER

The Chalker laboratory's current research interests include organic chemistry, polymers, functional materials, sustainability, waste valorisation, environmental remediation, protein chemistry, chemical biology, sulfur chemistry, mercury, and mercury- and cyanide-free gold mining.

Justin joined Flinders University in 2015 as a Lecturer in Synthetic Chemistry and a recipient ARC Discovery Early Career Researcher Award. Justin has been awarded the South Australian Tall Poppy of the Year (2017), South Australian Tertiary STEM Educator of the Year (2018), and the AMP Tomorrow Maker award (2018). In 2019, Justin was promoted to Associate Professor. For more on his research, visit [www.chalkerlab.com](http://www.chalkerlab.com)



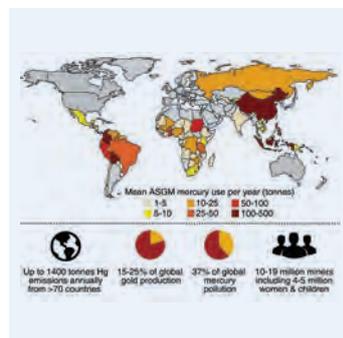
### Chemical biology of oxidative stress

New chemical probes have helped map protein oxidation during oxidative stress, providing insight into diseases such as cancer and heart disease.



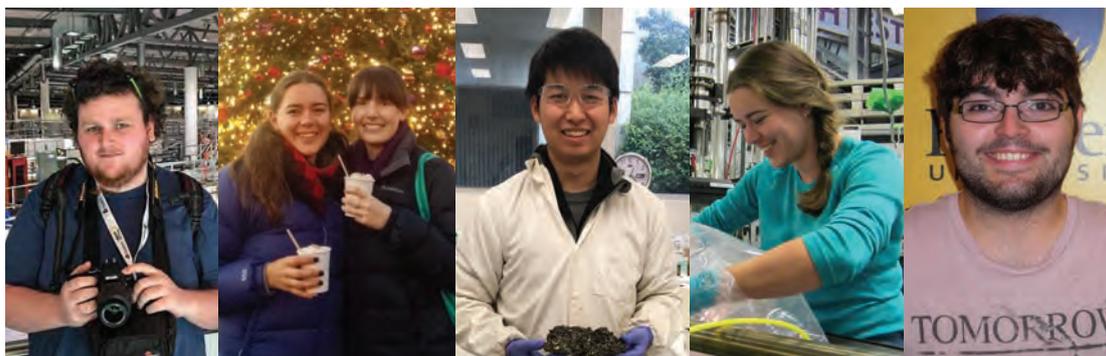
### Precision fertilisers

Waste cooking oil and sulfur were converted into a polymer carrier for slow-release fertilisers, preventing harmful runoff and improving crop yields



### Safe and sustainable gold mining

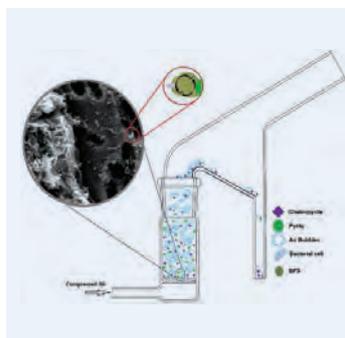
Artisanal gold mining is the largest source of anthropogenic mercury emissions on Earth. The Chalker Lab is developing mercury- and cyanide-free mining techniques to combat this pollution.



## PROFESSOR SARAH HARMER

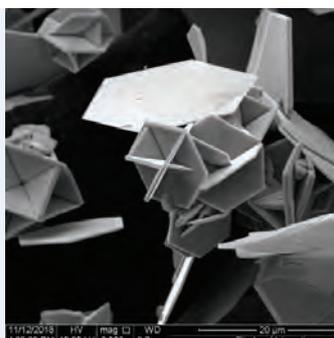
The Harmer group's research interests range from condensed matter physics, surface spectroscopy and biominerals processing with extensive international collaborators including the University of Utrecht, McMaster University, University of Western Ontario, Canadian Light Source, Swiss Light Source, Norcada Inc. and BHP Billiton.

Sarah joined Flinders University in 2012 as an Australian Research Council Future Fellow. In 2018 she formed Flinders Microscopy and Microanalysis, bringing together microscopy facilities across the university.



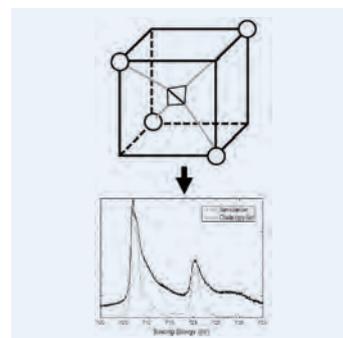
### Bacteria-mineral interactions

Microorganisms and their metabolites have been successfully applied in the leaching of metals from medium and low-grade sulphide minerals. The Harmer group is seeking to enhance this technique to decrease the use of toxic chemicals.



### Formation of covellite by replacing chalcopyrite

Most sulphide ores form through modified hydrothermal fluids. Mineral alteration reactions occur in the top of ore bodies known as the supergene zone resulting in the enrichment and concentration of metals, particularly copper. The Harmer and Pring groups in collaboration with BHP Billiton aim to understand the mechanism and first order controls on low temperature hydrothermal mineral replacement reactions that lead to the enrichment of minerals in the supergene zone.



### Transitional metal compounds

3d-transition metal compounds are some of our most exploited materials for the extraction of metals, battery technologies and memory devices. Charge transfer MC-SCF calculations allows for the elucidation of their properties through advanced simulation and interpretation of photoemission and x-ray absorption spectra.



## ASSOCIATE PROFESSOR MARTIN JOHNSTON

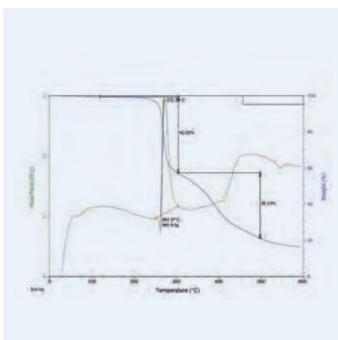
The Johnston lab focusses on Nuclear Magnetic Resonance spectroscopy, an analytical chemistry technique used in quality control and research for determining the content and purity of a sample as well as its molecular structure.

Martin has extensive experience in the defence field working with the Defence Science and Technology Group (DST). Martin has worked collaboratively with both CSIRO and Forensic Science SA (FSSA) investigating clandestine drug chemistry and organic chemistry-based projects.



### Opal authentication

What makes opals special? Opals are a unique gemstone because they display a rainbow-like colouring due to their intrinsic microstructure which diffracts white light into all the colours of the spectrum. The Johnston lab is using fundamental chemistry to understand opals crystalline structures to pinpoint provenance and authenticity.



### Reimagining the spectrum of flares

A new generation of heat seeking missiles, that uses the ratio of the heat signature to detect military aircraft is rendering current flares obsolete. This work is synthesising and testing new organic fuels to create spectrally matched flare formulations.



### Chemistry of clandestine drugs

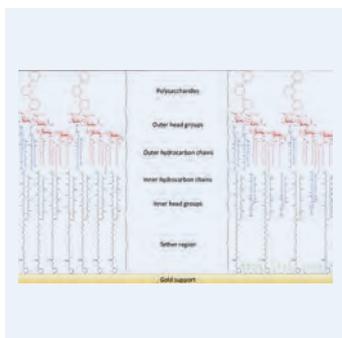
With greater restriction being imposed on access to pharmaceuticals, everyday chemicals are increasing being used as precursors in the production of clandestine drug production. The Johnston lab is working to ensure authorities stay ahead of the curve and examines the novel chemistry being used by these clandestine drug laboratories.



## ASSOCIATE PROFESSOR INGO KÖPER

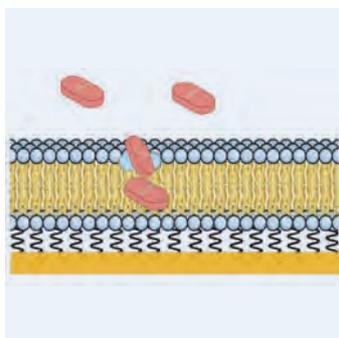
The Köper group focuses on the biological aspects of nanotechnology, mainly in the use and characterisation of model membrane systems. Related research topics include the synthesis and use of nanoparticles as drug-delivery vehicles. Electrochemical impedance spectroscopy, surface plasmon resonance spectroscopy and neutron scattering are the main techniques used.

Ingo came to Flinders University in 2009, from the Max Planck Institute for Polymer Research in Mainz, Germany.



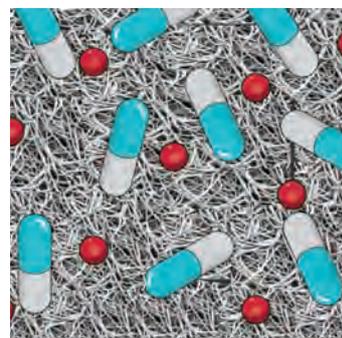
### Model membrane architectures

Model membranes are used to provide an environment that replicates the physicochemical properties of the cellular membrane while reducing their inherent complexity. The Koper group designs and characterises these model platforms to closely mimic natural membranes.



### Membrane-nanoparticle Drug Interactions

Only few nanoparticles for medical applications are available on the market. One reason is the lack of understanding and data about the fate and behaviour of nanoparticles upon contact with cell membranes. We use biomimetic membrane models to understand the interactions between cell membranes, nanoparticles and drug interaction for improved drug delivery.



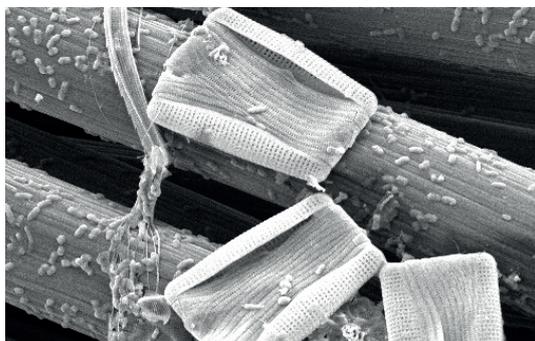
### Nano-mesh

Health experts are increasingly concerned about the rise in medication resistant bacteria. Our group in collaboration with partners in Japan have produced a nanomesh that is capable of delivering drug treatments, therefore limiting drug resistance.



## ASSOCIATE PROFESSOR SOPHIE LETERME

The Leterme Laboratory works on aquatic microbes via two streams: (1) the effects of drought and acidification on plankton biology and ecology, focussing on diatoms and copepods (2) biofilm formation on surfaces immersed in aquatic systems, including water treatment and desalination plants. Sophie joined Flinders University in 2006 working on the ecology of the Coorong wetlands. Promoted to lecturer in 2008 to continue her research on plankton adaption to salinity fluctuations funded by an ARC Discovery Project. She leads a research program on microplastic in local coastal waters (@MicroplasticW) and is Director of the Biofilm Research and Innovation Consortium funded by the College of Science and Engineering (@BRIC\_Flinders).



### Marine biofilms

Within minutes of immersion of a surface into seawater, eDNA, proteins, polysaccharides and microbial cells attach and develop a biofilm. This biofilm can lead to the attachment of macro-organisms such as barnacles and mussels but can also cause the deterioration of the immersed surface via corrosion. Our aim is to better understand the initial stages of development of marine biofilms and the interactions between microbial cells and these surfaces.



### Microplastic pollution of the marine environment

Plastic waste degradation can take hundred years and involves fragmentation and leaching of additives into the environment. The long-term fate, lifecycle and circulation of plastic in marine environments is poorly understood. It is likely to be influenced by abiotic and biotic factors. These could include ocean currents, physical shearing, fragmentation and natural sinking, fouling, consumption and aggregation.

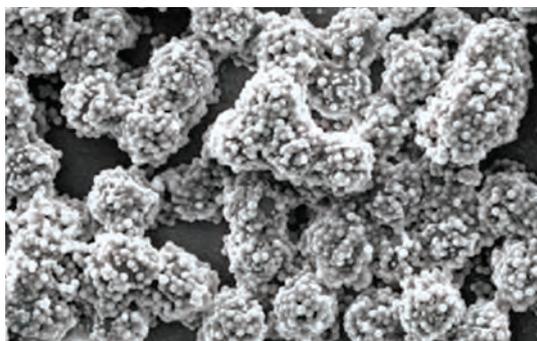
Our aim is to better understand how these issues are impacting Australian waters and identifying what needs to be done to reduce this issue.



## PROFESSOR DAVID LEWIS

Professor Lewis is the founding Director of the Institute. The Lewis research group are currently focused on the creation of functional particles and surfaces at the nano and micro scales to address challenges in 3D printing, the creation of self-assembled biomimetic surfaces and printable solar cells.

David is a materials scientist with extensive experience in polymer chemistry through a career in both industry and academia, having held positions at IBM Research (in NY), SOLA Optical (now Carl Zeiss Vision) before joining Flinders University in 2009.



### Biomimetic systems

The surface roughness of coatings can be controlled through the incorporation of raspberry particles (particles chemically attached to particles) can be cleverly adapted to a variety of uses, in this case to make a surface that mimics the famous lotus leaf. A useful application is controlling the roughness of coatings to make solar panel mirrors dust-free.

The Lewis lab is learning lessons from nature and applying these through physical solutions to real-world problems.



### Functional particles and materials

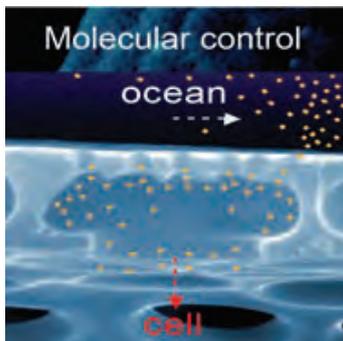
When creating new polymeric materials for 3D printing, controlling the viscosity and flow as well as the cure chemistry is critical. The Lewis lab brings this knowledge together to create new resin systems for a wide range of high-performance applications.



## PROFESSOR JIM MITCHELL

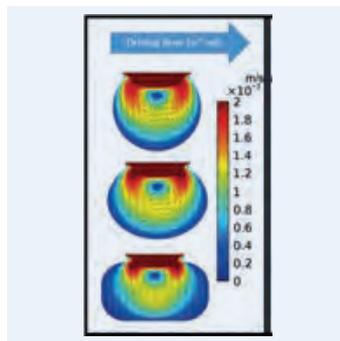
Research in the Mitchell group focuses on the influences of nanometre to micrometre scale processes on microbial ecosystems. Research outcomes have been used in creating new nanotechnology, including microfluidics and nanofabrication. As part of this research the group also investigates environmental viruses ( $>10^8$ / ml) and metagenomics.

Jim is the leading expert on small scale microbial processes with publications in Nature, Science and PNAS. He has been invited to present at the Massachusetts Institute of Technology, Cambridge University and the Gordon Research Conference on marine microbiology. Collaborators include the University of Tokyo, MIT and the University of Chicago.



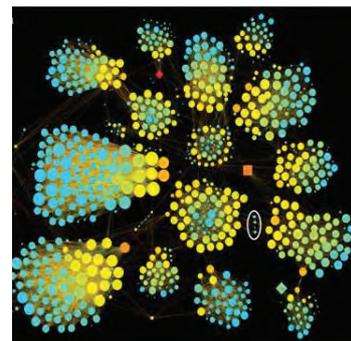
### Diatom nanostructures and their influence on nutrients diffusion

Diatoms are important single-celled autotrophs that dominate most aquatic environments and are distinguished by surficial frustules with intricate designs of unknown function. We have found that the submicrometre surface structures of diatoms control nutrient diffusion.



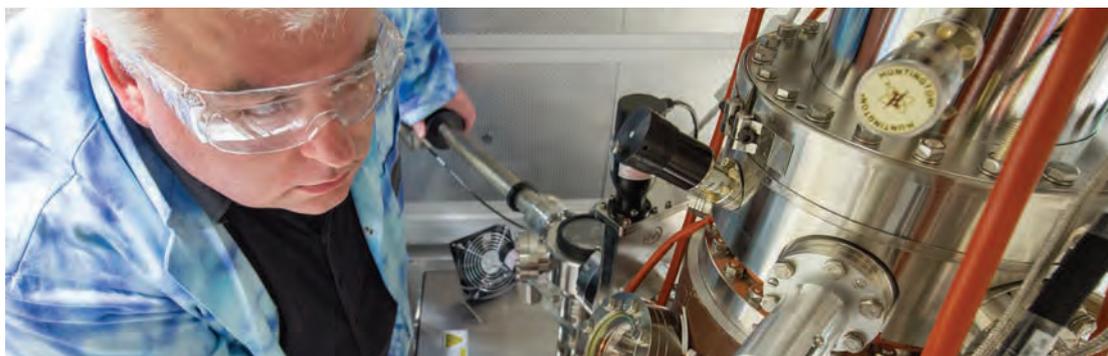
### Femtolitre chamber flow

Micrometre scale surface geometry can create trapped micrometre scale fluid vortices.



### Investigating the bioinformatics of microenvironments

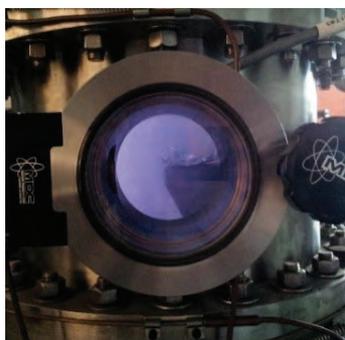
A single microliter of environmental water can contain up to a million individual bacteria and hundreds of separate species carrying out distinct processes and interacting in unique ways.



## PROFESSOR JAMIE QUINTON

The Quinton research group focuses on the atomic and molecular mechanisms at play on surfaces and interfaces with the goal of producing new technology enabled by nanostructures. This work encompasses surface modification, additive manufactured materials, corrosion protection, applied surface science and instrumentation development.

Jamie joined Flinders University in 2003 and was named the Flinders winner in the UniJobs Lecturer of the Year in 2009. He also received the Australian Learning and Teaching Council's Citation for Outstanding Contribution to Student Learning in 2010. He is a passionate, life-long learner who wants to apply science toward solving real world problems.



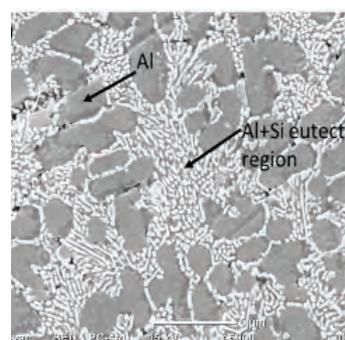
### Corrosion protection using plasma surface modification

With the increased use of light-weight alloys such as magnesium and aluminium in industrial application from automotive to aerospace. The is ongoing need for environmentally benign anti-corrosive coatings for these materials.



### Characterization of nanomaterials

Using the Scanning Auger Nanoprobe, the Quinton lab has been developing a reliable surface imaging of  $sp^2$  and  $sp^3$  carbon nanomaterials. Auger Spectroscopy is an analytical technique for determining the elemental composition of sample surfaces to a depth of less than 10 nm.



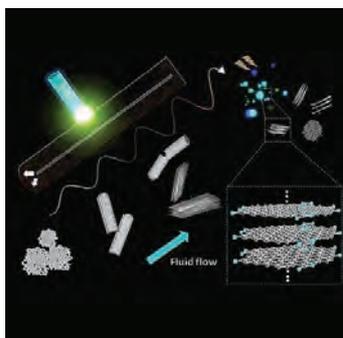
### 3D printing of metals

The successful collaboration continues with the Joint Laboratory of Marine Technology for Additive Manufacturing, Ecole Centrale Nantes, France. The research and collaboration is linked to Naval Group (France) who will be building Australia's submarines.



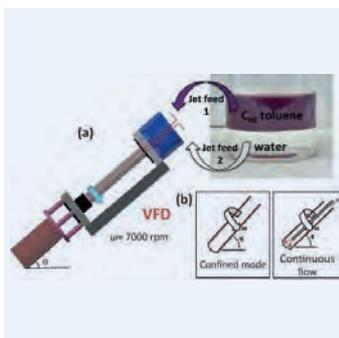
## PROFESSOR COLIN RASTON AO FAA

The Raston lab focusses on clean technology and green chemistry, microfluidics and self-assembly. Since 2012, the Raston lab has conducted over 100,000 experiments and published over 80 papers on the vortex fluidic device alone. This device invented by Colin Raston and has caused a paradigm shift in continuous flow processing. In 2015, international recognition was achieved with an Ig Nobel Prize in Chemistry for 'partially unboiling' an egg. Professor Raston has received multiple awards including the RACI's Green Chemistry Challenge Award, the H.G. Smith Award, the Burrows Award, the Leighton Memorial Award and the Applied Research Award. In 2016 he was appointed an Officer in of the Order of Australia, and in 2018 was elected Fellow of the Australian Academy of Science.



### Nanomaterials

The vortex fluidic device is being used to synthesise carbon quantum dots in avoiding using cadmium (a material with many environmental and toxicity concerns) for use in security, medical and device applications.



### Controlling self-assembly

Self-assembly is the phenomenon where the components of a system assemble themselves to form a larger functional unit. The vortex fluidic device has been used to create functional materials, including fullerenes without the use of harsh and toxic reagents, or surfactants.



### Organic synthesis and catalysis

Enzymes and catalysts, that are used on an industrial scale for therapeutic applications are subject to a high degree of downstream processing. The vortex fluidic device can be used to attach both enzymes and catalysts to its surface allowing for different zones along the tube. This results in continuous flow production that is scalable.



## PROFESSOR YOUHONG TANG

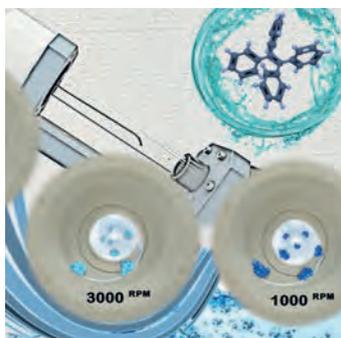
Tang group focuses its research efforts on the structure-process-property relationships of fibre reinforced composites and structures. The emphasis is on marine applications, bioresources, biomaterials and biosensors, especially incorporating novel aggregation-induced emission materials (AIEgens).

Youhong moved to Flinders University in 2012 from the Centre for Advanced Materials Technology, University of Sydney and is the recipient of a with an ARC Discovery Early Career Researcher Award. Youhong obtained his PhD degree from the Hong Kong University of Science and Technology in 2007. He is a Fellow of Royal Society of Chemistry.



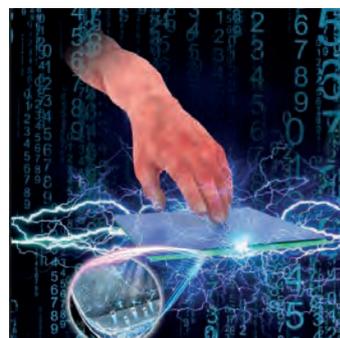
### AIEgen based personal bio-probes

In collaboration with the Australia-China joint research centre for personal health technology, our group is developing AIEgen bioprobes for biomarkers detection in body fluids.



### Tuning aiegen using thin film formation

Thin film formation technique is successfully being used to tune the size of AIEgen nanoparticle and their properties for a variety of biomedical applications



### High-output and lightweight triboelectric nanogenerators

Predict and optimize the behaviour of triboelectric nanogenerators based on some key parameters is leading to the development of high-output and light-weight sliding-mode triboelectric nanogenerators.

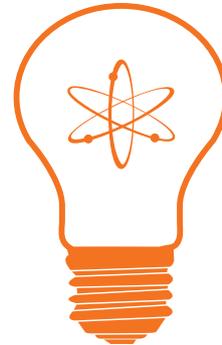
# OUR STRATEGIC RESEARCH AREAS



## ENVIRONMENT

We're working to protect, preserve and restore the Earth's most precious resources.

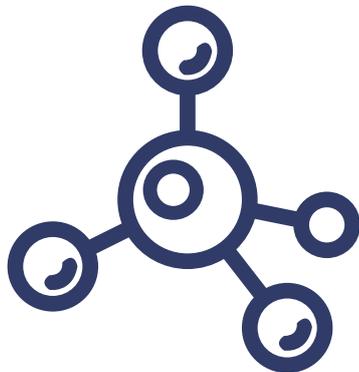
- clean technology
- antifouling coatings
- environmentally friendly mining
- mercury remediation



## ENERGY

We aim to innovate the ways we generate, store and use energy to meet the demands of the 21st century.

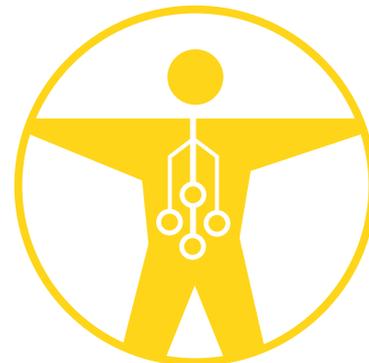
- flexible electronics
- hydrogen generation
- energy storage
- concentrated solar



## SECURITY

We are protecting Australian people from threats at home and abroad.

- explosives detection at a distance
- forensic drug chemistry
- 3D printed energetics
- chemical sensors



## BIO-NANO

We want to better understand biological processes and improve health and quality of life around the world.

- biosensors
- antibacterial coatings
- drug-membrane interactions
- synthesis via biomimicry



# ENVIRONMENT

Our researchers are driving forward environmental change and contributing to the development of sustainable technologies.

We want to stop exploiting the Earth's natural resources and damaging the environment; so we're looking to change the way we live and work. Among our projects, we're working on marine, mining and manufacturing processes—finding green and sustainable ways of doing things.

We're using clever chemistry, repurposed materials and new ways of thinking to disrupt various industries. With the help of government, not-for-profit and business partners, we are striving to make a difference to the world around us.



## CHARACTERISING SURFACE CHEMISTRY STATES FOR MINERAL SEPARATION THROUGH BIO-FLOTATION

Belinda Bleeze and Sarah Harmer

**Sulfide minerals processing is the most common source of precious metals, although it is also the leading cause for Acid Mine Drainage. This project aims to reduce the environmental impact of minerals processing while maintaining the economic gain.**

Depletion of high-grade ore has driven developments of this technique, such as micro – flotation and bio – flotation, to create economically viable low – grade and complex ore processing. Flotation techniques are physicochemical separation techniques, utilizing the difference in surface chemistry of different mineral phases for separation. Traditionally, excessive addition of inorganic chemicals is used to enhance the separation.

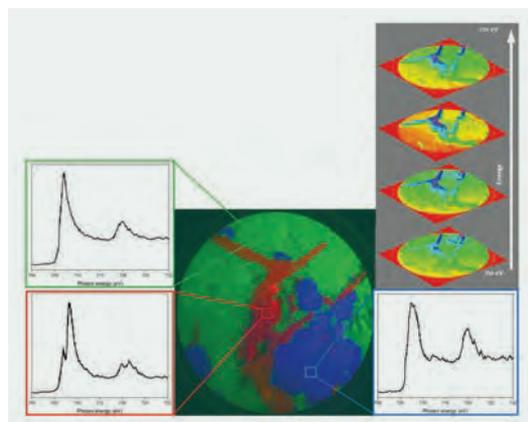
Bio-flotation replaces the inorganic chemicals with biological alternatives, such as bacterial cells and their metabolites, known as extracellular polymeric substances (EPS). While the use of bio-reagents is environmentally favourable, a lot is still unknown about the complexities of this technique. Optimisation of bio-flotation can be achieved through understanding the surface chemistry and the interactions which occur between the mineral's surface and the bio-reagents.

This project has investigated the surface chemistry and spatial distribution of chemical states of a mixed sulfide ore exposed to EPS from *Leptospirillum ferrooxidans*, using Photo Emission Electron Microscopy (PEEM). Analysis of the Near Edge X-ray Absorption Fine Structure (NEXAFS) spectra and the corresponding images allow identification of the different mineral phases present and the distribution chemical states

responsible for the change in surface chemistry observed in bio-flotation tests. Our research has indicated the increased presence of polysaccharides and oxyhydroxide species, due to exposure to EPS, are influencing the surface chemistry of sulfide minerals, resulting in positive bio-flotation separation.

**Figure 1**

Photo Emission Electron Microscopy image showing the different mineral phases and the distribution chemical states responsible for the change in surface chemistry observed in bio-flotation tests.



### Acknowledgments

The authors acknowledge the funding provided by the Australian Research Council (FT110100099), and the International Synchrotron Access Program (ISAP) managed by the Australian Synchrotron for travel to the National Synchrotron Radiation Research Centre, Taiwan.



## POLYMERS FOR ENVIRONMENTAL REMEDIATION

Louisa Esdaile (Clean Earth Technologies); Justin Chalker

**I focus my attentions on the commercialisation of research that was conducted by the Chalker lab. There is a wide variety of applications in environmental clean-up, including mercury remediation, oil spill removal, and replacing mercury in artisanal and small-scale gold mining. This work has recently culminated in the launch of the launch of the Flinders-Clean Earth Technologies partnership.**

Through my work at Clean Earth Technologies, I am engaging with engineers to take a material developed by the Chalker lab from lab scale to a commercial scale. Together we are designing entirely new machinery for this process and now have the capacity to producing this material on the tonne scale.

Engagement with a variety of interested parties in numerous industries, around the globe has been an emphasis. Some of the application include cleaning

up the pollution caused by mining for mercury from artisanal gold mining, working with recovering used cooking oils, and companies that work on mercury clean up and containment.

As the project manager and technical specialist, I discuss the issues companies and individuals are experiencing and examining ways the Chalker's lab invented material can be supplied and used to solve their environmental problems. It's an exciting area and I'm looking forward to bringing this solution to the public.

### Photo

Celebrating the launch of the Flinders-Clean Earth Technologies partnership. L-to-R: Dr Louisa Esdaile (CET), Mark Bruce (Flinders Partners), Wayne Sims (CET), Professor Rob Saint (Flinders University), Paul Hanna (CET), and Associate Professor Justin Chalker (Flinders University).





## NANO-TEXTURED COATINGS FOR SELF-CLEANING FAN BLADES

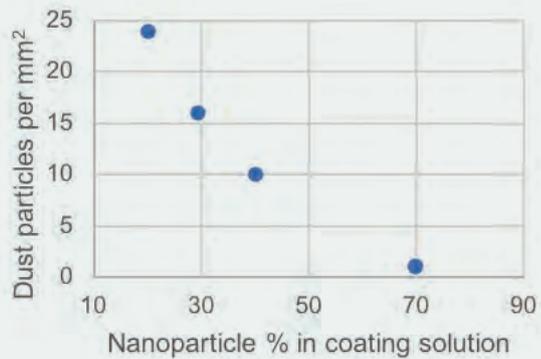
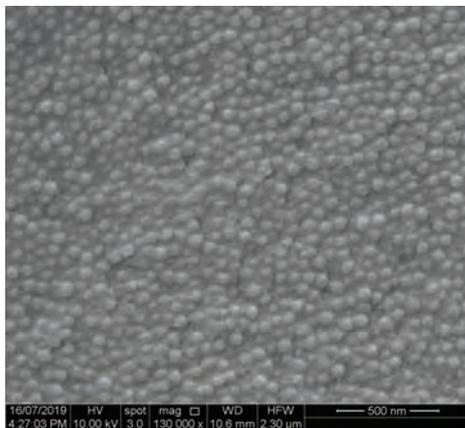
Schannon Hamence, Jon Campbell and David Lewis

**Dust build up on ceiling fans can impart stale odours and can exacerbate some people's allergy symptoms. Nano-textured coatings prevents dust build-up so that the air movement generated by the fan is enough to remove the dust. Self-cleaning technologies such as this are applicable for factories and hospitals, where fans are hard to reach, and air quality is important.**

Nano-textured coatings seek to minimise the contact area between dust particles and the surface, lowering the adhesion. Scalability of nanotech is frequently an issue so the novel use of spray painting was deployed to apply the coating. This technique allowed for ease of implemented on existing production lines. A variety of particle sizes and binder materials were tested to create a coating that easily shed household dust and particles.

Using a higher concentration of nanoparticles improved surface roughness which translated to better dust shedding performance. This insight has much wider application than just fan blades and could be used to develop solutions in other areas such as solar power and energy storage facilities which both require clean surfaces to operate at maximum efficiency.

**Figure 1**  
(Left) Nanotextured coating. (Right) Observed relationship between particle concentration and dust shedding performance.





## THE CLOSED COPPER CYCLE - A GREEN AND SUSTAINABLE TECHNOLOGY TO COMBAT BIOFOULING

Sait Elmas, Karuna Skipper, Sophie Leterme and Mats Andersson

**Most marine anti-fouling coatings are based on biocide-release containing up to 30 wt% cuprous oxide ( $\text{Cu}_2\text{O}$ ). Over the past decades, the copper level in marinas and harbours has increased due to the uncontrolled leaching of copper from these antifouling coatings becoming a substantial threat to non-targeted species.**

**To protect their marine ecosystems, some countries have banned the use of copper in antifouling coatings for maritime use. This research aims to overcome the ban on copper use by reducing its dissemination into the marine environment.**

Marine growth on underwater surfaces is a longstanding challenge. Specifically, biofouling is a multistep process that causes severe damages to the marine constructions and costs billions of dollars to the marine transport sector. Biofouling results in the accumulation of microorganisms, plants, algae, or small animals on wetted surfaces that have a mechanical function, causing structural or other functional deficiencies.

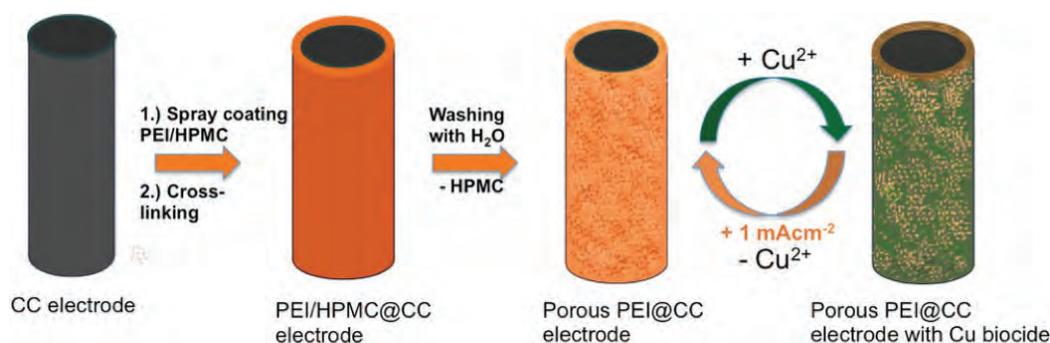
The consequences of biofilm growth on ship hulls are reduced manoeuvrability resulting in increased fuel consumption and greenhouse gas emissions. Copper-based antifouling coatings currently dominate the commercial products available due to its high biocidal activity. Copper's innate ability to kill a broad range of microorganisms and deter settlement of higher organisms together with its natural abundance in oceans has led to its widely acceptance. However, gradual and uncontrolled leaching has increased the copper concentration in protected waters of harbours and marinas putting the most effective biocide under regulatory pressure.

Our research focuses on developing a method for the controlled release of copper from underwater-coatings by means of electrochemical stimulation (Scheme 1).<sup>[1]</sup> The first proof-of-concept results showed that the copper-based biocide could be electrochemically released from a porous and cross-linked PEI structure on demand and over multiple cycles without suffering the loss of its stability (Figure 1).<sup>[1]</sup>

This electrochemical method opens the potential to develop new and sustainable antifouling technologies as alternative to current coatings. Additionally, the release can be tailored from high flux over shorter times, to slow release with flux like the conventional copper-based coatings of today. Since cross-linked PEI is known for its exclusive selectivity to uptake copper from seawater, further investigations showed that sub-ppb levels of copper in real seawater was accumulated in the porous PEI structure and could be released by electrochemical stimuli to combat biofouling. Compared to the non-electrochemical control electrode (coupon), the population of grown diatom-species on the electrochemically-cycled coupons was reduced by more than 68 – 95 per cent when the copper was released back at 1.1-1.4 V vs. Ag|AgCl.

### Acknowledgements

The authors acknowledge the expertise, equipment and support provided by the Australian Microscopy and Microanalysis Research Facility (AMMRF) and the Australian National Fabrication Facility (ANFF), funded by the National Collaborative Research Infrastructure Strategy.



Scheme 1

Preparation of the porous PEI@CC electrode and working principle of the reversible copper uptake and electrochemical release, simplified on a segment of a carbon cloth (CC) fiber (HPMC = hydroxypropylmethylcellulose). Reproduced with permission. <sup>[1]</sup> Copyright 2020, John Wiley and Sons.

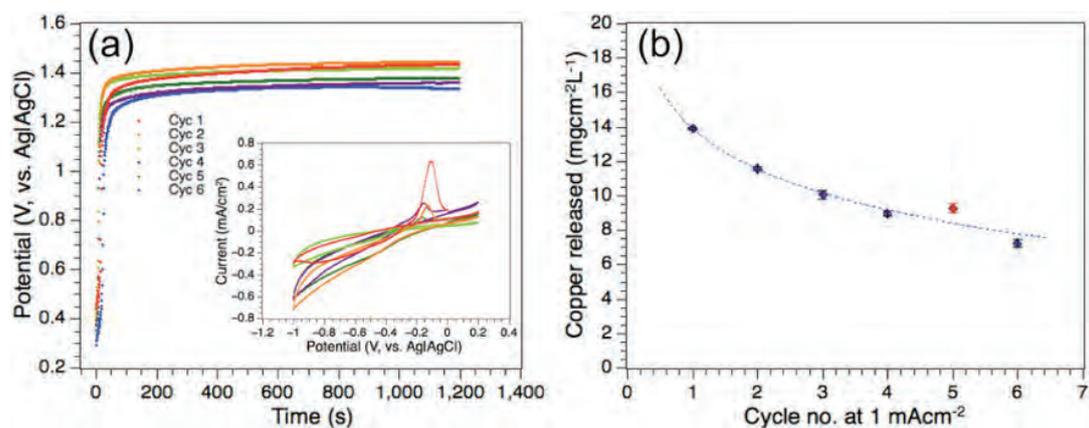


Figure 1

a) Overlapped chronopotentiograms of six consecutive copper release steps by means electrochemical water spitting in artificial seawater (AS). The inset shows five recorded cyclic voltammograms for the electrochemical recovery (deprotonation after copper release). b) Detected copper levels in mgcm<sup>-2</sup>L<sup>-1</sup> via ICP OES analysis. Reproduced with permission. <sup>[1]</sup> Copyright 2020, John Wiley and Sons.

#### References

<sup>[1]</sup> S. Elmas, D. A. Gedefaw, M. Larsson, Y. Ying, A. Cavallaro, G. G. Andersson, M. Nydén, M. R. Andersson, *Adv. Sustainable Syst.* 2020, 4, 1900123.



## POLYMER SUPPORTED CARBON FOR SAFE AND EFFECTIVE REMEDIATION OF PFAS-CONTAMINATED WATER

Nic Lundquist, Martin Sweetman, Kimberley Scroggie, Max Worthington, Louisa Esdaile, Salah Alboaiji, Sally Plush, John Hayball, Justin Chalker

**Per- and polyfluoroalkyl substances (PFAS) pollution threatens water safety on a global scale, with these chemicals having been detected in water systems all over the world. This research demonstrates that the formation of a novel sorbent material consisting of a blend of powdered activated carbon and poly(S-r-canola) is effective at removing PFAS from water to below regulation limits. A fundamental discovery in PFAS self-assembly on sorbents has also been demonstrated.**

Powdered activated carbon (PAC) is an economical sorbent for the removal of micro pollutants from water, its use is limited because it generates hazardous dust plumes that are both flammable and a respiration hazard. PAC is also incompatible with continuous flow processes because it cakes and blocks filtration and membrane systems. To use PAC as an effective sorbent, some form of appropriate support material is required.

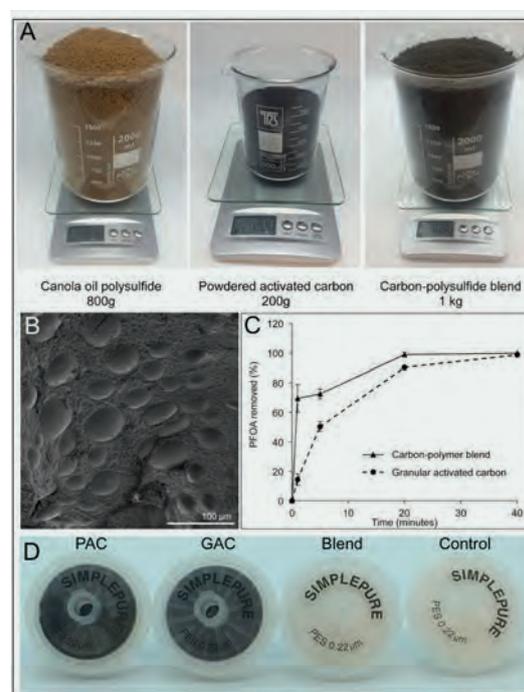
Our research demonstrates that PAC binds to the surface of poly(S-r-canola) particles, preventing the formation of hazardous dust and reducing the associated dangers. This treatment also prevents caking and filter and membrane blocking during continuous flow treatment. Due to these properties, its low costs, simple and scalable synthesis and limited associated hazards, poly(S-r-canola) material was determined to be a perfect support material for PAC.

The optimum blend ratio, when no more free carbon was observed, was determined to be 80:20 of poly(S-r-canola) to PAC. This novel blend sorbent was tested in the remediation of Per- and polyfluoroalkyl substances (PFAS) in water. These persistent micro pollutants are found in water systems globally threatening global water safety. We have demonstrated that not only does PFAS bind with the poly(S-r-canola) support material but hemi-micelles on the surface are formed. The formation of hemi-micelles has been postulated in literature but our scanning electron microscopy (SEM) is the first recorded direct evidence of their formation.

Using higher than typical concentration observed in public water systems (5 ppm) and environmentally relevant concentrations obtained from field samples at a PFAS contaminated RAAF Base, we have demonstrated that the blend can reduce PFAS concentrations, to below the Australian regulation limits.

**Figure 1**

A) Canola oil polysulfide, PAC and blend, B) SEM of hemimicelles on polymer surface, C) Plot of PFAS removed over time comparing our novel blend with the current industry standard GAC, D) image showing how PAC and GAC blocked up filters where as the blend did not.





## SULFUR POLYMER COMPOSITES AS CONTROLLED-RELEASE FERTILISERS

Maximilian Mann, Jessica E. Kruger, Firas Andari, Joshua McErlean, Jason Gascooke, Jessica Smith (University of Liverpool), Max Worthington, Cheylan McKinley, Jonathan Campbell, David Lewis, Tom Hasell (University of Liverpool), Michael Perkins and Justin Chalker

**Over fifty percent of fertilisers applied are not utilised by plants due to tailwater runoff, leaching and volatilisation. Although slow-release fertilisers are available, they suffer from several limitations such as high cost, difficulty in controlling the rate of fertiliser release and their persistence in the environment. To overcome these problems, nutrients were embedded into a polysulfide polymer made from canola oil and sulfur to produce a slow-release fertiliser from cheap and abundant materials which have shown promising results in a tomato growth study.**

Conventional fertilises usually contain sources of nitrogen, phosphorous and potassium (NPK). Unfortunately, when these fertilisers are applied over fifty of the nutrients are not taken up by the plants but lost to the environment through leaching tailwater runoff and volatilisation. This leads to loss of materials, economic losses and ecological harm through water eutrophication.

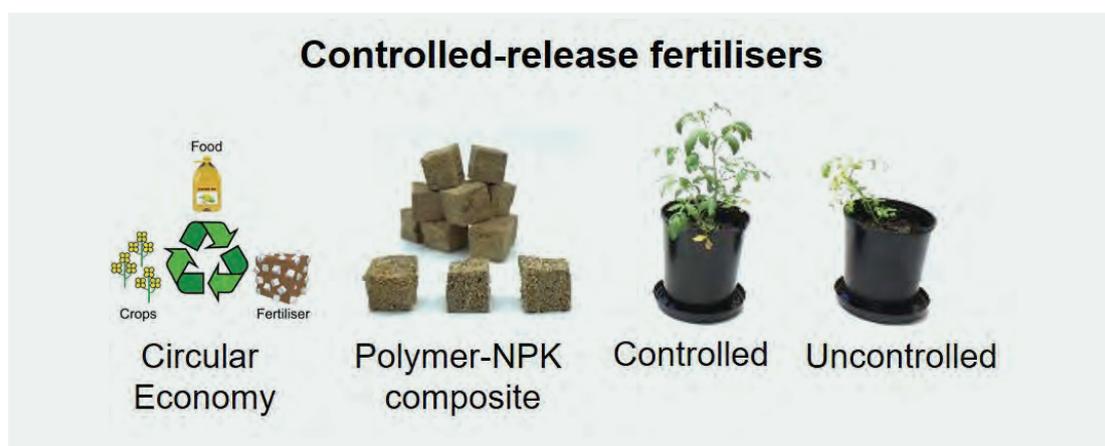
To combat these issues NPK nutrients have been embedded into a polysulfide made by the reverse vulcanisation of canola oil and elemental sulfur to produce a slow-release fertiliser composite. These composites containing 0, 50, 60 and 70 wt% NPK nutrients were synthesised. Elution studies revealed that more nutrients are released with each of the watering cycles performed at 2-day intervals over

7 days. This was in stark contrast with the elution of an unbound NPK nutrient sample in which all the nutrients eluded with the first watering cycle.

To test this new slow-release fertiliser on plants, a tomato growth study was performed using a group of plants containing no polymer or NPK, a group containing polymer but no NPK, a group containing the 60 wt% NPK fertiliser composites and a group containing free, unbound NPK. After 56 days the plants treated with the NPK composite were the healthiest. These results indicate that the NPK-polysulfide composites can release the nutrients over time during multiple watering cycles and can prevent excessive nutrient release. The growth study also demonstrates that nutrient burn and fertiliser loss in the tailwater can be achieved using the composite. Additionally, the polysulfide can be made from used cooking oil and therefore has the prospect of being part of a circular economy in which canola oil is produced as food and recycled into fertiliser for food production. Future biodegradation studies and studies on how the fertiliser changes the soil will shed light on the future of polysulfide-based flow-releasee fertiliser and their potential contribution to sustainable food production.

### Figure 1

Schematic showing how the polysulfide polymer fits into the circular economy, what the polymer looks like and its impact on tomato plants.





## SYNTHETIC MANIPULATION OF NATURAL PYRETHRINS TOWARDS INCREASED STABILITY

Todd Markham, Andrew Kotze (CSIRO Agriculture and Food),  
Peter Duggan (CSIRO Manufacturing), Martin Johnston

The natural extract Pyrethrum is an insecticidal material commercially produced in Australia and is used in both agricultural and domestic insecticide formulations globally. The insecticidal activity is due to constituent pyrethrin compounds. The widespread use of Pyrethrum stems from beneficial qualities such as broad-spectrum activity, low mammalian toxicity and lack of environmental impact. However, the extract can suffer from ready degradation ultimately affecting its long-term storage and applicability. Our research focusses on the synthetic manipulation of the individual constituents of Pyrethrum in an attempt to stabilise the extract for increased shelf-life without compromising the insecticidal activity.

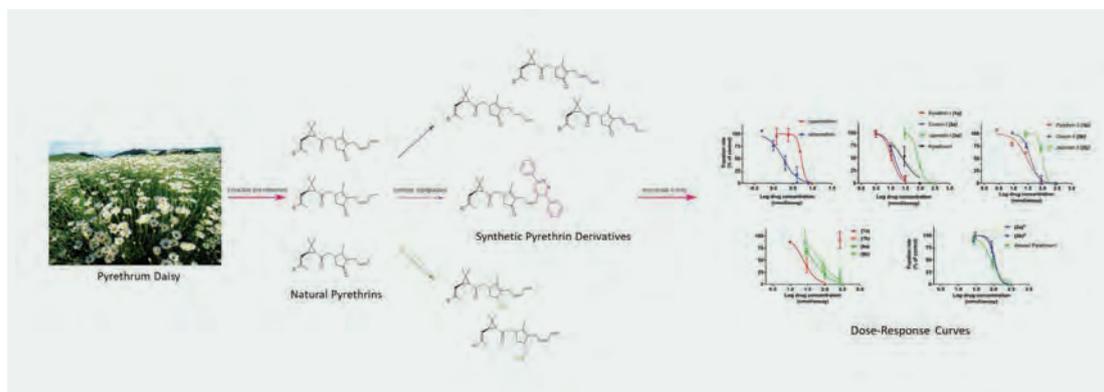
Pyrethrum daisies are the main source of the Pyrethrum extract which has long been used as an insecticide and insect repellent. These daisies are commercially grown, and the Pyrethrum extracted, refined and, ultimately used in both domestic and agricultural pest control. Pyrethrum's continued use in insecticidal formulations stems from its ability to act on a myriad of insect species, lack of environmental persistence and, its low toxicity to humans. The Pyrethrum extract derives its

activity from six structurally related esters known as the pyrethrins. These esters imbue the extract with its beneficial qualities due to their ready degradation under typical environmental conditions however, this degradation can also negatively affect their long-term shelf life and applicability. Extended exposure to heat, light and oxygen results in the loss of insecticidal constituents and whilst some countermeasures exist, they do not entirely alleviate the pyrethrin losses.

This project focusses on the synthetic modification of the natural pyrethrins to develop stabilised derivatives for increased shelf-life whilst retaining the insecticidal activity. The functionality rich skeleton of the pyrethrins has lent itself to a range of different chemical transformations ultimately generating a library of semi-synthetic pyrethrin analogues. Some of these isolated analogues have been subjected to insecticidal activity testing with some of the derivatives showing bioactivities like the natural pyrethrins.

### Acknowledgements

The authors wish to thank CSIRO and Botanical Resources Australia for co-investment in this project.





## DOMINANCE VIA DIFFUSION: HOW THE SHAPE OF DIATOMS DRIVES THEIR ECOLOGICAL SUCCESS

Jody McKerral, Mark Doubell (SARDI), James Herringer (RMIT), Ratnesh Lal (UCSD), Dusan Losic (The University of Adelaide), Gary Rosengarten (RMIT), Laurent Seuront (CNRS), Alison Taylor (University of North Carolina), and James Mitchell

**Diatoms - single celled algae - are hugely abundant and provide up to 50 per cent of the planet's oxygen. Diatoms are encased in glass shells, which form intricate patterns at the nanoscale with each species having its own unique shape. How diatoms achieve their ecological success is still an open question. Using numerical modelling, we have been able to show that diatom nanostructures help them efficiently source nutrients, giving them a competitive edge and helping to explain their huge species diversity.**

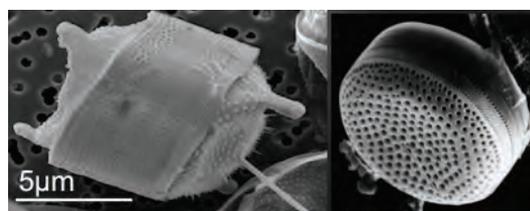
Diatoms are a dominant group of phytoplankton whose intricate and varied structures have fascinated biologists for centuries. With over 100,000 species, each with its own distinct morphology, diatom diversity has been described as breath-taking and remarkable. Diatoms are responsible for approximately 40 per cent of oceanic primary productivity, of high ecological importance, and have been intensively studied. Yet, a satisfactory explanation of their diversity in physical structure, and how they have achieved success across a large range of environments, have eluded ecologists for five decades. It is widely acknowledged that for single cell organisms, nutrient uptake is key to success. Diatoms can be found in all types of water-based environments, such as damp soil, freshwater or the ocean. Yet, diatoms are non-motile, meaning they cannot swim to access nutrients, and their cell membrane transporters have comparatively poor uptake capability, making their ecological dominance a puzzle.

Our research has successfully demonstrated that the diatom frustule – a silica-based casing enclosing the cell – explains both their diversity and success. Nutrients must transit through pores in the frustule to enable utilisation by the cell. Using numerical modelling, we demonstrate that morphology can bias

diffusion, which allows diatoms to passively improve their nutrient uptake which is highly biologically efficient. Crucially, the fluid environment inhabited by diatoms changes in tens of milliseconds and over the scale of micrometres. This means that whilst one morphology may be advantageous for nutrient uptake at one snapshot in time, moments later the competitive edge may be given by another. We hypothesise that this dynamic environment leads to a situation where no one species is able to outcompete each other, giving rise to the high species diversity.

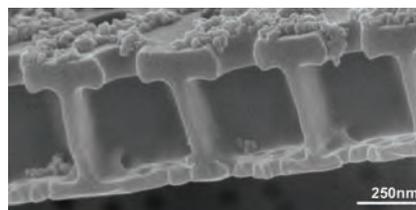
**Figure 1**

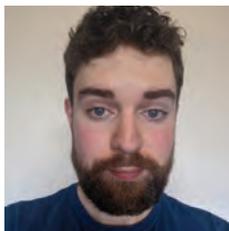
Diatom species *Odontella aurita* (Left) and *Thalassiosira* sp. (Right), and a cross-section of the *Thalassiosira* frustule.



**Figure 2**

The cross section shows an example of the intricate pore structures and frustule chambers which may bias diffusive processes and improve the nutrient uptake of the cell.





## VORTEX FLUIDIC MEDIATED PROCESSING OF GRAPE JUICE & WINE

Spencer Peticrew, Colin Raston, Paul Kirkbride, Paul Smith (Wine Australia)

**The stabilisation of both proteins and tartrates is an ongoing issue for the wine industry. This project aims to explore the potential use of the vortex fluidic device as a green alternative to currently used methodologies.**

Protein content and composition within wines is influenced by many factors including the cultivar and fermentation processes. Protein instability, specifically chitinases and thaumatin-like proteins result in amorphous sediments or flocculants causing the formation of undesirable hazes in the finished product.

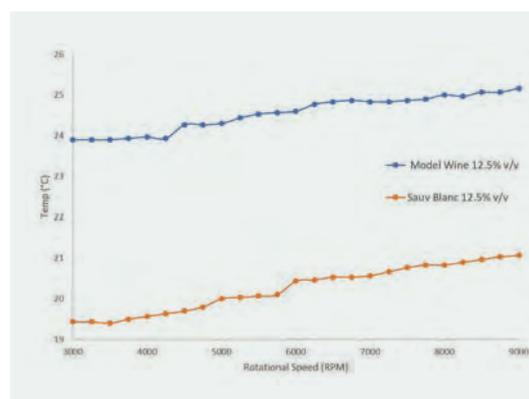
Fining materials, such as bentonite, are the most efficient and commonly used removal technique, however, still result in significant economic losses. Similarly, bitartrates are typically instable within bottled wine, leading to crystal formation, unless incredibly energy and time-intensive cold stabilisation methods are also deployed.

This project seeks to provide alternatives to the wine industry by employing thin film, microfluidic processing techniques which are enabled by the vortex fluidic device. Our specific targets are degradation of haze-forming proteins and stabilising the tartrate species present by processing both grape juice and finished wine.

Additionally, more explorative issues such as the conversion of finished wine into a low, or no alcohol products without suffering any loss of sensory

properties is currently being extensively researched. While characterising and understanding the roles macromolecular complexes play in wines at a fundamental level is an ongoing query.

**Figure 1**  
Temperature changes of a sauvignon blanc compared to a model wine when processed within the vortex fluidic device.



### Acknowledgements

Spencer Peticrew has been supported via a top-up scholarship from Wine Australia and would like to acknowledge their support.



## HOW MICROPLASTICS ARE TRANSPORTED IN AUSTRALIAN OCEANS, AND WHO'S HITCHHIKING WITH THEM?

Elise Tuuri, Assoc. Sophie Leterme, John Luick, George Cresswell (University of Western Australia).

**Microplastics are prevalent in the world's aquatic systems. Our research aims to understand the transportation and distribution of microplastics in Australian oceans and their role at the base of the marine food web. How do these fragments impact our marine ecosystems and what, if any, threats do they pose to human health?**

Sea time onboard Australia's Blue Water Research Vessel, the RV Investigator has been granted by the Marine National Facility and CSIRO allowing the opportunistic sampling of coastal blue waters around Australia for microplastic concentrations. These voyages will take the research team from Darwin to Fremantle, Hobart to Sydney, Cairns to Hobart, Hobart to Auckland, and Hobart to Broome (Figure 1). Further voyages are planned to fill data gaps such as understanding the relationship of the Antarctic Circumpolar Current on microplastic movements and the areas between Darwin and Cairns.

Our team plans to build a comprehensive data set on the abundance of plastics from 0.001 mm to 5 mm in size, at intermittent locations in oceans around Australia. The aim is to increase the understanding of not only surface concentrations but the vertical distribution of microplastics. Additionally, we aim to understand how microplastics are transported in oceanographic features allowing the pinpointing of microplastic accumulation zones along our coastlines.

We also seek to understand the role of microplastics at the base of the marine food web by using Scanning Electron Microscopy imaging to visualise the epipelagic communities that attach and grow on the biofilm of the microplastics, focusing on bacteria and phytoplankton. These biofilms will be further characterised through molecular identification, to identify the bacterial species present that may act as a vector for disease within fisheries or have negative consequences to human health. Furthermore, zooplankton communities will be collected and assessed for microplastic ingestion and if the plastics are attaching to their morphological characteristics.

Our final aim is to determine the polymer type of the microplastics found. This will allow the team to determine the origin of the plastic and its recyclable categories to understand how much microplastic could have been stopped with appropriate waste management practices.

You can follow the seafaring journey of our team on our social media platforms @MicroplasticsW on Twitter and @MicroplasticsWarrior on Instagram and Facebook.

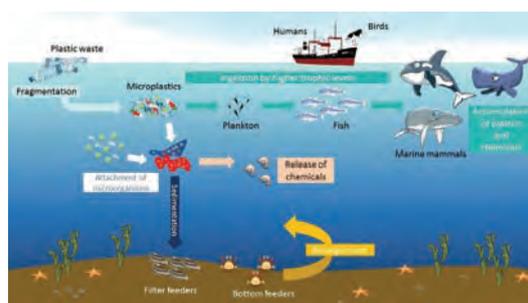
**Figure 1**

Currently granted voyage routes on the RV Investigator to assess. Source: black images sourced from shutterstock.com. and vectors.co.nz



**Figure 2**

The fate of plastic pollution in oceans, and their interactions with the marine food web.





## BIOREMEDIATION BARRIERS AND HOW TO BREAK THEM

Reuben Wheeler, Sarah Giles, Jessica Carlson-Jones, James Paterson, James Mitchell

**Contamination of groundwater with industrial pollutants can result in water resources that pose an environmental health risk. To mitigate this, bacteria are often used to degrade these pollutants in a process called bioremediation. However, bacteria find some pollutants difficult to degrade, due to the large input of energy required. By providing bacteria with additional energy, in the form of electricity, we aim to break this barrier to efficient bioremediation. As it has been shown that current remediation strategies are often ineffective and costly, it is paramount these new technologies are highlighted.**

The early to mid-1900s saw an increased production of industrial chemicals with little regard to appropriate disposal practices. Once used, these chemicals were often disposed via on-site dumping. This caused leaching into the surrounding soil resulting in contamination of the groundwater below. Such practices have resulted in extensive groundwater contamination that, to this day, pose environmental health risks and a significant economic burden.

Fortunately, soil is home to a diverse range of microbes, where the number of individuals per gram of soil compares to the totality of stars in the Milky Way. With their genetic complexity and easy mutability, microbes have adapted to detoxify pollutants and we can use these microbes for targeted remediation. Although microbes are experts at pollutant degradation, some pollutants are more difficult to degrade than others. Of recent concern is a class of chemicals known as per- and poly-fluoroalkyl substances, or PFAS.

PFAS have been globally mass produced since the 1950's, being valued for their surfactant or foam-forming properties. These chemicals have been broadly used; from the production of food packaging and non-stick cookware to stain repellents, insecticides and fire-fighting foams. The PFAS group of chemicals have unfortunately become a pervasive groundwater contaminant that are toxic and bioaccumulative – they are also environmentally stable and recalcitrant to microbial attack.

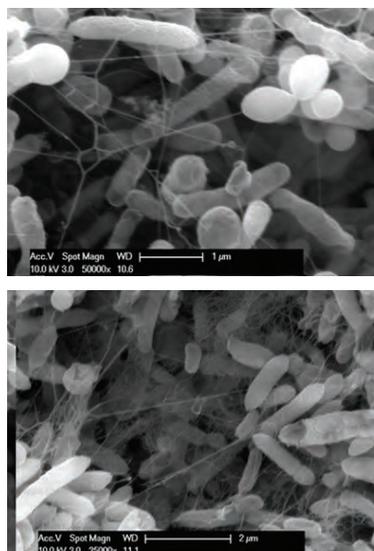
This recalcitrance is thought to be due, in part, to the strong carbon-fluorine bonds that PFAS harbour. The carbon-fluorine bond is the strongest known

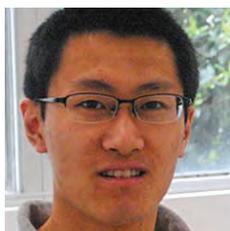
bond in organic chemistry, requiring substantial energy input to be broken. From an evolutionary perspective, microbes are less likely to develop degradative mechanisms if a large input of energy is required, particularly if they are otherwise thriving. However, microbes have evolved novel mechanisms to degrade recalcitrant chemicals before, and so all that may be required is a nudge in the right direction.

Using Microbial Electrolysis Cells (MECs), our research seeks to 'nudge' bacteria to facilitate the evolution of microbial PFAS biodegradation. To increase the genetic pool, and hence likelihood of success, mixed microbial communities from diverse environments have been included. To drive evolution, PFAS is provided as the sole-carbon source in an 'evolve or die' approach. Additionally, by providing bacteria with more energy, in the form of electricity, it is hypothesised that breaking the carbon-fluorine bond will be more energetically favourable. Although PFAS biodegradation currently seems improbable, current remediation strategies are costly and ineffective, and it is therefore imperative that new technologies are investigated that focus on scalability and efficiency.

**Figure 1**

Electron micrograph displaying network of bacterial nanowires. Bacterial nanowires enable inter-species electron transfer and have shown to aid in bioremediation.





## COMPOSITION OF SURFACES OF SALTY SOLUTIONS

Xianyuan Zhao and Gilbert Nathanson (University of Wisconsin, Madison); Gunther Andersson

**The reaction of gases with aerosols in the atmosphere has major implication on the climate in the lower atmosphere. One example is how N<sub>2</sub>O<sub>5</sub> is reacting with the surface of aerosols which has a major influence on the ozone concentration. This reaction is strongly influenced by the composition of the surface of aerosol droplets which is investigated in this project. This is part of the collaboration with the Centre for Aerosol Impacts on Chemistry of the Environment (CAICE) in the United States.**

A truly atomic-scale picture of interfacial reactions demands knowledge of the distribution of solution-phase species (depth profiles) throughout the surface region. The Nathanson group continued a partnership with the Institute for Nanoscale Science and Technology to use He<sup>+</sup> scattering experiments to determine the depth profiles of halide and alkali ions, cationic and anionic surfactants, and solvent on the Angstrom scale. The daunting analysis of this scattering data has produced a beautifully simple picture of interfacial charge attraction and repulsion: the reactive anions Br<sup>-</sup> and Cl<sup>-</sup> are drawn to the surface of a solution coated with a cationic surfactant and repelled by an anionic surfactant.

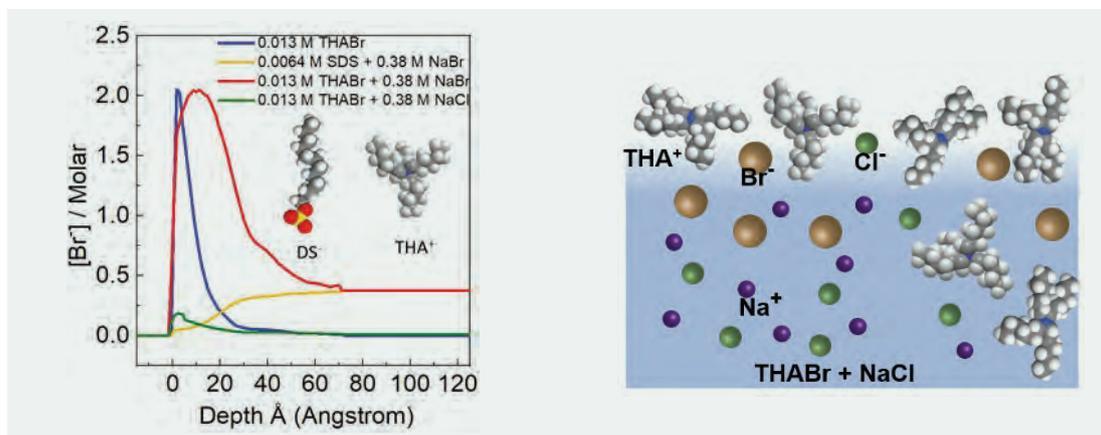
The depth profiles of the bromide ion (Figure 1) for the surface-active organic ions tetrahexylammonium

(THA<sup>+</sup>) and dodecyl sulfate (DS<sup>-</sup>) dissolved in liquid glycerol. Br<sup>-</sup> ions in a solution of just THA<sup>+</sup>/Br<sup>-</sup> (blue curve) segregate in a narrow 10 Å region at the surface, equal to the size of one THA<sup>+</sup> ion. When extra NaBr is added, both Br<sup>-</sup> (red) and THA<sup>+</sup> ions (not shown) spread over a thicker 30 Å region. Br<sup>-</sup> is instead repelled from the surface by the adsorbed anionic surfactant DS<sup>-</sup> because of charge repulsion. Finally, the addition of NaCl to THABr squeezes Br<sup>-</sup> (green) to a narrow surface region and severely dilutes it (bottom figure).

Separate experiments show that the reaction  $\text{Cl}_2(\text{g}) + 2\text{Br}^- \rightarrow \text{Br}_2(\text{g}) + 2\text{Cl}^-$  indeed follows the relative Br<sup>-</sup> depth profiles. The addition of THA<sup>+</sup>/Br<sup>-</sup> to an NaBr solution enhances reaction by 14-fold because it draws Br<sup>-</sup> to the surface, while the addition of Na<sup>+</sup>/DS<sup>-</sup> suppresses reaction by 5-fold because it repels Br<sup>-</sup>. Added NaCl also lowers reactivity because it dilutes the surface Br<sup>-</sup> population. The results imply that ionic surfactants dissolved in seawater and sea spray can have a dramatic effect on gas-liquid reactivity, promoting or inhibiting reactions of gases such as Cl<sub>2</sub>, N<sub>2</sub>O<sub>5</sub>, HOBr, and O<sub>3</sub>.

**Figure 1**

Depth Profiles of Br<sup>-</sup> (left) and Br<sup>-</sup> vs Cl<sup>-</sup> surface competition (right).



# ENERGY

The way we consume energy is unsustainable. Climate change is the biggest threat facing us today; it will affect our environment, health and livelihoods. And yet, fossil fuels remain the leading source of energy. Renewable energies can offer a green alternative that don't deplete the Earth's resources. Our researchers are working to improve clean energy—the way we collect, store and harness it.



## METAL CLUSTERS ON SEMICONDUCTORS

Liam Howard-Fabretto, Gunther Andersson, Scott Anderson (University of Utah),  
Tim Gorey (University of Utah), Guangjing Li (University of Utah)

**There is a strong push in modern society towards the use of renewable energy sources not derived from traditional fossil fuels, and one energy production method with strong potential is the use of photocatalytic splitting of water into hydrogen and oxygen, enabling the hydrogen to be utilised as a fuel.**

**Titanium dioxide (titania) is as well-known photocatalyst and our research examines modifying its structure by adding small, nano-scale metal clusters which can greatly improve its photocatalytic capabilities.**

Our work focussed on measuring the outer shell electronic properties of small, 3-4 atom sized metal clusters on top of titania. Outer shell electrons are involved in chemical bonding and understanding their properties will assist in the prediction of the catalytic and photocatalytic abilities of the clusters. This is turn will allow better exploitation for hydrogen production.

All measurements were performed using ruthenium clusters of size 3 and 4, however the results we found were unexpected. These clusters did not have the expected electronic properties and did not act like standard, bulk-size ruthenium metal.

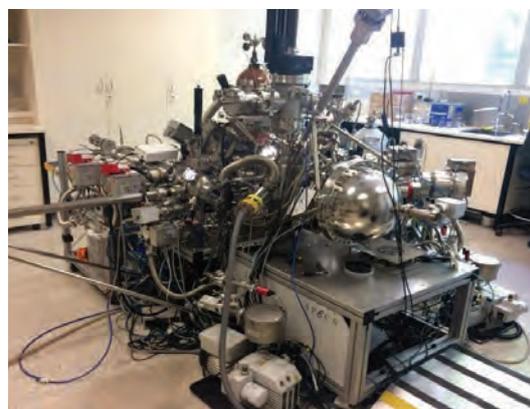
A collaboration with the University of Utah was necessary to characterise this material. The Andersson group is expert in two techniques which helped determine the nature of the cluster system. These techniques are temperature programmed desorption and ion scattering spectroscopy – both techniques can probe changes in the cluster system with increasing temperature.

While heating, the clusters become encapsulated by the titania photocatalyst surface, which forms

a shell layer around them. These results helped reconceptualise our earlier measurements of outer shell electronic properties. This system of surface-encapsulated clusters has the potential to be beneficial for photocatalysis applications, because the encapsulation may assist to keep the clusters in one location and prevent them from agglomerating.

### Figure 1

The Flinders University high vacuum rig used for experiments on the metal cluster systems. Samples are loaded inside, and all the air is removed to perform experiments without interference from atmospheric gasses.



### Acknowledgements

The work is supported by the US army project FA5209-16-R-0017. The authors acknowledge the expertise, equipment, and support provided by the Australian Microscopy and Microanalysis Research Facility (AMMRF) and the Australian National Fabrication Facility (ANFF) at Flinders University.



## STRUCTURE-PROPERTY RELATIONSHIPS IN CONJUGATED POLYMERS

Elliott Jew, David Lewis, Mats Andersson, Caroline Pan, Jonathan Campbell

**Understanding the properties of the materials used in organic solar cells is crucial to improving their performance and stability. Dielectric thermal analysis was used to measure the impact of temperature a variety of materials currently used in organic solar cells.**

Currently, there is a shortfall in the efficiency of organic solar cells when they are produced on a large scale, compared to lab-scale preparation. This issue effects the medium to longer term scale-up and feasibility of this technology for more general use. This research seeks to investigate the cause of this inefficiency by focusing on the conjugated polymer donor materials used in the active layer of the organic solar cell.

Dielectric thermal analysis was used to probe the frequency dependent transitions, such as the glass transition and side chain motion over a large temperature range. These transitions provide information about how the material will behave at specific temperatures and furthermore the activation energy of the transitions can be determined.

It was found that the activation energy of the glass transition was in the range of 100 -1000 kJ/mol. This is a whole decade larger than what is seen in side-chain movement. This information proved useful as many more exotic donor structures utilise large side chains and it is difficult to identify the molecular origin of this transition. This lead to the finding that some conjugated polymers did not exhibit glass transitions as the main chains had formed  $\pi$ -stacked "hairy" aggregates (Figure 1).

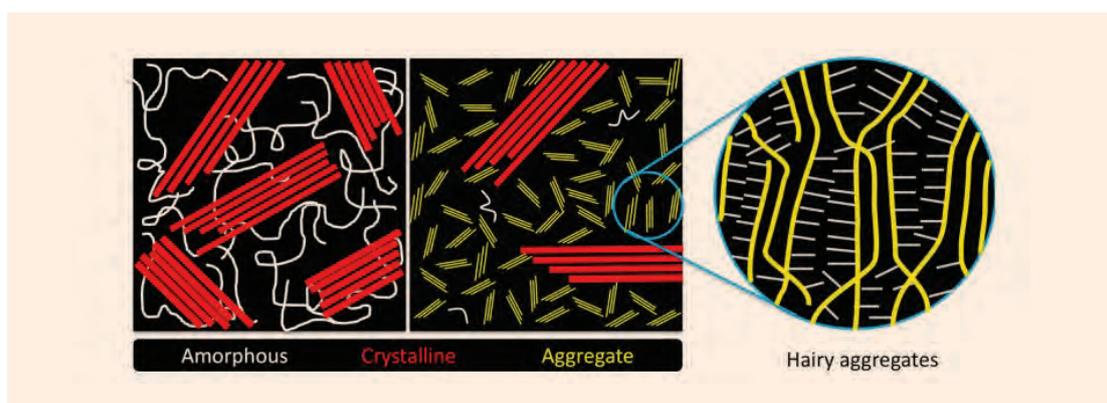
Additionally, various heat treatments prior to testing with dielectric thermal analysis aimed to exploit the thermodynamics of this polymer chain movements. This resulted in the finding the conjugated polymers were highly susceptible to cooling rates. Quenching the polymer from above its glass transition resulted in side chain motion being restricted whereas using a slow cool does not limit the motion of these side chains.

The impact of this on the overall performance of polymer solar cells is yet to be fully investigated however, this is a significant finding as this phenomenon is not typically seen in classical polymers.

### Figure 1

Schematic illustration of the morphology corresponding to the two groups in which conjugated polymers can be divided into according to the presented study: polymers with amorphous and crystalline phase (left) and polymers having mainly hairy aggregate and crystalline phase (right).

Reprinted with permission from Sharma, A., et al. (2019). "Probing the Relationship between Molecular Structures, Thermal Transitions, and Morphology in Polymer Semiconductors Using a Woven Glass-Mesh-Based DMTA Technique." *Chemistry of Materials*. Copyright 2019 American Chemical Society.





## THEORETICAL AND EXPERIMENTAL STUDY ON TRIBOELECTRIC NANOGENERATORS

Mohammad Khorsand and Youhong Tang

**Triboelectric nanogenerators can efficiently harvest mechanical energy from various sources including vibrations, ocean waves and human motion. This scavenged energy can be used to drive portable devices such as wearable microdevices and smart wearables. Using the power of artificial intelligence, The Tang group can successfully predict the outputs of these nanogenerators as well as optimise their creation.**

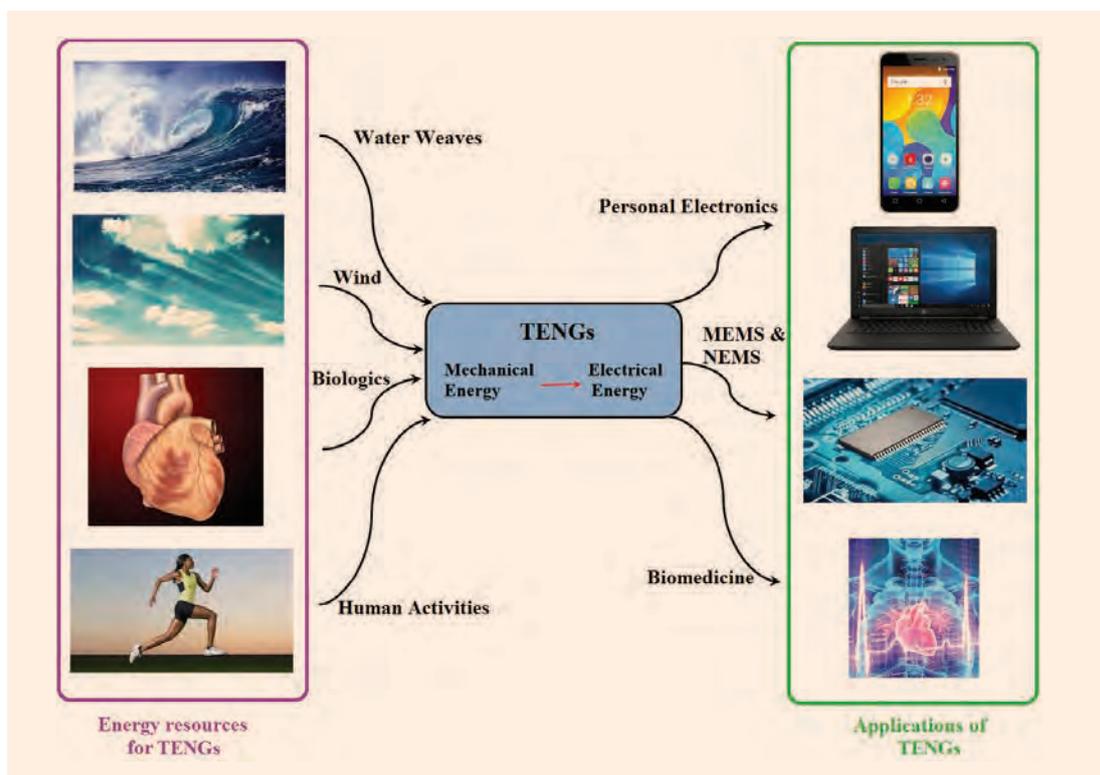
A triboelectric nanogenerator, or TENG, is an energy harvesting device that converts external mechanical energy into electricity by a conjunction of triboelectric effect and electrostatic induction. TENGs have recently emerged as a sustainable candidate in energy harvesting applications.

The energy output and average power distribution

generated by a nanogenerator is highly dependent on certain key parameters including the contact area, the thickness of electric films and external resistance. This project seeks to investigate the optimum conditions for the creation of a high-powered sliding-mode TENG.

To achieve this goal, this study focussed on numerically predicting the outputs of TENGs by measuring their voltage, current, power and energy under various electric specifications and geometries of dielectric films. Experimental setups are conducted to verify the accuracy of these simulation results.

Using artificial intelligence, the size of dielectric layers was able to be minimized. This work clearly demonstrated that attributing the appropriate values to the resistor, and thickness of the dielectric layers sharply increase the efficiency of the TENGs.





## OPTIMISATION OF POLYMER SOLAR CELL FABRICATION VIA SLOT-DIE PRINTING

Bradley Kirk, Gunther Andersson, Mats Andersson

**Large-scale printing of polymer solar cells has shown to be effective method of manufacturing solar panels that are flexible, cost-effective and light weight.**

**Even with these advantages, there is still a considerable performance gap between lab-based and roll-to-roll fabricated devices. This project investigated methods of improving printed polymer solar cells by adjusting the preparation of the active layer ink used in slot-die printing.**

For the past decade, large-scale printing of polymer solar cells has been a promising method for future solar panel production resulting in the fabrication of low-cost, flexible and light-weight devices. Recently, the overall performance and stability, especially in association with small-scaled devices has achieved an efficiency beyond 16 per cent, however, there is still a considerable gap between lab-based and roll-to-roll fabricated devices.

Our research focuses on improving the performance and stability of printed TQ1:Fullerene devices that have been fabricated using a mini-roll coater using a slot-die printing technique. This process requires choosing a well-suited solvent combination that allows for the optimal material staking within the film.

One strategy that has been used involves combining high-temperature-low vapour pressure solvents as additives, such as 1-methylnaphthalene or 1-chloronaphthalene. Being the last solvent to evaporate during printing of the active layer, this additive sets the morphology. This results in a more desired blend in the

bulk-heterojunction with smaller size domains and an improved mixing of materials. By using a small amount, as low as 0.5 per cent V/V of o-xylene as the base solvent, our results indicate an efficiency improvement from 1.4 to 2.1 per cent.

A second strategy that increased performance, was the addition of neat fullerenes. Fullerenes such as C70 can be added and increase both light absorption capability as well as thermal stability of the active layer.

By combining these two strategies active layer efficiency can be increased from 2.0 to 2.4 percent.

### Acknowledgements

The authors would like to thank the Australian National Fabrication Facility (ANFF) and Microscopy Australia for access to specialised equipment. Bradley Kirk has been supported via a scholarship from the Playford Memorial Trust and would like to acknowledge their support.





## UNUSUAL MORPHOLOGY IN SEMICONDUCTING POLYMERS USED IN ORGANIC SOLAR CELLS

Xun (Caroline) Pan, Anirudh Sharma, David Lewis, Mats Andersson

**Understanding how temperature influences the stability and properties of the molecules used in plastic solar panels is crucial to achieve maximum efficiency. This research investigated molecules that poses a rigid backbone and side groups. In molecules with a flexible backbone it was found thermal transition was influenced by both the backbone and side chains, whereas for molecules with rigid backbones noticeable transitions were affected by the side chains only.**

The glass transition temperature of polymers is a crucial parameter for the application of polymers to organic solar cells. The understanding of this temperature is also beneficial for achieving a thermally stable photoactive layer consisting of semiconducting polymers.

Differential scanning calorimetry is the most common techniques to determine the glass transition temperature of polymers. However, since most of the semiconducting polymers have rigid backbone and highly conjugated structure, using this method is difficult.

Therefore, an alternative technique, dynamic mechanical thermal analysis DMTA, was used to directly probe the thermal transitions of a variety of polymers. Additionally, a new method to prepare samples, using a woven glass fibre-based technique (Figure 1) that reduces the amount of material for each measurement has been developed.

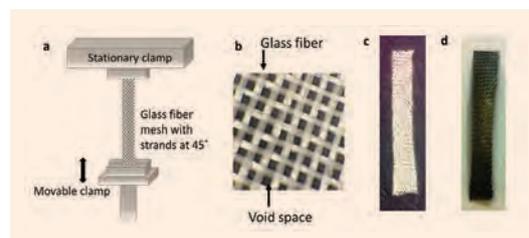
Using a combination of these methods both the glass transition temperature and sub-glass transition temperature were evaluated, where the latter is normally attributed to the thermal relaxation of side groups of polymers.

A systematic study on a range of semiconducting polymers commonly used for organic solar cells discovered that several polymers failed to show a detectable transition temperature. Figure 2 illustrates a representative high-performing polymer, its dynamic mechanical thermal analysis thermogram and a schematic of its anticipated morphology. Due to this polymer's rigid backbone, the thermal transition at approximately  $-10^{\circ}\text{C}$  is very unlikely to be related to the relaxation of the main chain segments. Thus, the non-detectable transition temperature suggests extremely small amorphous part that are unusual associated with more classic polymers such as polystyrene.

Our results suggest that these semiconducting polymers mainly consists of hairy aggregates (see Figure 2c) with few stacked polymer chains and movable side groups. This unusual morphology provides new insights into the thermomechanical behaviour of semiconducting polymers.

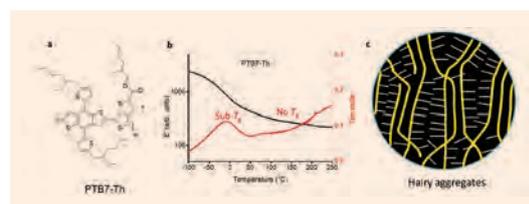
**Figure 1**

Schematic depicting a sample mounted between the clamps for DMTA measurement. (b) Optical image of glass fibre. Pictures of (c) uncoated glass fibre and (d) glass fibre coated with a semiconducting polymer.<sup>1</sup>



**Figure 2**

Chemical structure (a) and DMTA thermogram (b) of PTB7-Th. (c) Schematic illustration of the morphology of hairy aggregates.<sup>2</sup>



### Acknowledgements

The authors acknowledge the expertise, equipment and support provided by Australian Microscopy and Microanalysis Research Facility (AMMRF) and the Australian National Fabrication Facility (ANFF) at the South Australian nodes under the National Collaborative Research Infrastructure Strategy.

This research is supported by the Australian Research Council's Discovery Projects funding scheme (Project DP170102467).

<sup>1</sup> 10.1021/acs.macromol.7b00430

<sup>2</sup> 10.1021/acs.chemmater.9b01213



## PHOTOELECTRON AND ION SPECTROSCOPY STUDY FOR LONG TERM STABILITY OF THE DEGRADATION MECHANISMS IN THE INTERFACES OF DYE-SENSITIZED SOLAR CELL.

Altaf Shamsaldeen, Gunther Andersson, Lars Kloo (KTH-Royal Institute of Technology, Sweden)

**In 2018, the world's energy consumption was estimated at 14,000 mega-tonnes of oil equivalent. With projected population increases the demand for energy is only expected to continue to increase. This means that new or more efficient sources of energy are needed.**

**One such technology is the dye-sensitized solar cell or Grätzel cell after its inventor Michael Grätzel. A dye-sensitized solar cell is a low-cost solar cell belonging to the group of thin-film solar cells. It is based on a semiconductor formed between a photo-sensitized anode and an electrolyte, a photoelectrochemical system. The modern version of a dye solar cell was originally co-invented in 1988 by Brian O'Regan and Michael Grätzel at the University of California, Berkeley.**

**These low-cost solar cells are a viable option to produce clean and cheap energy due to their high light-to-electricity conversion efficiency and low production cost. However, there are some challenges to overcome before these solar cells can be fully commercialized. Improving cell efficiency and stability are among the most critical problems. Our research focuses on gaining new insights into aging-induced changes that are known to occur in dye-sensitized solar cells.**

In the past three decades, dye-sensitized solar cells have attracted attention due to their reasonable conversion efficiency, low production cost, and simple fabrication compared with silicon solar cells. Another advantage is the requirement of few resources or the use of non-toxic materials. dye-sensitized solar cells also work under low light conditions and shade making them suitable for use on buildings and indoors. However, the challenge of long-term stability must be addressed before these cells can successfully enter into the photovoltaic market.

A typical cell consists of two transparent substrates, usually glass, coated with a thin conductive material

such as fluorine or indium doped tin oxide. The working electrode is further coated with a thick layer (approximately 10  $\mu\text{m}$ ) of  $\text{TiO}_2$  nanoparticles, forming a mesoporous structure to provide a high surface area for sufficient dye adsorption, thus improving light harvesting. The working electrode is immersed in a sensitized dye solution, and the dye is chemisorbed onto the  $\text{TiO}_2$  surface. The counter electrode is coated with a thin layer of catalytic material, usually platinum as the conductive substrate. Both electrodes are sealed by a heat press using a thermal plastic surlyn gasket sealant. The surlyn gasket also acts as a spacer that provides a room between the two electrodes allowing electrolytes to fill this gap. Commonly, the electrolyte solution contains I-/I<sup>3-</sup> redox mediators that have direct contact with the dye and could penetrate through to the mesoporous  $\text{TiO}_2$ .

An enormous research effort has attempted to improve the performance and increase the efficiency of these cells, with little success. The first issue is charge recombination, where the electrons injected into  $\text{TiO}_2$  tend to recombine with I-/I<sup>3-</sup> couple and cations of the dye. Secondly, dye aggregation on the  $\text{TiO}_2$  surface results in current decline. Finally, the protonation of  $\text{TiO}_2$  surface results in changes in dye adsorption leading to the low cell stability.

Our research focuses on using electron and ion spectroscopic techniques to understand the fundamentals of the degradation process of dye-sensitive solar cells at the molecular level. We have focusses on light exposure, heat, and room-temperature conditions using a 1000-hour stability test. The changes of the dye and electrolyte components on the interfaces of  $\text{TiO}_2$  was investigated using X-ray Photoelectron Spectroscopy (XPS), Ultraviolet Photoelectron Spectroscopy (UPS), Metastable Induced Electron Spectroscopy (MIES) and Neutral Impact Collision Ion Scattering Spectroscopy (NICISS).



# SECURITY

Constantly new demands are being placed on Australia's security. We face a rapidly shifting landscape across modern warfare, terrorism, disaster relief and policing. Security is an exciting area for researchers enabling them to work with cutting-edge technologies. We're working in explosives detection, the fabrication of chemical sensors and many other projects.

The Institute has a long and productive history of research collaborations in security and defence. Due to the sensitive nature of this work we are unable to disclose the details. Our past and present collaborators have included the Reserve Bank of Australia, Forensic Science South Australia and the Defence Science and Technology Group. All projects focus on low technology readiness and seek to use fundamental research to explore innovative solutions to far-reaching problems.

The Institute would like to take the opportunity to thank the following organisations for their supporting this research.

## DEFENCE INNOVATION PARTNERSHIP (DIP)

The Defence Innovation Partnership is a collaborative initiative of Defence SA, Defence Science and Technology and South Australia's three public universities, the University of Adelaide, Flinders University and the University of South Australia. Bringing together a world-class collective of thinkers, practitioners and experts in defence research and development, each of the partners is committed to a model of genuine collaboration between governments, industries and universities.



## DEFENCE SCIENCE AND TECHNOLOGY GROUP (DSTG)

DSTG is responsible for leading technology development for Australia's defence forces. Research collaborations that leverage our unique capabilities are expanding and offering new and exciting projects to Flinders researchers.



The Institute is exploring the development of photochromic dyes as part of a collaborative program with DSTG Group on adaptive camouflage for combat uniforms, nets and coverings. The development aims to allow camouflage pattern to adapt to changes in the environmental lighting conditions and thereby improve signature management effectiveness.

## FORENSIC SCIENCE SA (FSSA)

Forensic Science SA (FSSA) provides services to some of South Australia's largest government departments and undertakes award-winning research in forensic science.

## OFFICE OF NAVAL RESEARCH (ONR)

The Office of Naval Research is an organization within the United States Department of the Navy responsible for the science and technology programs of the U.S. Navy and Marine Corps.



The Office of Naval Research makes broad investments in basic and applied research that will increase fundamental knowledge, foster opportunities for breakthroughs and provide technology options for future naval capabilities and systems.

## THE AUSTRALIAN FEDERAL POLICE

The Australian Federal Police is the national and principal federal law enforcement agency of the Australian Government with the unique role of investigating crime and to protect the national security of the Commonwealth of Australia.



## UNITED STATES DEPARTMENT OF DEFENSE - US ARMY

The Department of Defense provides the military forces needed to deter war, and to protect the security of the United States. The U.S. Army organizes, trains, and equips active duty and Reserve forces to preserve the peace, security, and defense of the United States.



The background is a solid yellow color. A white, irregular geometric shape, resembling a stylized house or a large letter 'A', is outlined in white. In the background, there are faint, semi-transparent images of laboratory glassware, including beakers and test tubes, suggesting a scientific or medical setting.

# BIO-NANO

When it comes to our bodies, bio-nanotechnology is helping us to develop drug therapies, implant technology and diagnostic tools. It's going beyond what we know, from how our cells become cancerous to how single-celled organisms adapt to their environment. Our researchers are passionate about uncovering new knowledge around some of the world's most complex systems.



## THE MICROBIAL ABUNDANCE DYNAMICS OF THE PAEDIATRIC ORAL CAVITY BEFORE AND AFTER SLEEP

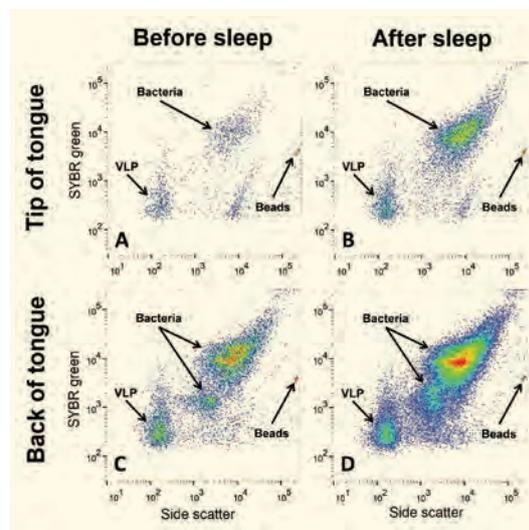
Jessica Carlson-Jones; Anna Kontos\*; Declan Kennedy\*; James Martin\*; Kurt Lushington (UniSA);  
Jody McKerral; James Paterson; Renee Smith; Lisa Dann; Peter Speck; Jim Mitchell  
\*(Women's and Children's Hospital, University of Adelaide)

**The oral cavity is a dynamic numerically heterogeneous environment where microbial communities can increase by a count of 100 million during sleep. IN this research, quantification of the paediatric oral microbiome complements taxonomic diversity information to show how biomass varies and shifts in space and time.**

Flow cytometry was used to count bacteria and viruses at 6 different locations in the paediatric oral cavity before and after sleep. As identified through the cytograms produced from the flow cytometer (Figure 1), we identified that the paediatric oral cavity is highly dynamic and can significantly increase by counts of 100 million bacteria and 70 million viruses during sleep. For the first time, this research shows that different locations in the oral cavity differed in the total counts of bacteria and viruses (Figure 1). For example, the back of the tongue recorded the highest abundance of bacteria and viruses (108 bacteria and 107 viruses), whereas the roof of the mouth (palate) reported the lowest counts (105 bacteria and 106 viruses).

Our research demonstrates that the oral cavity is an active microbial environment during sleep and that changes in oral environmental conditions could have a large impact on the absolute microbial abundances observed. Microbial abundance heterogeneity means that some microhabitats would contribute disproportionately to the overall microbial abundance of saliva that has previously been reported. This research highlights the importance of defining the oral cavity by its microhabitats and controlling for sample collection time in future studies. The large ranges observed among healthy individual's oral cavities could indicate that high microbial abundances may not be indicative of oral related illnesses. This suggests, like taxonomy, microbial abundances are distinct to individuals even at the paediatric age group, where there has been less time for community and abundance divergence.

**Figure 1 - Flow cytometric identification of bacterial and virus-like particle (VLP) populations.** Each 'dot' on the cytogram is a measurement of a virus or bacterium. These cytograms were produced from one participant showing the bacterial and VLP populations/counts at (a) the tip of the tongue before sleep (b) the tip of the tongue after sleep (c) the back of the tongue before sleep and (d) the back of the tongue after sleep. Bacterial and VLP abundances increased after sleep (as indicated through the increase in the number of 'dots'). Differences in bacterial and VLP abundances can also be seen between both sample locations (i.e. the back of the tongue versus the tip of the tongue).





## NANOPARTICLES IN AN ANTIBIOTIC-LOADED NANOMESH FOR DRUG DELIVERY

Melanie Fuller, Ashley Carey, Harriet Whiley, Rio Kurimoto (National Institute for Materials Science, Tsukuba, Ibaraki, Japan, Mitsuhiro Ebara (National Institute for Materials Science, Tsukuba, Ibaraki, Japan) and Ingo Köper

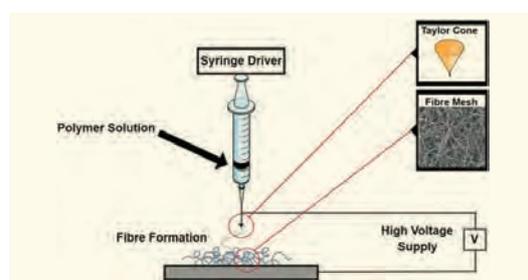
**The fight against global antibiotic resistance has taken a major step forward with the concept of fabricating nanomeshes as an effective drug delivery system for antibiotics. This targeted delivery should lead to lower doses and consequently reduced side-effects.**

Antibiotic loaded nanomeshes were fabricated by electrospinning polycaprolactone, a biocompatible polymer, with 12.5% w/w Colistin, 1.4% w/w Vancomycin and either cationic or anionic gold nanoparticles in varying combinations. The resulting nanomeshes had different antibiotic release profiles, with citrate capped gold nanoparticles combined with Colistin having the highest sustained release over 14 days for a 4 mg, 1.5 cm<sup>2</sup> nanomesh. The electrospinning parameters were optimised to ensure the spinning of a homogenous mesh and the addition of antibiotics was confirmed through 1H NMR and ATR-FTIR. This research, as a

proof of concept, suggests an opportunity for fabricating nanomeshes which contain gold nanoparticles as a drug release mechanism for antibiotics.

**Figure 1**

Schematic of the electrospinning process that produces a nanomesh.





## VORTEX FLUIDIC FABRICATION OF ULTRA-FAST GELATED SILICA HYDROGELS WITH EMBEDDED ENZYME NANOFLOWERS FOR BIOSENSORS

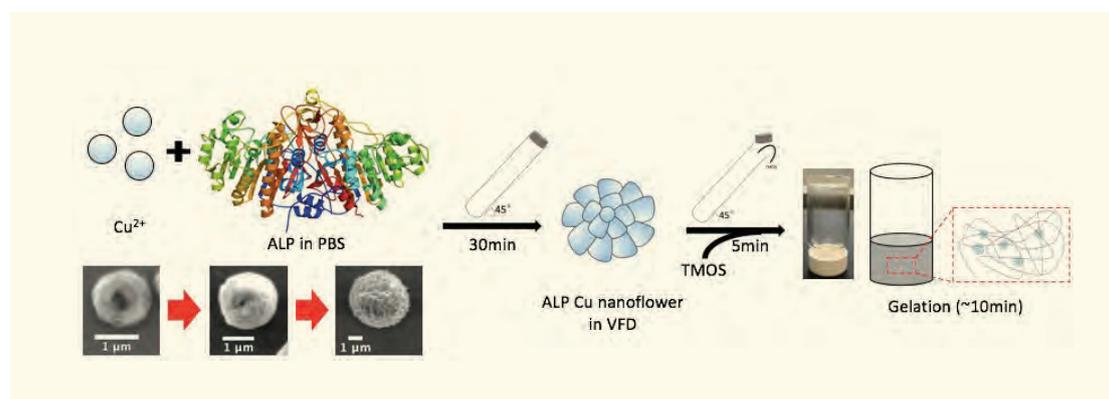
Xuan Luo and Colin Raston

**A hierarchical flower-like structure with hundreds of nanopetals is rapidly formed by mixing copper sulphate with a protein in a vortex fluidic device. This single step process significantly reduces the conventional processing time from 3 days into half an hour, with the material ready to be used for continuous flow enzymatic reactions.**

The fabrication of hybrid enzyme copper phosphate nanoflowers is dramatically facilitated using a thin film processing platform named vortex fluidic device. For the first time, a hierarchical flower-like structure with hundreds of nanopetals is rapidly formed (~30 min). This structure forms an intermediate toroidal structure where the protein molecules are linked by copper phosphate nanoparticles.

This hybrid material incorporating alkaline phosphatase as the enzyme also features a new portable colorimetric sensor where the nanoflowers are embedded and immobilised in silica hydrogel. This fabrication process provides another example of the diversity of applications of the vortex fluidic device.

This portable silica hydrogel-enzyme nanoflower offers rapid qualitative monitoring of molecules spectroscopically with good stability and reusability, being readily prepared within an hour. The utilisation of the vortex fluidic device enables the generation and immobilisation of hybrid nanoflowers into silica hydrogel in a single step, which greatly simplifies the fabrication process and has potential for the future of diagnostic research.





## SYNTHETIC BACTERIAL MEMBRANES FOR NOVEL ANTIMICROBIAL TESTING

Brodie Parrott, Ingo Köper, in collaboration with The Boyer Lab, UNSW

**Antibiotic resistance is an increasing problem in modern medicine, with greater numbers of bacteria becoming immune to our currently available antimicrobials. Work at UNSW in the Boyer Lab has been focussed on developing novel polymers which attack bacterial cell membranes, which could provide a near infinite array of new antimicrobial drugs.**

**This research takes the polymers produced at UNSW and analyses them using a synthetic bacterial membrane, which could reduce analysis time from days to hours and speed the development of new drugs to fight antimicrobial resistant bacteria.**

Most antimicrobial drugs kill bacteria via highly specific cellular processes which mammalian cells lack, thereby providing targeted toxicity. While this method is specific and effective, bacteria are quickly able to evolve resistance to these drugs. The exception to this are a class of antibiotics which include colistin and polymyxin B which instead attack bacterial cell membranes. This method effectively creates holes in the membranes causing the bacteria to leak to death.

Evolving resistance to this class of drugs are much harder as a bacterium must either change its entire cell membrane composition and structure or develop a specific enzyme to remove the drug, which would require significant and unlikely mutations. Unfortunately, these drugs are non-specific resulting in toxicity to mammalian cells, severely limiting their usefulness.

Fortunately, a group of molecules found naturally in all plant and animal life known as antimicrobial peptides shows potential for medical use. These peptides attack bacterial cell membranes, are difficult to evolve resistance to, and specifically target bacteria cells.

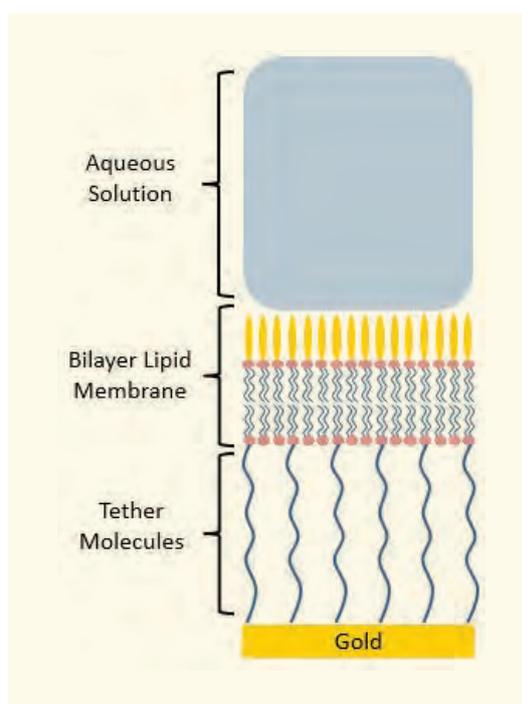
Polymers that mimic these peptides have been developed by the Boyer Lab, UNSW. These antimicrobial polymers are easy to produce and are nearly infinitely customisable. The current bottleneck with the availability of these potential new drugs is the speed at which they can be screened for effectiveness.

This research uses a novel synthetic bacterial membrane system to evaluate these polymers faster and more easily. The system is a tethered lipid bilayer membrane,

where long tether molecules are bonded to a gold surface and provide attachment points for the self-assembly of a lipid bilayer. By using lipids found in Gram-negative bacteria, the bilayer simulates a natural Gram-negative bacterial membrane, without all the membrane proteins and sugars that are normally present.

This construction allows the bilayer to be tested electronically for quality and permeability in a shorter timeframe compared to traditional cell cultures. Tracking the permeability and quality changes over time with the addition of small doses of antimicrobial polymers allows the effectiveness of these polymers to be measured. Additionally, some mechanistic and kinetic information can be obtained. Initial results suggest that this system can evaluate antimicrobial activity as well as traditional cell culture and demonstrates species specificity.

**Figure 1**  
Structure of a tethered lipid bilayer membrane used to evaluate the effectiveness of novel antimicrobial polymers.





## CONTINUOUS-FLOW PHAGE-DISPLAYED ANTIBODY AND PEPTIDE SELECTIONS

Jessica Phillips, Colin Raston, and Sudipta Majumdar and Gregory Weiss (University of California, Irvine)

**The display of antibodies and peptides on bacteriophage offers a powerful tool for biosensor diagnostics, protein engineering and drug discovery. The process of selecting an antibody or peptide that binds to a protein target, from large libraries, can be intensified using continuous-flow. In this work, an antibody binder for a bladder cancer biomarker was discovered using the vortex fluidic device and shows great promise for use in future biosensor development.**

Tailor made antibodies and peptides can be displayed on bacteriophage and selected, from diverse libraries, for specific recognition of a target molecule. Selections are achieved by multiple rounds of binding to an immobilised target molecule, washing to remove non-specific phage and elution for collection of specific binders. In this work, the target protein, a bladder cancer biomarker named protein deglycase (DJ-1), was immobilised onto the surface of the vortex fluidic device using macro-porous nickel-affinity resin (Figure 1).

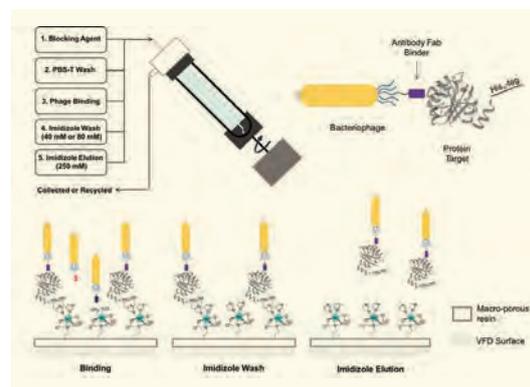
Each step of the selection process is achieved by continuously feeding all protein, phage and buffer solutions into the vortex fluidic device. The eluted phage was used to infect *e. coli* cells which generates more copies of the selected phage. This phage is then used for a second round of vortex fluidic selection with increased stringency. After the second round a phage-displayed antibody binder was identified from 96 randomly selected phage variants collected and its binding affinity to DJ-1 determined through an enzyme-linked immunosorbent assay.

The binder was tested against a panel of proteins and was shown to be selective for DJ-1. The system has

been applied to phage-displayed peptide selections and potential peptide binders are currently being screened to determine binding affinity to DJ-1 and to demonstrate generalisability of the method. These results show the successful application of continuous-flow for phage-displayed antibody selections. The identified binders have potential application in biosensor development for early bladder cancer detection.

**Figure 1**

Continuous-flow phage-displayed antibody selections in the vortex fluidic device.



### Acknowledgments

J. Phillips is grateful to the Australian Research Council (ARC), the South Australian Government and the National Institute of Health (NIH) for funding this research, and to Professor Gregory Weiss and the University of California, Irvine for the opportunity to visit and conduct this research.



## AGGREGATION-INDUCED EMISSION LUMINOGENS FOR BIOMEDICAL APPLICATIONS

Javad Tavakoli, Colin Raston and Youhong Tang

**Fluorescence microscopy is a powerful tool for biological research and understanding the relationship between the structure and properties of a material. Nevertheless, effective use of this technique is limited to studies performed at low concentration. When studying luminogens the fluorescence properties of luminogens are negligible at high concentrations. To tackle this problem, luminogens with aggregation-induced emission (AIE) property have been developed with increasing brightness at high concentrations. Our research focuses on the application of these AIE luminogens for a variety of biomedical applications.**

In a series of novel experiments aggregation-induced emission luminogens (AIEgens) were used to investigate a variety of biomedical applications for the first time. Different AIEgens were successfully employed for the characterization of hydrogels including the measurement of swelling properties, the kinetics of degradation process in alginate hydrogels cross-linked by  $\text{Ca}^{2+}$  and visualization of crystalline regions in physically cross-linked hydrogels.

The observation of the change in relative fluorescence intensity at various concentrations of tetraphenylethylene (TPE), suggests a new approach for accurate measurement of the swelling process in hydrogels. Our observation suggests that the diffusion of TPE into the hydrogel during the swelling process resulted in a decrease of its concentration in the swelling media, leading to this fluorescence change.

In order to characterize the physical stability of alginate-based biomaterials, SA-4CO<sub>2</sub>Na for real-time detection and quantification of  $\text{Ca}^{2+}$  ions was employed. It was observed that the aggregation of SA-4CO<sub>2</sub>Na in the presence of calcium ions accurately monitored the biodegradation process.

Since no traditional method can directly link the freeze-thaw process to the final properties of physically cross-linked PVA hydrogels, we employed TPE-2BA to effectively demonstrate the crystallization process using a significant color and brightness difference in crystalline regions (Figure 1) compared

to the amorphous areas. This capability allows us to visualize the crystalline regions and study their kinetics, formation, and transition into a solid-state and measure the changes in crystallinity-induced properties.

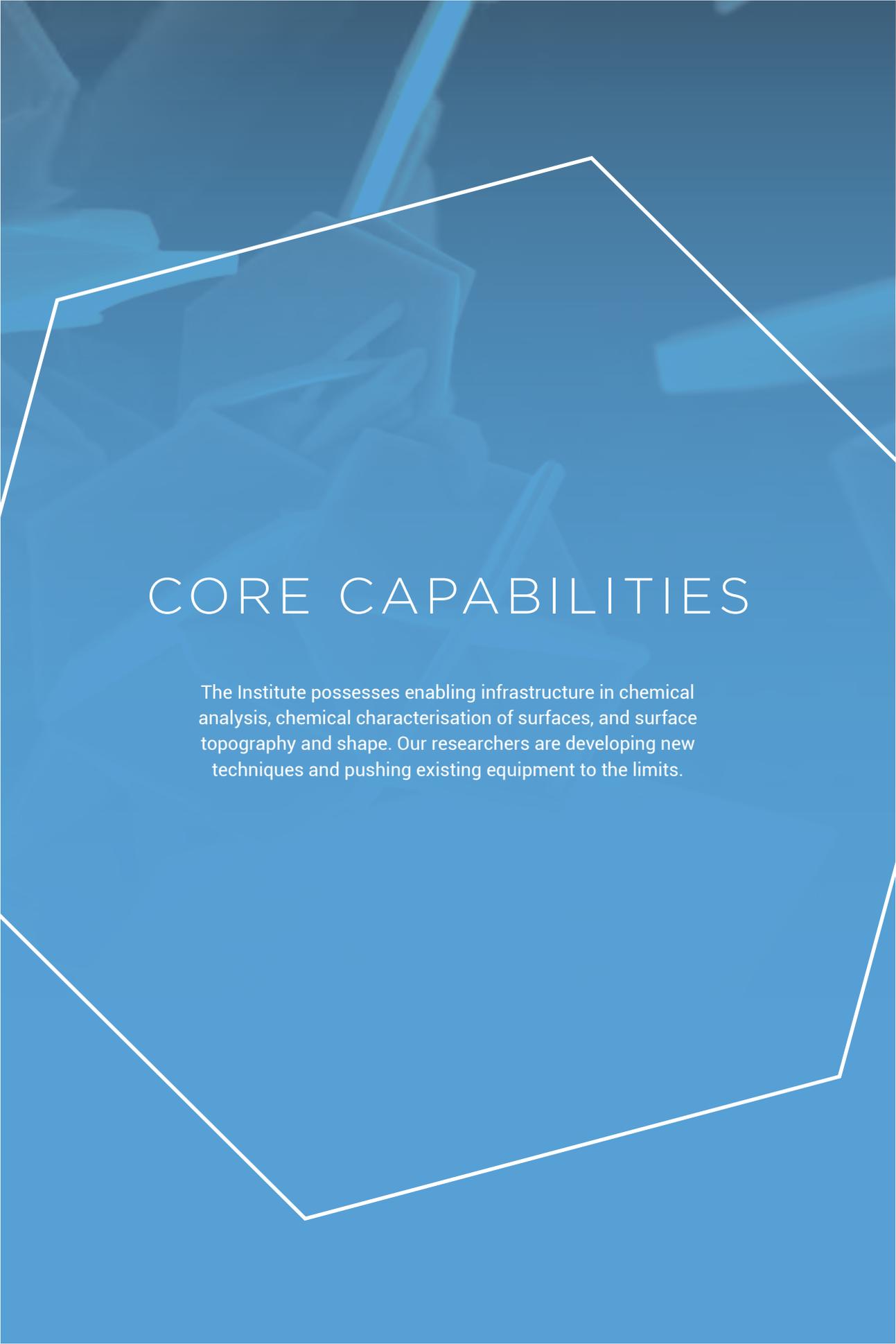
Upon successful application of AIEgens for characterization of hydrophilic biomaterials, we realized that tuning the size of AIEgens is critical to efficiently address biomaterial characterization and cell tracking. The precipitation process, which is a traditional method for the preparation of AIEgen particles lacks size control. We employed a vortex fluidic device to tune the size of TPE under thin film formation for the first time.

We found that the preparation of TPE nanoparticles under thin film formation could support tuning their size and were associated with the intensity of fluorescence. By increasing both TPE concentration and rotation speed during the preparation, the size of the particles can be controlled and significantly reduced, with the smaller particles responsible for the increasing the brightness. The direct diffusion of nanoparticles within the cell or in a single-celled organism, as an advantage of size reduction, opens new many opportunities for biological and material studies.

### Figure 1

Enlightening a crystalline region in physically cross-linked poly (vinyl alcohol) hydrogels (PVA) using an aggregation-induced emission molecule (TPE-2BA).





# CORE CAPABILITIES

The Institute possesses enabling infrastructure in chemical analysis, chemical characterisation of surfaces, and surface topography and shape. Our researchers are developing new techniques and pushing existing equipment to the limits.

## FLINDERS MICROSCOPY AND MICROANALYSIS

We are home to advanced microscopy, microanalysis, spectroscopy and imaging equipment. These instruments are funded by government grants, Microscopy Australia and the Australian National Fabrication Facility – which means that they're available for use by scientists around Australia and the world. Our facility is led by a multi-disciplinary team of expert chemists, biologists, physicists and engineers undertaking novel research and providing service to industry.

Our equipment and facilities are cutting-edge and often custom built. Many are one-of-a-kind in Australia – or even the world. They are used by researchers working across materials science, nanotechnology and nuclear chemistry on exciting projects like replacing toxic mining materials with rock-eating bacteria or creating solar cells that could one day power buildings.

Our friendly staff can help you select the appropriate technique for your problem. Through training and advice, we can ensure you capture the best data possible, and get the most from your data.

### Our instruments:

- Scanning electron microscopy (FEI Inspect F50)
- Scanning auger nanoprobe (PHI-710 AES)
- Large-volume micro-CT (Nikon XT H 225ST CT Scanner)
- Neutral impact collision ion scattering Spectroscopy (NICISS- Custom built)
- Metastable induced electron spectroscopy - custom built and includes ultraviolet photoelectron spectroscopy, inverse photoemission spectroscopy and x-ray photoelectron spectroscopy, NICISS
- Atomic force microscopy (Multimode 8 AFM with Nanoscope V Controller and Dimension FastScan AFM with Nanoscope V controller)
- Tip enhanced raman spectroscopy (Nanonics TERS with XplorRA Horiba Scientific confocal Raman microscope)
- Confocal raman microscopy (WiTec alpha 300R confocal Raman microscope)
- Confocal fluorescence microscopy (Zeiss LSM 880 Fast Airyscan confocal microscope; Olympus FluoView 1000 laser scanning confocal microscope; Leica TCS SP5 laser scanning confocal microscope)

Get in touch to find out how we can help you: Email: [microscopy@flinders.edu.au](mailto:microscopy@flinders.edu.au) or Phone: +61 8201 3534.

## FABRICATION AND MODIFICATION

The Institute hosts fabrication facilities enabling the production of nanoscale materials, such as porous silicon, lipid bilayers, carbon nanotubes, functional nanoparticles, microfluidic devices and quantum dots. This also includes instrumentation to modify the surfaces of these structures and to print materials for applications such as next generations solar power.

## MATERIALS PROPERTIES

The institute has the capabilities to characterise and analysis materials but equipment to define the properties of the material structure such as measuring the hydrophilicity or hydrophobicity of a surface, assess the reactivity of materials, investigate particle size and explore particle-particle interactions.

## POLYMER CHARACTERISATION

A complete range of polymer characterisation equipment is available including characterisation equipment with methods such as: Gel Permeation Chromatography, Dynamic Mechanical thermal Analysis, Differential Scanning Calorimetry, Simultaneous Thermal Analysis, tensile testing and a rheometer.

## ADVANCED MATERIAL LABORATORY - TONSLEY INNOVATION PRECINCT

The Institute for Nanoscale Science and Technology is co-located between the main campus and Tonsley, occupying several offices, a meeting space and two laboratories;

- The Advanced Materials laboratory is shared with the materials engineering group. This space houses an FTIR spectrophotometer, tensile and impact testing machines, salt spray durability test, ovens and 6 fume cabinets for chemical synthesis research.
- A clean room, used for fabrication of electronic devices, and other high sensitivity material and device preparation work. Also present are a lithography processing system, glove box and other preparation equipment.

## NATIONAL RESEARCH FACILITIES

### Microscopy Australia

This is a national collaborative research facility for the characterisation of materials at the micro, nano and atomic scales. Microscopy Australia facilities are accessible to all Australian researchers, comprising of over 300 instruments and 100 expert staff nationwide, dedicated to supporting research. This enables all researchers to access expert support, training and instruments and facilitates world-class Australian research and innovation. Research leader Associate Professor Sarah Harmer is the Deputy Director of the South Australian Research Facility (SARF), the SA branch of Microscopy Australia. SARF is an alliance of Flinders Microscopy and Microanalysis, Adelaide Microscopy and the Future Industries Institute.

### The Australian National Fabrication Facility

The Australian national fabrication facility links eight university-based nodes to provide researchers and industry with access to state-of-the-art fabrication facilities. Each node offers a specific area of expertise including advanced materials, nanoelectronics and photonics and bio nano applications. The SA node is co-located at the Future Industries Institute, UniSA and Flinders University, and brings together expertise in surface modification, characterisation, nanotechnology, and advanced materials.



## SYNTHESIZING AGGREGATION-INDUCED EMISSION LUMINOGENS UNDER SCALABLE LIQUID THIN-FILM TECHNOLOGY

Clarence Chuah, Jichao Li (Qilu University of Technology, Shandong Academy of Science),  
Javad Tavakoli, Scott Pye, Xuan Luo, Youhong Tang, Colin Raston

Every day, researchers are required to leave experiments running overnight, coming back the next day to obtain their products. Sometimes, these experiments require further alterations or even worse, fail and need to be re-run.

The vortex fluidic device, a unique microfluidic platform, is a game-changer for both researchers and producers of chemical reagents. Not only does it shorten the experimental time, but it also decreases the amount of the sample and reagent consumption, which significantly reducing costs.

The vortex fluidic device can generate liquid thin film at micron-size dimensions along the inner surface of the reaction tube. This achieves an extremely high surface area to volume ratio. Therefore, this allows for reactants to be efficiently mixed, thereby achieving excellent mass and heat transfer.

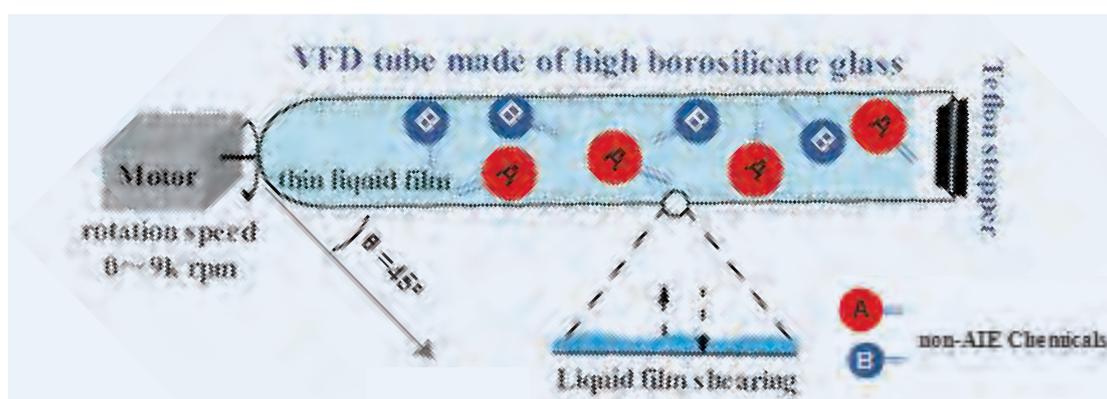
Our team demonstrates the construction of aggregation-induced emission luminogens in the vortex fluidic device for the first time. Aggregation-

induced emission luminogens are used for a myriad of applications including but not limited to bioimaging, bio-probes, chemo-sensors, as well as light-emitting materials in optoelectronics and sensory systems.

Our method is compared to the classic Suzuki and Knoevenagel reactions as the most common techniques used to construct carbon-carbon single bonds and carbon-carbon double bonds, respectively, for the synthesis of aggregation-induced emission luminogens.

Current results suggest that the vortex fluidic device method has the advantages of reduced reaction time, minimised volume of catalyst, improved reaction efficiency and simplified purification process.

**Figure 1**  
Fabrication of aggregation-induced emission luminogen via vortex fluidic device.



### Acknowledgements

This project is support with funding from the International Laboratory for Health Technologies.



## FLUID DYNAMIC DIASTEREOISOMERIC CONTROL OF DIELS-ALDER REACTIONS

Matt Jellicoe and Colin Raston

**This research seeks to use the vortex fluidic device to control the ratio of diastereoisomers in a dynamic thin film. The ultimate purpose is to move away from traditional batch processing and therefore reduce the production of waste, the use of auxiliary substances and reduce processing time.**

The Diels–Alder reaction is the reaction between a conjugated diene and an alkene (dienophile) to form unsaturated six-membered rings. The Diels–Alder reaction is an electrocyclic reaction, which involves [4+2] cycloaddition of 4  $\pi$ -electrons of the conjugated diene and 2  $\pi$ -electrons of the dienophile (an alkene or alkyne). The reaction involves the formation of new  $\sigma$ -bonds, which are energetically more stable than the  $\pi$ -bonds. This reaction has great synthetic importance and was discovered by two German chemists, Otto Diels and Kurt Alder in 1928. They were awarded the Nobel Prize in 1950.

Application of the microfluidic platform - the vortex fluidic device - to control the ratio of diastereoisomers in a dynamic thin film is the focus of our research. This project examined, at various fluid dynamics, the Diels–Alder reaction to control the formation of the exo

and endo oxoborene products. The ultimate purpose is to move away from traditional batch processing and therefore reduce the production of waste, the use of auxiliary substances and reduce processing time.

A new method to control the formation of the diastereoisomers in a Diels–Alder reaction of furan and maleic anhydride was the focus of this work. The vortex fluid device was used to systematically explore a variety of parameters, including rotational speed,  $\omega$ , and tilt angle,  $\theta$ .

It was discovered that the ratio of diastereoisomers can be altered and is dependent on the rotational speed and tilt angle. The selective diastereoisomeric control is from the unique topological fluid flow of the dynamic thin film produced by the vortex fluidic device. This fluid dynamics can control the formation of various organic and biological reactions and has implications for materials processing.

**Figure 1**

Schematic of the a new method to control the formation of the diastereoisomers in a Diels–Alder reaction.





## UNDERSTANDING MATRIX EFFECTS ON PHOTOCHROMIC DYES

Rowan McDonough and David Lewis

Photochromic dyes reversibly change colour from transparent to coloured when irradiated by UV light. These dyes have a variety of uses including eyewear, novelty items such as clothing and for solar energy storage.

The speed of this colour change is highly dependent the surrounding environment, with rapid switching in solution and much slower switching in rigid solids. To achieve rapid colour switching and the desired colouration, the interactions of photochromic dyes with their surrounding environment on the nano-scale needs to be better understood.

The ability of photochromic dyes to reversibly transition from a transparent to coloured state in response to UV light offers many applications in sensing, ophthalmic lenses, textile coatings and novelty items.

However, the development of these applications has been limited by slow switching speeds in solids, photo-degradation over time and a lack of knowledge on the interactions between the dye and its environment, particularly at the nanoscale.

The characterisation of these dyes in different solvents at different concentrations aims to develop an understanding of the relationship between solvent properties, the colouration and fading rates, as well as the steady state colour intensity. This knowledge will aid in developing an understanding of the properties and controlling mechanisms of photochromic dyes applied to solid materials, allowing the dyes used in a wider range of products.

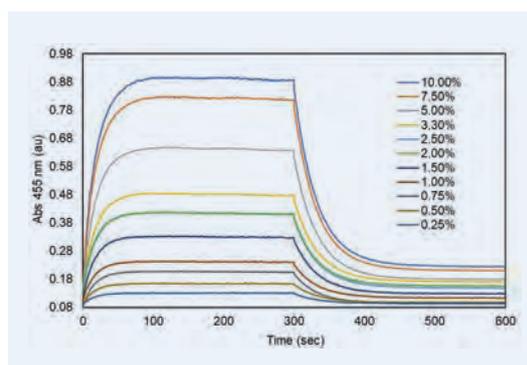
Figure 1

Films of poly(methacrylate) containing different w/w % of Reversacol Gold dye before (left) and after (right) irradiation with 370 nm light.



Figure 2

Activation and fading at 455 nm of poly(methacrylate) films containing different w/w % of Reversacol Gold dye at 23°C and 50 klux irradiation intensity





## UNRAVELLING THE SPECIFIC ION EFFECT USING NEUTRAL IMPACT COLLISION ION SCATTERING SPECTROSCOPY

Anand Kumar, Professor Gunther Andersson, Vince Craig (Australian National University), Erica Wanless, Alister Page, Grant Webber, Edwin Johnson, Kasimir Gregory, Gareth Elliott, Hayden Robertson, (University of Newcastle)

**Himalayan salt is pink in colour and contains trace minerals such as potassium, magnesium and calcium but common table salt is white being essentially pure sodium chloride. It is believed that this colour alteration is caused by specific ion effect, which is present everywhere and governs important function of life forms.**

**Specific ion effects are important in numerous fields of science and technology. They have been discussed for over 100 years, ever since the pioneering work done by Franz Hofmeister. Over the last decades, hundreds of examples have been published and many explanations have been proposed. However, it is only recently that a greater understanding of the basic effects and their reasons has been elucidated.**

**This research focuses on understanding these specific ion effects on various solvents and polymer systems.**

Specific ion effect is based on preeminent effects of salts found by Franz Hofmeister in late 19<sup>th</sup> century. Hofmeister investigated effects of salt in precipitating protein from egg globulin and developed an order followed by ions. Almost a century later researcher started to find irregularity in this series as it started to fail for high concentration of salts and when solvents other than water were used. An immense amount of work has been done over the years to solve these problems but still a concrete explanation or new series has not been obtained.

Our group has focused its attention on unravel these ionic properties by using a combination of ions with different solvents selected on basis of physical properties such as the dielectric constant, surface tension and hydrogen bonding nature.

This project focuses on analysing different electrolyte solutions at the air-solvent interface, polymer-solvent interfaces in systematic order to determine the ionic interaction at these interfaces.

One important missing element of the specific ion effect is the location of the ion interaction. That is, where do the ions interact with interfacial molecules of the solvent. Many research articles have been published on this topic but are based on simulations, but none have presented experimental results. Neutral impact collision ion scattering spectroscopy (NICISS) has been used here and has a novel advantage for finding this missing piece of information.

By obtaining concentration depth profile using NICISS, information about where ions interact with solvent molecules in different systems can be obtained. To date, our research has investigated CsBr and CsCl salts in glycerol and discovered the depletion of Cs<sup>+</sup> ions from glycerol interface. This is interesting information since Hofmeister series categorises Cs<sup>+</sup> as weakly hydrated ions and according to the Hofmeister effect, weakly hydrated ions tend to accumulate at interfacial region or the topmost layer.



# COLLABORATION

## AUSTRALIAN NUCLEAR SCIENCE AND TECHNOLOGY ORGANISATION (ANSTO)

ANSTO manages both Australia's national nuclear facility in Lucas Heights, NSW and the Australian Synchrotron in Melbourne, Victoria. Researchers from the Institute benefit from this partnership through access to state of the art equipment, participation in research networks and the opportunity to apply for ANSTO research grants through the Australian Institute of Nuclear Science and Engineering.



## AUSTRALIAN SOLAR THERMAL RESEARCH INITIATIVE (ASTRI)

ASTRI is an \$87 million, eight-year international collaboration with leading research institutions, industry bodies and universities which aims to position Australia in concentrating solar thermal power technologies. Flinders University is a key partner in this initiative, a partnership which operates through the Institute and contributes to projects in high temperature corrosion and materials compatibility, catalysts for solar fuels and coatings for heliostats.



## COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (CSIRO)

CSIRO is the federal government agency for scientific research in Australia. Its primary role is to improve the economic and social performance of industry, for the benefit of the community. The Institute has partnered with CSIRO on projects in our Energy stream such as looking at enzyme reactions as well as light assisted RAFT polymerisation.



## NATIONAL INSTITUTE FOR MATERIALS SCIENCE (NIMS), JAPAN

NIMS is not only one of the largest research centres in Japan but also one of the world leaders in nanotechnology research. In 2011 Flinders University signed an MoU with NIMS, this relationship has gone from strength to strength. In addition to ongoing research collaborations between academics, the Institute is the only Australian participant in the International Graduate Cooperative Program, where PhD students can work at NIMS for between 6-12 months. In 2015 this collaboration was extended further with the Institute participating in an annual international summer school with students from NIMS.



## DEFENCE SCIENCE AND TECHNOLOGY GROUP (DST GROUP)

DSTG is responsible for leading technology development for Australia's defence forces. Research collaborations that leverage our unique capabilities are expanding and offering new and exciting projects to Flinders researchers.

The Institute is exploring the development of photochromic dyes as part of a collaborative program with DSTG Group on adaptive camouflage for combat uniforms, nets and coverings. The development aims to allow camouflage pattern to adapt to changes in the environmental lighting conditions and thereby improve signature management effectiveness.



## THE AUSTRIAN INSTITUTE OF TECHNOLOGY (AIT)

The Austrian Institute of Technology takes a leading role in the Austrian innovation system and is a key player in Europe as the research and technology organisation focusing on the key topics for the future.



AIT provides research and technological development to realize basic innovations for the next generation of infrastructure related technologies in the fields of Energy, Mobility Systems, Low-Emission Transport, Health & Bioresources, Digital Safety & Security, Vision, Automation & Control and Technology Experience.

## 3RT

3RT Holdings Pty Ltd is the first nanotechnology company in the forestry industry in Australia and most likely the world. Its patented technology converts softwood pulp logs into 3Wood™, a new wood that looks and performs like tropical hardwood only with enhanced properties.

The development of 3Wood™ is all thanks to 3RT's partnership with the Institute for Nanoscale Science and Technology and its Director Professor David Lewis. 3Wood™ is environmentally sustainable and uses a non-toxic resin in its production, with the added benefits of being termite-resistant and fire-retardant. Further work with Flinders University is aiming to look at other improvements including UV light and water resistance.



## 2D FLUIDICS

2D Fluidics is equally owned by Flinders University and First Graphene and will commercialise the SA-designed Vortex Fluidic Device to produce environmentally friendly safe supplies of high quality graphene at a price and scale viable for use in energy storage devices, coatings polymers and other modern materials.

The Vortex Fluidic Device was invented at Flinders University by Professor Colin Raston and allows for new approaches to the manufacturing process.



## MICRO-X

Micro-X Ltd designs, develops, and manufactures a range of innovative, ultra-lightweight, mobile x-ray imaging systems for medical and security applications. The competitive advantage of these miniaturised products stems from a new technology of electronic x-ray tube using Carbon Nano-Tube field emission devices, enabling the miniaturisation of several X-ray applications relevant to large global markets.





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