Institute for
Nanoscale Science & Technology

BIENNIAL REPORT 2021-22

Flinders University

INSTITUTE FOR NANOSCALE SCIENCE & TECHNOLOGY
FLINDERS UNIVERSITY

Sturt Road, Bedford Park, SA 5042

GPO Box, 2100 Adelaide SA 5001, Australia

flinders.edu.au/nanoresearch
nano@flinders.edu.au

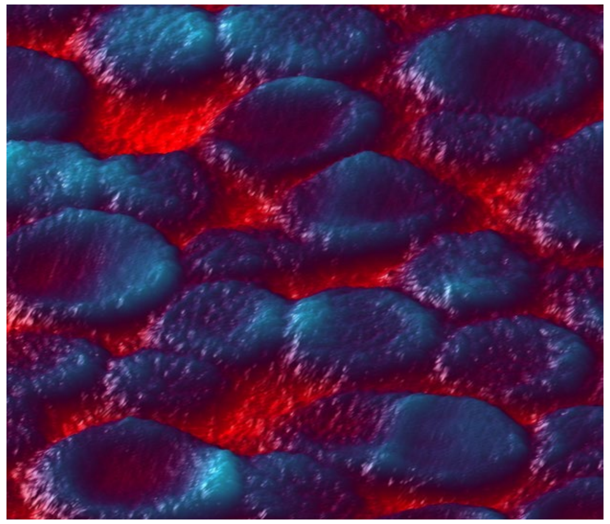


IMAGE OF THE YEAR 2021

Organic Solar Cell Active Layer, Bradley Kirk

A three-dimensional image of the surface of an organic solar cell active layer. The active layer was prepared via slot-die coating and contains a mixture of donor-polymer and acceptor-fullerene material.

The image of the surface was collected using the technique of Atomic Force Microscopy (AFM) by scanning an area of 5.0 µm x 5.0 µm in Tapping Mode. A false colour scale was applied and adjusted using the Nanoscale Analysis software, with the image zoomed at an approximate area of 3.0 µm x 3.0 µm, with a height range from 0 to 40 nm.

The Scientific Image of the Year Competition covered 3 categories plus an overall winner with images selected by the Institute executive team. The 2021 overall image of the year was awarded to, PhD candidate, Mr Bradley Kirk.

INSTITUTE FOR NANOSCALE SCIENCE & TECHNOLOGY BIENNIAL REPORT 2021-22

CONTENTS

MATS ANDERSSON
DIRECTOR

2021-2022 can be described as eventful, exciting, and very fruitful years. Throughout 2021 all members and university staff were affected by the COVID-19 pandemic, particularly due to severe travel restrictions in South Australia. During that year, online teaching and meetings were the standard. Thanks to the hard work from all members of the institute, both 2021 and 2022 turned out to be successful with several prestigious awards, grants, and research achievements.

In the beginning of 2021 our institute manager, Dr Mary Rieger, resigned to take on a new position at Flinders Research Development and Support (RDS). I would like to take the opportunity to thank Mary for her support in developing and managing the Institute during the last years. We were very happy to welcome Kim Hutchins who provided administrative support for the institute in June and in October we were even happier when our new Institute manager, Dr Martin Cole, started his position. They both helped our activities, at the institute, run significantly smoother. Kim Hutchins moved on to a new position in March 2022 and we miss her help and support.

During 2021 and 2022 we increased the number of research leaders from 12 to 16, including two adjunct research leaders. Dr Zhongfan Jia joined the institute in the beginning of 2021. He brings an important research competence within the areas of organic batteries, electrochemistry, and polymer synthesis. A/Prof Melanie MacGregor started as a new research leader at the institute towards the end of 2021. Her research strengths include nanotextured surfaces, surface chemistry, and plasma coatings. Prof Jamie Quinton who has been a research leader of the Institute since its start in 2009 moved to a new position as the Head of the School of Natural Sciences at Massey University, New Zealand. Jamie maintains full academic status at Flinders University and transferred into an affiliate research leader at the Institute. In the beginning of 2022 Prof Michelle Coote joined Flinders University and the institute, she has significant research experience within computer-aided chemical design and polymer chemistry. Prof Joe Shapter also re-joined the institute as an affiliate research leader in 2022. As one of the original founders, he has vast experience in nanoscale and associated research areas.

In the middle of February 2021, it was finally time for the 2020 SA Science Excellence Award ceremony. Prof Colin Raston was the joint winner of the category Scientist of the Year 2020. The Micro-X Carbon Nano Tube Project Team received the prize in the category Innovator of the Year. During the spring it was again time for the SA Science Excellence and Innovation Awards and A/Prof Justin Chalker was awarded with the 2021 Innovator of the Year! The Institute for Nanoscale Science and Technology is very fortunate to have several successful researchers. Our immense congratulations again to all award recipients from the Institute!

Fortunately, some of the COVID19 pandemic restrictions were removed mid-year 2021 and we could hold our annual conference in person rather than online. Our conference mainly focused on research activities at Flinders with most of the institute research leaders presented their ongoing research activities. We also had two excellent external talks from Dr Melanie MacGregor (UniSA), and Prof Michelle Coote (ANU). The final activity of the conference was a poster presentation and networking session, for many of us this was the first in-person presentation event of the year and all the posters were excellent!

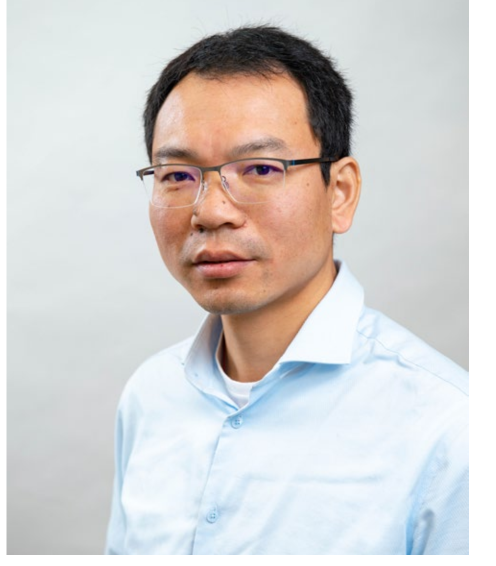
The 2022 annual conference benefited from an external research focus with excellent presentations provided by Prof Douglas MacFarlane (Monash University), Prof Greg Metha and Prof Chun-Xia Zhao (Uni. Adelaide), A/Prof Craig Priest (UniSA) and A/Prof Christine Bressy (Toulon University). Before the poster session some of our members gave short and well received updates about their industry related research. Again, the poster session was very successful. The quality was superb, and submissions exceeded capacity prompting us to re-design the session to accommodate everyone!

In August 2022 we organised an event called "Industry Meets Research @ Flinders". This attracted 9 new companies for us to engage with. During the event we discussed different industry focused challenges from diverse sectors and areas spanning energy, exploration, engineering, fabrication, waste, sustainability, and analytical services. Researchers and industry representatives alike gave positive feedback, and we have ongoing discussions with several companies.

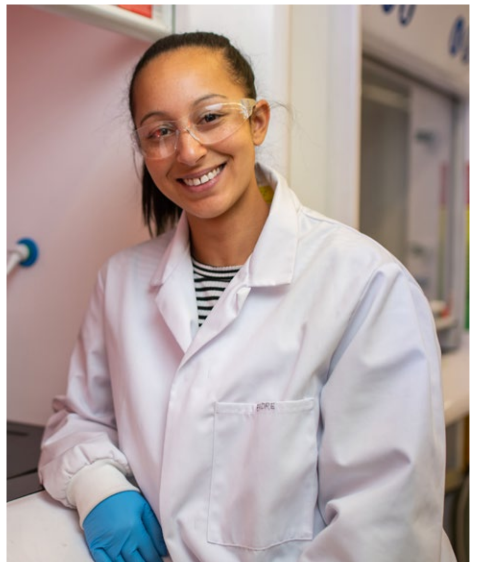
We have initiated several new prizes in different categories to recognise our excellent young researchers working in the Nanoscale Science area and it is fantastic to see Nano students gaining recognition in external awards (see highlights section). Furthermore, institute members have been very successful in winning competitive research grants during the last two years, especially from the Australian Research Council (ARC) and also the AusIndustry Cooperative Research Centre (CRC) grant scheme. More details of CRC, Discovery, Linkage, LIEF, Future Fellow, ITTC and COE grants as well as industry partnerships can be found in the highlights section. Keep up the good work everyone!

Overall, the last two years have been interesting with many different challenges but thanks to the members of the institute, the deputy directors, Prof Gunther Andersson and Prof Sarah Harmer, and our manager Dr Martin Cole the institute has accomplished a lot! I hope you enjoy reading about our recent successes in the following report.

WELCOME TO NEW MEMBERS



ZHONGFAN JIA,
Research leader, joined February 2021.



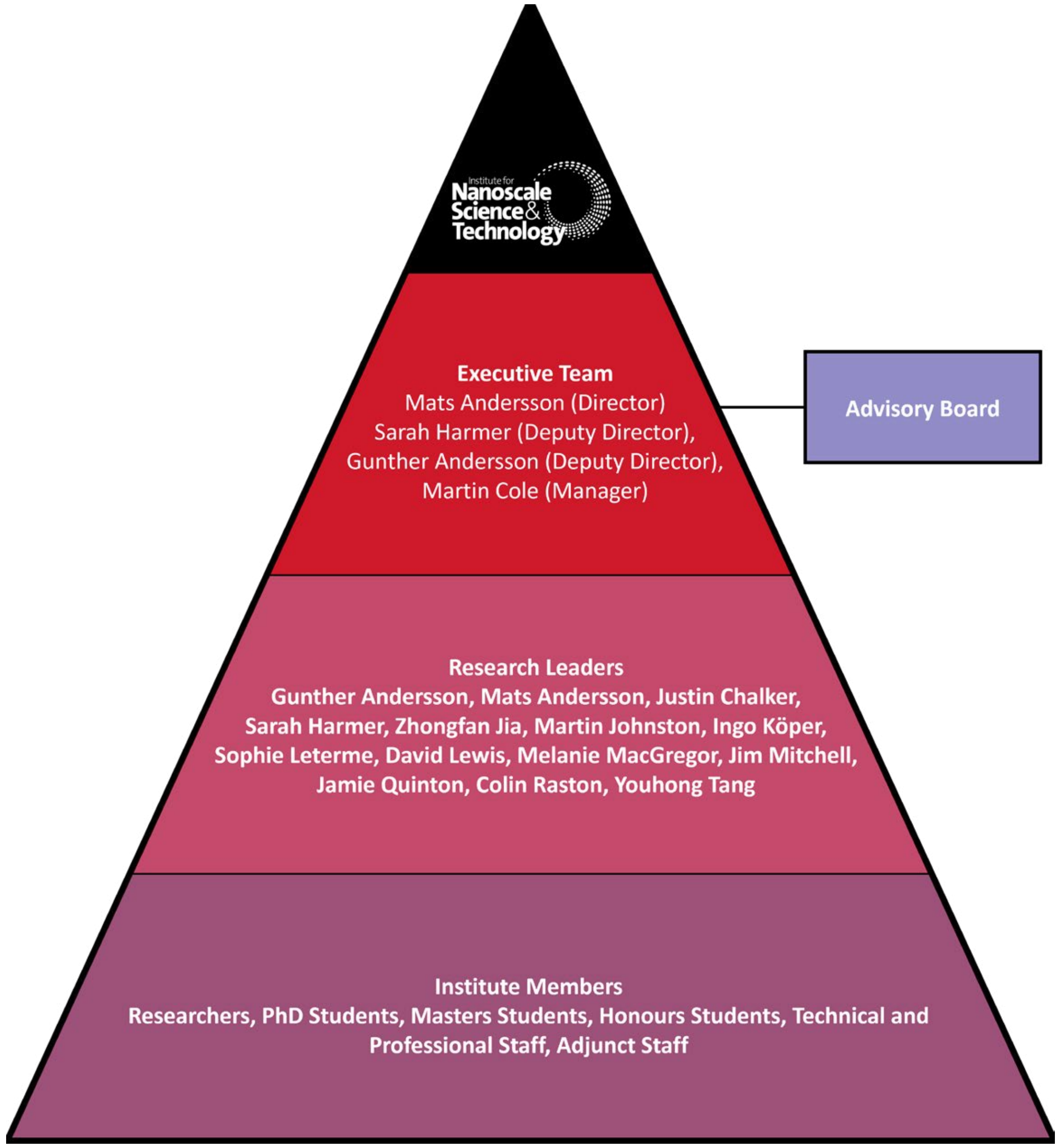
MELANIE MACGREGOR,
Research leader, joined November 2021.

MARTIN COLE,
Institute manager, joined October 2021.

MICHELLE COOTE,
Research leader, joined March 2022.

ORGANISATION

The Institute for Nanoscale Science & Technology at Flinders University is a hub for problem solving, research and education. With a cohort of approximately 150 researchers, a broad subset of both specialist and interdisciplinary expertise, INST tackles issues across diverse fields. We work across materials, energy, environment, security and bio-interactions. The institute undertakes research to discover new scientific knowledge and seeks to apply knowledge with business and industry, to connect research-driven solutions with real-world problems.



HIGHLIGHTS 2021

ANNUAL NANO CONFERENCE AWARDS JUNE 2021

2021 Annual Nano Conference Student Poster Award Winner, **Sam Tonkin**

2021 Runner up Student Poster Award and People's Choice Award: Granted to **Bradley Kirk** (left) and **Dr. Chris Gibson** (right) respectively.

BEST PHD THESIS OF 2021

A new award was established to recognise an outstanding graduate from the Nano Institute. Congratulations to all 2021 PhD students who completed their postgraduate degrees.

Nano Institute Best PhD Thesis 2021 Awarded to: **Dr. Liam Howard Fabretto**, for thesis titled, Spectroscopic Studies of Size-Selected Ru and Pt Clusters on Titania, Supervisor(s); Gunther Andersson, Sarah Harmer and Jamie Quinton.

Commendation to **Dr. Jessica Philips** for her thesis titled, Enhancing Chemical and Biochemical Transformations in Dynamic Thin Films Under Flow.

OTHER INTERNAL AWARDS IN 2021

2021 Best Nano Institute Masters Student: **Nguyen Nguyen Ho Ho** "Enhanced syntheses of benzimidazoles and benzoxazoles in vortex fluidic device". Supervisor Colin Raston

2021 Best Nano Institute Honours Student: **Mitchell Griggs** "Multiplet structure of transition metal sulphides" Supervisors Sarah Harmer and Jamie Quinton

2021 Scientific Image Competition Winner: **Bradley Kirk.** The scientific image is shown on the front and described inside the front cover of this report.

Congratulations to all Nano Institute award winners!

EXTERNAL AWARDS IN 2021

Institute members gained recognition for their outstanding work at the **South Australian Science Excellence and Innovation Awards.**

Award Winner: Justin Chalker for **SA Innovator of the year.** *Image supplied by the Department for Industry, Innovation and Science – SA Science Excellence and Innovation Awards.*

Congratulations to Finalists: Jon Campbell and David Lewis (3RT) who were also finalists for **SA Innovator of the year.**

Congratulations to Finalists: STEM Fast Track, Micro-X and Flinders University Collaboration – **SA Excellence in Science and Industry Collaboration** (Teresa Janowski from STEM Fast Track, A/Prof Ingo Köper Flinders University and Susanne Sahlos from Micro-X Ingo with SA Chief Scientist, Prof Caroline McMillen). *Image supplied by the Department for Industry, Innovation and Science – SA Science Excellence and Innovation Awards*

COMPETITIVE GRANTS AND RESEARCH FUNDING ANNOUNCED IN 2021

Congratulations to Nano Institute member recipients of competitive research funding.

ARC DISCOVERY:
Prof Mats Andersson and Prof David Lewis (together awarded DP220102900) to Develop materials for stable and efficient printed polymer solar cells $480,000.

Prof Jim Mitchell (together with Rob Edwards) for DP220102915 Quantitative Metagenomics $548,230.

ARC LINKAGE:
Prof Justin Chalker
ARC Linkage (LP200301661) E-waste Recycling (w/ Clean Earth Technologies) $884,669

ARC Linkage (LP200301660) Oil spill remediation and slow-release fertilisers (w/ Clean Earth Technologies) $708,984

ARC LINKAGE INFRASTRUCTURE, EQUIPMENT AND FACILITIES (LIEF):
Martin Johnston, Justin Chalker, Colin Raston, Zhongfan Jia, LE210100139 Revitalizing facilities for nuclear magnetic resonance in South Australia, $1,240,000

(Prof Andrew Abell, **A/Prof Martin Johnston,** A/Prof Anton Blencowe, Prof Janna Morrison, Prof Vincent Bulone, Prof Shudong Wang, Dr Susan Semple, Prof Andrew Zannettino, Prof Dr Volker Hessel, **Prof Justin Chalker, Prof Colin Raston,** Dr Thomas Fallon, **Dr Zhongfan Jia,** A/Prof Michael Perkins, Dr Ruben Arrua)

Mats Andersson and Martin Johnston LE210100163 Structure Determination Pipeline Capabilities for South Australia, $860,365
(Prof Christopher Sumby ; Dr John Bruning ; A/Prof Sally Plush ; Prof Vincent Bulone ; Prof Christian Doonan ; **A/Prof Martin Johnston** ; Prof Dr Volker Hessel ; Prof Shudong Wang ; A/Prof Michael Perkins ; **Prof Mats Andersson** ; Dr Ruben Arrua ; A/Prof Henrietta Venter ; Prof Deborah White ; Dr Peter Elliott ; Prof Nikolai Petrovsky)

Sarah Harmer, Gunther Andersson, Colin Raston, Mats Andersson, Jamie Quinton LIEF 220100179 A Spectromicroscopy Facilty: Band Mapping to Atomic Resolution Imaging, $405,049

(Prof Sarah Harmer; Prof Gunther Andersson; Prof Colin Raston; Prof Mats Andersson; Prof Paul Dastoor; A/Prof Jennifer MacLeod; Prof William Skinner; Prof Nicole Stanford; **Prof Jamie Quinton)**

ARC INDUSTRY TRANSFORMATION RESEARCH PROGRAM

The ARC Training Centre for Green Chemistry in Manufacturing officially **launched in 2021** and will receive $3.68 million in funding over four years through the ARC's Industrial Transformation Research Program (ITRP). **Prof Colin Raston** (deputy director/CI) and **Prof Youhong Tang** (CI) are participating from the Nano Institute.

The Training Centre for Green Chemistry in Manufacturing was officially launched on 18th of November 2021.

INDUSTRY CATEGORY:

Prof Sarah Harmer (Project Leader). CRC Transformations in Mining Economies (CRC TiME) Project 3.10: Improved prediction, remediation, and closure of AMD/NMD sites by examination of mine waste behaviour at the meso-scale.

Total project is $10.2M with 9 Chief Investigators and 18 Partner Investigators. Duration 5 years

Project Partners: Flinders University; Newmont Mining Services; MMG Australia Limited; Rio Tinto Services Limited; Fortescue Metals Group Ltd; BHP Group Operations Pty Ltd; Teck Resources Limited; Genome Research Facility Limited; Okane; Minerals Research Institute of Western Australia; Department for Energy and Mining, South Australian Government; Australian Department of Agriculture, Water and the Environment; Mineral Resources Tasmania; The University of Queensland; University of Windsor, Blue Minerals Consultancy.

PARTNERSHIP WITH SPARC TECHNOLOGIES

Prof Gunther Andersson. Led by Adelaide University, Prof Gregory Metha and Gunther Andersson have secured funding for a research project funded by SPARC Technologies Ltd to develop photocatalytic water splitting. Sparc Green Hydrogen is seeking to commercialise a process which applies photocatalytic water splitting technology to produce green hydrogen directly from water and sunlight (Sparc Green Hydrogen Project). The technology has been progressed closer to commercialisation by the University of Adelaide (UoA) and Flinders University with their solar reactor design.

HIGHLIGHTS

INNOVATION PARTNERSHIP ESTABLISHED WITH AML3D LIMITED :
Prof Jamie Quinton and Prof Sarah Harmer. Research leaders from Flinders Institute for Nanoscale Science and Technology and Flinders Microscopy and Microanalysis, Prof Quinton and Prof Harmer will investigate the microstructure and corrosion qualities of AML3D's Wire Arc metal alloys.

AML 3D members Andrew Sales (left) and Dr Paul Colegrove (3rd from left) with Prof Jamie Quinton (2nd from left) and Prof Sarah Harmer (right).

Wire ARC metal alloy sample

HIGHLIGHTS 2022

ANNUAL NANO CONFERENCE AWARDS JUNE 2022

2022 Annual Nano Conference Student Poster Award Winner, **Elise Tuuri**

2022 Runner up Student Poster Award and People's Choice Award: Granted to **Zoe Gardner** (left) and **Sam Tonkin** (right) respectively.

BEST PHD THESIS OF 2022

This year we recognised two outstanding graduates from the Institute and have jointly awarded the Best PhD Thesis to Maximilian Mann and Matt Jellicoe.

Congratulations to Max, Matt and all PhD students who completed their postgraduate degrees in 2022.

Nano Institute Best PhD Thesis 2022 awarded to:

Joint Winner, **Dr. Maximilian Mann**, for thesis titled Sulfur Copolymers for Coatings, Composites and Mining Applications. Supervisors: Justin Chalker and Claire Lenehan

Joint Winner, **Dr. Matt Jellicoe**, for thesis titled Vortex Mediated Catalysis and Physico-Chemical Process Control. Supervisors: Colin Raston and Jamie Quinton

OTHER INSTITUTE AWARDS IN 2022

2022 Best Masters Student: **Zuhur Habib Alotaibi** "Investigation of Thin Aluminium Oxide Films Grown by Atomic Layer Deposition on Various Metal Oxide Substrates". Supervisor: Gunther Andersson

2022 Best Honours Student: **Georgina Tilly-Scholes** "Spatial and Temporal Assessment of Microplastics in a Constructed Stormwater Treatment Wetland via Flow Cytometry". Supervisor: Jim Mitchell

Prof Youhong Tang was the recipient of the Vice Chancellor's Award for Excellence in HDR Research Supervision in 2022.

National Institute for Materials Science, Japan, ICGP Fellowship: PhD student, **Qi Hu** was accepted into the National Institute for Material Science (NIMS) International Cooperative Graduate Program. This student fellowship will allow Qi to spend 12 months at NIMS in Japan conducting research into aggregation-induced emission (AIE) fluorescent sensors thanks to a long-standing partnership between NIMS and Flinders University, Institute for Nanoscale Science and Technology.

EXTERNAL AWARDS IN 2022

SA Environment Awards – Innovation Award

Award winner, **Dr Maximilian Mann**, with SA Environment Minister Susan Close MP. Max has been developing an innovative process to leach precious metals from e-waste using a cheap, widely available, water chlorination compound. His non-toxic precious metal extraction method promises to lessen the environmental impact of e-waste recycling in South Australia and beyond. Image credit – *Darren Clements/Conservation Council of SA.*

GREEN INDUSTRIES SA - CIRCULAR ECONOMY AWARDS

Dr Maximilian Mann – Chief Executive's Award

Maximilian's research investigated new technologies for e-waste recycling and included development and patenting of safe and low-cost methods to extract gold from e-waste, and the invention of methods to convert plastic and fibreglass from printed circuit boards into new construction materials. The Chief Executive's Award is awarded to the best overall application.

GREEN INDUSTRIES SA - CIRCULAR ECONOMY AWARDS

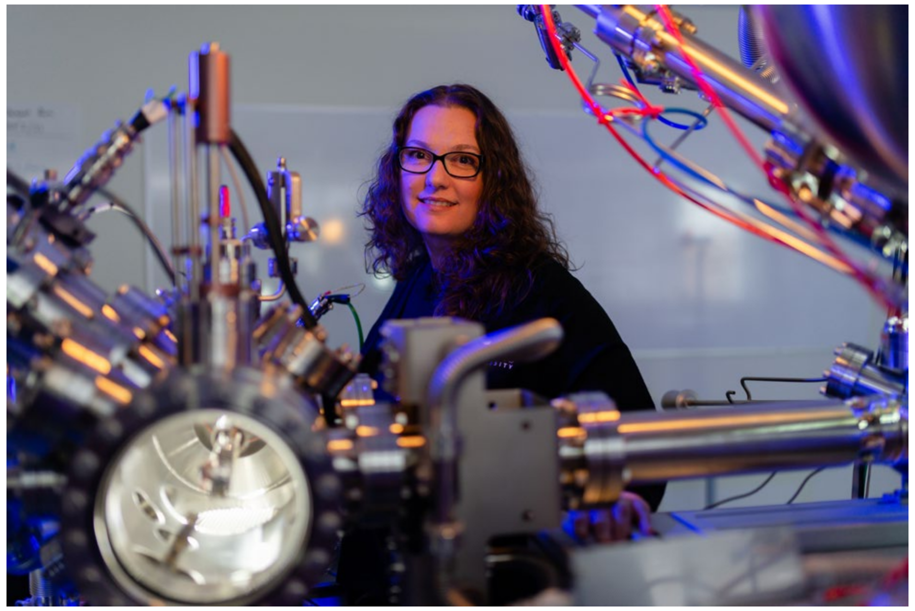
Yunzhong Wang – Honours Student Award

Yunzhong's research investigated the design, fabrication and evaluation of a novel, low-frequency ocean wave-driven generator that produces no pollution, has a lower cost and is environmentally friendly.

The generator utilises recyclable and sustainable material to fabricate an energy converter to harvest electricity from the low-frequency movement of the ocean wave and reduce carbon emissions during generation. The generator provides a potential application for offering electricity to the rural/remote areas close to the coastline, and to offshore islands.

Deputy Premier and Minister for Climate, Environment and Water Dr Susan Close, with Circular Economy Student Award winner Yunzhong Wang, and Green Industries SA Chief Executive Ian Overton. *Image credit Green Industries SA*

SA Women In Innovation – Winnovation Award for Science



Prof Sarah Harmer, the founding director of the Flinders Microscopy and Microanalysis facility, and deputy director of the Flinders Institute for Nanoscale Science and Technology won the 2022 SA Science Winnovation Award!

HIGHLIGHTS

SOUTH AUSTRALIAN SCIENCE EXCELLENCE AND INNOVATION AWARDS 2022

Congratulations to Finalists: **Jon Campbell** and **David Lewis** (3RT) who were finalists for 'SA Innovator of the year' for the second year running!

From left: Susan Close, Deputy Premier and Minister for Industry, Innovation and Science with Assoc/Prof Jon Campbell, Ashley Gabriel and Andrew Nunn. Image supplied by the Department for *Industry, Innovation and Science – SA Science Excellence and Innovation Awards*

COMPETITIVE GRANTS AND RESEARCH FUNDING ANNOUNCED IN 2022

Congratulations to Nano Institute member recipients of competitive research funding.

ARC Discovery

Dr Zhongfan Jia; Professor Kenichi Oyaizu; Professor Jodie Lutkenhaus (DP230100642). Folding polymers for high-performance energy storage. $389,349

Prof Justin Chalker; Dr Zhongfan Jia; Dr Thomas Hasell (DP230100587). Unusual trisulfide chemistry. $405,186

Prof Colin Raston AO FAA; Professor Qin Li; Dr Elsa Antunes (DP230100479). High shear fluid flow driving carbon foundry for advanced manufacturing. $590,136

Prof Vincent Craig; Prof Erica Wanless; **Prof Gunther Andersson;** Prof Alister Page; Prof Grant Webber (DP230102030). Deciphering ion specificity in complex electrolytes. $460,000

ARC Linkage Infrastructure, Equipment and Facilities (LIEF)

Dr Zhongfan Jia; Dr Xiaoguang Duan; **Professor Michelle Coote; Professor Justin Chalker; Dr Melanie MacGregor;** Dr Cameron Shearer; **Dr Christopher Gibson. LE230100168 Materials for Sustainability Analysis Facility.** $620,000

ARC Future Fellowships

Prof Justin Chalker. Sulfur-based materials for infrared optics and thermal imaging (FT220100054). $1,039,924

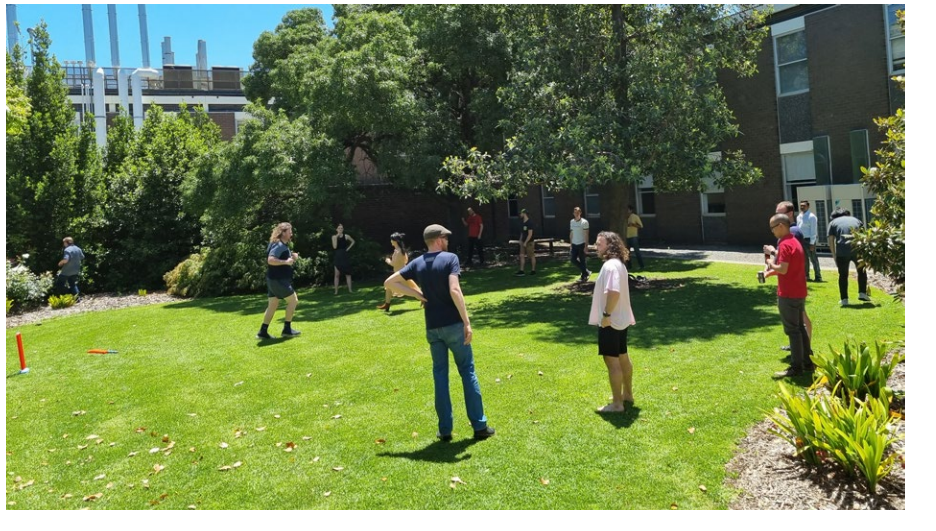
ARC Industrial Transformation Research Program

Prof Sophie Leterme (The Centre Director), Prof Mats Andersson (one of the Chief Investigators) in the Flinders University led, ARC Training Centre for Biofilm Research and Innovation. $4,930,205; Total project is $12.5M with 14 Chief Investigators and 18 Partner Investigators.

ARC Centre of Excellence

Prof Michelle Coote, one of the Chief Investigators in the 7 year, University of Queensland led, ARC Centre of Excellence in Quantum Biotechnology. Total project is $35M with 36 Chief Investigators.

NANO INSTITUTE SOCIAL EVENT 2022



In December 2022 we held our end of year event on campus at the Physical Sciences Courtyard.

Top: Research leaders and staff prepare a BBQ lunch for hard working students and ECRs.

Middle: Institute members celebrate achievements and enjoy food and drink together in the shade.

Bottom: Members relax and enjoy a friendly game of courtyard cricket.

HIGHLIGHTS

2021 PHD COMPLETIONS

TAYLOR, Jade Kirsten
Supervisors: Jamie Quinton and Sarah Harmer
Thesis title: Development of a High Spatial Resolution Mapping Technique for Pristine and Modified Carbon Surfaces using Scanning Auger Microscopy

PHILLIPS, Jessica Megan
Supervisors: Colin Raston and Justin Chalker
Thesis title: Enhancing Chemical and Biochemical Transformations in Dynamic Thin Films Under Flow

HOWARD-FABRETTO, Liam James Armand
Supervisor: Gunther Andersson, Sarah Harmer and Jamie Quinton
Thesis title: Spectroscopic Studies of Size-Selected Ru and Pt Clusters on Titania

SINGHAI, Gaurav
Supervisors: Ingo Köper and Jeroen Cornelissen (University of Twente)
Thesis title: Virus Coated DNA Nanostructures: A Biological Way for Drug Delivery

MARKHAM, Todd
Supervisors: Martin Johnston and Justin Chalker
Thesis title: Synthetic Modification of the Natural Pyrethrins

LUNDQUIST, Nicholas Aiden
Supervisors: Justin Chalker and Martin Johnston
Thesis title: Sustainable Sulfur Polymers for Environmental Remediation and Multifunctional Composite Materials

MCKERRAL (FISHER), Jody Claire
Supervisors: Jim Mitchell, Jerzy Filar and Nima Dehmamy
Thesis title: Universal Laws in Ecology

JOSEPH, Nikita
Supervisors: Colin Raston and Michael Michael
Thesis title: Advances on Vortex Fluidics for Processing Soft Matter Nanomaterials

AL-ANTAKI, Ahmed Hussein Mohammed
Supervisors: Colin Raston and Warren Lawrance
Thesis title: Manipulating 0D, 1D and 2D Nanomaterials by Vortex Fluidic Device

2022 PHD COMPLETIONS

MANN, Maximilian
Supervisors: Justin Chalker and Claire Lenehan
Thesis title: Sulfur Copolymers for Coatings, Composites and Mining Applications

JAMIESON, Tamar L.
Supervisors: Sophie Leterme and Harriet Whiley
Thesis title: Impact of Marine Organisms on the Functioning of a SWRO Desalination Plant

REZA, A. H. M. Mohsinul
Supervisors: Jian Qin, Youhong Tang, Sophie Leterme and Greg Barritt
Thesis title: A Novel Approach to Determine Lipid Inducing Conditions in Microalgae with Aggregation-Induced Emission-Based Fluorophores

HE, Zhen
Supervisors: Sarah Harmer, Guije Qian and Allan Pring
Thesis title: The Replacement of Chalcopyrite by Copper Sulphides and Its Application in Cu Extraction

CRAWLEY, Emily M.
Supervisors: Colin Raston and Briony Forbes
Thesis title: Towards Improved Methods of Insulin Production Utilising Vortex Fluidics

ASHENDEN, Alex J.
Supervisors: Ingo Köper and Jason Gascooke
Thesis title: Stability and Applications of Model Membranes

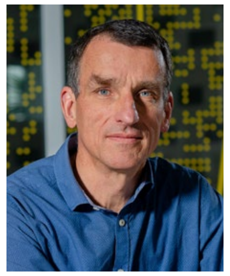
STACEY, Kaili N.
Supervisors: David Lewis and Joe Shapter
Thesis title: Synthesis and Characterisation of Tuneable, High Attachment Density, Raspberry Particles

JELLICOE, Matt
Supervisors: Colin Raston and Jamie Quinton
Thesis title: Vortex Mediated Catalysis and Physico-Chemical Process Control

SPANGLER, Jordan
Supervisors: Martin Johnston and Mike Perkins
Thesis title: Amphetamine Type Stimulants: An investigation of clandestine synthesis, impurity profiling and metabolic synthesis

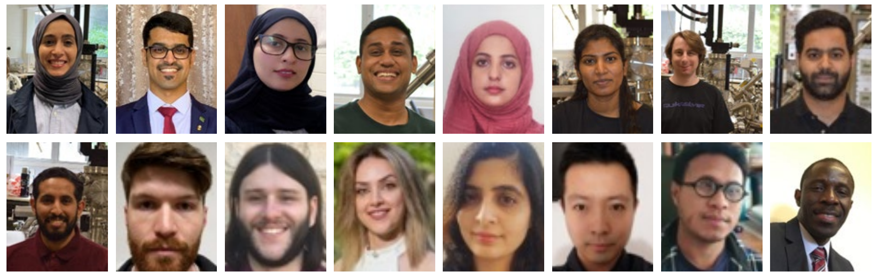
RESEARCH LEADERS

PROFESSOR GUNTHER ANDERSSON Deputy Director



The G. Andersson lab focusses on surfaces and interfaces, specifically clusters on solid surfaces, liquid surfaces, corrosion and polymer interfaces. The lab has unique methods and equipment available and can investigate surfaces under broadly varying conditions ranging from ultra-high vacuum conditions to liquid surfaces with finite vapour pressure. The latter capability allows analysing surfaces under conditions that are relevant for their application under conditions relevant in industrial applications.

Gunther joined Flinders University in 2007 after working in Germany, where he developed the depth profiling technique Neutral Impact Collision Ion Scattering Spectroscopy (NICISS) with sub-nanometre depth resolution. In his labs he now uses a large range of electron spectroscopy techniques for chemical surface analysis and determining the valence electron structure of occupied and unoccupied electronic states. His lab has specialised in developing methodology and techniques to analyse interfaces under a broad range experimental conditions including high temperature and corrosive environments.

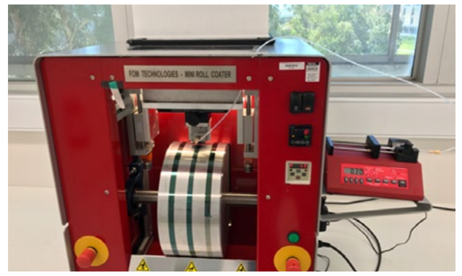


Top. Amira Alghamdi, Abdulrahman Alotabi, Ahlam Alharbi, Anand Kumar, Fatimah Al Sharyah, Gowri Krishnan, Alex Griesser, Abdulaziz Almutairi. Bottom: Mohammed Asiri, Jesse Daughtry, Dr Liam Howard-Fabretto, Anahita Motamedisade, Sunita Adhikari, Dr Yanting Yin, Thomas Ceme, Dr Gaius Eyu

PROFESSOR MATS ANDERSSON Director

Research in the M. Andersson lab includes organic chemistry, polymer synthesis and the structure–property relationship of conjugated materials. The lab has expertise in morphology characterisation as well as the application of polymers for many different industrially relevant topics including nanoparticles, polymer electronics, organic solar cells, insulating materials and antifouling coatings.

Mats is the Director of the Nano Institute and originally 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.



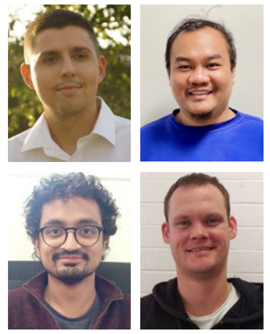
Top. Hussain Albattat, Anbarah Alzahrani, Ethan Bodey, Sait Elmas, Naveen Jain, Martyn Jevric,

Bottom. Bradley Kirk, Guler Kocak, Federico Muller, Caroline Pan, Leilaina Stefaniak, Po-Wei Yu.

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 remediation, 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 and recently to Professor. In 2020, Justin was awarded the Prime Minister's Prize for New Innovators. For more on his research, visit **the Chalker Lab.**

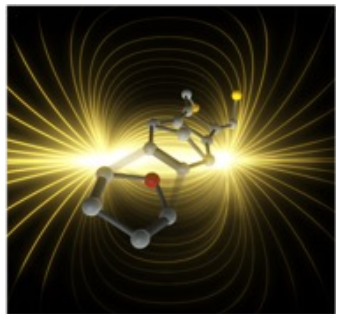


Back row from left. Imogen Smith, Dr. Maximilian Mann, Jasmine Pople, Samuel Tonkin, Dr. Nicholas Lundquist, Dr. Max Worthington, Prof. Justin Chalker. Front row from left. Batool Abdullah M Aljubran, Paris Pauling, Caroline Andersson, Israa Bu Najmah, Kilahney Murphy, Yousef Shayim Alshammari. Inset: Dr Witold Bloch, Alfrets Tikoalu, Dr Harshal Patel, Dr Thomas Nicholls. Not shown:, Dr. Louisa Esdaile, Ryan Shapter, Aoife Rutley, Noor Rezai

PROFESSOR
MICHELLE COOTE

The Coote lab applies a combination of theory and experimentation to study chemical reactivity and to design new catalysts and synthetic methods for application across polymer chemistry and small molecule synthesis. The current focus is on non-traditional methods of bond activation using electricity and light, and the group is a member of the ARC Centre of Excellence for Quantum Biology.

Michelle joined Flinders University in 2022 as a Matthew Flinders Professor in Chemistry, having moved from the Australian National University where she was a Georgina Sweet ARC Laureate Fellow. She is an Executive Editor of JACS, an elected fellow of the Australian Academy of Science, and has received numerous awards including the RACI Leighton, HG Smith, Rennie and Cornforth Medals. For more details on her research, see **the Coote Lab.**

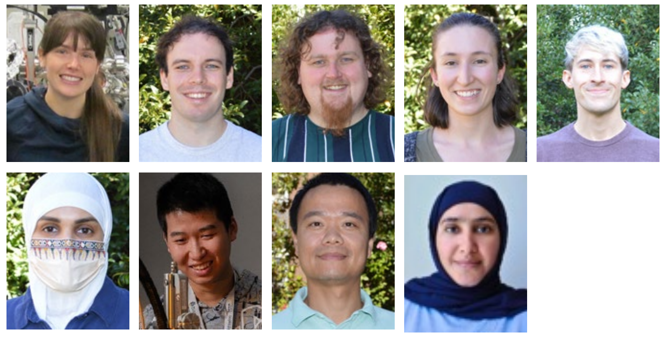


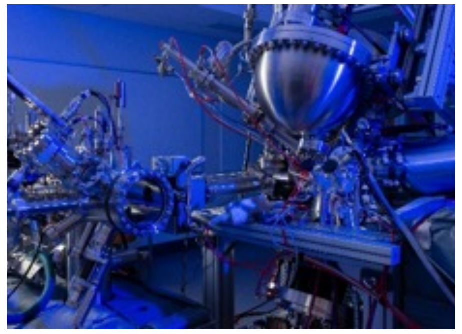
Members include Dr Le Nhan Pham, James Deng, Zhipeng Pei, Sayan Paul, Dr Jiao Yu Wang

PROFESSOR
SARAH HARMER Deputy Director

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, AML 3D, Norcada Inc., GLIER, BHP Billiton, Rio Tinto, MMG, FMG, Teck, Newmont, Okanes, MRIWA, AWE and the SA Government.

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 and unique instrumentation through NCRIS and ARC LIEF grants.



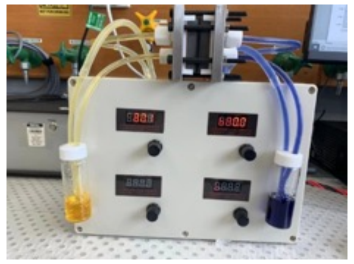


Top: Belinda Bleeze, Reece Waltrovitz, Alex Hayes, Danielle Hughes, Dylan Ricardi.
Bottom: Samar Safar S Almojadah, Zhen He, Dr Gujie Qian, Amal Alsaedi.
Not shown: Mitchell Griggs, Garrick Foy. Note – Danielle, Dylan and Garrick are 2022 Harmer group / 2021 Quinton group members.

ASSOCIATE PROFESSOR
ZHONGFAN JIA

The Jia lab focuses on the design, preparation, and characterisation of functional macromolecular structures to enable specific attributes and functions in engineered polymers. Using advanced organic and polymer chemistry, the group develops designer materials for applications in clean energy storage, green catalysis, sustainable environment, and health sectors.

Before joining Flinders University in 2020 as a Senior Lecturer in Chemistry, Zhongfan was a researcher and lecturer, with awards including an ARC Future Fellowship (2014–2018) and an Advance Queensland Industry Research Fellowship (2018–2020).



From Left: Chanaka Mudugamuwa, Yanbo Han. Not shown: Imogen Smith

ASSOCIATE PROFESSOR
MARTIN JOHNSTON

The Johnston lab focuses on using organic chemistry to solve applied chemical problems. Martin has worked extensively with a number of industries including Defence Science and Technology Group (DST), CSIRO, Forensic Science SA (FSSA) and Thales (Australian Munitions). The group extensively uses Nuclear Magnetic Resonance (NMR) spectroscopy for the characterisation of samples.

Rear: Martin Johnston, Jordan Oatway, Michael Mugford, Caroline Andersson.

Inset: Jordan Spangler. Front: Emma Kent, Todd Markham, James Tsoukalas.

Not shown: Joshua Gebhardt, Cameron Mellier.

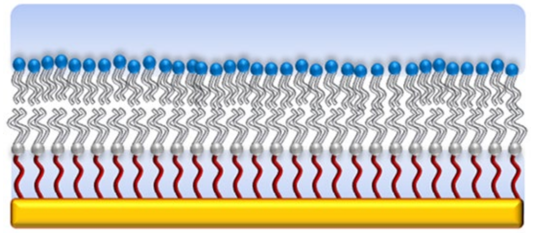
RESEARCH LEADERS

RESEARCH LEADERS

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.

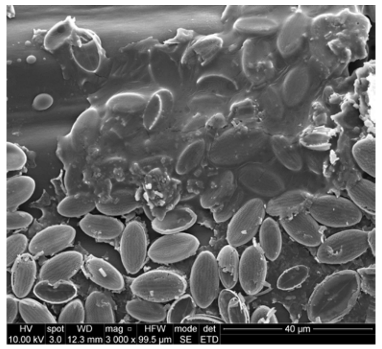


Top: Alex Ashenden, Braden Page, Brodie Parrot, Izaak Weidenhofer. Bottom: Essi Christian, Louisa Howard, Mayisha Ahmedullah, Ashley Carey.

PROFESSOR
SOPHIE LETERME

The Leterme Laboratory focuses on aquatic microbes via two research streams: (1) the effects of environmental change such as drought, eutrophication on plankton biology and (2) biofilm formation on surfaces immersed in aquatic systems, including water treatment and desalination plants.

Sophie joined Flinders University in 2006 as a post-doctoral researcher working on the ecology of the Coorong wetlands. She won a Lecturer position in 2008, conducting research on the adaptation of plankton to salinity fluctuations. She was the deputy node leader of SA-IMOS (South Australian Integrated Marine Observing System); 2009-2015) and was promoted to Associate Professor in 2016. Sophie led the Biofilm Research & Innovation Consortium (2018-2021) and is now the director of The ARC Training Centre for **Biofilm Research and Innovation.** Sophie also leads a research program on microplastic pollutants in Australian coastal waters **(@MicroplasticW).**

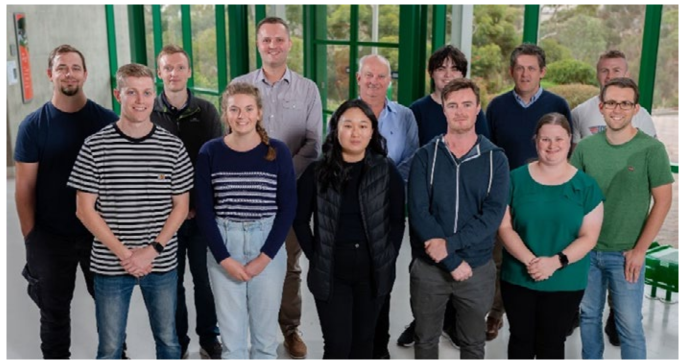


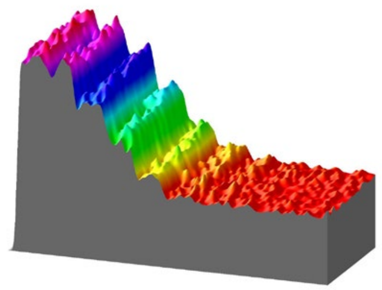
Top: Tamar Jamieson, Melissa Court, Bottom: Elise Tuuri, Sally Komar

PROFESSOR
DAVID LEWIS

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, printable solar cells and concentrated solar thermal energy.

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. Professor Lewis is the founding Director of the Nano Institute.



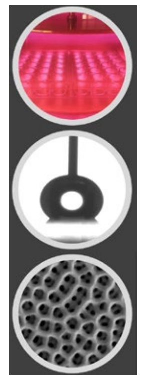


Back: Schannon Hamence, Dr Nick Rudgley, Dr Oskar Majewski, Prof David Lewis, Zac Dalton, A/Prof Jonathon Campbell, Nicholas Tugwell. Front: Elliott Jew, Kaili Stacey, Kay Chen, Dr. Rowan McDonough, Dr Jennie Bartle, Dr Jonas Bjuggren.

ASSOCIATE PROFESSOR
MELANIE MACGREGOR

The MacGregor lab's current research interests are functional nano-coatings. The research focuses on chemistry, wettability, reactivity and nano-topography of surfaces as key parameters to control the interaction between (bio)materials and their environment. The group specialises in plasma coating technology to produce engineered surfaces, primarily to address challenges faced by the biomedical and energy industries.

Melanie joined Flinders University in November 2021 as an ARC Future Fellow, after completing a Santos–University College London Research Fellowship at the Future Industries Institute. For her work on translational industry-driven projects she received the 2017 Winnovation Award in the Engineering category, and a 2018 SA Young Tall Poppy Science Award. She was also named a Superstar of STEM by Science & Technology Australia for promoting diversity in the STEM sector.



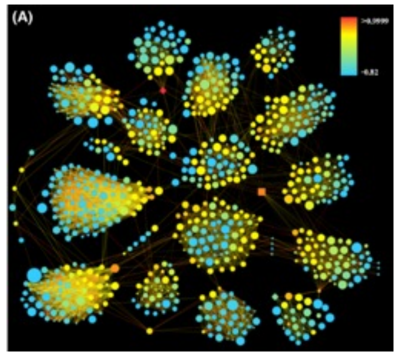
From left: Edward Hui, Manpreet Kaur, Melanie MacGregor, Iliana Delcheva, and Alex Gheorghiu

RESEARCH LEADERS

PROFESSOR JIM MITCHELL

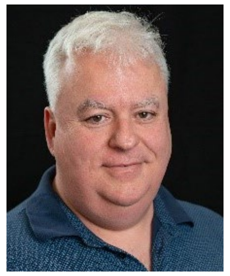
Research in the Mitchell group focuses on the influences of nanometre to micrometre scale processes on microbial ecosystems. Research outcomes have been used in creating new nanotechnology, including microfluidics and nanofabrication. As part of this research the group also investigates environmental 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



From left: Dr Jessica Carlson-Jones, Connor McIvor, Amy Annells, Abbey Hutton, Brooke Scott, Jacob Reeves, Reuben Wheeler, Dr James Paterson, Niki Romeo, Susie Grigson, Nicola Papazis, April Van Der Kamp, Dr Jody Fisher (McKerral), Prof Jim Mitchell. Not shown: Georgina Tilly-Scholes, Kristen Zidek, Dr Qi Yang

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.

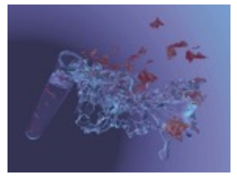
Jamie joined Flinders University in 2003 and was named the Flinders winner in the UniJobs Lecturer of the Year in 2009. He also received the Australian Learning and Teaching Council's Citation for Outstanding Contribution to Student Learning in 2010. From 2022 he is taking on the role of Professor and Head of the School of Natural Sciences at Massey University in Aotearoa, New Zealand, though remains a Research leader at the Nano Institute with full academic status.

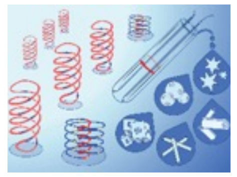
Left: Prof Jaime Quinton. Top: Danielle Hughes. Bottom: Dylan Ricardi. Not shown: Nathan Garner, Garrick Foy. Note – Danielle, Dylan and Garrick are more recently members of the Harmer group.

PROFESSOR COLIN RASTON

The Raston lab focuses its research on clean technology and green chemistry, microfluidics and self-assembly. With the invention of the vortex fluidic device (VFD), Prof. Raston has introduced a paradigm shift in continuous flow processing. Since 2012, over 100 publications have been completed on the VFD alone. In 2015, the device earned international recognition when Prof. Raston was awarded an Ig Nobel Prize in Chemistry for 'partially unboiling' an egg.

A Professor in Clean Technology and a former President of the Royal Australian Chemical Institute (RACI) 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 the Order of Australia, in 2018 was elected Fellow of the Australian Academy of Science and in 2020 was SA Scientist of the Year.





Back: Dr Shan He, Matt Jellicoe, Professor Colin Raston, Zoe Gardner, Ho Ho Nguyen Nguyen, Fayed Alrashaidi, Pradeep Malvi. Front: Dr Aghil Igder, Clarence Chuah, Dr Xuan Luo, Kilahney Murphey, Badriah Alotaibi, Amjad Alotaibi. Not shown: Dr Kasturi Vimalanathan, Spencer Petticrew, Soraya Rahpeima, Nikita Joseph, Emily Crawley.

PROFESSOR YOUHONG TANG

The Tang lab focuses its research efforts on the structure–process–property relationships of composite materials and chemo-/biosensing. The emphasis is on the design and manufacture of materials and devices to solve broad challenges faced by industry. Marine, bioresource, biomedical and sensing sectors are of particular interest, as well as integration of novel aggregation-induced emission luminogens (AIEgens).

Youhong joined Flinders in 2012 from the University of Sydney. His awards include a Flinders University Vice-Chancellor's Award for Early Career Researchers and an ARC Discovery Early Career Researcher Award. He is a Fellow of the Royal Society of Chemistry and a Fellow of the Royal Australian Chemical Institute.

From left: Tran Tam Anh Pham, Qi Hu, Voon Leong Chung, Clarence Chuah, Dr AHM Mohsinul Reza, Sharmin Rakhi, Dr Thanh Hoang Hai, Nyi Nyi Tun, Prof Youhong Tang, Yunzhong Wang, Zhijie Xu, Dr Damian Tohl, Dr Wenjin Xing, Yekai Jin. Not shown. Xinyi Zhang, Hao Fu, Chris Zhu, Dr Sanaz Naghibi, Amin Jamshidi Ghahfarokhi, Yu Guo

RESEARCH LEADERS

SHOWCASE STUDIES

ASSESSING BARRIERS TO REDUCING ENVIRONMENTAL RISKS USING ACID MINE DRAINAGE AS A CASE STUDY

Prof Sarah Harmer, Prof Andrea Gerson (Flinders University), Prof Roger Smart (University of South Australia), Dr Gujie Qian

This project aims to increase opportunities for post-mining community utilisation of mine wastes in Australia. The remediation of acid mine drainage wastes will be investigated at the mesoscale using microbiological and geochemical resources. The outcomes will impact policy and community practice through training and dissemination of best practice for prediction, remediation, and prevention.

Acid mine drainage (AMD, Figure 1) management and remediation in Australia at a significant cost of approximately $80 Billion dollars per year and hundreds of billions world-wide. Accurate forecasting and appropriate control of AMD is a common issue for mine sites with climate, geochemistry and microbiology all playing key roles. Incorrect forecasting may result in (1) Inadequate controls and strategies being put in place leading to downstream contamination of water ways, ecosystem and/or human health impacts and constraints on future site repurposing; (2) Inaccurate geochemical risk assessments (non-acid forming, NAF, waste rock and tailings being wrongly classified as potentially acid forming, PAF) resulting in inefficient utilisation of resources through expenditures that are not warranted; (3) Use of on-site remediation resources not being recognised; and (4) Lack of recognition of opportunities to understand and control beneficial microbial action.

This project aims to provide links between prediction, scale up and residual risk. There are potential improvements, utilising both mineralogy and microbiology, for assessment and remediation of the undersaturated mine waste zone through examination of the behaviour of mine wastes at a range of scales. This project aims to bridge the gap between lab-scale methodologies and mine-site implementation through emphasis on meso-scale testing of AMD/NMD (Neutral Mine Drainage) behaviours of mine waste at >1 t. By developing 1) understanding and using microbial activity for AMD control, 2) improved acid-base testing procedures for AMD/NMD waste disposal planning, and 3) accurate identification and quantification of sources of neutralisation end-user environments that are fit for purpose may be achieved.

The investigation of mine wastes from across a range of climatic zones and evolutionary stages of weathering and closure planning has been made possible by the $10.2M AUD cash and in-kind support from CRC TiME, MMG, Rio Tinto, BHP Billiton, FMG, Newmont, Teck, AGRF, Okanes, MRIWA, AWE, SA Govt., Tasmanian Govt, UQ and University of Windsor.

Figure 1: Queen River, Tasmania where 100 million tonnes of mine waste has been disposed over from the Mount Lyell mine [1].

[1] https://en.wikipedia.org/wiki/Queen_River,_Tasmania

HYDROGEN PRODUCTION FROM RENEWABLE ENERGY RESOURCES

Prof Gunther Andersson, Prof Greg Metha (University of Adelaide)

Achieving significant reduction in the emissions of CO_2 by society is critically dependent on sourcing energy from renewable resources rather than fossil fuels. Solar panels and wind turbines are well developed technologies for production of electric energy from sustainable resources, light and wind. However, energy demand, transport and storage pose a challenge due to the cyclic, intermittent and geospecific nature of the resources. Hydrogen is considered as a potential solution to these challenges. Most hydrogen is currently produced from fossil fuels and thus, through this process, cannot be considered as sustainable. Electrolysis[1], photoelectrochemical[2], and photocatalysis[3] methods are emerging technologies for producing hydrogen from renewable energy sources on sufficiently large scale to be industrially viable. The first of these technologies is at the highest technological readiness level (TRL) and the last is at the lowest TRL. All three technologies are at different stages in their development. It is expected that these technologies will have to produce hydrogen for $2 USD per kg hydrogen to be competitive in the energy market and thus to be used in future.

In electrolysis a combination of an electrolyser, water and a source of renewable electric energy, such as photovoltaic or wind energy, is used to split water into hydrogen and oxygen. It is expected that at an electricity price of $40 USD/MWh and capital costs of $500 to $1000 USD, 1kg of hydrogen can be produced for $2.00 – $2.50 USD.[1] This is about the same price as the stock market price of one gallon of gasoline which has approximately the same energy equivalent as 1 kg of hydrogen. Electrolysers have a high efficiency of > 80%. The challenge for this technology is to reduce the capital costs and in particular the use of precious metals in the electrolyser and to have renewable electric energy available at low costs. At the **Flinders Institute for Nanoscale Science and Technology**, research is undertaken to develop single atom catalysts needing an ultra-low amount of precious metal. While electricity from photovoltaic and wind energy has the lowest costs at the moment, the price for green energy could increase with increasing need for rare and expensive metals used in electrolysers in the future.

In photoelectrochemical water splitting, electrolysis and the solar cell function are integrated in one device. The challenge for this technology is to increase the efficiency to reduce the costs.

In photocatalysis (Figure 1) solar energy is directly converted into hydrogen thus there is no need for electric energy for the actual water splitting process. Photocatalysts with an apparent quantum efficiency (AQY) close to 100% exist[4], however, only from catalysts with a large bandgap allowing only the usage of the UV part of the solar spectrum. Thus, the solar to hydrogen (STH) efficiency of these photocatalysts is rather low, currently around 1 %. Key challenges for photocatalytic water splitting are to 1) develop catalysts with a smaller band gap to absorb a larger fraction of the solar spectrum thus increasing the STH efficiency, and 2) to develop large scale reactors. Researchers at Adelaide University and **Flinders Institute for Nanoscale Science and Technology** are working together on photocatalyst and reactor development in partnership with industry.

At the end of 2021 approximately 1 million barrels oil were used per day which is approximately 5.8 L of crude oil per person per day. The solar radiation per square metre per day is about 25 MJ. At an efficiency of 10% of a process, an area of approximately 50 x 50 km^2 would be needed to produce hydrogen with the same energy equivalent as one billion barrels of crude oil. Given how solar panels are already broadly installed in countries like Australia, the challenge of upscaling the technology for hydrogen production from renewable energy sources is a feasible target and could replace a significant fraction of crude oil and significantly reduce undesirable CO_2 emissions.

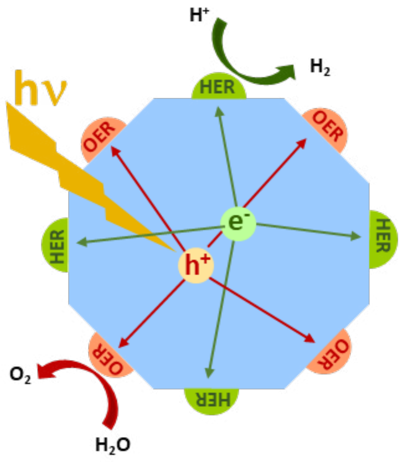


Figure 1: Schematic of photocatalytic water splitting. Light absorbed by a semiconductor (light blue) generates an electron (e^-) and hole (h^+) pair. The electron migrates to the hydrogen evolution site (HEC) to generate H_2 and the hole to the oxygen evolution site (OEC) to produce O_2.

References

1. Agency, I. E. The Future of Hydrogen; International Energy Agency: 2019.

2. Park, K.; Kim, Y. J.; Yoon, T.; David, S.; Song, Y. M. A methodological review on material growth and synthesis of solar-driven water splitting photoelectrochemical cells. RSC Advances 2019, 9, 30112-30124.

3. Wang, Q.; Domen, K. Particulate Photocatalysts for Light-Driven Water Splitting: Mechanisms, Challenges, and Design Strategies. Chem. Rev. 2020, 120, 919-985.

4. Takata, T.; Jiang, J.; Sakata, Y.; Nakabayashi, M.; Shibata, N.; Nandal, V.; Seki, K.; Hisatomi, T.; Domen, K. Photocatalytic Water Splitting with a Quantum Efficiency of Almost Unity. Nature 2020, 581, 411.

ACTIVE ANTIFOULING COATINGS FOR PREVENTING MARINE GROWTH

Prof Sophie Leterme and Prof Mats Andersson

Biofilms grow on all surfaces immersed in sea water and costs billions of dollars to control. Today there exist several ways to reduce the macroscopic biofilm growth. The most common and effective antifouling coatings include biocides such as copper that are slowly released into the seawater to prevent the marine growth. However, their widespread use has contaminated protected waters and raised concern about their toxic effect on non-targeted organisms. Our ongoing research on active antifouling technologies focuses on biocide-free, non-hazardous and sustainable antifouling alternatives.

Marine organism growth on underwater surfaces is a longstanding challenge for the marine industry. Once visible on a macroscopic scale, the growth on ship hulls reduces manoeuvrability and causes an increase in fuel consumption and concurrent greenhouse gas emissions. Unwanted marine species may also be introduced into non-native environments, putting marine ecosystems under increasing anthropogenic pressure. Specifically, biofouling causes severe damage to marine constructions and vessels and costs billions of dollars to control.

Traditionally antifouling is managed by applying antifouling coatings on ship hulls and other underwater surfaces that slowly release a toxic biocide, for example, a copper compound. The efficacy of these coatings depends on the type and release rate of the biocide. The continued use of these coatings has also led to increased contaminations of biocides in protected waters posing an existential threat to non-targeted species. These coatings are nowadays under regulatory pressure due to increased copper levels in protected waters and estuaries. An alternative to the biocide-based coatings is foul-release coatings but they are ineffective under stationary conditions and are prohibitively expensive.

Our ongoing research focuses on developing active antifouling coatings that are biocide-free, non-hazardous and scalable. Our focus is on developing electrically conducting coatings based on graphite filled paints and to evaluate the antifouling properties of these coatings under different electrochemical stress levels. To verify the efficacy of this method in situ testing was performed in Port River, Adelaide. The test coupons were connected in pairs and stressed with different currents. After 55 days in the sea water a significant amount of macrofouling could be seen on the control coupon, Figure 1 (left coupon). Macroscopic biofilm formation could be completely avoided using very small intermittent electrochemical stress levels, Figure 1 (right coupon).

Figure 1. Biofilm formation on conducting coatings after 55 days in in Port River (April-June), Adelaide. Control coupon (left) and a coupon exposed to intermittent electrochemical stress (right) during the experiment.

SHOWCASE STUDIES

TURNING LOW VALUE WOOD INTO QUALITY HARDWOOD

A/Prof Jonathan Campbell, Dr Jennie Bartle, Prof David Lewis

Researchers at the Institute of Nanoscale Science and Technology have collaborated with Australian company 3RT to create a range of high-quality hardwood products from low value forest residue. Whilst governments are tightening regulations on timber use and sustainability, the global market for hardwood is forecast to double by 2050. This demand cannot be met by current wood manufacturing practices. In creating their unique Designer Hardwood technology, the collaborative research team have responded to this alarming rate of forest and habitat loss, and a global shortage of hardwood.

Flinders researchers are working with Australian company 3RT to create innovative wood products called Designer Hardwood that you can now buy at your local hardware store!

There is simply not enough hardwood available due to increasing legislation to protect native forests, outdated sawmilling technology (conversion of a log to sawn hardwood can create 70% waste), and very slow natural growing process (it takes up to 100 years to grow full-sized hardwood trees). Current supply chain issues are exacerbating this problem in many industries that use wood and wood products.

The collaboration between 3RT and Flinders grew from a desire to use Australian wood species to create a novel wood product that has the visual appeal and excellent properties of natural hardwood, and which could be economically manufactured locally using undervalued and underutilised timber resources.

The Flinders team have leveraged skills in nanotechnology and polymer science to develop a combination of unique materials and processes for manufacture of this novel wood product that has equivalent stiffness and strength to hardwoods, high hardness and greater uniformity than sawn timbers despite being made from low grade timber materials such as forest residue. The properties of Designer Hardwood are superior to other common engineered wood products, such as medium density fibreboard (MDF) and particle board. Importantly these products can be machined like timber, so any normal wood working tools and finishing equipment can be used, and stains and coatings work similarly to regular wood products. Another important difference is preclusion of toxic ingredients, such as formaldehyde-based resins common in the wood industry, and a focus on water-based non-toxic components.

To enable the production of Designer Hardwood, the team has developed a new, programmable logic controlled digital production unit (PLC - DPU) incorporating advanced automation and robotics that produces consistent quality high-value hardwood blocks. This prototype machine produces products from a wide range of timber species enabling 3RT to scale up and successfully commercialise a suite of hardwood products and address this significant global environmental challenge. 3RT has recently formed a partnership with Bosch Australia to manufacture second generation production lines for installation here and abroad.

Current commercial products include panels, benchtops, posts and stair treads, with many other trial products made to test the capabilities of Designer Hardwood including tables, stairs, and even a cricket bat and skateboard. Research is continuing to introduce new features that are built-in to the product (rather than being added as a post-treatment) such as weather, water, UV, termite, rot and fire resistance by pre-treating the veneers and adhesives. Major research projects include developing structural properties using durable adhesives which prevent creep and delamination over the life of a building. Resistance to weather exposure is also a key focus. Weathering performance depends partly on the timber species used, but further preservative treatments are required in order to meet strict standards and certification requirements. Pre- and post-treatment trials include long term outdoor exposure and accelerated ageing studies to identify the best performing components.

Designer Hardwood won two awards at the prestigious Good Design Awards Ceremony: Engineering Design and a Gold Accolade for Design Excellence.

Figure 1. Variable patterns can be achieved through process parameter changes, here in Red Mahogany (image width 250mm)

Figure 2. Optical microscope image of product cross-section showing interface between recombined veneers and adhesive, similar to growth rings in timber (image width 15mm)

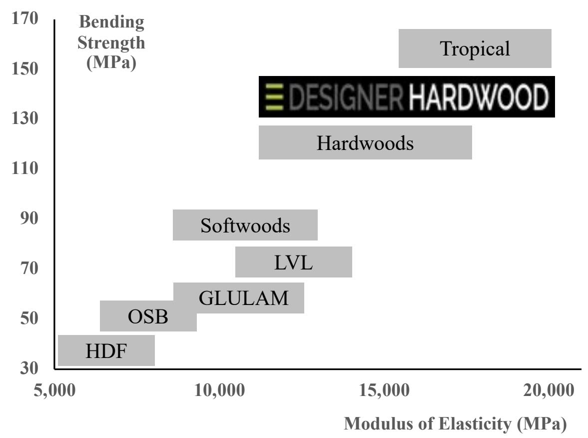


Figure 3. 3RT Designer Hardwood has the mechanical properties of hardwood and is superior to common engineered wood products, illustrated schematically as a comparison of bending strength and modulus of elasticity for various wood products.

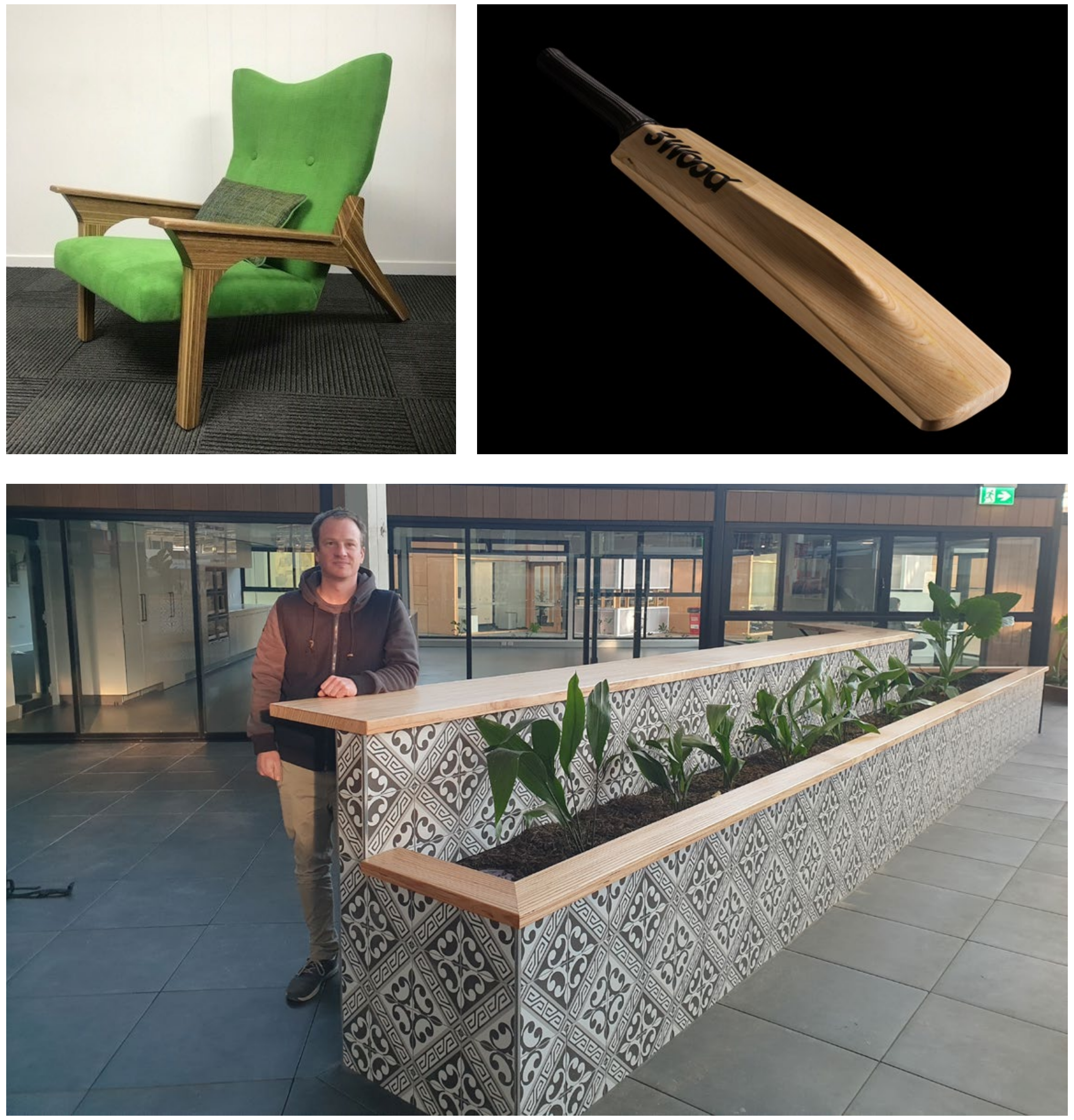


Figure 4. 3RT hardwood used for furniture, a cricket bat, and landscape edging made of joined and coated boards at the Tonsley MAB.

SHOWCASE STUDIES

SURFACE NANOENGINEERING FOR ENERGY AND BIOTECHNOLOGY APPLICATIONS

A/Prof Melanie Macgregor, Dr Iliana Delcheva

Associate Professor Melanie Macgregor joined the nano Institute in November 2021. Her research group brings new expertise and capabilities in surface nanoengineering and thin film characterisation.

Using fabrication methods such as plasma polymerisation, nanoparticle self-assembly and electro-etching, the MacGregor lab develops functional materials for application in the biotechnology, energy and environment fields. The coatings created can be deposited on all types of bulk materials (metals, ceramics, polymers, and composites) to control their surface chemistry, reactivity, wetting and structural properties.

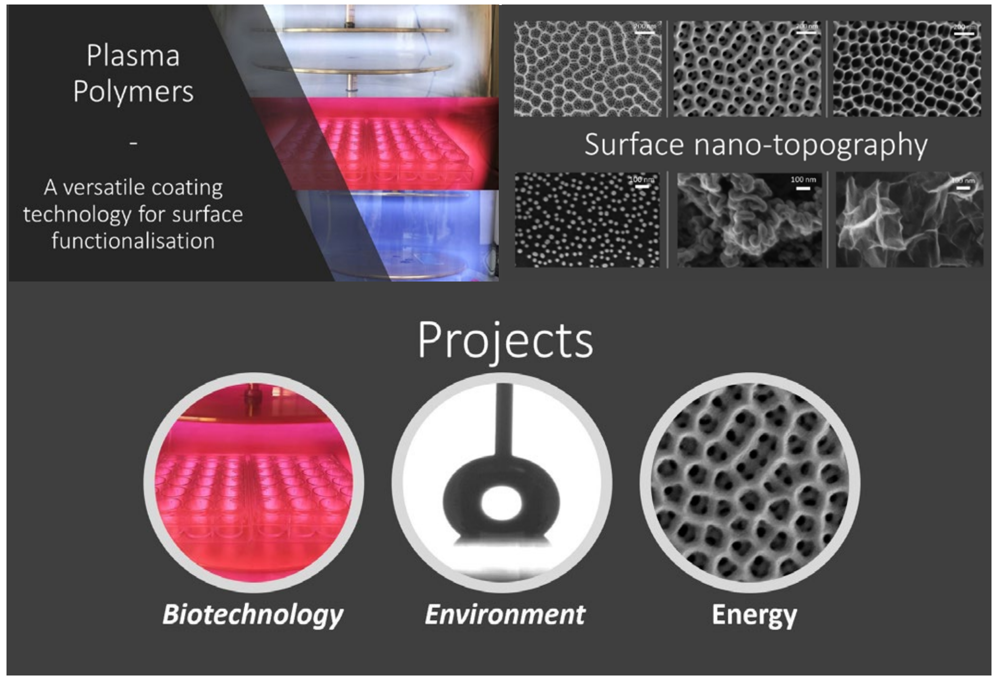
The Macgregor lab brings capability for thin film physico-chemical characterisation via contact angle measurement, surface tension, surface energy (OCA15EC system), film thickness and optical properties (Vase ellipsometer J.A. Woollam). Additional features include PC2 cell culture facility, laminar flow cabinets, O_2 plasma cleaner and curing oven for microfluidics preparation.

Project examples:

Energy: Collaboration with ETH group leader Prof Victor Mougel, on the development of superhydrophobic nano-engineered catalyst interfaces for nitrogen conversion into Ammonia.

Bio-Nano: On-going collaboration with clinicians and biologists at Flinders Medical Centre (FMC), where the interdisciplinary team explore new biotechnologies for the detection of urological cancers from urine samples, via the capture of cancer cells and exosomes with surfaces and devices designed and fabricated in the Macgregor Lab.

Environment: Part of her ARC Future fellowship, A/Prof Macgregor is engineering functional surfaces/materials and studying surface-particle interactions with RAMAN spectroscopy to discover new approaches for capturing nano-plastic pollutants.



Plasma polymerisation is used to modify surface reactivity of biomaterials towards the selective capture of nano-analytes in biomedical devices. Control over surface wetting is vital for microfluidic devices and surface interactions. Nano-structured titanium surfaces prepared via electro etching, where the high surface area created is used to reach superhydrophobic wetting states for heterocatalysis.

DESIGNER POLYMERS FOR AQUEOUS REDOX FLOW BATTERIES

Chanaka Mudugamuwa, Thidas N. Abeysinghe, Prof Justin M. Chalker, Prof Jodie L. Lutkenhaus (TAMU, USA), A/Prof Zhongfan Jia

Aqueous redox flow batteries (ARFBs) have emerged as large-scale and safe energy storage systems that are ideal for storing renewable energy from solar or wind farms. While water-soluble redox-active polymers (RAPs) have emerged as attractive electroactive materials for ARFBs, little is known about how charged functionalities dictate their electrochemical behaviour. Our ongoing efforts are to produce optimised RAP structures to improve ARFB performance.

Water-soluble redox-active polymers (RAPs) have emerged as attractive electroactive materials for aqueous redox flow batteries because these systems rely on readily available size-exclusion membranes, rather than expensive ion-selective membranes. While incorporating ionic units to polymers is the most effective strategy to form water-soluble RAPs, little is known about how charges dictate their electrochemical behavior.

The Jia group have designed a series of water-soluble TEMPO (2,2,6,6-tetramethylpiperidyl-1-oxy) radical polyelectrolytes with identical radical distribution but various charges through a sequential post-modification method. Physical and electrochemical characterizations show disparate diffusion coefficients (D) and charge transfer kinetics (k^0) of these radical polyelectrolytes at various pH. In particular, pH exerts a strong impact on k^0 of the negatively charged polymer. The determined bimolecular reaction rate k_{ex} shows electrostatic interactions between charged segments can enhance the electron self-exchange reaction rate by 10-fold.

The results suggest that charge effects are of great importance when designing water-soluble redox polymers for ARFBs and other applications. This work also provides crucial insights into the charge transfer mechanism of redox-active polyelectrolytes and the application of macromolecules in the emerging polymer energy storage fields.

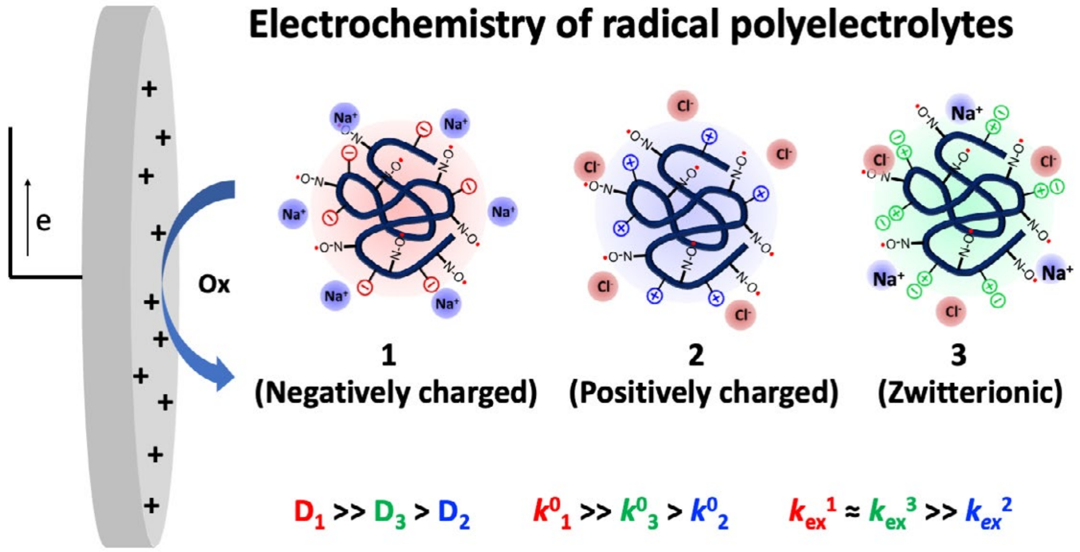


Figure 1. Charge-dictated electrochemical kinetics of radical polyelectrolytes for ARFBs

PHOTOEMISSION ELECTRON MICROSCOPY

Dr Benjamin Chambers, Dr Darryl Jones and Prof. Sarah Harmer
Flinders Microscopy and MicroAnalysis (FMMA):

Photoemission is the most information rich and widely used techniques for the elucidation of the electronic structure, surface states and chemistry of materials. The NanoESCA III, recently commissioned in Flinders Microscopy and Microanalysis, is a photoemission electron microscope (PEEM) that images surfaces by focussing and detecting electrons emitted from a material following irradiation with UV and X-ray light. The primary capabilities include spatial mapping of the surface morphology, elemental and chemical compositions, and the electron band-structure of the materials.

Photoemission electron microscopy is suitable for measuring the chemical and physical properties of conductive samples in an ultra-high vacuum environment.

Photoemission electrons generated by UV light (21.2 / 40.8 eV) can be focused and detected to construct an image of the surface. PEEM images have contrast created by variations in the surface morphology, probability of photoemission, and work function across the surface. The PEEM energy-filtered images have a lateral resolution of <50nm.

The photoemission process can also be used for chemical analysis by imaging photoemission electrons generated by X-ray light (monochromated Al K_α 1486 eV) (XPEEM). These XPEEM images allow for chemical mapping of the sample with lateral resolutions of ~50 nm. The NanoESCA III is also capable of small spot (~500 nm - 200 µm) X-ray photoelectron spectroscopy (XPS).

In addition to imaging the surface in real space, the electrons can be focused onto the detector in a way to observe the momentum of the photoemission electrons. These momentum images map the variation in electron ejection angles, to provide a form of angle-resolved photoelectron spectroscopy (ARPES). This enables momentum microscopy, where imaging is combined with ARPES to provide a powerful technique for investigating the electronic band structure of materials.

The NanoESCA III enables the direct correlation between electron band-structure of advanced materials with device function. This is essential for understanding electron transport in materials including topological insulators and transistors for quantum computing, nanomaterials for energy storage devices and catalysis, and minerals for geoscience.

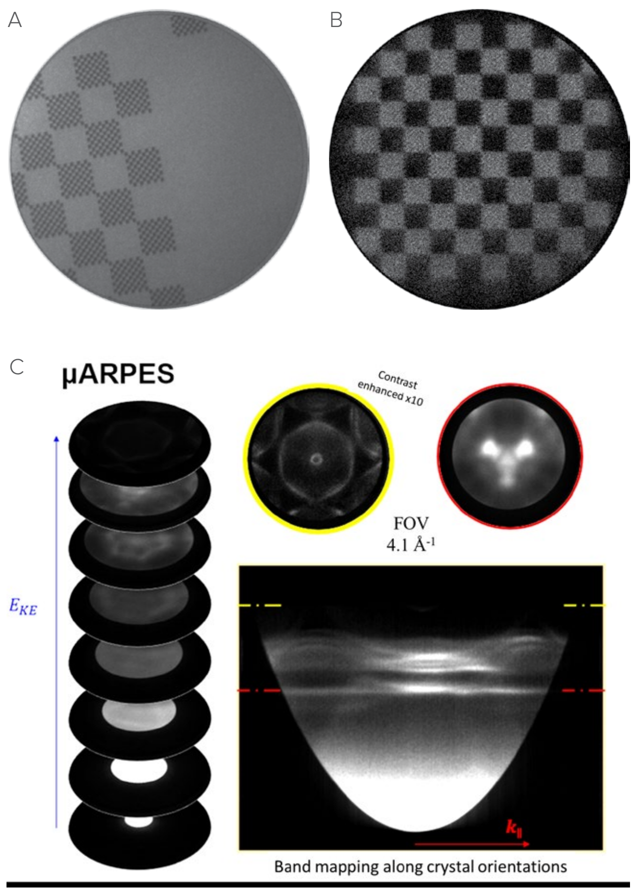


Figure 1 (A) PEEM image of silicon sample with 1 µm gold squares in a grid of 10 µm. FoV 82.8 µm. (B) XPEEM Gold 4f filtered energy image of gold on silicon. FoV 112 µm.

(C) Fermi surface map and band mapping of Au (111) surface using ARPES and momentum microscopy. FoV 4.1 $Å^{-1}$.

CATALYSING CHEMICAL REACTIONS WITH ELECTRIC FIELDS

Prof. Michelle Coote

From fertilisers and fuels to pharmaceuticals and smart phones, chemical synthesis underpins virtually every aspect of modern life. However, assembling complex molecules from simpler building blocks often requires significant energy inputs, uses dangerous reagents, and generates significant waste streams. A revolution in chemical synthesis is urgently needed: one that will directly address the global demands for safer and greener chemical processes. Electricity offers an untapped opportunity to promote chemical reactions under mild conditions, often without the need for additional chemical reagents or catalysts, and with fewer processing steps. Our on-going research is aimed at developing effective methods for harnessing electricity to promote cleaner, greener chemical synthesis.

At their most fundamental level, chemical reactions can be thought of as the rearrangement of positively charged nuclei and negatively charged electrons, and, as such, they should be amenable to influence by electric fields (Figure 1A). Although electrostatics are harnessed widely in nature by enzymes, they have been largely ignored in chemical synthesis until now. Recently, we provided the first demonstration that external electric fields can catalyse an ordinary bond forming reaction, using a technique called scanning tunnelling microscopy to deliver an electric field, align molecules in it and measure the effect of that field on the reaction rate. We also designed and demonstrated a simpler 'low-tech' approach for harnessing electric fields in chemical catalysis using charged functional groups. These charged groups generate their own internal electric fields that have dramatic effects on chemical reactions. We have shown that these can increase the activity of catalysts and improve their selectivity. For instance, by including a positively charged functional group on a modified proline catalyst for aldol reactions, we can either increase the % enantioselectivity from 12% to 71%. Alternatively, including a negatively charged group allows one to target the other isomer instead. Using this approach, we have developed improved catalysts for a broad range of chemical and photochemical transformations.

Nonetheless, the holy grail is to develop a simple scalable platform for harnessing external electric fields for chemical-free catalysis. As a first step in this direction, we have now shown that when ionic liquids are exposed to an external electric potential, they align themselves to the applied field generating their own internal electric field that can persist for hours after the external potential is removed. Our multiscale simulations have shown that these internal fields are capable of extraordinary chemical catalysis, even after the external potential is removed. We are now working on the design of experimental reactors for carrying out reactions in these ordered solvent environments (Figure 1B).

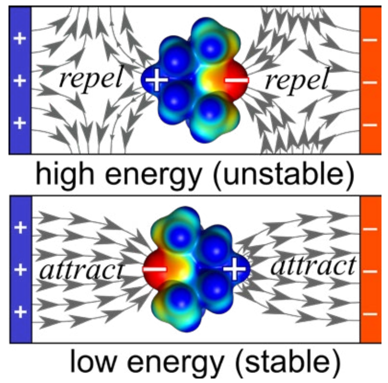


Figure 1A. Depending on their orientation, electric fields can stabilize or destabilize molecules.

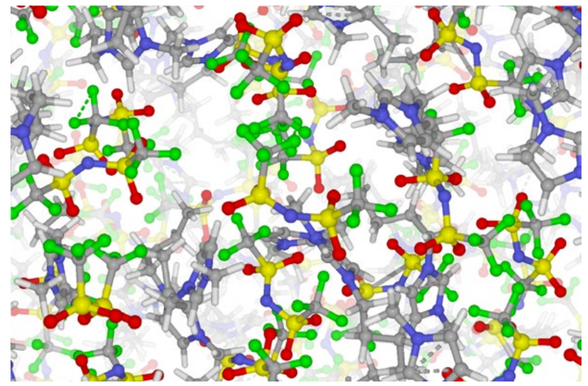


Figure 1B. When an electric field is applied to an ionic liquid the ions align to this field, and this ordered solvent environment generates a large internal field capable of persisting for multiple hours. This ordered environment can be harnessed for electrostatic catalysis.

SHOWCASE STUDIES

STRATEGIC RESEARCH AREAS

ENVIRONMENT

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

Our researchers are driving positive environmental change and contributing to the development of sustainable technologies. We are working on marine, mining and manufacturing projects with key goals to find green and sustainable ways of doing things. We're using clever chemistry, repurposed materials, and ways approaches 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.

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

ENERGY

We aim to innovate the ways we generate, store and use energy.

Ever increasing demand for energy has strained non-sustainable resources and contributed to adverse climate change, the biggest threat facing the planet. Renewable energy, a sustainable and green alternative to fossil fuels, provides energy that doesn't deplete the Earth's resources and pollute the environment. Our researchers are working to improve clean energy—the way we collect, store and harness it.

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

SECURITY

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

New security demands are constantly being placed on Australia. We face a rapidly shifting landscape across industry, 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 to protect against the undesirable.

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

BIO-NANO

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

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.

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

CORE

We develop advanced material fabrication methods and advanced characterisation techniques that enable our strategic research areas. We drive fundamental science and technologies for the advancement of knowledge in nanoscience and work towards a sustainable world.

RESEARCH STORIES

SUPPRESSION OF PHOSPHINE-PROTECTED Au_9 CLUSTERS AGGLOMERATION ON $SrTiO_3$ PARTICLES USING A CHROMIUM HYDROXIDE LAYER

Abdulrahman S. Alotabi, D. J. Osborn (University of Adelaide), Shuhei Ozaki (Tokyo University of Science), Yuki Kataoka (Tokyo University of Science), Yuichi Negishi (Tokyo University of Science), Siriluck Tesana (University of Canterbury), Gregory F. Metha (University of Adelaide) and Gunther G. Andersson

Photocatalytic water splitting is a renewable method for producing hydrogen and oxygen using photocatalysts and solar energy. Where water can be split, at the surface of a semiconductor material under solar irradiation, into hydrogen and oxygen. Here, our aim is to improve the efficiency of the water splitting process by modifying a photocatalyst with metal clusters consisting of a few atoms and then covering the clusters with a metal oxide layer to improve their stability.

Gold (Au) clusters have been shown to have great potential for use as co-catalysts in photocatalytic water splitting. However, agglomeration of Au clusters into larger particles when deposited onto semiconductor surfaces, is a major challenge that must be overcome. Metal oxide overlayers can be used to improve the stability of Au clusters on surfaces and avoid their agglomeration. The aim of this work is to use phosphine-protected Au_9 clusters beneath a $Cr(OH)_3$ overlayer investigate inhibition of agglomeration under photocatalytic water splitting conditions (i.e. UV irradiation). Au_9 was deposited on the surface of $SrTiO_3$ using a solution impregnation method followed by photodeposition of a $Cr(OH)_3$ layer. After UV light irradiation for 7 hours, uncovered Au clusters on $SrTiO_3$ agglomerated into larger particles. However, agglomeration was inhibited when a thin $Cr(OH)_3$ layer was deposited onto the $SrTiO_3$-Au_9 system. From careful XPS measurements, the chemical state of the overlayer is initially determined to be $Cr(OH)_3$ but upon heating at 200 ˚C for 10 mins it converts to Cr_2O_3. Through photocatalysis experiments it was found that the $Cr(OH)_3$ overlayer blocks the sites for O evolution reaction on the $SrTiO_3$-Au_9.

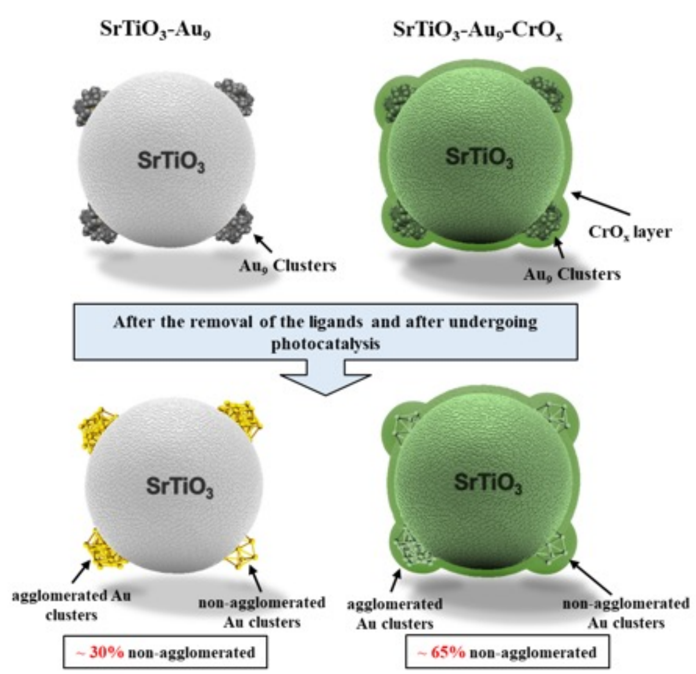


Figure 1. Schematic illustration of experimental procedure showing the clusters are covered by the overlayer.

UNDERSTANDING SPECIFIC ION EFFECT AT AQUEOUS AND NON-AQUEOUS SOLVENT SURFACES USING NEUTRAL IMPACT COLLISION ION SCATTERING SPECTROSCOPY (NICISS)

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

The specific ion effect relates to the influence of specific ions over various physicochemical phenomena. Key is the identity of the ions in question, for example potassium iodide salt is used to hypothyroidism but changing the anion (i.e., iodide to fluoride) makes a potassium salt poisonous for humans. Such effects also influence a wide range of topics like electrode performance in batteries and reactions at aerosol droplets in the atmosphere.

Our research group is looking for the physicochemical mechanism or cues in order to predict dramatic changes in properties related to specific ion effects. As a part of this research group, I am studying specific ion effects at various solvent surfaces.

The specific ion effect has been under investigation since Jean Léonard Marie Poiseuille in the early 19th century measured the viscosity of various salty solutions and found that some salts increase the viscosity of water while other salts decrease it.

Our research group is investigating these specific ion effects in various unrelated phenomenon like S_N2 reaction pathways, in bulk of various solvents, at different solvent surfaces, around biomimetic polymer structures and polymer brushes by the means of computational calculations and various experimental approaches.

As a part of this research group, Prof. Andersson and I are investigating specific ion effects at glycerol, formamide, benzyl alcohol, propylene carbonate and water surfaces employing NICISS. For specific ion investigation at solvent surfaces, NICISS provides advantages over most currently available surface-sensitive techniques as it can measure separate ion contributions. With NICISS we have made novel observations of complex ionic behaviour at various solvent surfaces. Most significant observations measured so far are:

1. The process for enhanced concentration of anions and depletion of cations at solvent surfaces behind the overall depletion of electrolyte solvent surfaces. This has been a poorly understood matter for few decades.
2. We have observed that specific ion effects at formamide surfaces is completely reversed when compared to specific ion effects at water surfaces.
3. After combining all the observations of specific ion effects at 5 listed solvents surfaces, we have built a hypothesis that, this specific ion effects at solvent surface can be defined based on ionic behaviour in solvent's bulk which is currently being analysed in detail.

Throughout this detailed investigation we have looked at various physical properties of ions and solvents that is simplified in figure 1.

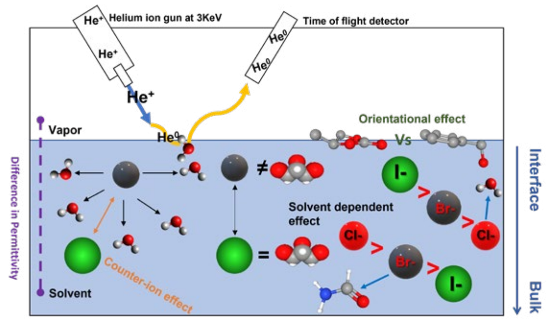
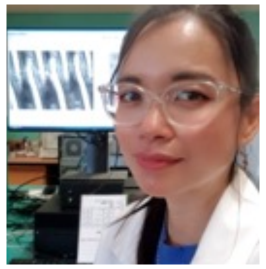


Figure 1. Using NICISS we have measured the concentration depth profile of ions at 5 different solvent surfaces and examined physical properties of dielectric permittivity, ion and solvent polarizability, solvent orientation effects at vapor-solvent interfaces and counter-ion dependent effect in order to explain specific ion behaviour.



TRACING MICROPLASTICS AT WASTEWATER TREATMENT PLANTS: METHODS DEVELOPMENT

Anggelia Essi Christian, Melody Lau (SA Water), Milena Fernandes (SA Water), Shima Ziajahromi (Griffith University), Paul Kirkbride (Flinders University), Ingo Köper

Microplastics, small particles of plastic found in the environment, are one of the major environmental issues that have emerged over the past decade. Yet, to date, there are not standard methods to identify, quantify, and characterize microplastics, especially for solid waste, i.e., sludge and biosolid, at wastewater treatment plants.

This research aims to develop a technique for microplastics analysis focusing on waste solid stream so that the results can be used to study the treatment efficacy in removing microplastics as well as spatial and temporal distribution of microplastics.

One of the pathways of microplastics is believed to be through biosolids from wastewater treatment plants that are applied for land and agricultural purposes (Figure 1A). While their abundance limit in the environment is still unknown, there is an urgent need to establish methods for microplastics analysis in environmental sample matrices.

Recognizing that there are no standard methods for microplastics as yet, and that a wide variety of instruments are used with different parameter obtained, this research is combining some analytical instruments. This includes stereomicroscopy, FTR and Raman micro spectroscopy, Flow Cytometry, and Pyrolysis-Gas Chromatography/Mass Spectrometry.

An analysis flow chart process has been developed as the first step of this research project so that systematic data on amount of microplastic, size (ranged 0.2 µm – 3 mm), chemical characteristics, as well as possible source, are obtained. The next step of this research is validation and verification of the developed analysis flow chart, so that it can be used for routine analysis and further stages of the project i.e., to study treatment efficacy, effect of season, mapping, and trend analysis.

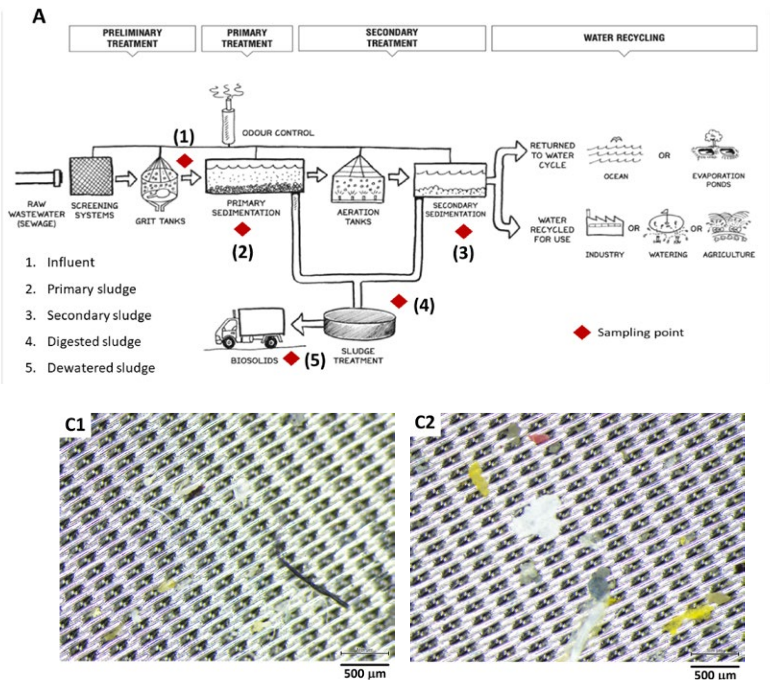


Figure 1: (A) Sampling points in which samples were collected and analyzed for microplastics.

Examples of microplastics/fibers >25 µm under stereomicroscope (40X magnification; 500 µm size scale) isolated from (C1) Primary Sludge; (C2) Secondary Sludge

ENVIRONMENT

DEVELOPMENT AND CLINICAL EVALUATION OF A FLUORESCENT SENSING BASED PORTABLE MEDICAL OPEN PLATFORM

Anh Tran Tam Pham, Damian Tohl, Angus Wallace, Qi Hu, Jordan Li (Flinders Medical Centre), Karen J Reynolds, Youhong Tang

Fluorescence measurement, a powerful method to monitor analytes present in solutions, has been applied to the development of portable analysers for decades. However, personal use of these portable fluorescence analysers is limited due to the sensitivity of the recognising reagents, the skilled-training requirement for the users, device complexity. In this study, we developed an open platform, which can detect multiple analytes following the principle of fluorescence measurement. This platform is being tested to support patients to screen and monitor kidney disease biomarkers in body fluids, such as urine at home or remote and rural limited healthcare facilities.

In this study, we have developed an open platform running fluorescence measurement to monitor biomarkers in body fluidic samples. The open platform allows users to simply modify the optical parameters to perform different measurements of multiple biomarkers in body fluids. Essentially, the device can provide a wide range of excitation wavelengths for various fluorescence measurements. Meanwhile, the optical sensor has a wide sensitivity range in the visible spectrum for detecting most of the fluorescent signal yielded the tests.

The evaluation case study consisted of screening and monitoring albumin concentration in urine samples. The study comprises of two stages. Stage one is to confirm the "open" feature of the platform by using the platform to monitor albumin level in different required optical conditions of excitation and emission wavelengths. Stage two is to examine the platform's reliability and accuracy by comparing the albumin results obtained from the platform with the clinical results from SA Pathology.

The preliminary results have shown a promising performance in that the platform satisfies the "open" feature to detect specific biomarkers under different optical conditions with acceptable sensitivities. In the next step, the platform will continue to be evaluated on reliability with a larger number of patient samples.

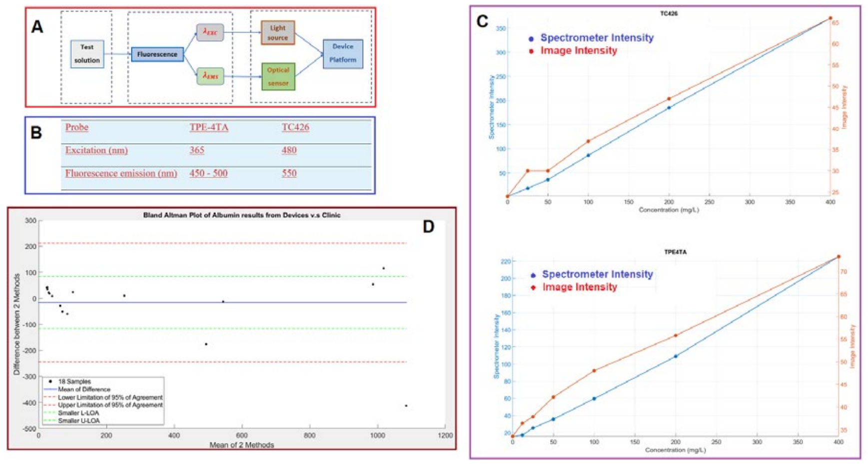
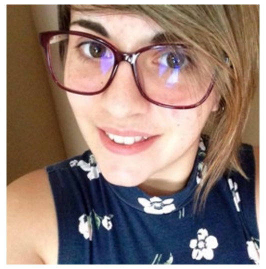


Fig. 1. A. The design principle of the fluorescence measuring open platform. B. Florescent biosensors having different optical features have been used in the platform to measure urine albumin. C. Case study – Stage 1 – Albumin results obtained from the developed platform compared with the commercial fluorescence spectrometer. D. Case study – Stage 2 – Albumin results obtained from the developed platform compared with the clinical results from SA Pathology.

BIO-NANO, CORE



FROM SUPERBUGS TO SUPERMODELS: EXPOSING ANTIMICROBIAL RESISTANCE THROUGH MEMBRANE MODELLING

Ashley Brooke Carey, Bart Eijkelkamp (Flinders University), Ingo Köper

The structure and composition of multidrug-resistant pathogen membranes can dictate the effectiveness of antibiotics. With the global epidemic of antibiotic resistance unfolding, membranes of such pathogens are modelled using whole-cell extracts to obtain a biologically accurate study platform. The models can be used to study membrane-active antibiotics and resistance proteins to help elucidate the poorly understood mechanisms behind antibiotic resistance development and antibiotic action.

Despite antibiotic potency, the rapid evolution of bacterial pathogens that are resistant to the biocidal action of multiple antibiotic compounds threatens the efficacy of all available antibiotics. Understanding the mechanisms behind antibiotic function and pathogen resistance development will offer new pathways to combat bacterial infections.
The cellular membrane of bacterial pathogens is a highly complex and organised structure that can vary significantly between different species and within strains.
The membrane has a high degree of functional, chemical, and physical variability which is determined by its composition. Pathogen survival adaptions in response to antibiotics can induce changes in the native membrane composition which, in turn, alters intrinsic membrane properties. These changes can not only help pathogens defend against antibiotic effects but also evade the host immune attack and influence protein function. Given the influence the membrane has on antibiotic efficacy, it is an attractive target for antibiotic treatment which, for development, requires a comprehensive biophysical understanding of drug-membrane interactions.

Bacterial models have size, biosafety, structural complexity, methodological and analytical diversity limitations which makes the measurement of biophysical interactions difficult. To mitigate these limitations, the in vitro model membrane systems tethered bilayer lipid membranes (tBLMs) were utilised (Figure 1). tBLMs consist of a phospholipid bilayer anchored to a solid substrate via the proximal leaflet. tBLMs are stable, robust, and analytically-versatile biomimetic membrane systems that recreate the fundamental features of biological membranes whilst reducing their innate complexity.

tBLM models of two clinically-relevant bacterial Gram-negative and Gram-positive pathogens, Acinetobacter baumannii and Staphylococcus aureus, were generated by fusing whole-cell bacterial extracts with a tethered monolayer. Both strains seemed to form functional bilayers as seen by their electrical properties. The lipid composition of the bacterial extracts was retained in the model systems. Their structures have been analysed using neutron scattering. The addition of antibiotics led to slight structural changes.

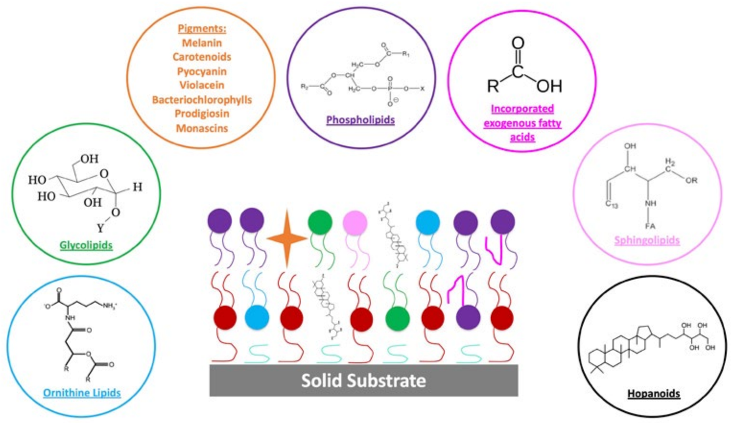


Figure 1: Schematic of the compositional diversity in the model pathogen tBLM architectures. The circle represents the lipid headgroup moieties, and the attached lines represent the fatty acid moieties. The red structures represent the membrane-substrate anchoring molecule, and the turquoise line representing the spacer molecule.

INVESTIGATING THE THERMAL STABILITY OF SLOT-DIE COATED ORGANIC SOLAR CELLS

Bradley Kirk, Gunther Andersson, Mats Andersson

Large-scale printing of Organic Photovoltaic (OPV) devices have shown to be an effective method of manufacturing solar panels that are flexible, cost-effective, light-weight, and are able to work effectively under low light conditions. Though OPV research has seen massive strides in the improvement of device performance, there are still issues with lifespan when these solar cells are exposed to outdoor conditions. Our ongoing research is aimed at investigating and developing methods for improving the stability of scalable organic solar cells.

Organic Photovoltaics (OPVs) are devices that use organic-based material to absorb light and convert it into electrical power. As these materials can be dissolved into solvents, they are able to be coated on a variety of surfaces via a range of coating and printing methods. Coupled with the improvement of device performance (up to 18%), the efficiency for small-scaled OPVs has opened up the potential for fabrication of solar panels that are flexible, light-weight, cost-effective, and effective under low-light conditions.

Despite improvements in device performance there are challenges, such as short lifespan, associated with OPVs. Elevated temperature due to direct sunlight exposure is one of the major factors that impacts the lifespan. This can result in physical changes in the OPV that can lead to performance degradation. Our research aims at understanding the mechanics associated with OPV degradation and determine methods to improve the thermal lifespan. Additionally, our research focuses on the fabrication of scalable OPVs via the use of a mini-roll coater attached with a slot-die coating head, allowing for strategies for improved stability to be translated to large-scale fabrication methods.

We have been using an active layer blend of a polymer called PPDT2FBT and fullerene derivatives (PCBM) to fabricate cost-effective, yet efficient OPVs. After adjusting ink formulations and coating parameters, device performances of 8.49% and 7.63% for PPDT2FBT:$PC_{71}BM$ and PPDT2FBT:$PC_{61}BM$ blends were achieved respectively.[1] With an optimal device fabrication process determined, the next stage of the research was to find methods for improving the thermal stability.

Recently, we were able to improve the thermal properties of the active layer by the addition of neat C_{70}, a fullerene molecule that is relatively cheap to purchase. With the addition of C_{70} to the active layer (PPDT2FBT:$PC_{61}BM$), it was demonstrated to decrease the impact of the thermal degradation. The next stage of the investigation is to trial other potential small molecules to improve the thermal stability of scalable organic photovoltaics.

[1] Bradley Kirk, Xun Pan, Martyn Jevric, Gunther Andersson and Mats R. Andersson, Materials Advances, 2022, 3, 2838

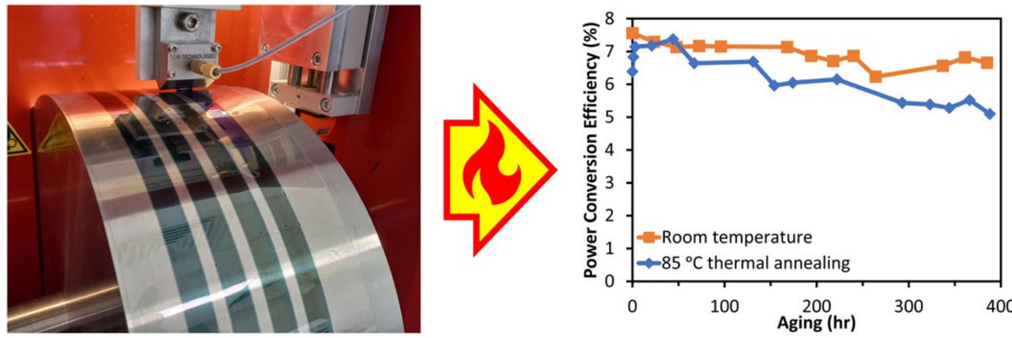


Figure 1: Mini roll coater with active layer coated with slot-die coater (LEFT), and the performance degradation of PPDT2FBT:$PC_{61}BM$ devices at room temperature and 85 °C thermal aging (RIGHT).

MEASURING THE THICKNESS OF 2D MATERIALS

Abigail Mann*, Schannon Hamence, David Lewis, Christopher Gibson*

Knowing the thickness of 2D materials, such as graphene, is crucial as this dimension determines their optical, electronic and mechanical properties. These properties determine what applications these materials can be used for, such as solar cells. In this work we develop experimental procedures and test different substrates to improve the accuracy of measuring the thickness of graphene using atomic force microscopy (AFM) and Raman.

2D materials are a class of nanomaterials defined as being one to ten atoms thick. 2D materials possess remarkable properties such as exceptional strength, lightweight, flexibility, and are excellent conductors of heat and electricity. The first, and most researched 2D material, Graphene, is one million times thinner than paper, nearly transparent, and believed to be the strongest material in the world. 2D materials have the potential to revolutionize many electronics applications such as solar cells and batteries. The number of layers that a 2D material possess determines their properties and applications. Therefore, precise characterisation of the thickness is crucial. One of the techniques commonly used to determine the thickness of 2D materials is AFM. The AFM operates by scanning a sharp silicon tip across the sample surface effectively tracing it. The AFM then combines a series of traced lines to produce a 3D image of the sample. The advantage of AFM is that it can be applied to any 2D material unlike some techniques, such as Raman spectroscopy, which are limited to certain types. One disadvantage of AFM is that the thickness for single layer graphene (SLG) has been measured to be between 0.34 to 1.7 nm which corresponds to 1 to 5 layers, a significant error. In our research we studied the relationship between imaging force and measured thickness as well as testing which substrate, silicon dioxide, or mica is the most suitable for characterising SLG. Our results indicated that imaging SLG on mica with relatively high imaging force produced measurements closest to the expected value of 0.34 nm (refer to figure 1c). The advantage of using Graphene for this study is that this material can also be analysed using Raman. This can be seen in figure 1 which shows an AFM image of SLG and a Raman spectrum typical for SLG. The results of this work can be applied to other 2D materials, such as Phosphorene and Gallenene, and will allow researchers to precisely characterise the thickness of these materials using AFM.

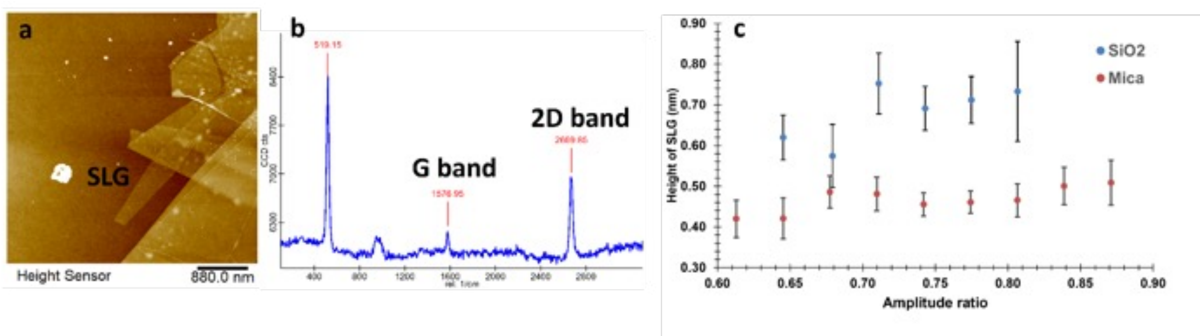


Figure 1a AFM image indicating SLG (b) Example of a Raman spectrum for graphene. The ratio of the peak heights of the 2D and G bands is characteristic for SLG (c) Graph showing measured thickness of SLG as the AFM tip amplitude ratio decreases, which corresponds to increasing imaging force. Results indicated that high imaging force and mica is the most suitable substrate.

MICROPLASTICS IN AUSTRALIAN OCEANS: SPATIAL DISTRIBUTIONS AND IMPACT ON THE BASE OF THE MARINE FOOD WEB

Elise Tuuri, Dr. Jason Gascooke, Dr. John Luick (Flinders University), Dr. George Cresswell (Flinders University), Prof. Paul Kirkbride (Flinders University), A/Prof. Sophie Leterme

Microplastics are prevalent in all aquatic systems. Our research aims to understand (i) transportation and distribution of microplastics in Australian Oceans and (ii) their role at the base of the marine food web. Can we identify microplastic aggregation hotspots to be targeted for clean-up and mitigation efforts?

Plastic debris is a prominent form of marine pollution, which is exacerbated with time. Primary microplastics (millimetre-sized plastics) and secondary microplastics (from the degradation of macroplastics) are abundant in Australian oceans (Figure 1A and 2A). The size of environmental microplastics enables them to be confused for prey by numerous planktonic and benthic organisms. However, little is known about the environmental association of microplastics with zooplankton communities, if some species of zooplankton are more likely to consume them, and the spatial distributions and abundance of microplastics with depth, and at the surface, of Australian oceans.

Zooplankton represent an essential trophic link between primary producers and secondary consumers in the marine environment. Zooplankton also play an important role in the transportation not only of energy but also potential pollutants across the marine food web (Figure 1B). They contribute to the biological pump through the production of dense faecal pellets with fast sinking velocities providing food for sediment-dwelling biota. Detrimental impacts of microplastic ingestion have been reported in laboratory-based zooplankton cultures. These impacts have the capability of occurring in nature as plastic ingestion has been observed in environmental zooplankton samples.

Our work aims to identify microplastic abundances in Australian Oceans through our work on board the RV Investigator with the Marine National Facility. Currently we have sampled 10 sites spanning the Northern Coast of Australia between Brisbane and Perth (Figure 2B). At each site we have collected samples from the sea surface, the deep chlorophyll maximum, and close to the sea floor. These samples will allow us to extract the microplastics from zooplankton communities and identify environmental microplastic abundances, within these planktonic communities, and model how the microplastics move in surface and subsurface currents.

By understanding microplastic abundances and movements around Australia, we will be able to develop a better understanding of where microplastics are entering the marine environment, where microplastics may be accumulating, and identify how much is available and ingested by plankton at the base of the marine food web. By identifying these issues, we hope that we will be able to develop mitigation policies that will aid in amending marine pollution.

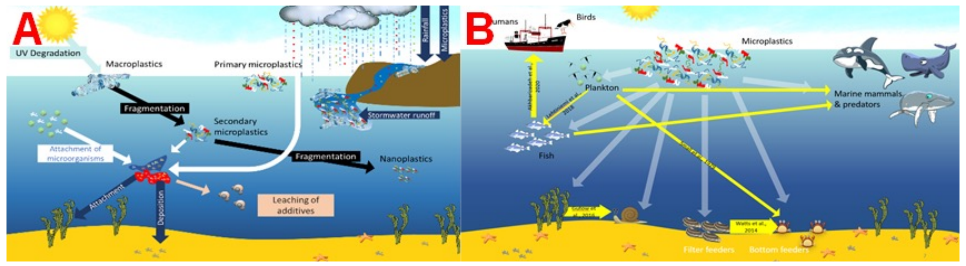


Figure 1. A) Depicts the entry pathways of plastic pollution into the marine environment and the process for waste degradation into secondary microplastics, B) The white arrows show the process for microplastic ingestion in the food web, and the yellow arrows show reported trophic transfers of microplastics between organisms.

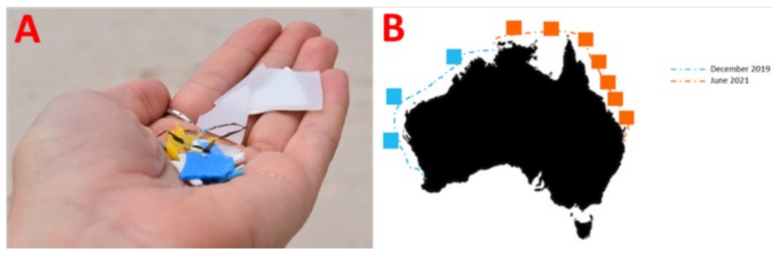


Figure 2. A) Large sized fragments of microplastics (> 1 mm) found in the sand at a South Australian beach, B) A map of Australia indicating the sites sampled for microplastics and zooplankton communities, the blue squares show the sites sampled in December of 2019 and the orange squares show the sampling sites in June 2021. The dashed lined indicates the voyage path.

HIGH SHEAR IN SITU EXFOLIATION OF 2D GALLIUM OXIDE SHEETS FROM CENTRIFUGALLY DERIVED THIN FILMS OF LIQUID GALLIUM

Kasturi Vimalanathan*, Timotheos Palmer (Charles Darwin University), Zoe Gardner, Irene Ling (Monash University,Malaysia) Soraya Rahpeima, Sait Elmas, Jason R. Gascooke, Christopher T. Gibson, Qiang Sun (University of Queensland), Jin Zou (University of Queensland), Mats R. Andersson, Nadim Darwish (Curtin University) and Colin L. Raston*

Gaining access to large scale high quality 2D nanomaterials beyond graphene while avoiding the likelihood of any downstream issues, including adverse effects on the natural environment has been a difficult challenge. Therefore, a new technique has been developed to synthesize 2D gallium oxide sheets using a green chemistry method with scalability addressed at the inception of the science.

2D nanomaterials, specifically graphene has attracted significant attention due to its extraordinary properties and diversity in applications. Nevertheless, there are shortcomings on gaining access to such material where scalability is addressed for industry uptake. In addition, graphene itself is a zero-band semiconductor and exhibits quasi metallic features, which is a limitation particularly for applications in devices and electronics. To overcome these issues, having access to a library of 2D nanomaterials with different properties offers scope of being able to tune the properties to suit specific applications.

2D Metal oxides derived from liquid metals and/or eutectic melts of the metals are envisaged to break new barriers, offering unique electronic, optical and magnetic behaviour for then translation into different applications.

We have thus explored the potential of mechanical energy induced within thin films of liquid in the variable angle vortex fluidic device (VFD) for the exfoliation of highly insulating ultrathin sheets of Ga_2O_3 with an average thickness of ~5-6nm, directly from bulk gallium metals. The simple and benign method developed generates these ultrathin sheets in ~60% yield and avoids the use of high molecular weight solvents, surfactants, and chemical stabilizers. In addition, the ability to prepare these highly insulating gallium oxide sheets show potential in device technology, and the catalytic prowess show promise for application in water splitting in avoiding the use of precious metals and materials for which its use is questionable on environmental grounds.

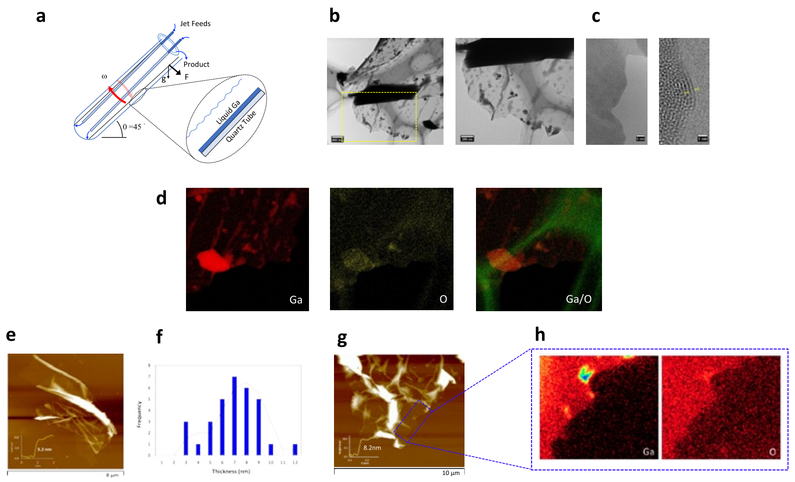


Figure: (a) Schematic of the VFD (b) Bright field TEM images of an ultrathin sheet. (c) HRTEM images illustrating the lattice spacing of the sheets of ~0.25 nm. (d) EDS maps of the corresponding sheet in (b). e) AFM height image of an ultrathin sheet. (f) an average thickness distribution plot based on AFM measurements and (g,h) EDX map of the ultrathin sheet confirming the presence of Ga and O on the surface of the area corresponding to the section in (g).

DESIGN, FABRICATION, AND EVALUATION OF COMPOSITE HELICAL SPRINGS

Ling Chen, Joel Chong (Nano 6C Pty Ltd, Australia), Liwei Wu (Tiangong University, China), Youhong Tang

The helical spring is one of the fundamental mechanical elements in a wide range of industrial applications such as automobile suspension. However, the special helical structure of composite springs demands more complex manufacturing processes. In addition, it is difficult to change the spring constant for conventional metal-based springs. Therefore, it is important to explore simple manufacturing methods and accurately manipulate spring constants of newly developed composite helical springs.

In general, a manufacturing scheme with environmentally friendly, low cost, short production cycle and high yield is desirable for composite helical springs. Most desirable is to achieve accurate control over the spring constant during fabrication. To simplify the manufacturing method, a new process based on vacuum assisted resin infusion (VARI) is developed. The VARI produced composite springs with different fiber contents, twisted multistrand composite springs with different reinforcement twists and braided composite springs (single and double layer) with different braiding angles are shown in Fig. 1. After manufacture, the torsion, compression, and resilience of the composite springs is tested. The influence of the parameters of the reinforcement structure on the mechanical properties of the springs was assessed to study the resultant spring constant of composite helical spring.

A 3D geometric model was established to adapt the characteristics of the internal reinforcement structure of each spring, and the mechanical properties of the spring under axial compression load were simulated by a numerical method. The accuracy of simulation compared favourably with experimental results. The spring constant law is further revealed by analyzing the simulation results.

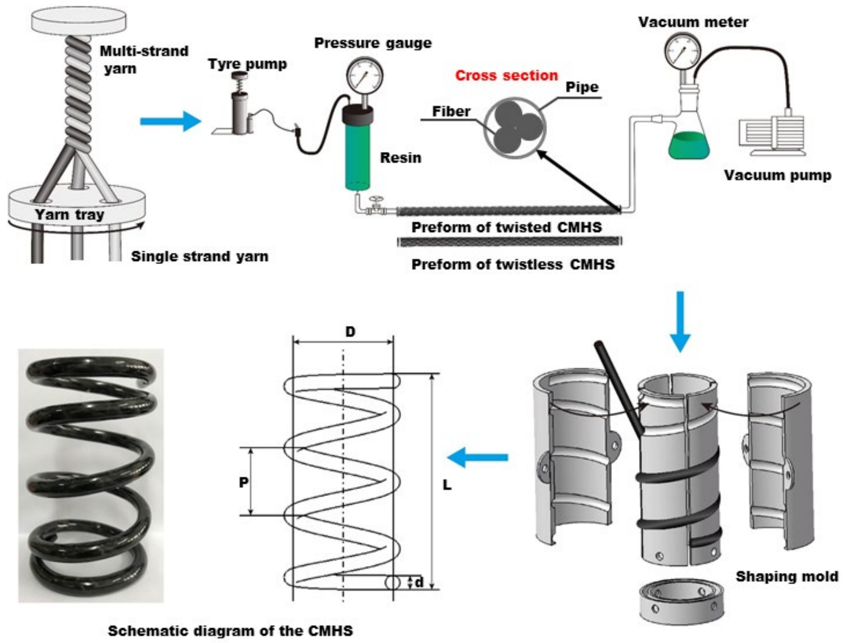


Fig. 1 Composite helical spring fabrication by the integrated forming process using VARI technology.

PROCESSES FOR COATING SURFACES WITH A COPOLYMER MADE FROM SULFUR AND DICYCLOPENTADIENE

Maximilian Mann, Bowen Zhang (Department of Chemistry, University of Liverpool), Samuel J. Tonkin, Christopher T. Gibson, Zhongfan Jia, Tom Hasell (Department of Chemistry, University of Liverpool) and Justin M. Chalker

Polysulfide polymers utilise sulfur, which can be found in vast feedstocks around the world to produce useful materials. In this case a safe synthesis protocol for a polymer made from sulfur and dicyclopentadiene (a by-product from the petroleum refining industry), which was previously prone to result in runaway reactions, was developed. The material has shown its use in heavy metal remediation, and protective coating applications.

The reaction between sulfur and dicyclopentadiene was optimised by performing the reaction at a lower temperature under an inert nitrogen atmosphere to form a shelf stable, and soluble low molecular weight oligomer. After a simple curing process at 140 °C the material was rendered insoluble. This characteristic of the material was utilised to coat aluminium and the resultant coating was found to be acid resistant. Likewise, the coating was applied to cement where is has shown to not only protect the cement from acid corrosion, but it also prevented the uptake of water or acid by the porous cement. In another coating application, a solvent free coating process was used to coat a PVC pipe with the polymer. This coating proved to be resistant to solvent and protected the pipe from solvent attack. Taking advantage of the soluble oligomer, silica gel was coated with the soluble oligomer and cured to render the polymer insoluble. The polymer coated silica gel was successfully used in mercury removal from aqueous solutions as well as from a mix of water and diesel. The coating was also repairable, with surface scratches removed through the application of heat. In this way, the coating is active in metal binding, protective against acids and solvents, and repairable when damaged.

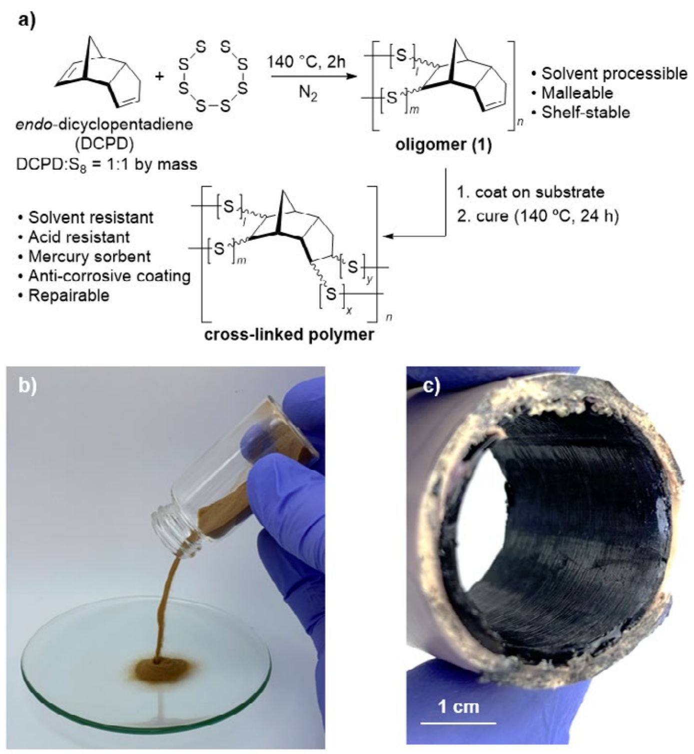


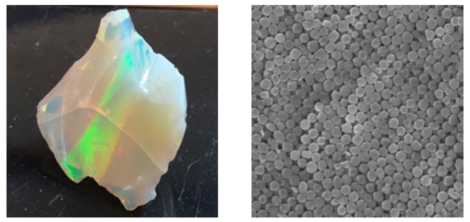
Figure 1A. a) Synthesis pathway of oligomer (1) and curing process to access cross-linked polymer. b) Polymer coated silica gel. c) Polymer coated, solvent resistant PVC pipe.

EXPLORING THE INTERMEDIATE SCALE BY SOLID-STATE ^{29}Si NMR OF OPAL

Neville J Curtis (South Australian Museum), Martin R Johnston, Jason R. Gascooke and Allan Pring (Adelaide University)

Opal may be characterised by a variety of techniques such as X-ray diffraction, scanning electron microscopy, and Raman and infra-red spectroscopy. All forms of precious and other forms of opal-AG, however, look essentially the same by these techniques and are thus of limited value for provenance. A recent discovery at Flinders University, using solid-state ^{29}Si NMR, has shown potential as a means of opal differentiation.

Play-of-colour in precious opal (Figure 1a) derives from ordered arrays of hydrated silica spheres (Figure 1b) that diffract visible light. Samples with irregular arrangements (e.g. potch) of spheres that are too large or too small (e.g. fire opals) do not show play-of-colour but still have scientific value.



a) b)

Figure 1: *(a) Sample of opal-AG from Coober Pedy, SA showing a band of play-of-colour (b) scanning electron microscopy showing arrangement of spheres*

The major unanswered scientific questions about precious opal relate to its structure which is known to be a mix of Q_3 ((SiO)$_3$SiOH) and Q_4 ((SiO)$_4$Si) centres and the necessary conditions for its formation (particularly play-of-colour samples). The opal industry has different requirements including identification of opal-bearing strata both within the existing sites and for new areas for exploration. A more recent concern has been of provenance, with Australia's dominance in opal production being challenged by overseas competition which may have inferior quality (e.g. resistance to water).

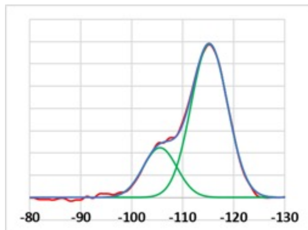


Figure 2: *Curve fitting of a typical ^{29}Si solid state NMR spectrum of opal showing resonances for Q_3 (-104ppm) and Q_4 (-114ppm) silicon species.*

The influx of opals from newer sites and the development of advanced analytic techniques has led the authors to undertake a fundamental review, based on the world-class collection at the South Australian Museum. While the original (scientific) classification of opal-A (opal-AG, opal-AN and other forms of opaline silica), opal-CT and opal-C remains largely sound, the large survey has revealed trends and possible differences within each type. However, the structure of the silica tetrahedra within all forms of opal still remains tantalisingly elusive.

Whereas opal-AG (e.g. play-of-colour Coober Pedy opal) and opal-AN (hyalite) are very different under the scanning electron microscope they both have the same X-ray diffraction patterns and more or less the same Raman and infra-red spectra suggesting similar structures at least at the bond level. Precious opals (opal-AG) from all worldwide sites have identical spectroscopic characteristics. However, using solid-state ^{29}Si nuclear magnetic resonance (NMR), a typical spectrum of which is shown in Figure 2, we have shown that samples of precious opal (e.g. from Coober Pedy, Australia and Dubnik, Slovakia) may be differentiated and we now have a credible visualisation that shows that opal-AG and opal-AN have different molecular architectures.

Within NMR spectroscopy one of the key parameters is the longitudinal relaxation time (T_1) of the nucleus after exposure to radiofrequency excitation. This relaxation time can vary from seconds to hours depending on the chemical environment of the nucleus under investigation. While this is time-consuming, the relaxation process is measurable and thus a source of valuable scientific data usually following an exponential decay with time. The technique applies in the intermediate region between bond length studies (X-ray diffraction and Raman spectroscopy) and larger scale studies from scanning electron microscopy. It emphasises molecular architecture rather than chemical composition.

In the case of ^{29}Si nuclei in opals we have found the relaxation follows a Weibull relationship, rather the more usual exponential (Figure 3). The Weibull relationship is sometimes referred to as a 'stretched exponential' as it differs from the conventional form. The key parameters relate to the relaxation time (the scale factor) and the shape of the relaxation curve (the shape factor). The key results are as follows:

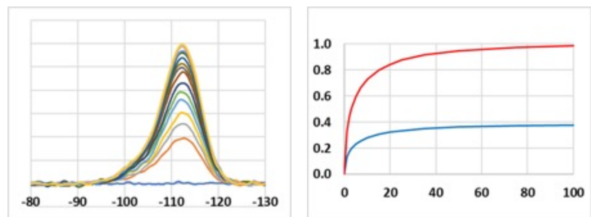
• Samples of opal-AG all show shape factors of 0.5.

• Seam opals from the southern part of the Great Artesian Basin (Coober Pedy, Andamooka, White Cliffs, Lighting Ridge etc) show relatively fast relaxation whereas those from Slovakian are slower.

• Hyalite (opal-AN) and geyersite sinters show shape factors of greater than 0.5 and have slow relaxation.

• A peculiarity was seen for opalised molluscs (opal-AG) from Coober Pedy where the relaxation of the Q_3 and Q_4 centres was similar. This is unlike relaxation of Q_3 and Q_4 centres for other examples.

The authors are of the opinion that the shape and scale factors are mostly dominated by the amount and distribution of the Q_3 centres and water molecules in the sample. These are the major source of the paramagnetic centres required for relaxation. For the Australian seam opals, the arrangement is uniform with ready access to the protons. This is consistent with a relatively slow and ordered formation of silica spheres. In contrast, opal-AN (hyalite) forms at high temperature leading to more localised distribution, for instance, zones of Q_3 centres and pockets of water.



a) b)

Figure 3(a): An example of relaxation time spectra (units ppm) and (b) fitting for Q_3 and Q_4 components (units seconds)

PLATINUM SINGLE-ATOM CATALYSTS FOR ELECTROCATALYTIC HYDROGEN PRODUCTION

Po-Wei Yu, Sait Elmas and Mats Andersson

Production of 'Green Hydrogen' by means of electrochemical water splitting is considered one of the most clean and sustainable methods to meet net zero carbon emission targets. Typically, electrocatalytic production of hydrogen requires noble metals, which are highly reactive, but scarce and expensive. In our ongoing research activities on hydrogen production, we developed a platinum metal electrocatalyst based on the strategy of favourable atom economy. Being among the most active catalysts in terms of mass activity, the value of the used platinum metal was reduced from 2.1 to 0.1 US$/m² compared to the commercial catalysts.

Hydrogen is considered the most promising and competitive energy carrier, as it is clean, renewable and available in abundance. With an energy density of 120-140 MJ/kg being three times higher than the same amount of energy gasoline can provide and the possibility to feed hydrogen gas into the existing infrastructures, the transition from fossil based fuels to the hydrogen economy has started. Undoubtedly, when combined with renewable energy sources such as wind and solar power, hydrogen has enormous potential to become one of the main alternative energy carriers to push toward zero greenhouse gas emissions in the near future (green hydrogen).

The most active catalysts are noble metals and their alloys, these metals are unfortunately scare and expensive requiring limited use in such applications. Since electrocatalysis occurs only at the electrolyte-electrode interface, most of the bulk noble metal atoms in traditional electrocatalysts is buried as electrode material and does not participate in electrocatalysis reaction at all.

In our studies on electrocatalytic hydrogen evolution reaction (HER) we developed a molecular catalyst that is embedded in a stable coordination environment and electro-grafted on porous, three-dimensional (3D) commercial electrodes, Figure 1. The so-called, platinum single atom catalyst (PtSAC) performed at an ultra-low metal loading as one of the most active catalysts. The value of the used Pt amounts only to 0.1 US$/m² compared to 2.1 US$/m² for the commercial catalyst 20% Pt/C.

Furthermore, the electro-grafted ligand (coordination environment), which is selective for stabilising noble metals, revealed to recover leached platinum ions from the counter electrode and re-use them as additional metal loading. The method to synthesise single-atom catalysts is facile, non-hazardous and versatile without involving any elaborate pre- and/or post-treatment steps.

Reference: Po-Wei Yu, Sait Elmas, Tanglaw Roman, Xun Pan, Yanting Yin, Christopher T. Gibson, Gunther G. Andersson and Mats R. Andersson, ***Highly Active Platinum Single-Atom Catalyst Grafted onto 3D Carbon Cloth Support for the Electrocatalytic Hydrogen Evolution Reaction.*** *Applied Surface Science 2022, 595, 153480*

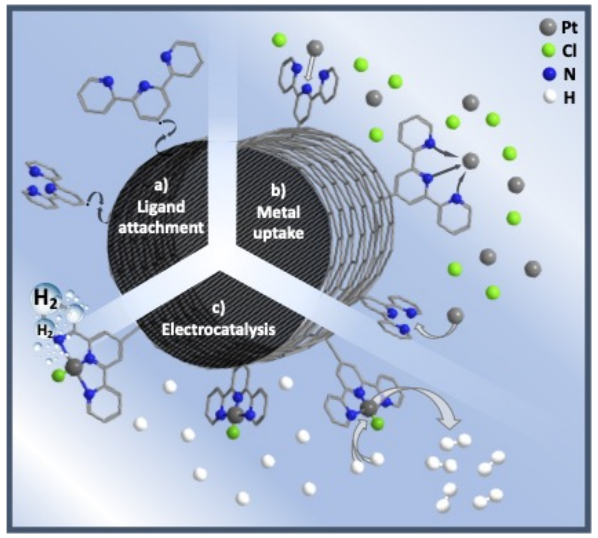


Figure 1. a) Ligand attachment onto a carbon cloth surface by using electro-grafting synthesis. b) The ligand acts as an efficient scavenger to capture platinum ions from the solution under the formation of the platinum single atom catalyst (PtSAC). c) Conversion of hydrogen ions from the electrolyte to hydrogen gas in the electrocatalytic hydrogen evolution reaction (HER).

DETECTION OF URINARY ALBUMIN USING A "TURN-ON" FLUORESCENT PROBE WITH AGGREGATION-INDUCED EMISSION CHARACTERISTICS

Qi Hu, Bicheng Yao (La Trobe Uni), Tze Cin Owyong (Melbourne Uni), Sharon Prashanth, Changyu Wang, Xinyi Zhang, Wallace W. H. Wong (Melbourne Uni), Yuning Hong (La Trobe Uni) and Youhong Tang

Urinary albumin is deemed as an important clinical indicator of chronic kidney disease (CKD). Immunoassays, as a routine method for urinary albumin detection, not only require a long reaction process and incubation time, but also it is expensive and tends to underestimate the amount of albumin. Therefore, improved methods for urinary albumin detection are required for disease monitoring and diagnosis. Aggregation-induced emission (AIE)-based fluorescent techniques offer advantages of simple operation, rapid response, high sensitivity, and cost efficiency to improve these issues.

For healthy people, minimal amounts of albumin leak through the glomerulus into the urine, with a urinary albumin level less than 20 mg/L under normal physiological conditions. However, during end-stage kidney failure (the last stage of CKD), a large amount of albumin will be spilled into the urine, resulting in a urinary albumin concentration greater than 200 mg/L.

In this work, a fluorescent probe TC426 with aggregation-induced emission (AIE) characteristics is reported as a sensitive and specific probe for albumin. This probe is non-emissive in aqueous solution, meanwhile it shows bright fluorescence upon interacting with albumin, which makes it applicable in detecting albumin with a high signal to noise ratio. Besides, the fluorescence of TC426 exhibits a high linear correlation with the concentration of albumin in the range of microalbumin (20–200 mg/L), which has a significant importance for the early diagnosis of CKD.

TC426 shows comparable anti-interference ability towards creatinine and other major components in urine but is excited by a longer excitation wavelength at the visible light range. Finally, with the established assay, it shows excellent performance in detecting albumin in real human urine, indicating its great potential in practical urinalysis.

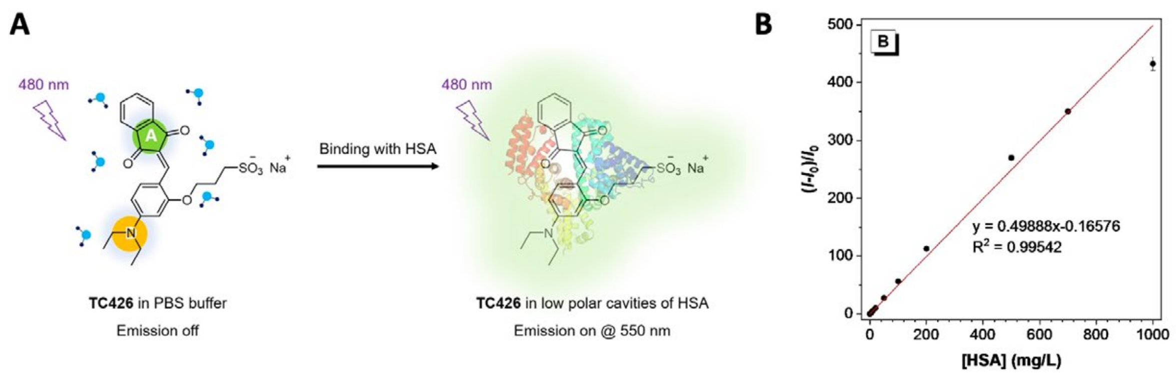
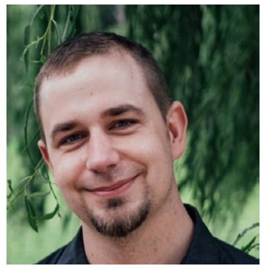


Figure 1 (A) Schematic illustration of TC426 binding to human serum albumin (HSA) (B) Master curve of TC426 between fluorescent intensity and albumin concentration.



NON-STICK SURFACES TO IMPROVE EFFICIENCY OF SOLAR COLLECTORS

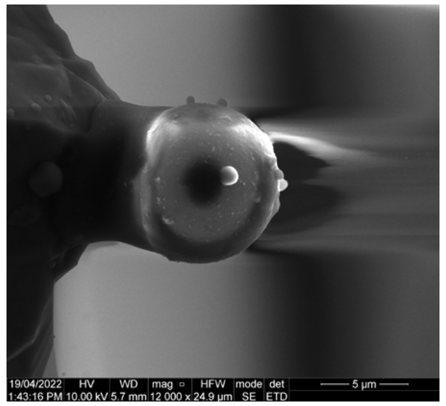
Schannon Hamence, David Lewis, Christopher Gibson

Australia is a great place harvest solar energy, but unfortunately the dry & dusty conditions means that dirt quickly builds up on solar collectors - lowering their efficiency. Designing non-stick, easy to clean surfaces can help to reduce the cost of maintaining solar energy collectors. We are using functionalised nanoparticles to control the chemistry and surface roughness of collectors to slow the build-up of dust.

Solar energy harvesting materials require light to function, but when particulates build up on these surfaces it scatters the light reducing efficiency. These transmission losses vary depending on factors such as tilt angle, geographic location, concentration of airborne particulates, weather, and time of the year. Many studies have investigated soiling with losses in efficiency range from the extreme (10-50% per day) during dust storm events, very high (1-5% per day) where high dust conditions and low rainfall occur, and low (>0.05% per day), where conditions are optimal. Particles attach to surfaces through a variety of mechanisms, but the main forces involved are Van der Waals (VdW) and capillary forces. The primary aim of the project is to reduce the contribution of these forces by changing the structure and chemistry of the surface through an easy to apply, durable coating.

We have created a series of nano-roughened coatings to investigate the relationship between dust adhesion and surface topography. A scalable process using controlled size silica nanoparticles in abrasion resistant coatings avoids complicated or costly steps such as laser etching or photolithography.

Particle adhesion measurements, using dust-sized particles attached to the tips of atomic force microscopy (AFM) cantilevers, has shown that the nano-roughened surfaces show a significant reduction in the fundamental adhesion forces between particles and the coating.



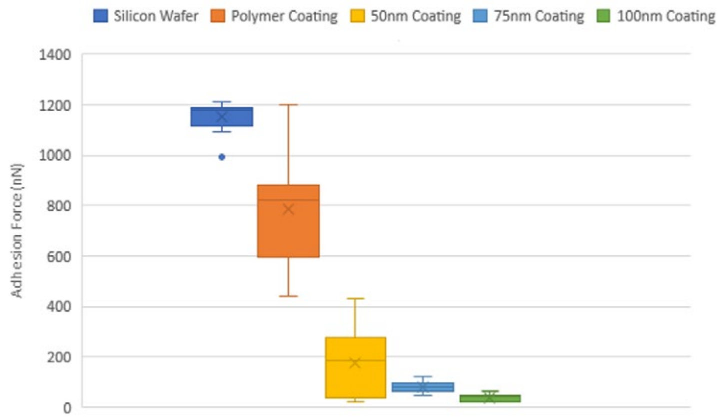


Figure 1) Left - Image of 5.5um particle attached to tip of AFM cantilever. Right - Measured adhesion forces for particle on different surface types

IMPERMEABLE GRAPHENE OXIDE PROTECTS SILICON FROM OXIDATION

Soraya Rahpeima, Essam M. Dief (Curtin University), Simone Ciampi (Curtin University), Colin L. Raston, and Nadim Darwish (Curtin University).

Graphene-based materials such as graphene oxide (GOx), are considered to be completely impermeably to all gases and liquids despite being single atomic layers. Therefore, the impermeable nature of GO should protect silicon (Si) electrodes from oxidative exposure to air and humidity. This protection is desirable as oxidation adversely effects the electrical properties of Si semiconductors leading to passivation of electron transfer

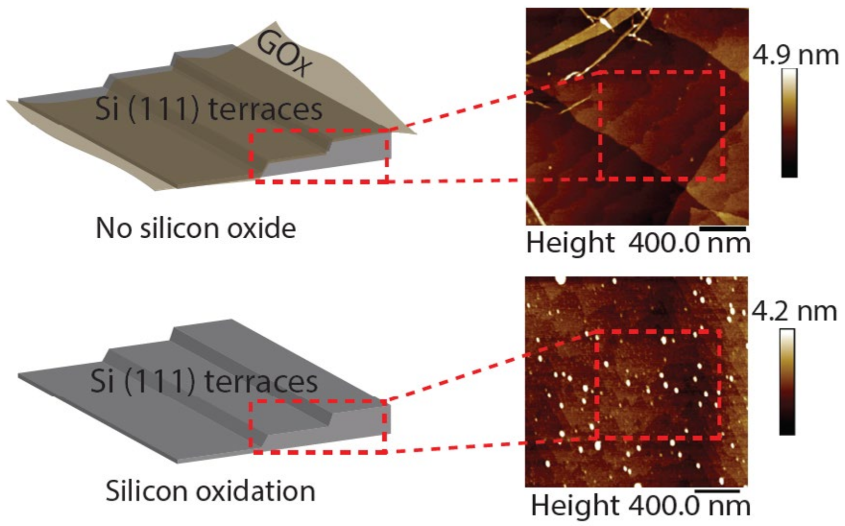
The presence of a natural oxide layer on the surface of Silicon (Si) electrodes acts as an insulator and therefore it is a limiting operational factor in electron transfer for a range of applications such as semiconductor technologies. Etching this native oxide layer results in a highly reactive Si–H surface which can be rapidly re-oxidized under ambient conditions.

Here, we showed that a thin layer of GOx prevents the surface of Si electrodes from oxidation for around 30 days under ambient conditions. GOx has the capability to make a direct covalent bond on the surface of fresh Si–H through Si–O–C bonding. Atomic Force Microscopy (AFM) technique (Figure 1) proves that Si–GOx surfaces remain unaltered during the 30 days. This is confirmed by presence of no oxide and Si (111)–H terraces underneath of GOx layers after 30 days.

A thin and invisible graphene oxide layer can be used as the best alternative to protective layers such as alumina and silica in electronic applications as it can modify and protect silicon electrodes in a simple way in the absence of any external catalysts and additives.

This research study has potential in corrosion prevention of metals and could be extended to protect artwork against damage and deterioration.

Figure 1: Top: AFM topography image of 30-day aged Si–GOx surface. It shows clearly the Si (111) terraces underneath the GOx layer with negligible oxide spots. A diagram describes the protection of Si by GOx layer, akin to a carpet over stairs.



Bottom: AFM topography image of 30-day aged Si–H surface demonstrating that the surfaces are covered with oxide spots.

KEY TO THE FUTURE OF ENERGY: A STUDY OF MATERIAL SUITABILITY FOR CONCENTRATED SOLAR THERMAL POWER

Yanting Yin, Alex Griesser, Reza Hashemi (Flinders University), Madjid Sarvghad (QUT), Stuart Bell (QUT), Teng-Cheong Ong (QUT), Geoffrey Will (QUT), Theodore A. Steinberg (QUT), David A. Lewis, Gunther G. Andersson

Concentrated solar power (CSP) plants harvest solar energy directly as heat. Their working principle allows incorporating thermal energy storage to facilitate the uninterrupted production of electric energy from a renewable energy source. Efficient CSP concepts are required to operate at high temperatures, above 600 °C. Such conditions have a high demand on the durability and resistance of the materials used against degradation and corrosion. The advanced corrosion study in this project investigates degradation mechanisms to facilitate the selection or development of materials which can sustain the harsh condition of CSP.

As a state-of-the-art sustainable energy technology, CSP involves a typical design consisting of a set of mirrors, lenses, storage modules and receivers. Thermal energy storage (TES) and a wide range of heat-transport fluids (HTF) are used in CSP to allow for more effective use of the power by storing excess energy, and later discharging when required. In our research funded by Australian Solar Thermal Research Institute (ASTRI), the novel CSP plants are designed to promote the advantage of renewable sources of energy by significantly increasing the operating temperature, from commercially 450-550 °C to 650-750 °C. The technique allows harvesting at least 30% higher thermal energy efficiency. However, the alloys used for lower temperature are generally not compatible with a high temperature environment due to the corrosion occurring severely at the presence of corrosive HTF, such as phase change salts and liquid sodium. Studies showed Iron and Nickel based superalloys may have the capability to effectively perform a long-term application under such corrosive environments, without compromising their intrinsic characteristics at the temperature required.

To understand the corrosion mechanism and be able to design better alloys for high temperature CSP applications, the materials group at the Institute of Nanoscale Science and Technology of Flinders University, in collaboration with the group at Queensland University of Technology commenced a comprehensive study on a wide range of steel alloys in the labs in expedited thermal cycles and isotherms to generate layers of corrosion on the materials under different corrosive environments, such carbonate salts or liquid Na. The treatments of alloys are expected to be a simulation for real plant applications. The study showed the corrosion layers are formed primarily due to the materials' compositions, and their reaction to high temperature and varying chemical environments. Since Chromium, Iron and Nickel are the most important elements in the corrosion studies of alloys, their presence, concentration and how they form compounds are closely monitored. The way these elements move out of the alloys and migrate to the corrosion layers is also a critical observation being achieved. Study also revealed the conditions of reactive chemicals in the environment that can trigger certain corrosion mechanisms. It has been demonstrated by choosing the right balance or of these elements or selecting alloys with additivities (such as Al and Nb), it is possible to predict and limit the progression of corrosion in the alloys.

A wide range of instrument including microscopy (SEM and AES), spectroscopy (XPS and NICISS), diffractometry (XRD), computer topography (Micro-CT) and mass spectrometer are applied to study the chemical and microstructure properties of stainless steels and super alloys subject to harsh environments. Hardness, fatigue, and tensile tests are further scheduled to test the mechanical properties of the alloys. By these methods, the teams can look at the materials' behaviour down to a nano level, allowing for a deep understanding towards the suitability of these superalloys in solar power industry.

Even though theoretical predications can help this industry design their power generation systems, advanced systematic research of corrosion behaviour of superalloys is the closest to ensuring success in Australia's strategic interest and investments in future renewable energy sector.

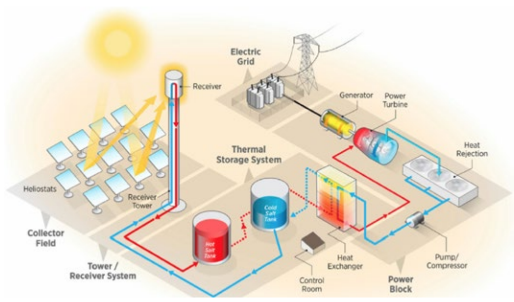


Figure 1. Solar thermal concept. Merchán, R. P., et al. (2022). Renewable and Sustainable Energy Reviews 155: 111828. License (CC BY NC ND)

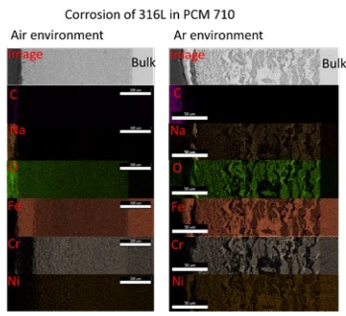
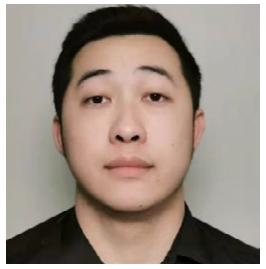


Figure 2. Surface corrosion study of a cross-section of 316L stainless steel before (left) and after thermal cycling (750 °C peak, right). The figure shows a backscatter electron image and elemental distribution maps of the sample.



WAVE-DRIVEN TRIBOELECTRIC NANOGENERATOR

Yunzhong Wang, Anh Tran Tam Pham, Xiangxi Han (Beibu Gulf University), Dongsheng Du (Beibu Gulf University), Youhong Tang

Energy and resource wastage are high priority global problems for the 21st century. In this research, a new concept for an ocean wave energy converter is proposed. It is called a wave-driven triboelectric nanogenerator (WD-TENG), and its purpose is to harvest and convert energy from the low-frequency movement of ocean waves to generate green electricity. WD-TENGs can be fabricated from recycled material from industry and daily waste such as aluminium, glass, and plastic. WD-TENGs have the potential to provide electricity for offshore islands and rural/remote areas located near coastline.

The development of the economy and industry highly depends on electricity and ocean wave energy converter is one of the top priority research hotspots. The annual global ocean wave power potential is estimated to reach nearly 93,000 TWh, and the ocean wave energy around the coastlines is estimated to be 2–3 TW. In South Australia, we have a wide 4,204 km coastline which provides sufficient ocean wave energy that can be used to generate electricity. Another benefit of ocean wave energy is that, unlike solar energy, it is not significantly affected by the day and night cycle.

The TENG mechanism utilizes the different charge characteristics on the surface of the triboelectric material to induce the electron flowing at relevant contact and separation movement with the aim to generate electricity. Based on this unique working mechanism, the size of the WD-TENG can be minimized to reduce material wastage and carbon emission.

A WD-TENG prototype has been designed based on the hydrodynamic performance of the TENG under an irregular wave spectrum through computational fluid dynamics (CFD) simulation. An experimental testing platform has been built to simulate wave frequency and amplitude to evaluate those external factors on the voltage output of the WD-TENG.

Based on the preliminary experimental results, the WD-TENG can achieve an output voltage of 133 V when the wave amplitude reaches 11.5 cm under a frequency of 2.2 Hz and can achieve the output voltage of 333.67 V under the wave frequency of 7 Hz and 0 cm amplitude. The WD-TENG demonstrated excellent durability and strong adaptability under different frequencies and amplitudes of ocean waves. The WD-TENG depicts an environmentally friendly generator, where reduced sustainable material usage was considered, and has considerable potential to contribute to growing green energy demand.

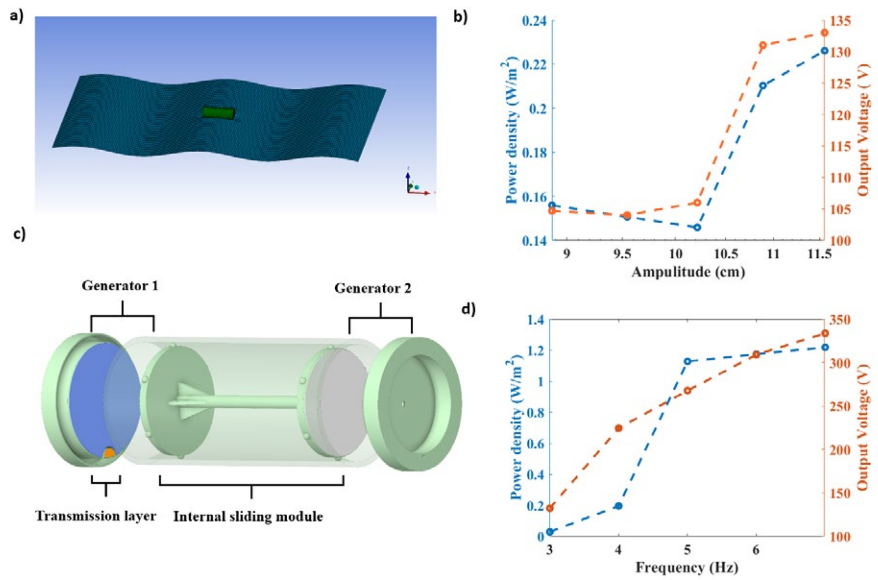


Figure. 1. (a) Hydrodynamic model of the WD-TENG during simulation. (b) Exploded view drawing of WD-TENG with the components. (c) Effect of external amplitude on the output voltage and the power density of the WD-TENG, and (d) Effect of external frequency on the output voltage and the power density of the WD-TENG.

NANO INSTITUTE ACCESS TO

CAPABILITIES, INFRASTRUCTURE AND TECHNIQUES

The Institute has direct access to a broad set of enabling infrastructure and techniques for synthesis and characterization of all kinds of matter. State of the art instrumentation and expert researcher and technical staff across Chemistry, Physics, Biology and Engineering give us the ability to tackle complex and multifaceted problems.

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.

Instruments:

- Photoemission Electron Microscope (NanoESCA III) – includes energy-filtered imaging (<50 nm), XPEEM imaging (~50 nm), Small-spot XPS and UPS (~500 nm to 200 µm), Momentum Microscopy (MM), micro Angle Resolved Photoelectron Spectroscopy (µARPES)
- Ultra-high vacuum, variable temperature scanning probe microscopy (VT-SPM) attached to the NanoESCA III

Scanning electron microscopy (FEI Inspect F50) - High resolution SEM of samples can be combined with elemental mapping using Energy Dispersive X-ray spectroscopy (EDX). An Electron Backscatter Diffraction (EBSD) detector is also installed allowing measurements of grain orientation and boundaries in crystalline samples.

Scanning auger nanoprobe (PHI-710 AES) - Combines microscopy with the ability to determine elemental composition, resulting the analysis of surface chemistry with a spatial resolution of 10 nanometres.

Large-volume micro-CT (Nikon XT H 225ST CT Scanner) - 3D scanning of large and heavy samples. Specialized stages allow tensile and compressive loading of the specimens while scanning.

Neutral impact collision ion scattering Spectroscopy (NICISS, Custom built) – For elemental concentration profile to a depth of 10-40 nanometres, with a depth resolution close to 0.3 nm near the surface. NICISS can be applied to solid samples, polymers and liquids.

Metastable induced electron spectroscopy – (custom built) - Ultraviolet Photoelectron Spectroscopy (UPS), Inverse Photemission Spectroscopy (IPES) and X-ray Photoelectron Spectroscopy (XPS) concentration depth profiles through NICISS, in-situ FTIR analysis, in situ sample preparation.

Atomic force microscopy (Multimode 8 AFM with Nanoscope V Controller and Dimension FastScan AFM with Nanoscope V controller) – For topographic information on a sample. Our AFM facilities are also able to map sample conductivity on the nanoscale, characterise stiffness and adhesion in air and fluid.

Tip enhanced raman spectroscopy (Nanionics TERS with XplorRA Horiba Scientific confocal Raman microscope) - Chemical mapping of a surface down to a few tens of nanometres.

Confocal raman microscopy (WiTec alpha 300R confocal Raman microscope) - single Raman spectra—and also confocal Raman—imaging

Confocal fluorescence microscopy (Zeiss LSM 880 Fast Airyscan confocal microscope; Olympus FluoView 1000 laser scanning confocal microscope; Leica TCS SP5 laser scanning confocal microscope)

Electronic structure simulation and materials modelling - complement our spectromicroscopy data with ab initio simulations using high-performance computing together with a suite of theoretical methods. Extensive developments in density functional theory (DFT), many-electron wave function theory and graphics processing unit (GPU) technology have made it possible to accurately predict bulk crystal structures and surface morphologies.

Get in touch to find out how we can help you – Email: microscopy@flinders.edu.au.

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.

POLYMER CHARACTERISATION

A complete range of polymer characterisation equipment is available including methods such as: Gel Permeation Chromatography, Dynamic Mechanical Thermal Analysis, Differential Scanning Calorimetry, Simultaneous Thermal Analysis, Thermo Gravimentric Analysis with Gas Chromatography Mass Spectrometry (TGA-GCMS), Fourier Transform Infra-Red (FTIR), 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 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 & photonics and bio nano applications. The SA node is co-located at the Future Industries Institute, UniSA and The College of Science and Engineering, Flinders University, and brings together expertise in surface modification, characterisation, nanotechnology, and advanced materials.

MATERIAL PROPERTIES

The institute has equipment to characterise and analyse materials and 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.

CAPABILITIES

MEMBERS 2021-2022

Research Leaders
Professor Gunther Andersson
Professor Mats Andersson
Professor Justin Chalker
Professor Michelle Coote
Professor Sarah Harmer
A/Professor Zhongfan Jia
A/Professor Martin Johnston
A/Professor Ingo Köper
Professor Sophie Leterme
Professor David Lewis
A/Professor Melanie Macgregor
Professor Jim Mitchell
Professor Jamie Quinton
Professor Colin Raston
Professor Youhong Tang
Professor Joe Shapter

Research Staff
Dr Jennie Bartle
Dr Witold Bloch
A/Professor Jonathon Campbell
Jessica Carlson-Jones
Mohsen Chitsaz
Dr Sait Elmas
Dr Louisa Esdaile
Dr Gaius Eyu
Hao Fu
Dr Jason Gascooke
Dr Chris Gibson
Dr Thanh Hoang Hai
*Dr Tamar Jamieson
Dr Darryl Jones
Dr Lynn Lisboa
Dr Nicholas Lundquist
Dr Xuan Luo
Dr Daniel Mangos
*Dr Maximillian Mann
Dr Rowan McDonough
Dr Sanaz Naghibi
Dr Thomas Nicholls
Dr Xun (Caroline) Pan
Dr Harshal Patel
Dr James Paterson
Dr Le Nhan Pham
Dr Gujie Qian
Dr Tanglaw Roman
Dr Abolfazl Dashtbani Roozbehani
Dr Nick Rudgley
Dr Raihan Rumman
Dr Ruby Sims
Dr Damian Tohl
Dr Kasturi Vimalanathan
Dr Jiao (Joseph) Yu Wang
Dr Wenjin Xing
Dr Yanting Yin
Xinyi Zhang

Professional Staff
Dr Martin Cole
Kim Hutchins

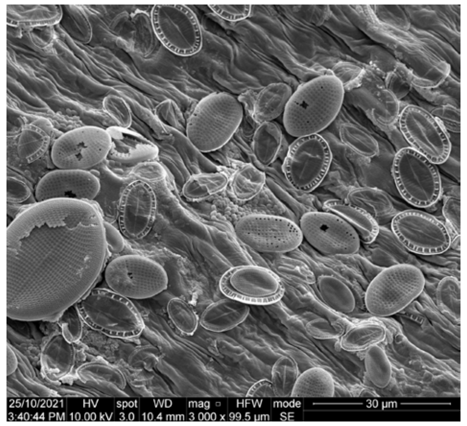
Technical Staff
Dr Benjamin Chambers
Dr Alexander Sibley
*Dr Liam Howard-Fabretto
Dr Ula Alexander
Dr Sophie Rapagna

Visitors
Dr Shan He
Dr Oskar Majewski
Mukeswaran Balachandran

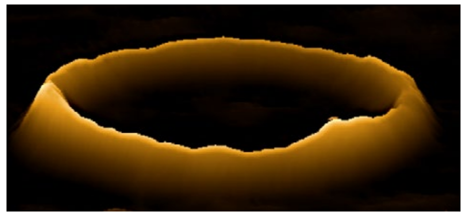
Students, Honours, Masters, PhD
Abeysinghe Mudalige Thidas-Nimnaka -Abeysinghe
Zac Adams
Sunita Guatam Adhikari
Naved Ahmed
Mayisha Ahmedullah
*Dr Ahmed Hussein Al-Antaki
Amira Ramadan Alghamdi
Ahlam Alharbi
Thaar Alharbi
Samar Safar S Almojadah
Abdulaziz Mudhhi Almutairi
Abdulrahman Alotabi
Badriah Alotaibi
Zuhur Habib D Alotaibi
Amjad Eid H Alotaibi
Fayed Abdullah J Alrashaidi
Amal Alsaedi
Anbarah Azib S Alzahrani
Caroline Andersson
*Dr Alex Ashenden
Safira Moura Barros
Belinda Bleeze
Ethan Bodey
Xuejiao Cao
Ashley Carey
Thomas Aquino Waso-Ceme
Kay Chen
Ling Chen
Ling Chen
Anggelia Essi Christian
Tim Chu
Clarence Chuah
Melissa Court
*Dr Emily Crawley
Zachary Dalton
Natalie Daou
Jesse Daughtry
James Deng
Kevin Do
Bradley Donnelly
Woody Drummond
Jackson Faulkner
Khamaael Fayyadh
Rhianna Gabell
Zoe Gardner
Nathan Garner
Joshua Gebhardt
Jason van Gent
Amin Jamshidi Ghahfarokhi
Alex Griesser
Mitchell Griggs
Susie Grigson
Schannon Hamence
Muhammad Tanzeem -Ul Haq
David Harvey
Alex Hayes
Claire Hayward
*Dr Zhen He
Louisa Howard
Qi Hu
Jin Hua
Danielle Hughes
Abbey Hutton
Aghil Igder
Naveen Jain
*Dr Matt Jellicoe
Elliott Jew
Yekai Jing
*Dr Nikita Joseph
Manpreet Kaur
Emma Kent
Mohammad Khorsand
Bradley Kirk
Guler Kocak
Sally Komar
Gowri Krishnan
Anand Kumar
Pradeep Kumar Malvi
Abigail Mann
*Dr Todd Markham
Stefan Martino
Connor McIvor
*Dr Jody Claire McKerral - (Fisher)
Cameron Mellier
Kyle Mitchell
Anahita Motamedisade
Michael Mugford
Muthuraman Namasivayam
Jordan Oatway
Braden Page
Nicola Papazis
Brodie Parrott
Sayan Paul
Zhipeng Pei
Jessica Penrose
Spencer Petticrew
Anh Tran Tam Pham
*Dr Jessica Phillips
Jasmine Pople
Scott Pye
Rakhi Rakhi
Soraya Ralpeima
*Dr AHM Mohsinul Reza
Dylan Ricardi
Niki Romeo
Brooke Scott
Max Scott
Fatimah Al Sharyah
Kristy Shipley
*Dr Gaurav Singhai
Imogen Smith
Tim Solheim
*Dr Jordan Spangler
*Dr Kaili Stacey
Leilaina Stefaniak
Kirrilee Stone
*Dr Jade Kirsten Taylor
Alfrets Tikoalu
Samuel Tonkin
James Tsoukalas
Nicholas Tugwell
Nyi Nyi Tun
Elise Tuuri
Gemedi Wako
Reece Waltrovitz
Yunzhong Wang
Ellen Wauchope
Izak Weidenhofer
Reuben Wheeler
Jordan Wray
Daniel Wright
Zhijie Xu
Po-Wei Yu
Xiaochen Zhu

* = PhD graduate of 21/22

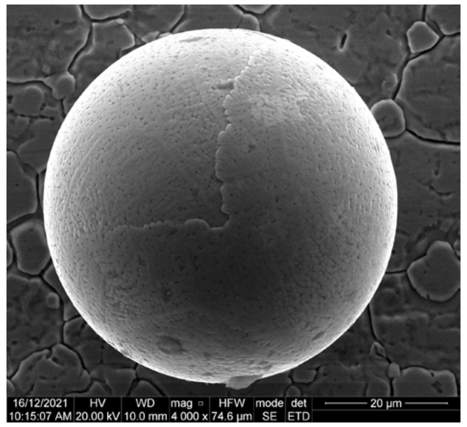
The 2021 Scientific Image of the Year Competition covered 3 categories plus an overall winner with images selected by the Nano Institute executive team. Below are the runner-up images.



Sally Komar, Skeletal remains of diatoms attached to the surface of a seagrass leaf amongst clusters of bacteria.



Matt Jellicoe, 3D AFM image of a single walled carbon nanotube ring.



Alex Sibley, A metallic particle found sitting on a polished steel surface. The particle was likely generated by the laser used to cut the steel. The individual grains of the steel surface can be seen in the background.

Institute for Nanoscale Science & Technology

flinders.edu.au/nanoresearch
nano@flinders.edu.au

INSTITUTE FOR NANOSCALE SCIENCE & TECHNOLOGY

FLINDERS UNIVERSITY
location: STURT ROAD, BEDFORD PARK, SA 5042
mail: GPO BOX, 2100 ADELAIDE SA 5001, AUSTRALIA

flinders.edu.au/nanoresearch

nano@flinders.edu.au