Institute for Nanoscale Science & Technology

ANNUAL REPORT 2020

Flinders
UNIVERSITY

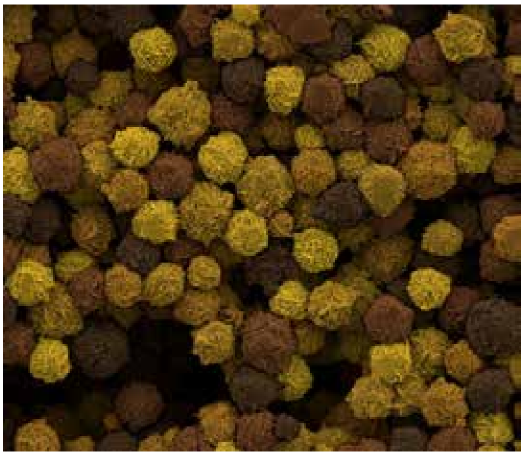

IMAGE OF THE YEAR

The Scientific Image of the Year Competition was awarded to Mr Maximilian Mann (PhD candidate supervised by Associate Professor Justin Chalker). This image is of gold particles captured using an FEI Inspect F50 Scanning Electron Microscope.

The 2020 winner was selected by an expert judging panel, including Monique Russell from Blend Creative Design Agency, Karen Ashford, Flinders Marketing and Mel Trebilcock, Executive Officer, College of Science and Engineering.

INSTITUTE FOR NANOSCALE SCIENCE & TECHNOLOGY
ANNUAL REPORT 2020

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SMALL
TINY
NANO

SMALL SCIENCE
BIG IMPACT

DAVID LEWIS
DIRECTOR

The year 2020 will certainly go down as a year to be remembered! While the impact of COVID-19 worldwide has been horrific, Adelaide was largely unaffected, with the University only shut down for a couple of days. However, life wasn't quite "normal", as COVID-19 was a constant distraction for our Research Leaders and Institute members – from preparations for a full lockdown of labs and equipment, to changing all of our teaching to online under the constant shadow of lockdowns and travel bans.

Our grand plans to celebrate the 10th anniversary of the Institute were dashed, but we will select another special anniversary to celebrate when things settle down (maybe the 12th anniversary!). Our members were very productive despite the challenges, with KPIs such as publications, grants success and graduations on target. We also had some notable successes, including:

- Associate Professor Justin Chalker won the Prime Minister's Prize for New Innovators 2020
- Professor Colin Raston was named Joint Winner of the 2020 South Australian Scientist of the Year Award in the SA Science Excellence and Innovation Awards
- Dr Kasturi Vimalanathan won the 2020 Vice-Chancellor's Award for Early Career Researchers
- Dr Melanie Farrier (nee Fuller) won the Early Career Alumni Award
- Dr Lisa Alcock (supervised by Research Leader Associate Professor Justin Chalker) won the 2020 Vice-Chancellor's Award for Doctoral Thesis Excellence with her thesis *Chemical tools for detecting cysteine sulfenic acid*
- A US Patent was issued for *Photocatalytic conversion of carbon dioxide and water into substituted or unsubstituted hydrocarbon(s)* and was invented by Gunther Andersson with colleagues Gregory Metha (The University of Adelaide), Vladimir Golovko (University of Canterbury, New Zealand) and Thomas Nann (University of Newcastle).

Phase 1 of the refurbishment of the Sir Eric Neal Building to house Flinders Microscopy and Microanalysis (FMMA) has been completed and led by Professor Sarah Harmer. The atomic force microscopes and Ramans have been moved and recommissioned with improved performance due to less electrical noise and a more constant environment. Professor Harmer's new flagship photoemission electron microscope arrived in late 2020, however COVID-19 travel restrictions delayed its installation, which will be completed in 2021.

Institute Directors David Lewis (right) and Mats Andersson (left).

While we were "inconvenienced", our international partners had extended lockdowns (but to our knowledge, there was no worse than that), which has obviously impacted plans to expand our collaborations and student exchanges/travel. We had the excitement of getting one student out of France just as that country went into lockdown the first time and within days of Australia's borders being closed. Another student became stranded in Japan and I would like to give a very special thank-you to our colleagues at the National Institute for Materials Science (NIMS), who were especially accommodating and supportive in what was also a difficult time for them.

Flinders University policy requires the University's Institutes and Centres to be reviewed every 3 years and I am pleased that the Academic Senate approved our Institute's continuation. There was very good support from Deputy Vice-Chancellor (Research) Professor Rob Saint, who formally presented the case, and spontaneous support from multiple College Executive Deans, which was very satisfying.

After 10 years in the role since the Institute was founded, this seemed to be a good time to stand down as Director and give others an opportunity to shape the Institute moving forward. The Institute will be in excellent hands with Professor Mats Andersson taking over as Director for the next 2 years.

MATS ANDERSSON
NEW DIRECTOR

As the new Director I want to thank Professor David Lewis on behalf of the whole Institute for all the fruitful years and for his engagement in the Institute. Over the years, he has built up a very successful organisation with strong academic and outreach activities, including engaging with many companies and organisations. Importantly, he has created a very strong collegiality within the Institute that is imperative for our activities. The transfer of the directorship happened at the end of November, and I now start to understand all efforts that David has put into the Institute. I am convinced that the Nano Institute will continue to thrive for many years to come!

ADVISORY BOARD

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

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

Dr Judy Halliday
Chief Operating Officer,
Office of the Chief Entrepreneur,
South Australian Government

Professor Paul Mulvaney (Chair)
Professor of Chemistry, University of Melbourne and Bio21 Institute

Mr Len Piro
Former Executive Director,
Department of State Development,
South Australian Government

Professor Alistair Rendell
Vice President and Executive Dean, College of Science and Engineering, Flinders University

Professor Kohei Uosaki
Director, Global Research Centre for Environment and Energy,
National Institute for Materials Science, Japan

Dr Greg Simpson
Former Deputy Chief
of Industry, CSIRO

INSTITUTE MEMBERS

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

Research Staff
Dr Jonas Mattiasson Bjuggren
Dr Jonathon Campbell
Jessica Carlson-Jones
Mohsen Chitsaz
Dr Sait Elmas
Dr Louisa Esdaile
Hao Fu
Dr Chris Gibson
Dr Martyn Jevric
Dr Darryl Jones
Dr Xuan Luo
Dr Daniel Mangos
Dr Rowan McDonough
Cheylan McKinley
Dr Sanaz Naghibi
Dr Rebecca Norman
Weixin Ou
Dr Xun (Caroline) Pan
James Paterson
Dr Raihan Rumman
Dr Ruby Sims
Dr Javad Tavakoli
Dr Kasturi Vimalanathan
Dr Max Worthington
Dr Wenjing Xing
Dr Yanting Yin
Xinyi Zhang
Dr Damian Tohl

Technical Staff
Dr Ben Chambers
Dr Alexander Sibley

PhD Students
Sunita Guatam Adhikari
Ahmed Hussein Al-Antaki
Ahlam Alharbi
Thaar Alharbi
Fayed Abdullah Alrashaid
Amira Ramadan Alghamdi
Abdulrahman Alotabi
Badriah Alotaibi
Alex Ashenden
Belinda Bleeze
Kay Chen
Gabriella Anggelia Essi Christian
Clarence Chuah
Emily Crawley
Jesse Daughtry
Bradley Donnelly
David Doughty
Jody Fisher
Melanie Fuller
Joshua Gethardt
Tom Grace
Alex Griesser
Schannon Hamence
David Harvey
Zhen He
Liam Howard-Fabretto
Jin Hua
Aghil Igder
Tamar Jamieson
Amin Jamshidi Ghahfarokhi
Elliott Jew
Matt Jellicoe
Nikita Joseph
Emma Kent
Mohammad Khorsand
Bradley Kirk
Guler Kocak
Gowri Krishnan
Renata Kucera
Anand Kumar
Nicholas Lundquist
Maximillian Mann
Todd Markham
Jake Marshall
Stefan Martino
Anahita Motamedisade
Muthuraman Namasivayam
Brodie Parrott
Spencer Petticrew
Zoe Pettifer
Anh Tran Tam Pham
Jessica Phillips
Jasmine Pople
Scott Pye
Soraya Ralpeima
Connor Retallick
AHM Mohsinul Reza
Yuya Samura
Brooke Scott
Altaf Shamsaldeen
Gaurav Singhai
Tim Solheim
Jordan Spangler
Kaili Stacey
Jade Taylor
Alfrets Tikoalu
James Tsoukalas
Elise Tuuri
Ruben Wheeler
Xiaochen Zhu
Samar Safar S Almojadah
Jordan Wray

Masters Students
Hussain Albattat
Yousef Alshammari
Amjad Eid H Alotaibi
Anbarah Azib S Alzahrani
Abdulrahman H.H. Alnafie
Jeetendra Chhetri
Muhammad Tanzeem Ul Haq
Haozhen Hu
Qi Hu
Israa Hussain
Nathan Garner
Pradeeep Kumar Malvi
Changyu Wang
Danielle Wong
Daniel Wright
Po-Wei Yu
Tianchi Zhang

Honours Students
Alex Bell-Male
Woody Drummond
Abbey Hutton
Susie Grigson
Nicola Papazis
Jessica Penrose
Niki Romeo
Connor McIvor
Jaimi Ross
Lachlan Stanton
Aoife Rutley
Karuna Skipper
James Cane
Reece Waltrovitz
Liam Smart
Brianna Young
Yu Guo
Jordan Ross

Visitor Since January 2020
Dr Shan He
A/Professor Wen Sun

Dr Lisa Alcock (supervised by Research Leader Associate Professor Justin Chalker) won the 2020 Vice-Chancellor's Award for Doctoral Thesis Excellence with her thesis *Chemical tools for detecting cysteine sulfenic acid.*

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On May 12, 2020 a US Patent was issued to Adelaide Research and Innovation for research conducted by The University of Adelaide, Flinders University of South Australia, University of Canterbury, New Zealand and University of South Australia for *Photocatalytic conversion of carbon dioxide and water into substituted or unsubstituted hydrocarbon(s)* and was invented by Gregory F Metha (The University of Adelaide), Gunther Andersson (Flinders University), Vladimir Golovko (University of Canterbury, New Zealand) and Thomas Nann (University of Newcastle).

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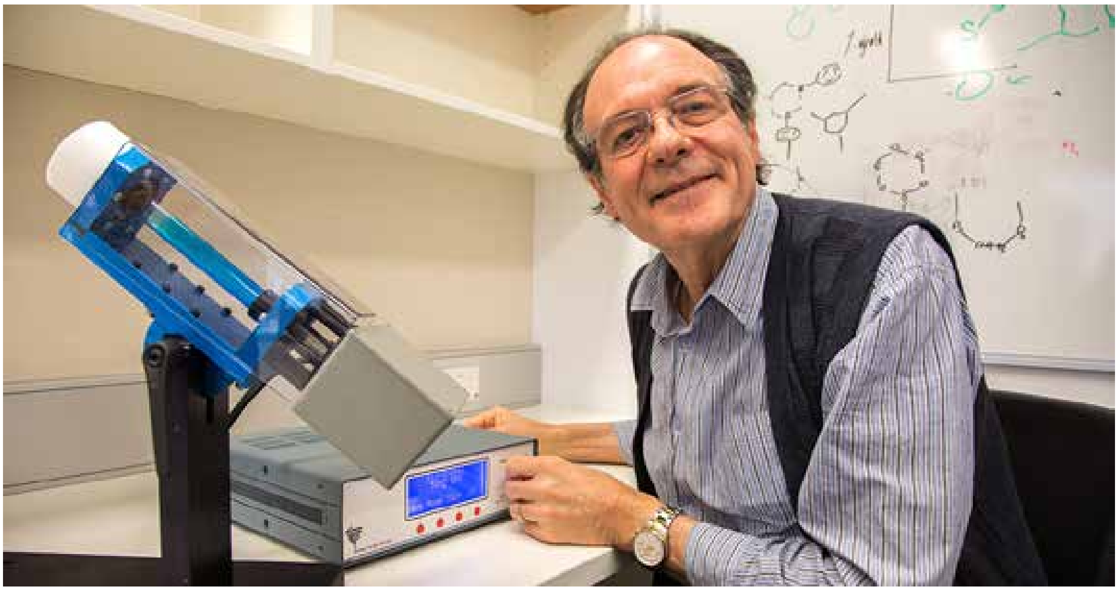

Professor Colin Raston – finalist and joint winner of the SA Government Science Excellence and Innovation Awards 2020 (Scientist of the Year category)

(Left to Right) Professor Carolyn McMillen, Chief Scientist for South Australia; Professor Colin Raston; David Pisoni, Minister for Innovation and Skills, SA Government; and Steve Murray, Member for Davenport

Professor Colin Raston is a highly recognised and prolific researcher and is the South Australian Premier's Professorial Research Fellow in Clean Technology, currently Professor of Clean Technology at Flinders University.

Since pioneering Australia's green chemistry movement in the 1990s, he has continued to focus on green chemistry and clean technology with research aimed at devising environmentally friendly alternatives to toxic chemicals processing. He invented the vortex fluidic device, which earned international recognition, and the research informing its creation and chemical process resulted in the establishment of a new science.

Professor Raston has commercialised his research, establishing successful spin-out companies 2D Fluidics and Hazer Group (ASX listed in 2015). In 2016, he was recognised for his outstanding achievement by appointment to the Office of the Order of Australia. In 2018, he was elected as a Fellow of the Australian Academy of Science.

●●●●●

Associate Professor Justin Chalker – finalist and winner of the Prime Minister's Prize for New Innovators 2020

Associate Professor Justin Chalker has invented a new class of polymers that stand to provide sustainable solutions to some of humanity's greatest challenges; namely ensuring clean air, fresh water and sustainable food production.

The polymers have proven effective in a range of real-world applications, including:

- removing mercury contamination from soil
- retrieving oil after a large-scale spill
- enabling a non-toxic method for leaching gold
- facilitating a slow-release fertiliser to reduce nutrient run-off.

Dr Kasturi Vimalanathan – 2020 Vice-Chancellor's Award for Early Career Researchers

As a Research Associate in Research Leader Professor Colin Raston's laboratory, Dr Vimalanathan's passion and sheer hard work is currently focused on developing fabrication methods under continuous flow using green chemistry metrics to manipulate 2D materials such as graphene, carbon nanotubes and fullerenes, to study their properties for a diverse range of applications.

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Professor Mats Andersson and Associate Professor Sophie Leterme won a $445,000 ARC Discovery Project (DP210101243) that will research coatings for the control and eradication of unwanted marine biofilms. Biofilms grow on all surfaces and environments, posing environmental threats and costly eradication efforts. This project aims to develop novel electrically conducting carbon-based paints that are stable in marine environments, and investigate how marine biofilms respond to these coatings. This work could result in a green solution for controlling the biofouling of surfaces immersed in oceans.

2020 PHD COMPLETIONS

2020 has been another successful year for PhD completions, with 13 students awarded their PhD

PhD – ALHARBI, Thaar
Supervisors: LAWRENCE, W and RASTON, C*
Thesis Title: Fabricating and Processing Carbon Nanomaterials using Vortex Fluidic Technology.

PhD – FULLER, Melanie
Supervisors: KÖPER, I* and LEWIS, D
Thesis Title: The Gold Standard; Enhancing Antibiotic Effectiveness through Gold Nanoparticles.

PhD – GRACE, Tom
Supervisors: ELLIS, A and SHAPTER, J*
Thesis Title: Investigations into the Carbon Nanotube/Silicon Heterojunction Solar Device.

PhD – KHORSAND, Mohammad
Supervisors: LEWIS, D and TANG, Y*
Thesis Title: Development of advanced energy harvesters: Theoretical and experimental studies.

PhD – McDONOUGH, Rowan
Supervisors: KÖPER, I and LEWIS, D*
Thesis Title: Silica Nanoparticles as a platform for intelligent cofactor immobilisation for biosynthetic applications.

PhD – NAMASIVAYAM, Muthuraman
Supervisors: ANDERSSON, M; LEWIS, D and SHAPTER, J*
Thesis Title: Enhancing the Properties of Polymer Nanocomposites by Inducing a Stable Dispersion of Carbon Nanotubes through Polymer Wrapping.

PhD – PETTIFER, Zoe
Supervisors: HARMER, S* and QUINTON, J
Thesis Title: New interpretations of pyrrhotite and pentlandite surface electronic structures: A route to the identification of minority species.

PhD – PYE, Scott
Supervisors: CHALKER, J and RASTON, C*
Thesis Title: Synthetic Applications of Vortex Thin Film Microfluidics.

PhD – SCROGGIE, Kym
Supervisors: CHALKER, J* and PERKINS, M
Thesis Title: Methods to incorporate silicon for the direct fluorination of proteins.

PhD – SHAMSALDEEN, Altaf
Supervisors: ANDERSSON, G* and ANDERSSON, M
Thesis Title: Interfacial study of dye-sensitized solar cells using photoelectron and ion scattering spectroscopy.

PhD – SITEPU, Eko Kornelius
Supervisors: HEIMAN, K; LETERME, S; RASTON, C; TANG, Y and ZHANG, W*
Thesis Title: Dynamic Thin Film Intensified Direct Transesterification of Oleaginous Biomass to Biodiesel.

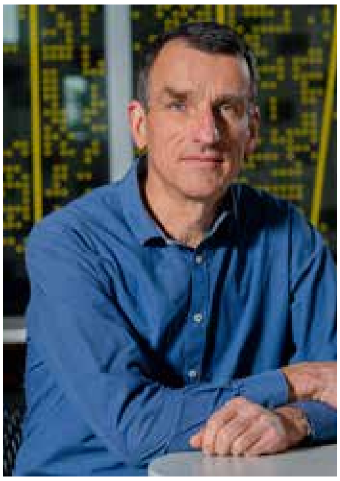
PhD – WILSON, Michael
Supervisors: ELLIS, A and SHAPTER, J*
Thesis Title: Synthesis and Characterisation of a New Class of Alkene Polymers Bearing Nucleotide Functionality.

PhD – WORTHINGTON, Max
Supervisors: CHALKER, J* and PERKINS, M
Thesis Title: Sulfur Polymers for Human Health and the Environment.

* Designates primary supervisor.

RESEARCH LEADERS

PROFESSOR
GUNTHER ANDERSSON



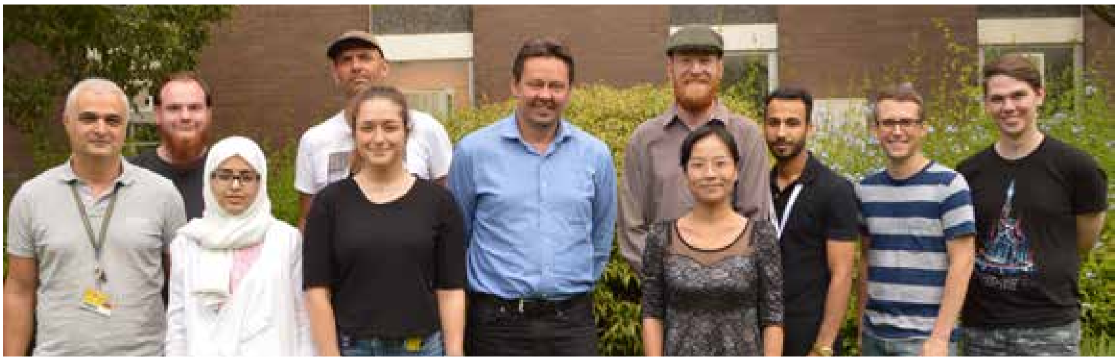
The G Andersson lab focuses on surfaces and interfaces, specifically clusters on surfaces, liquid surfaces and polymer interfaces. The lab has methods and equipment available and can investigate surfaces under ultra-high voltage conditions to liquid surfaces with finite vapour pressure. The latter capability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

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

PROFESSOR
MATS ANDERSSON

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

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



ASSOCIATE PROFESSOR
JUSTIN CHALKER

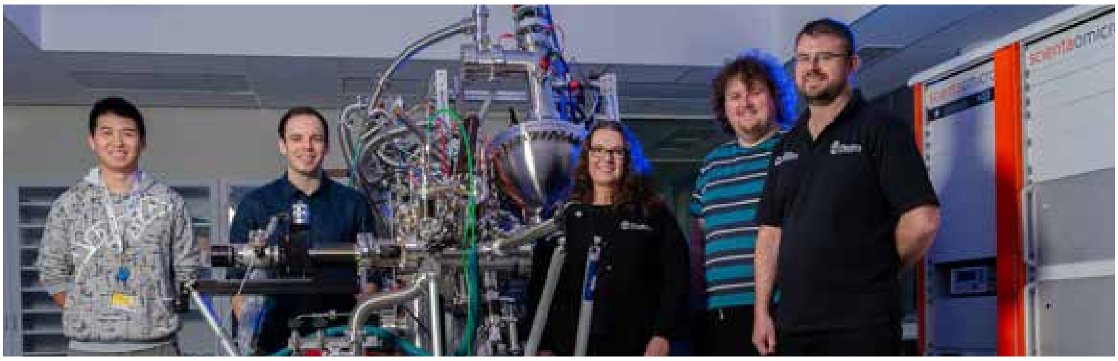
Justin Chalker's current research interests include organic chemistry, polymers, functional materials, sustainability, waste valorisation, environmental remediation, protein chemistry, chemical biology, sulfur chemistry, mercury, and mercury- and cyanide-free gold mining.

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

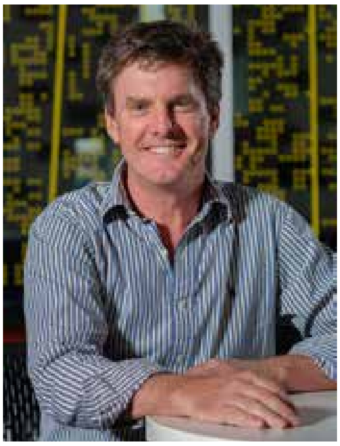
PROFESSOR
SARAH HARMER

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

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



ASSOCIATE PROFESSOR
MARTIN JOHNSTON



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

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

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.

ASSOCIATE PROFESSOR
SOPHIE LETERME

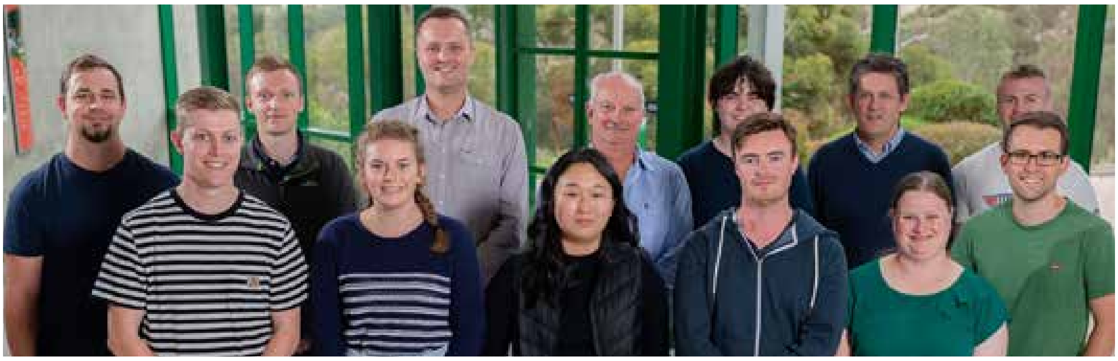
The Leterme laboratory focuses on aquatic microbes via two research streams: (1) the effects of environmental change such as drought, eutrophication on plankton biology, with a focus on diatoms and copepods; and (2) biofilm formation on surfaces immersed in aquatic systems, including water treatment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

Sophie joined Flinders University in 2006 as a post-doctoral researcher working on the ecology of the Coorong wetlands. She was promoted to Lecturer in 2008 and furthered her research on the adaptation of plankton to salinity fluctuations that was funded by the ARC through a Discovery Project. She currently leads a research program on microplastic in Australian coastal waters (@MicroplasticW) and is Director of the Biofilm Research & Innovation Consortium supported by the College of Science and Engineering (@BRIC_Flinders).

PROFESSOR
DAVID LEWIS

Professor Lewis is the founding Director of the Institute, commencing in 2010 and stepping down at the end of 2020. The Lewis research group is currently focused on the creation of functional particles and surfaces at the nano and micro scales to address challenges in 3D printing, the creation of self-assembled biomimetic surfaces and printable solar cells.

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

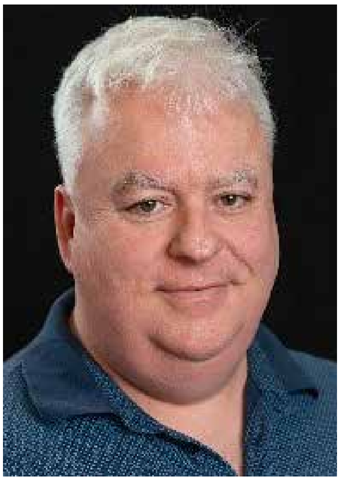


PROFESSOR
JIM MITCHELL

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.

PROFESSOR
JAMIE QUINTON



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

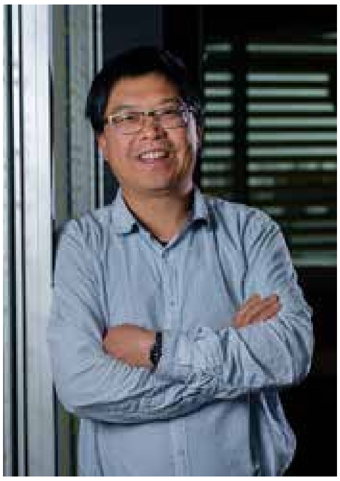
Jamie joined Flinders University in 2003 and was named the Flinders winner in the UniJobs Lecturer of the Year in 2009. He also received the Australian Learning and Teaching Council's Citation for Outstanding Contribution to Student Learning in 2010. He is a passionate, life-long learner who wants to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

PROFESSOR
COLIN RASTON AO FAA

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), Professor Raston has introduced a paradigm shift in continuous flow processing. Since 2012, the Raston lab has conducted over 100,000 experiments and published over 80 papers on the VFD alone. The global impacts of the VFD are ongoing. In 2015, the device earned international recognition when Professor Raston was awarded an Ig Nobel Prize in Chemistry for “partially unboiling” an egg.

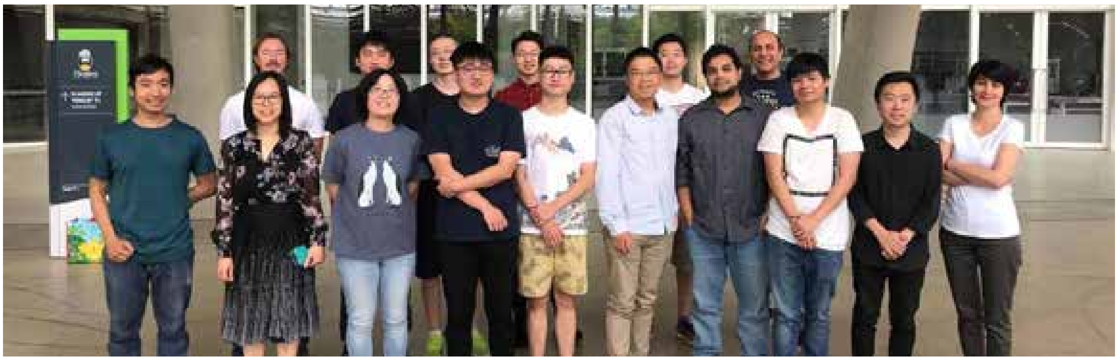
A Professor in Clean Technology and a former President of the Royal Australian Chemical Institute (RACI), Professor Raston has received multiple awards including the RACI’s Green Chemistry Challenge Award, the H.G. Smith Award, the Burrows Award, the Leighton Memorial Award for outstanding contributions to the profession, and the Applied Research Award. In 2016 he was Appointed an Officer of the Order of Australia, and in 2018 was elected Fellow of the Australian Academy of Science.

PROFESSOR
YOUHONG TANG



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

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



STRATEGIC RESEARCH AREAS

ENVIRONMENT

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

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

ENERGY

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

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

SECURITY

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

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

BIO-NANO

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

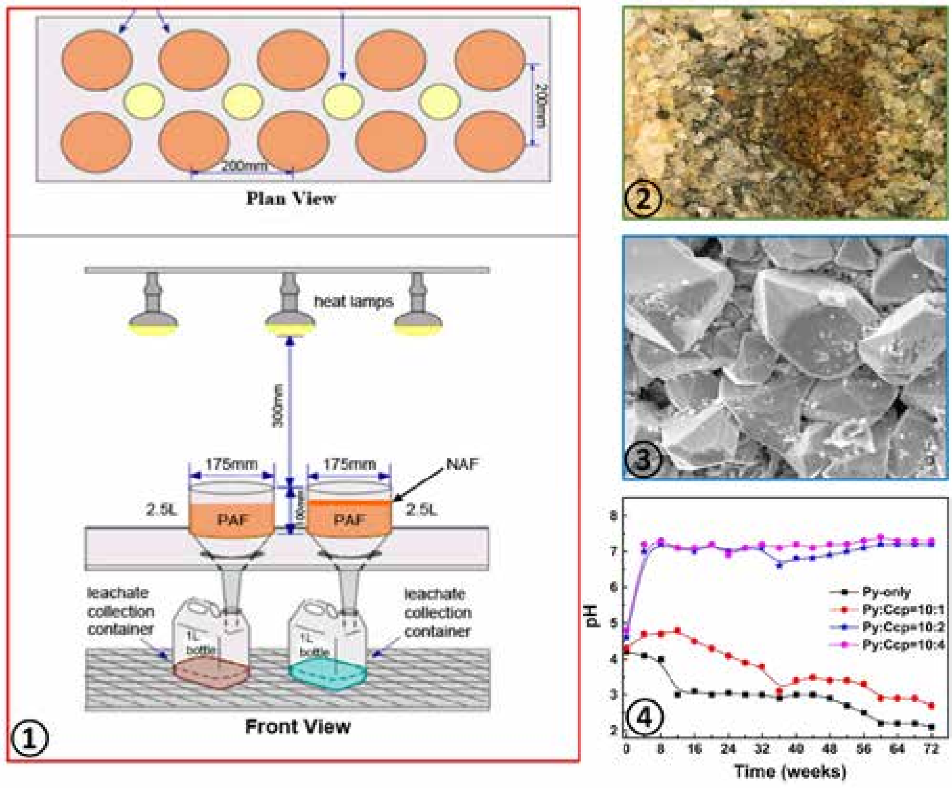
- biosensors
- antibacterial coatings
- drug-membrane interactions
- synthesis via biomimicry

ENVIRONMENT

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

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

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



1 – Kinetic leach column (KLC) setup; 2 – mixed sulfide waste rocks;
3 – Anglesite ($PbSO_4$) crystals formed on the sulfide surfaces;
4 – pH profile of the mixed pyrite/chalcopyrite bi-sulfide KLC.

ELUCIDATING THE MECHANISM OF ACID MINE DRAINAGE IN SINGLE AND MIXED SULFIDE SYSTEMS

Acid mine drainage, resulting from natural processes and mining activities, has been labelled by the United Nations as the second-largest global environmental issue after global warming. The Harmer group aims to address this issue by examining the dissolution behaviours of sulfide minerals, the source of acid mine drainage, under simulated conditions. This research seeks to provide a fundamental basis for sustainable and cost-effective remediation strategies that can be implemented by the government and the resource sector. The outcomes of this work will eventually bring benefits to the aquatic environment and human health and improve social acceptance of mineral resource development.

Chalcopyrite, galena, and sphalerite commonly co-exist with pyrite – the major contributor to the formation of acid mine drainage – in sulfidic mine wastes. Knowledge regarding their impact on pyrite oxidation and acid generation rate is limited and hinders the development of effective remediation strategies for mixed sulfide waste.

In work carried out by the Harmer group, single- and mixed-sulfide experiments used a kinetic leach column apparatus (Figure) at varying and realistic sulfide contents (several wt%) to mimic natural sulfidic waste rock conditions. Chalcopyrite was the most effective in limiting pyrite oxidation and acid generation with 77–95 per cent reduction in pyrite oxidation over 72 weeks, delaying a decrease in leachate pH. Galena had a lower impact than chalcopyrite, while sphalerite had the least with a reduction of pyrite dissolution by only 26 per cent. Our calculations and instrumental analyses revealed, for the first time, that the impacts of the three non-pyritic sulfides are due to variations in surface areas after dissolution and the bandgap and conductivity of sulfide minerals. The results are directly relevant to mine waste storage and demonstrate that the galvanic interaction plays a critical role in controlling acid generation in multi-sulfide waste even at low sulfide content. These findings will assist in predicting the dissolution behaviours of other sulfides under acid mine drainage conditions, enabling the development of sustainable and cost-effective remediation strategies for multi-sulfide waste rocks.

Collaborators: CSIRO Land & Water, the University of South Australia, Nanjing University, Monash University, Environmental Geochemisty International, and Blue Minerals Consultancy.

NEW GENERATION OF ACTIVE ANTIFOULING COATINGS FOR THE MARINE INDUSTRY

Sait Elmas, Tamar Jamieson, Sophie Leterme, Ingrid Brundin (ASC Pty Ltd.),
Mikael Johansson (ASC Pty Ltd.) and Mats Andersson

Traditional antifouling coatings incorporate high amounts of biocide such as copper and tributyltin (TBT) that are slowly released into the seawater to prevent marine growth. However, their widespread use has contaminated protected waters and raised concern about their toxic effect on non-targeted communities. Our ongoing research on antifouling technologies focuses on biocide-free, non-hazardous and sustainable alternatives.

Marine growth on underwater surfaces is a longstanding challenge for the marine industry and the marine ecosystem, both. Specifically, biofouling is a multistep process that causes severe damages to marine constructions, such as boats and costs billions of dollars to this sector. Once visible, on a macroscopic scale, this growth on ship hulls reduces its manoeuvrability and cause an increase in fuel consumption and greenhouse gas emissions. As a consequence of biofouling, unwanted marine species may also be introduced into non-native environments, putting marine ecosystems under increasing anthropogenic pressure. The application of antifouling coatings is both covered by legislation and regulations to help prevent such scenarios.

Traditionally antifouling is managed by applying antifouling coatings on ship hulls and other underwater surfaces that slowly release a biocide, for example, copper or tributyltin. 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.

Our ongoing research focuses on developing a new generation of active antifouling coatings that are biocide-free, non-hazardous and available on an industrial scale. To do this, commercially available coatings are made electrically conductive by applying multiple pulses of small current amplitudes per day, to suppress the biofilm growth. We have demonstrated that the formation and growth of diatom species have been reduced by up to 99 per cent under simulated laboratory conditions, compared to the control with no current amplitudes (Figure 1). We are now currently testing this technique on larger surfaces at the wharf of the ASC Pty Ltd.

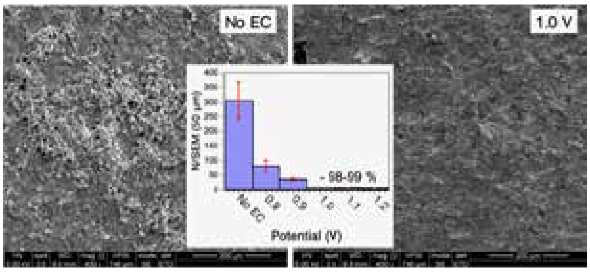


Figure 1
SEM image of diatoms grown on the control coupon (No EC) compared to the same coating with 1.0 V potential applied to the surface. Inset: Average number of diatom species per SEM image as function of applied potential compared to the control coupon (No EC).

PEELING BACK THE LAYERS: ULTRATHIN GALLIUM AND INDIUM NANOSHEETS PREPARED UNDER HIGH SHEAR

Zoe Gardner, Kasturi Vimalanathan
and Colin Raston

The climate crisis, need for green energy solutions and the push for efficiency in electronics, has increased attention on ultra-thin materials. These materials can be used for a range of applications (optoelectronics, energy harvesting and storage, and flexible electronics). Using an environmentally benign method of fluid flow in the Vortex Fluidic Device (VFD), the 2D outer layers of a eutectic melt of gallium and indium could be peeled off. The sandwich layers, which have gallium external and a thin indium richer layer, have potential applications in hydrogen evolution due to their high surface area and low toxicity.

The field of liquid metals in preparing nanomaterials has gained momentum as an emerging area of scientific research and takes advantage of low energy processing due to their low melting points.

Using the Vortex Fluidic Device (VFD) the planar or corrugated oxide skin of a eutectic melt of 84.7% gallium and 15.3% indium was exfoliated. This was achieved using high shear forces along with further understanding of the fluid flow in the thin film microfluidic platform. The 2D sheets contained 2 - 15% indium relative to gallium, which was found sandwiched between gallium(III) oxide layers, along with some un-oxidised gallium as established using Auger depth profiling. The sheets were found to be 20 to 42 nm thick and range from 5 to 20 µm in cross section in the lateral plane. These new findings represent an advance in understanding the structure, composition profile, and mechanism of formation of 2D-sheets from liquid metals.

The formation of the 2D sheets also provides insight into the mechanism of peeling with selective oxidation of the gallium and coupled with further advances in understanding the nature of the VFD fluid flow and sets the scene for expanding the processing using eutectic melts. This research adheres to the principles of green chemistry, providing an environmentally benign method for inclusion of elements into 2D materials, and this type of processing is attractive to industry beyond environmental consideration, with reduced capital outlay associated with small footprint processing.

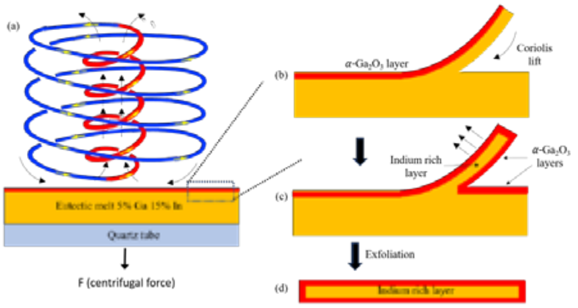


Figure 1
Proposed formation method a) Low pressure zone from the Coriolis fluid flow above the eutectic melt which is pressed against the quartz tube from the centrifugal force operating due to the rotational to the tube b) Initial peeling of the α -gallium oxide layer, due to lifting from the low pressure zone in the Coriolis flow c) Oxidation of exposed oxygen at the surface of the eutectic melt d) Resulting layered sheet structure with indium rich layer above the eutectic melt sandwiched between two layers of α-gallium oxide.

SURVIVAL OF THE FITTEST: PROKARYOTIC COMMUNITIES WITHIN A SWRO DESALINATION PLANT

Tamar Jamieson, Melissa Brown,
Amanda Ellis (University of Melburne), Sophie Leterme

Water scarcity is known to affect 40 per cent of the global population. By 2030 it is estimated that 700 million people will potentially become displaced due to drought. Seawater reverse osmosis (SWRO) desalination is recognised as one of the most cost effective and efficient methods to produce freshwater. However, biofouling of the SWRO membranes is detrimental to the efficacy of the desalination plants.

With biofouling influencing desalination plant production and costs, more effective methods of prevention and control are required. However, the origin of biofouling is often indeterminate. Several studies have focused on biofilm communities, especially bacteria, within water treatment plants to determine the origin of biofouling (Bereschenko et al., 2011; Chiellini et al., 2012; Pang and Liu, 2007). These studies are based on culture-dependent methods which are limited in providing insights into real conditions as a large portion of the microorganisms are uncultivable. Molecular methods allow for a more precise description of the microbial diversity and abundance. Characterisation of the biofouling parameters along the pre-treatment system and the membranes of a desalination plant also allows for a more effective management.

In this study, the community composition within the pre-treatment system used at the Penneshaw SRWO desalination plant (Kangaroo Island, South Australia) and the biological fouling parameters on the SWRO membranes were characterised. Membrane autopsies were also undertaken on the lead and lag positioned membranes that were operational for two and four years. 16S rRNA was extracted from (i) the intake seawater, (ii) the SWRO feed tank water, (iii) all the SWRO membranes to establish the communities within each environment. Scanning electron microscopy, attenuated total reflectance-Fourier transform infrared spectroscopy and transparent exopolysaccharide analysis was undertaken on the membranes, allowing for the characterisation of the fouling layers.

Results showed that the pre-treatment system allowed for the removal of microorganisms from the water, however niche communities were able to establish and proliferate within the plant due to environmental adaption.
The communities associated with the SWRO membranes were stable and had the ability to flourish on the membranes within biofilms. TEP accumulated significantly on the membranes, supplying a continuous source of nutrient for the communities of microorganisms. This study provides insights into the community structure within the pre-treatment system of the desalination plant, as well as on the SWRO membranes and examines the potential factors influencing their structure.

The key results obtained from our study in the Penneshaw SWRO desalination plant are consistent and complementary to each other:

- Niche environments exist within the Penneshaw SWRO desalination plant along the pre-treatment stages. Adaptive success of microorganisms to their surrounding environment permits the formation of dominant groups to form in each environment.
- The SEM analysis displays a cake-like layer on the lead membranes with particulate matter embedded within polymeric substrates, whereas, the lag membranes contain an amorphous matrix unevenly covering the membrane with particulate matter embedded within.
- Quantification of TEP on the fouled membranes determined that the membrane in the lead position was impacted more by TEP than the lag. The membranes that were in service for 4-years had more TEP than those in service for 2-years.
- Identification of functional groups using ATR-FTIR spectroscopy were consistent with proteins and polysaccharides which would suggest that they are a product of biofouling.
- The niche community structure on the membranes is stable and, diverse, but also dependent on the membrane position and year of service reflecting the water flow quality within the system.
- This study provides insights into the influence that the pre-treatment systems have on membrane fouling, as well as information on the unique environment that each membrane provides for fouling organisms.

Future considerations should focus on the fouling timeline especially regarding the fouling of all the membranes within each vessel within the SWRO compartment. Targeted approaches for the removal of TEP as well as TEP pre-cursors within water treatment systems needs to be established.

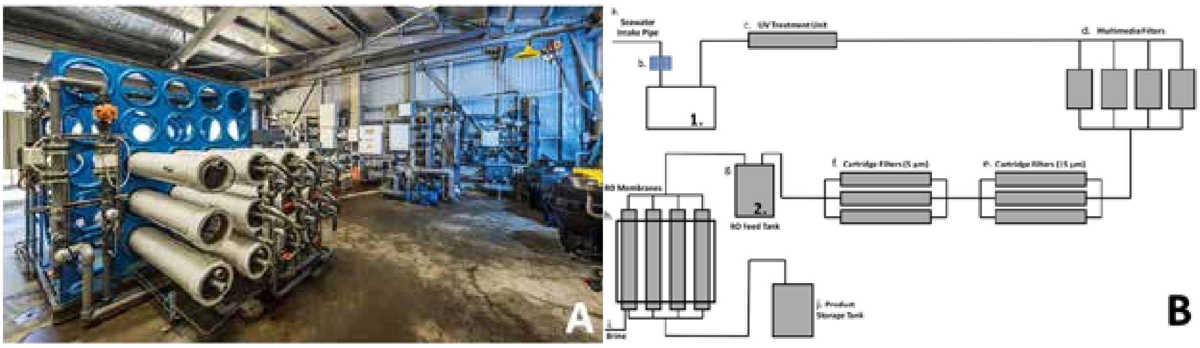


Figure 1
(A) Photo of the SWRO membrane unit at the Penneshaw Desalination Plant (credit: SA Water). (B) Schematic diagram of the Penneshaw SWRO desalination plant. Numbers indicate the different sampling points: (1) Intake seawater, (2) SWRO feed water and (3) SWRO membranes. Letters indicate the different aspects of the plant: (a) the Seawater intake pipe located 220 m offshore at a depth of 8 m, (b) intake seawater screen with 10 cm and 0.5 mm pore sizes, (c) medium pressure ultraviolet system, (d) multimedia medium pressure filter contains filter coal, quartz sand, garnet sand and graded gravel (e) 15 µm cartridge filters (f) 5 µm cartridge filters (g) SWRO feed tank (h) SWRO membrane unit (i) SW brine outlet (j) treated water storage tank.

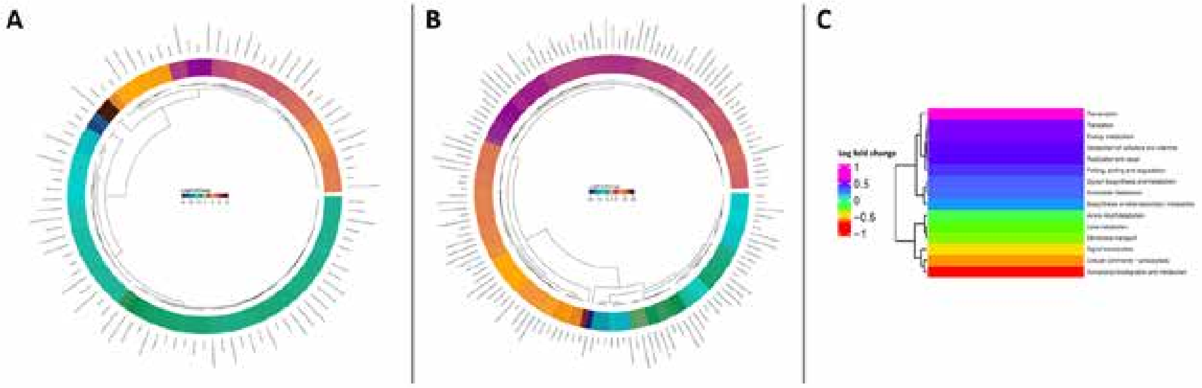


Figure 2
Circular heatmap representing the log fold changes of the prokaryotic organisms at the genus level which showed significant difference ($p < 0.005$) between (A) the intake seawater and the SWRO feed tank water (B) the SWRO feed tank water and the SWRO membranes. Heatmap representation of the log fold changes of the predicted functional genes which showed significant difference ($p < 0.005$) between (c) the SWRO feed tank water and the SWRO membranes. Dendrogram represents the hierarchical clustering of the column based on the Euclidean distance with complete linkage clustering. Shades of colour represent the log fold change increase and decrease (see colour scale).

NANO-ROUGHENED SURFACES FOR LOW-SOILING SOLAR INSTALLATIONS

Schannon Hamence, David Lewis,
Christopher Gibson

Central Australia is a great place to collect solar energy. Unfortunately the dry and dusty conditions quickly cover the collectors, lowering their efficiency. Nano-roughened surfaces can help reduce dust build-up by making surfaces that are harder for dust to stick to. Low-soiling materials are important because keeping solar collectors clean is one of the major ongoing costs associated with running a commercial solar farm.

Dust is loosely defined as particles under 500um. Because of their small size such particles are easily carried by the wind where they can be deposited on the surface of photovoltaics or solar reflectors. These particles attach 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.

VdW forces are a function of the amount of contact area between two surfaces. As such they can be reduced by minimising the contact area between particles and surfaces. A roughened surface has only a fraction of the surface area available to contact a dust particle compared with a smooth surface. We used nanoparticles to create a uniformly roughened surface that presents significantly less surface area than a smooth one.

Capillary forces occur when a thin layer of water on the surface forms a meniscus bridge between the surface and the particle. One way to reduce capillary forces is to have the water layer drawn to the spaces between prominences rather than coating the whole surface. This reduces the volume available to form meniscus bridges and where they do form they are anchored to points rather than flats making them easier to pull apart. We created surfaces with different degrees of roughness to investigate how it affected the adhesion of dust particles. These experiments showed an increase in dust shedding ability with increasing roughness. Further experiments are planned to optimise the surface chemistry of coatings to further decrease capillary forces.

Nanoparticles for these coatings have been developed in house using a novel and scalable process. This is an important step in making a useful surface treatment because it means the treatment doesn't involve any complicated or costly steps like laser etching or photolithography. Field tests of coatings has also begun so we are excited to see some real-world results in the coming year.

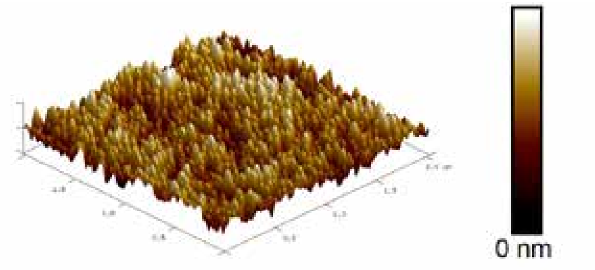


Figure 1
3D AFM image nano roughened surface.

REACTIVE COMPRESSION MOLDING POST INVERSE VULCANIZATION: A METHOD TO ASSEMBLE, RECYCLE, AND REPURPOSE SULFUR POLYMERS AND COMPOSITES

Nicholas Lundquist; Alfrets Tikoalu; Max Worthington; Ryan Shapter; Samuel Tonkin; Filip Stojcevski (Deakin University); Maximilian Mann; Christopher Gibson; Jason Gascooke; Amir Karton (University of Western Australia); Luke Henderson (University of Sydney); Louisa Esdaile and Justin Chalker

This story describes a new method for recycling high sulfur content materials after use in their desired applications.

To achieve truly sustainable materials, new recycling, reforming, and re-use strategies must be developed. Polymers prepared by inverse vulcanization and plant oils have demonstrated efficiency in a wide variety of applications however due to their thermoset nature, efficient recycling strategies have yet to be established.

This study demonstrated a new technique for recycling used polymer and converting it into a value-added product for use in construction and building. This process involves the use of compression to force the polymers reactive surfaces into direct contact, followed by heating (100 °C) to induce a sulfur exchange reaction between neighbouring S-S bonds. This process was not only an effective way to recycle waste polymer into new polymeric mats and blocks, but it could also be utilised to prepare high sulfur content composite materials.

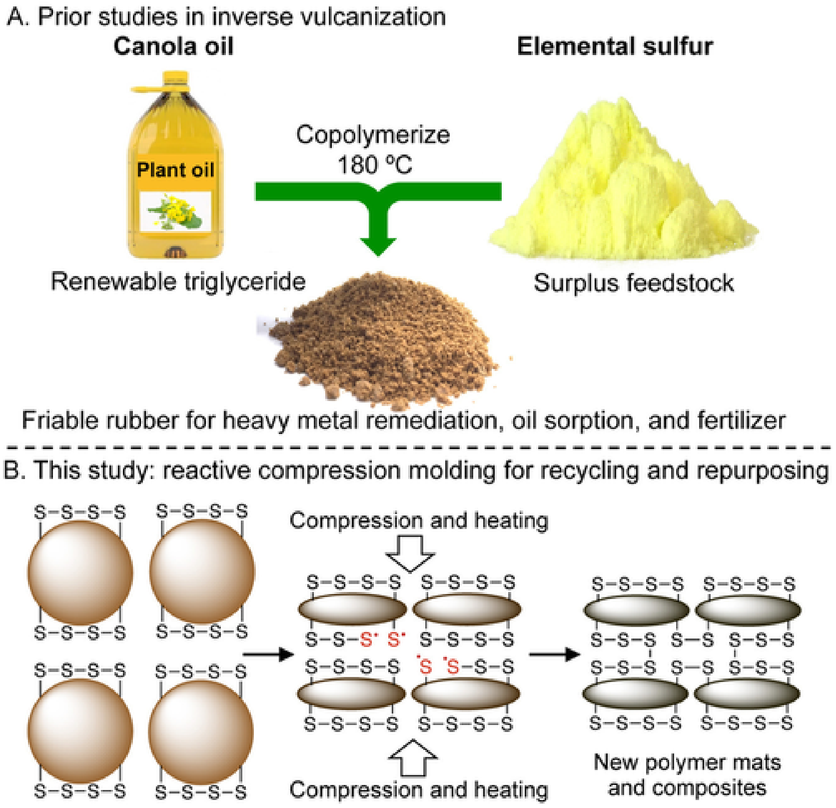


Figure 1
A) Image describing preparation of 50-poly(S-r-canola) polysulfide,
B) Mechanism for reactive compression molding via sulfur exchange.

INSULATING COMPOSITES MADE FROM SULFUR, CANOLA OIL, AND WOOL

Israa Bu Najmah, Nicholas A. Lundquist, Melissa K. Stanfield, Filip Stojcevski, Jonathan A. Campbell, Louisa J. Esdaile, Christopher T. Gibson, David A. Lewis, Luke C. Henderson (Deakin University), Tom Hasell (Deakin University) and Justin M. Chalker

This work examines a new application of inverse vulcanized sulfur polymer to produce a sustainable composite for evaluation as a building material and insulation. All building blocks are sustainable or obtain from waste.

New efforts to design and to use sustainable building materials are important to decrease our dependency on petroleum-based products such as synthetic plastics, rubbers and composites. construction materials have some issues such as expensive and not environmentally friendly. The current insulation materials made from polymer-like polystyrene and polyurethane foam harm the environment. Development of insulating materials with excellent properties and less environmental impact and low cost is absolutely necessary. Therefore, the final composite provided is the promising construction material for energy-saving insulation using inexpensive materials, and sustainable.

Using a sustainable building block raw wool, sulfur, and canola oil, an insulating composite was made. The synthesis starts with making a polysulfide polymer made from inverse vulcanization using sulfur and the canola oil triglyceride. This polymerization profit from the entire atom economy. In the second stage of the project, raw wool is mixed with the powdered polymer, through the electrostatic attraction to help the polymer to coat the wool. With mild heating to provoke S-S metathesis in the polymer, the polymer and wool mixture then compressed, which keeps the wool in the polymer matrix. Insulating properties, flammability and tensile strength improve in the composite by using the wool fibres. All building blocks are sustainable or obtain from waste and helpful for the next-generation insulation for energy conservation.

Our research demonstrates that reactive compression moulding method can be used to prepare composites of a mixture of polymer and wool as a filler material with applying heat and enough pressure. The preparation of the second composite was by mixed the poly(S-r-canola) with raw wool together directly at an equal amount. Fortuitously, the powdered poly(S-r-canola) readily retains static charge which assists its binding to the wool fibre. This phenomenon is important and helpful in the composite synthesis of this project because it assists create a relatively even distribution of polymer across the wool fibre surface. The polymer-coated wool undergoes in the reactive compression moulding resulting in a composite mat in which the raw wool fibres are randomly distributed through the polymer.

Dynamic Mechanical Analyzer (DMA) was used to assessed tensile strength of all composites. A polymer control mat with no filler had the lowest yield strength and lowest modulus of elasticity. All composites samples with raw wool as filler were superior in this compared to the polymer control mat. In addition, all composites using wool as filler were superior in yield strength and modulus regard to the polymer alone. The polymer can be improved by the reactive compression moulding process at any position of the shape of the fibres.

The insulation properties of the 50-poly(S-r-canola) and raw wool (1:1 ratio mixed randomly before reactive compression moulding) was illustrate by using an infrared camera to image the composite mat. The composite mat placed on a metal plate pre-heated to 60 °C. polymer control mat, a wool mat, polypropylene, glass, wood and a composite mat that was tested. The composite mat shows the best result comparing to all materials. The composite mat overheats slowly over the 3 minutes than the rest of materials. Also, all materials were cool down over 3 minutes at room temperature. During cool down time the composite mat show the elevated heat retention. The slow diffusion of heat is compatible with its low thermal conductivity.

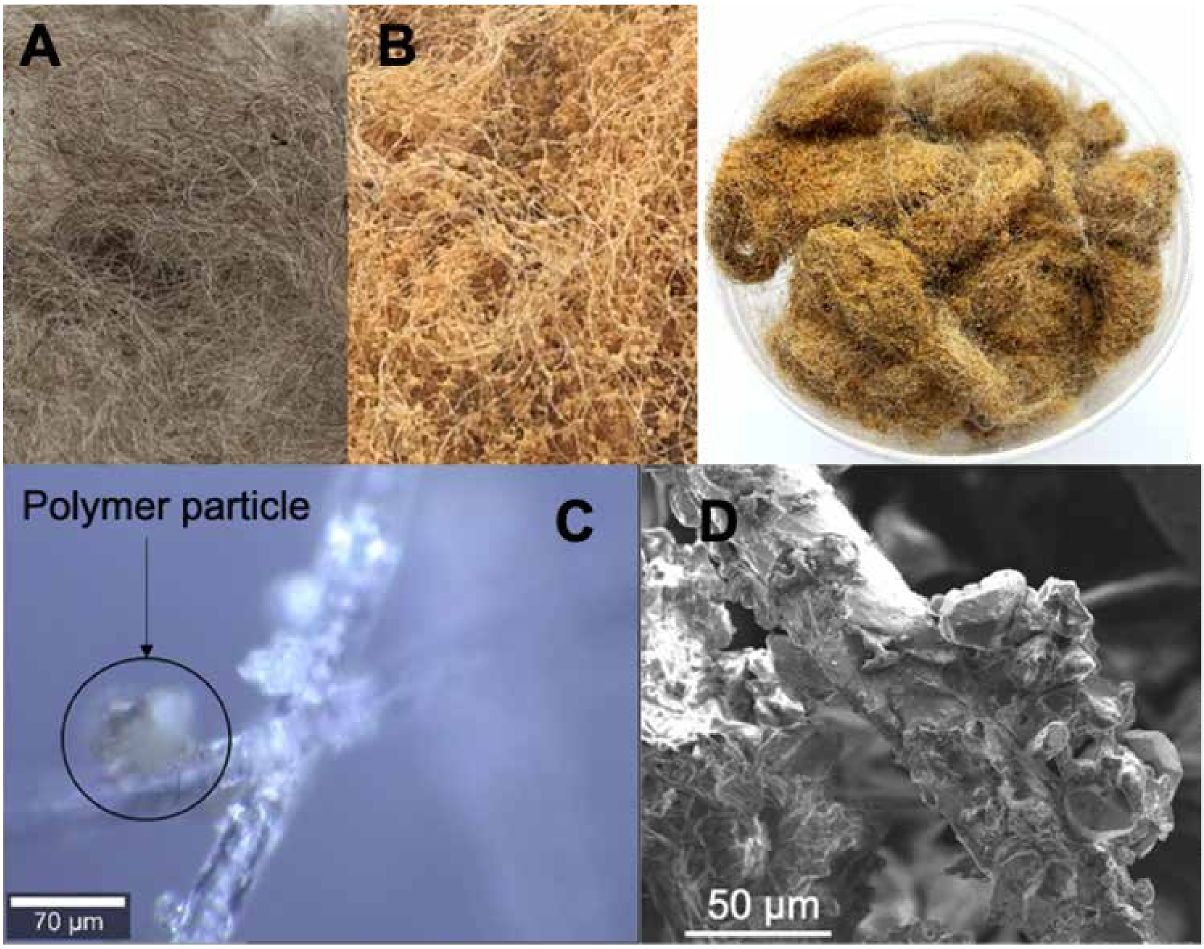


Figure 1
A) Raw wool, B) Raw wool and 50-poly(S-r-canola) mixture. C) SEM micrograph of the mixed poly(S-r-canola)/wool mixture, and D) optical image and of polymer on wool.

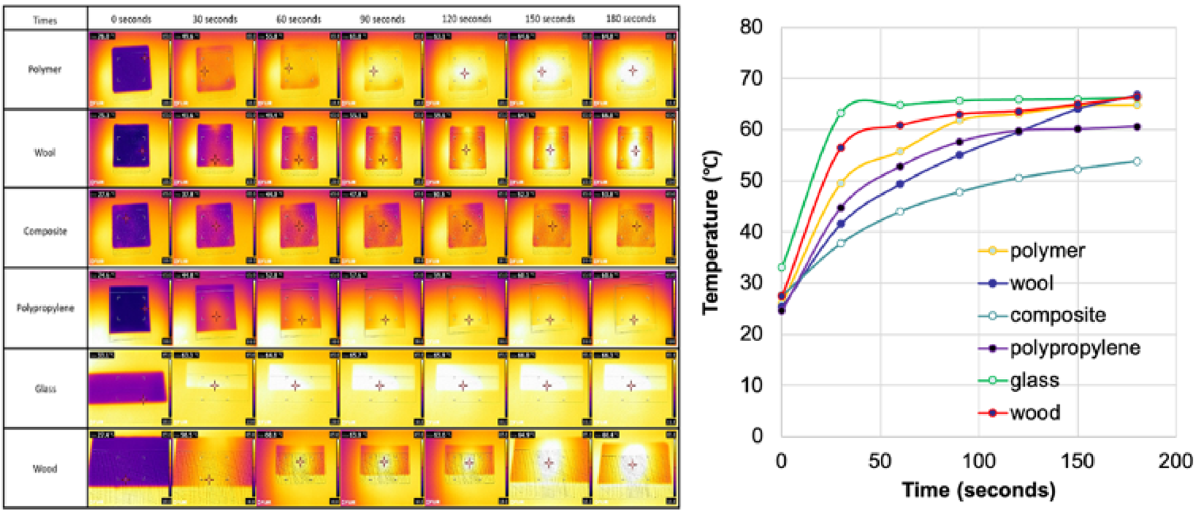


Figure 2
Images showing composite material and samples heating over three minutes using FLIR camera

A SIMPLE CARBONISATION PROCEDURE IMPROVES MERCURY UPTAKE OF A POLYMER MADE BY INVERSE VULCANISATION

Maximilian Mann, Xuan Luoa, Christopher T. Gibson, Riyadh Al-Attabi (Deakin University), Allan Pring,
Colin L. Raston, Luke C. Henderson, Tom Hasell (University of Liverpool) and Justin M. Chalker

Mercury pollution is a global problem. Therefore, new strategies are needed to address this issue. A promising way to remediate mercury pollution is by using sorbents to capture mercury. A polymer made from the low-cost and renewable canola oil and sulfur was carbonised to improve mercury uptake.

Mercury is a toxic element that can be found in multiple areas like gold mining, coal combustion and oil and gas refining. Along with the natural release of mercury through processes like geothermal or volcanic activity and the weathering of rocks, a large amount is released through anthropogenic sources. These sources include small-scale gold mining as well as the burning of fossil fuels. This leads to a concerning global mercury pollution. Hence, there is a need for new ways to remediate mercury pollution. A sulfur rich carbon that was prepared by using a simple carbonisation procedure of a polymer has been found to capture mercury from solution. This polymer is made by the bulk polymerisation of canola oil and sulfur at 180 °C for approximately 30 minutes. Canola oil is renewable and both canola oil and sulfur are low-cost and abundant resources.

To improve the mercury uptake capabilities, a simple carbonisation method was used. The polymer was carbonised at 600 °C resulting in a brittle black solid, that can be crushed using mortar and pestle. Mercury uptake experiments showed comparable or superior performance compared to commonly used commercial carbons. Additionally, the carbonisation process is far simpler and less energy intensive than the traditional methods of activated carbon manufacture.

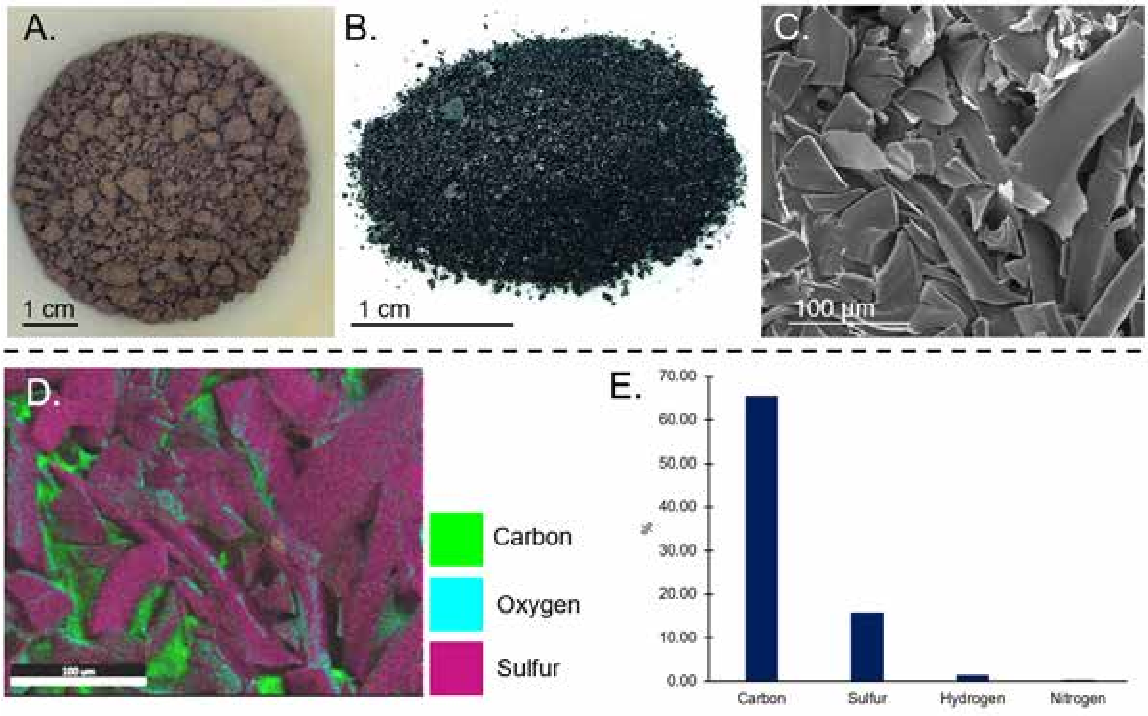


Fig. X **A.** 100 g of 50-poly-(S-r-canola) polymer before carbonisation. **B.** Final carbonised-1 after removal from crucible and coarse crushing. **C.** SEM micrograph of carbonised-1. **D.** EDX elemental map of carbonised-1. **E.** Combustible analysis of carbonised-1

CHEMICALLY INDUCED REPAIR, ADHESION AND RECYCLING OF POLYMERS MADE BY INVERSE VULCANISATION

Samuel J. Tonkin, Christopher T. Gibson, Jonathan A. Campbell, David A. Lewis,
Amir Karton (University of Western Australia), Tom Hasell (University of Liverpool) and Justin M. Chalker

This research provides a potential solution to one of humanity's greatest environmental challenges, plastic waste. In this paper, it was shown that polymers prepared through inverse vulcanisation could be repaired or completely recycled by nucleophilic catalysts at room temperature. It was then demonstrated how this unique property could be exploited to produce high-quality products which could be repaired and reused multiple times or cheaply recycled to fit a new application.

Plastic pollution has become a major issue in modern society. It has far reaching and devastating effects on ecosystems around the world and is estimated to result in billions of dollars of economic loss every year. Plastic pollution occurs as only a small proportion of plastic is recycled, largely due to high energy costs and low economic incentive. This issue is particularly prevalent with cross linked polymers as they cannot be easily recycled, leading to huge amounts of waste. The research presented in this paper demonstrates a catalytically induced reaction which can be used to repair damage or completely recycle polymers prepared through inverse vulcanisation at room temperature.

Polymers prepared through inverse vulcanisation contain a dynamic polysulfide backbone which gives them many unique properties. The reaction developed in this paper utilised nucleophilic catalysts like pyridine and tributylphosphine to attack the sulfur backbone which resulted in a reversible reaction that could break and reform the sulfur-sulfur bonds in the polymer. This would lead to the repair of the polymer by producing new sulfur bonds in areas of damage. It was shown that by using this reaction, the polymer could be repaired from a clean cut to over 90 % of its original tensile strength. Furthermore, as this reaction can occur at room temperature, there is no additional energy costs from heating. The results from the polymer tests were confirmed using a model study of di and tri-sulfides. These studies provided direct evidence of sulfur bond metathesis and indicated that the nucleophilicity of the catalyst and average sulfur chain length in the polymer is crucial for the reaction to occur.

The applications of this research was demonstrated through a series of experiments using a heavily crosslinked polymer prepared from sulfur, dicyclopentadiene and canola oil. These experiments showed that the reaction could be used in additive manufacturing techniques and could completely recycle the polymer despite its high level of crosslinking. This research indicates that polymers prepared through inverse vulcanisation could serve as an environmentally friendly alternative to conventional plastics. The removal of energy requirements from heating could drive down the cost of recycling and provide an economic incentive for governments and businesses to recycle plastics rather than produce virgin stock.of materials. Also, all materials were cool down over 3 minutes at room temperature. During cool down time the composite mat show the elevated heat retention. The slow diffusion of heat is compatible with its low thermal conductivity.

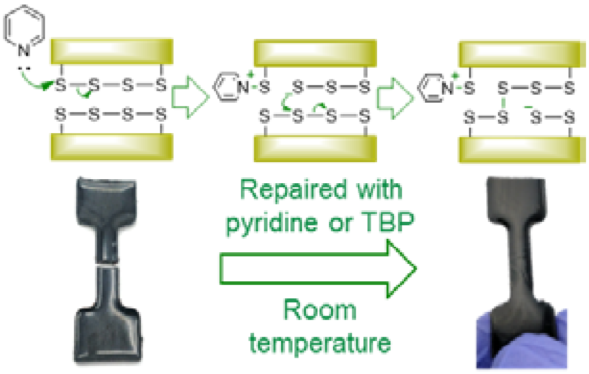


Figure 1
Mechanistic description of pyridine induced reaction and images showing the room temperature repair of a polymer prepared through inverse vulcanisation.

SELECTIVE MORPHOLOGICAL CONTROL OF SINGLE WALLED CARBON NANOTUBES

Matt Jellicoe, Chris Gibson,
Kasturi Vimalanthan and Colin Raston

Single walled carbon nanotubes (SWCNTs) are a highly versatile nanomaterial used in a multitude of applications. The ability to alter their morphology has unforeseen potential to nanotechnology. Coiled SWCNTs have been used in various devices due to their unique electromagnetic properties compared to straight pristine SWCNTs. We use the vortex fluidic device (VFD), a microfluidic device, to control the size and morphology of SWCNTs.

Using the vortex fluidic device (VFD), we can control the morphology of single walled carbon nanotubes (Fig. 1) through the alteration of solvents, tube size and tube type. We have observed the formation of rings previously seen in the VFD, however we can control the ring diameter and thickness of the rings through altering the aromatic solvent. Typically, we undertake most VFD projects in a 20mm (O.D) VFD quartz tube however we observe that alteration of the VFD tube size from 20 to 15 to 10mm (O.D) decreases the ring diameter. Furthermore, we observe the formation of SWCNT rods and figures of 8 under select conditions.

This study may help pave a new future for SWCNT application in nanotechnology, the formation of rings less than 50nm in diameter has potential to be used in multiple devices.

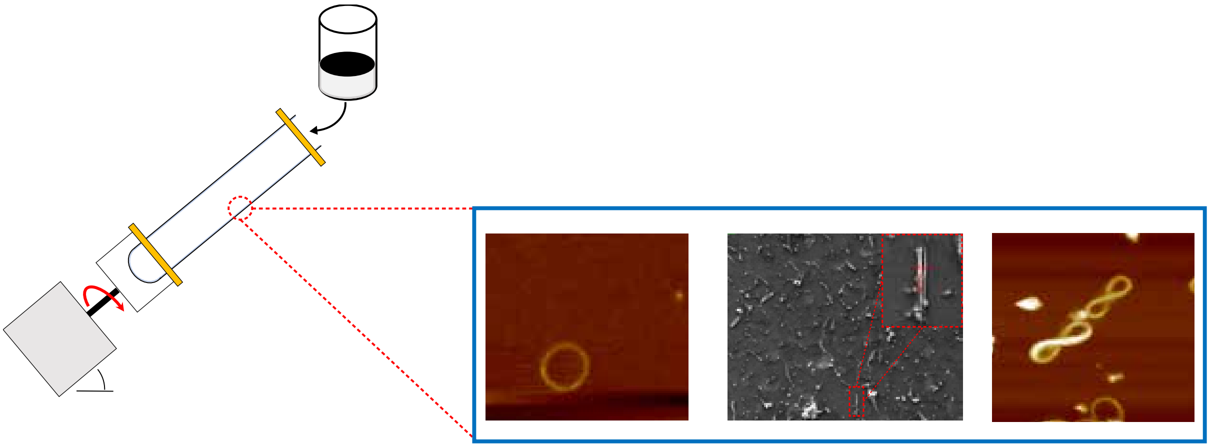


Figure 1
Schematic diagram of the various morphologies of SWCNTs formed in the VFD at various conditions.

THE REPLACEMENT REACTION OF CHALCOPYRITE BY COVELLITE UNDER HYDROTHERMAL CONDITION

Zhen He, Sarah Harmer, Allan Pring and Gujie Qian

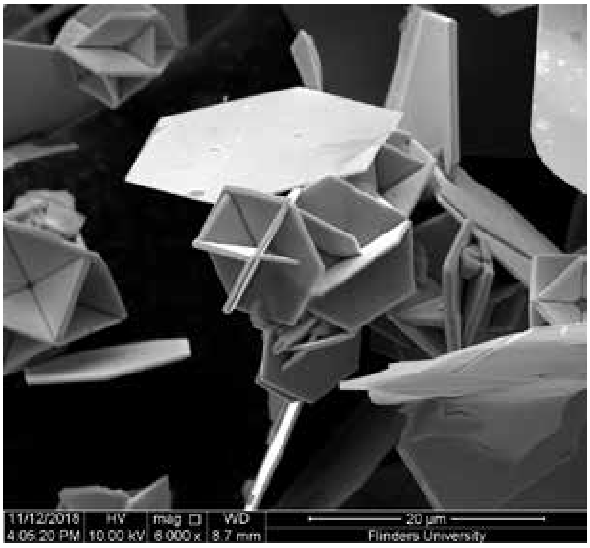
Chalcopyrite ($CuFeS_2$) and Covellite (CuS) are the major sources of copper in our daily life. Covellite is generally formed at supergene layer by replacing chalcopyrite, but the mechanism behind this is not fully understood. This research is discovering the optimum conditions that convert chalcopyrite to covellite and understand its mechanism and kinetics.

In the supergene layer, covellite (CuS) is commonly found and recognised as a secondary copper sulfide. Previous studies suggest that covellite is formed by a mineral replacement reaction from chalcopyrite ($CuFeS_2$) *in situ*. There have been a limited number of studies conducted on the replacement of chalcopyrite with covellite, and the reaction mechanisms are still not well-understood. The leaching of copper from covellite is more efficient as compared to chalcopyrite, and it could be an alternative copper leaching approach by converting chalcopyrite to covellite *in situ* and extracting the copper from covellite. In this research we aim to understand the mechanisms and kinetics of the replacement reaction of chalcopyrite by covellite/chalcocite under hydrothermal conditions enabling an extrapolation of the reaction rate at low temperatures, typically in supergene environment.

Figure 1a shows the formed covellite by replacing chalcopyrite has hexagonal, euhedral structure with sharp edges. The C-section SEM image (Figure 1b) presents the replacement reaction of chalcopyrite by covellite formed sharp front between the primary mineral (Chalcopyrite) and secondary mineral (Covellite), and it generates numerous pores and cracks. This provides evidence that the chalcopyrite replacing by covellite involves both the dissolution of chalcopyrite and re-precipitation of covellite as following chemical reaction pathway.

The results show the replacement reaction of chalcopyrite to covellite can be achieved under pH 1, 2 and 3 between 140-200°C. The replacement reaction rate increases as the pH value decreases. At pH 0.5, chalcopyrite is completely converted to covellite within 16 hours at 200°C. Under ambient condition, chalcopyrite needs more than 20,000 years (estimated by extrapolation of kinetic study) to be completely replaced by covellite.

In conclusion, the replacement reaction of chalcopyrite by covellite is a typical interfacial dissolution-reprecipitation mechanism. The replacement reaction is successfully achieved under acidic conditions and the reaction rate increases as the condition becomes more acidic.



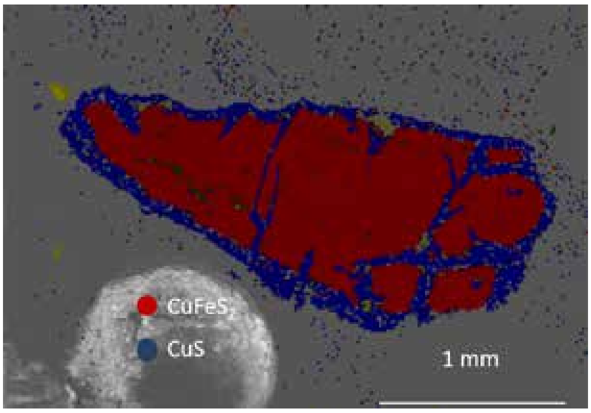


Figure 1
a) The synthetic covellite formed by replacing chalcopyrite; b) The C-section of chalcopyrite partially replaced by covellite.

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

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

Himalayan salt is pink in colour and contains trace minerals such as potassium, magnesium, and calcium but common table salt is white being essentially pure sodium chloride. This colour alteration is due to specific ion effect. This research focuses on understanding these specific ion effects on various solvents and polymer systems.

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

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

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

One important missing element of the specific ion effect is where ions accumulate. That is, where do the ions interact with interfacial molecules of the solvent. Many research articles have been published on this topic but are based on simulations, but only few have presented experimental results. Neutral impact collision ion scattering spectroscopy (NICISS) has been used here and has a novel advantage for finding this missing piece of information.

By obtaining concentration depth profile using NICISS, information about where ions interact with solvent molecules in different systems can be obtained. To date, our research has investigated 12 different salts in glycerol and discovered that smaller ions like chlorine ions are found closer to glycerol surface. The results found so far have implications towards understanding the chemistry of atmospheric aerosol spray of sea water where glycerol serves as a model constituent of sugary constitutes present in aerosol droplet.

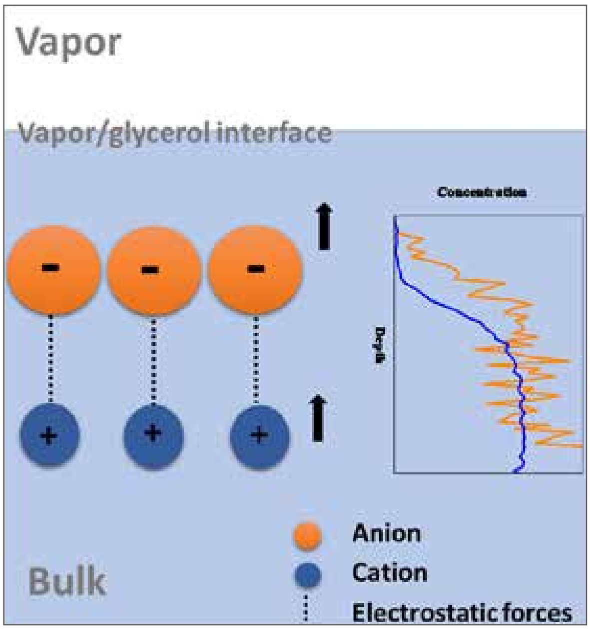
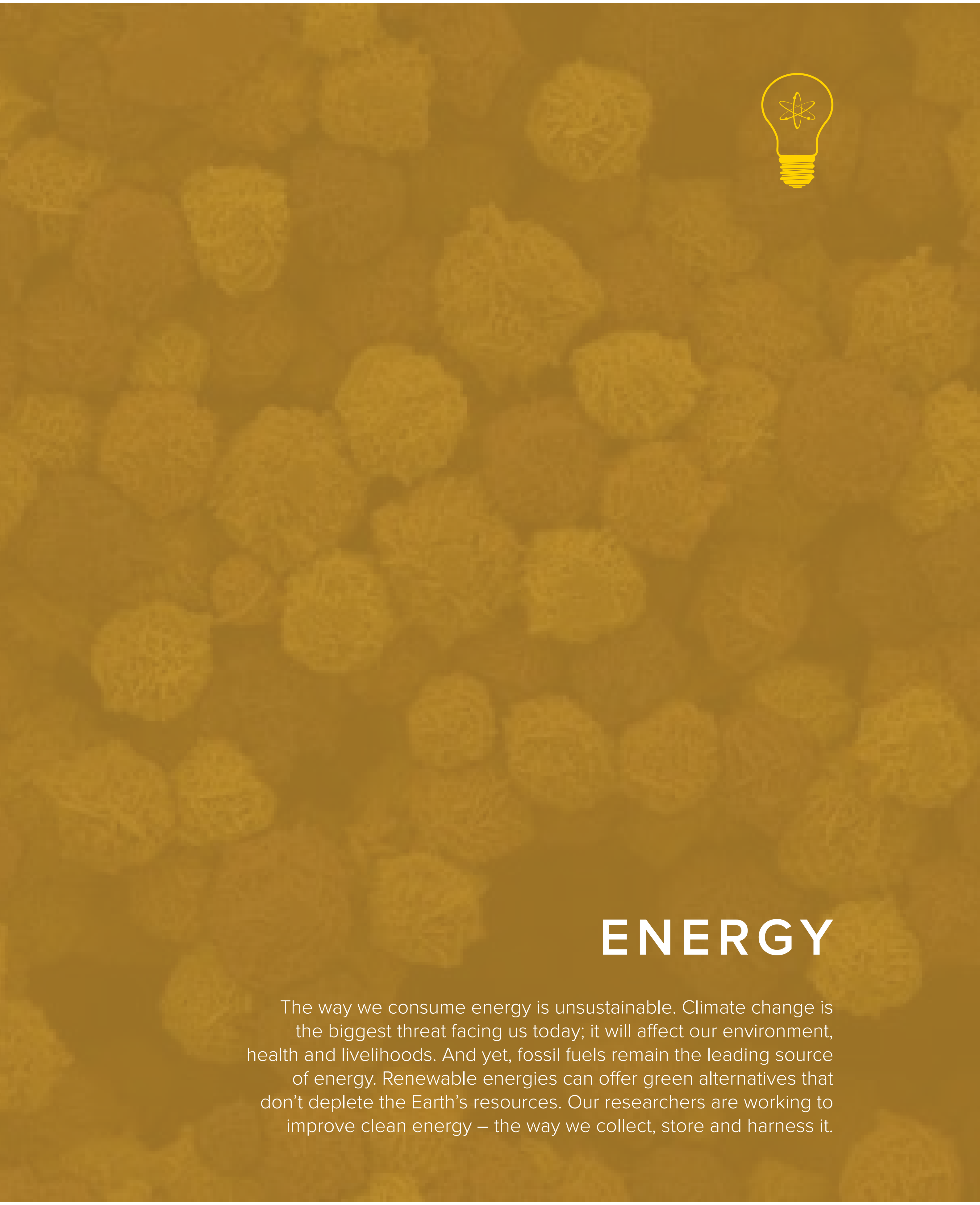


Figure 1
Cations following anions towards vapor/glycerol interface due to electric double layer formation.



ENERGY

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

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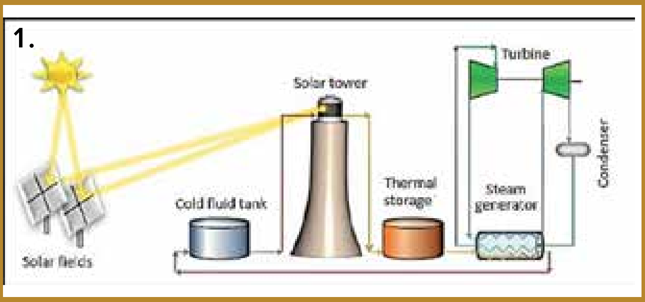

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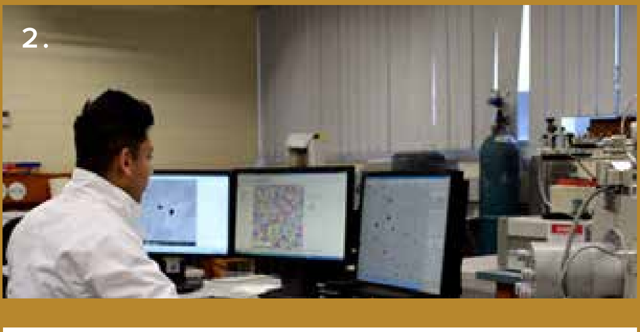

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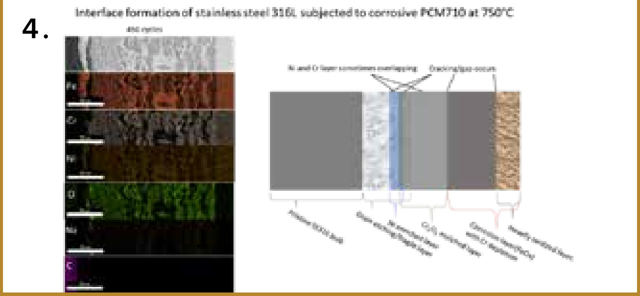


IS CONCENTRATED SOLAR POWER THE FUTURE OF ENERGY?

Concentrated solar power plants harvest energy from renewable sources such as the sun and tend to encounter harsh environmental conditions. This lengthy exposure can result in the untimely failure of components. By using appropriate alloys capable of withstanding extreme weather and operating conditions, the useful life of these plants can be extended and efficiency increased. The G Andersson lab has conducted advanced corrosion studies of the materials used in solar receivers, storage, and heat exchangers.

Conventional solar power plants use alloys that operate at lower temperatures allowing for greater flexibility in materials selection. However, this limits the performance and lifetime of these plants, paving the way to understand these materials' behaviour, primarily related to corrosion in high-temperature conditions. Recent research demonstrates that both iron and nickel-based superalloys can perform effectively long-term without compromising their intrinsic characteristics.

To understand corrosion mechanism and be able to design better alloys for concentrated solar plants, the G Andersson and Lewis labs collaborated to thermally treat a wide range of steel alloys in expedited cycles to generate layers of corrosion on the materials. These corrosion layers are formed primarily due to the materials' compositions, and their reaction to high temperature and varying chemical environments. By controlling the elemental composition, it is possible to reduce the degree of corrosion of these layers. Since chromium and nickel are the two most important elements in the corrosion studies of steel, their presence, concentration and how they form compounds are monitored. The way these elements move out of the alloys and migrate to the corrosion layers is also another critical observation. By choosing the right balance amongst these elements, it is possible to predict and limit the progression of corrosion. It is also important to identify the conditions of reactive chemicals in the environment that can trigger certain corrosion mechanisms. Since these elements are often exposed to phase-changing materials and liquid salts in real systems, the understanding of how they affect the alloys at high temperature is critical.

Using advanced analytical techniques such as Micro Computed Tomography, Scanning Electron Microscopy, X-Ray Photoelectron Spectroscopy, Scanning AUGER Microscopy, X-Ray Diffraction, we have looked at the materials' behaviour down to a nano-level, allowing for a deep understanding of the suitability of these superalloys in the solar power industry.

Even though theoretical predications can help this industry design its 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 the future renewable energy sector.

Image 1: Typical commercialised concentrated solar thermal loop, using heating fluid exchanger and phase change materials for storage medium, and superalloys for storage contaminant.

Image 2: Using high resolution scanning electron microscopy to observe high-temperature corrosion behaviour and microstructure in superalloys.

Image 3: Application of high-resolution electron spectroscopy for determining the chemical degradation of superalloys subject to high temperature corrosive environment.

Image 4: A typical analysis using microscopy and depth-profiling spectroscopy for determining the microstructure and elemental profiles of surfaces of superalloys subject to corrosive environments.

Collaborators: Flinders Microscopy and Microanalysis (FMMA), Australian Solar Thermal Research Institute (ASTRI), Australian Renewable Energy Agency (ARENA)

STABILISING Au_9 CLUSTERS ON TiO_2 FILMS WITH A Cr_2O_3 LAYER

Abdulrahman S. Alotabi, Yanting Yin, Ahmad Redaa (The University of Adelaide), Siriluck Tesana (University of Canterbury),
Gregory F. Metha (The University of Adelaide) and Gunther Andersson

Photocatalytic hydrogen (H_2) production can be an efficient renewable energy source. Photocatalytic water splitting is a renewable way of producing hydrogen using solar energy. This process produces hydrogen by splitting water into hydrogen and oxygen using semiconductor materials as photocatalysts. Here, our aim is to improve the efficiency of the photocatalytic water splitting by modifying a photocatalyst with metal clusters consisting of a few atoms covered with a metal oxide layer to improve stability.

The properties of semiconductor surfaces can be modified by the deposition of metal clusters consisting of a few atoms. The properties of metal clusters and of cluster-modified surfaces depend on the number of atoms forming the clusters. Deposition of clusters with a monodisperse size distribution opens the possibility of tailoring the properties of a surface to the needs of technical applications.

However, it is a challenge to retain the size of the clusters after their deposition due to the tendency of the clusters to agglomerate. The agglomeration can be reduced by covering the metal cluster modified surface with a thin metal oxide overlayer. Our work used ligand protected Au clusters, $Au_9(PPh_3)_8(NO_3)_3$, deposited onto RF-sputter deposited TiO_2 films and covered with a Cr_2O_3 layer with a thickness of a few monolayers.

After the deposition of the Cr_2O_3 layer, samples were heated to 200°C to remove the triphenylphosphine ligands (Figure 1). These clusters agglomerated to a large degree on the TiO_2 surface when no protecting Cr_2O_3 layer was present, whereas surfaces with a covering Cr_2O_3 layer showed little to no agglomeration. The size of the clusters was investigated with X-ray photoelectron spectroscopy using the final state effect.

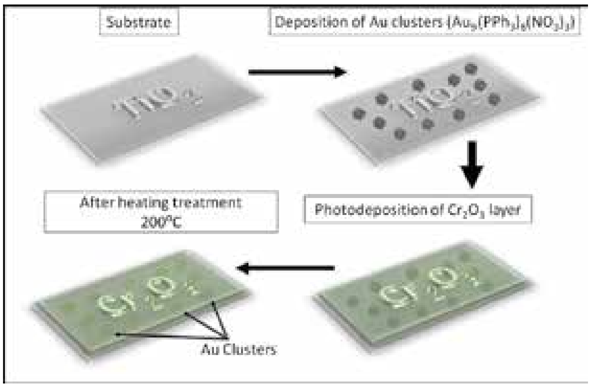


Figure 1
Shows the technique used to create Au clusters.

THEORETICAL AND EXPERIMENTAL STUDIES ON SLIDING AND ROTARY TRIBOELECTRIC NANOGENERATORS

Mohammad Khorsand and Youhong Tang

Triboelectric nanogenerators (TENGs) are a revolutionary technology to harvest electric power from low frequency vibrations. The generated power is used to drive personal electronics, medical equipment, and industrial electronic parts. In parallel with theoretical studies, we are fabricating and developing the design to enhance the outputs of TENGs.

TENGs are a favourite approach in renewable electrical energy generation at the micro/nanoscale. Based on the triboelectric effect and electrostatic induction, the input mechanical energy is converted into electricity. Because of its simple fabrication, non-invasive materials, and relatively high output, this technology has emerged as a sustainable candidate in energy harvesting.

We have fabricated high-output and lightweight sliding-mode TENGs based on dielectric-to-dielectric configuration. Nylon and Teflon were chosen as dielectric films due to their highly positive and negative sides of the triboelectric series. In parallel with experimental investigation, we present a theoretical formulation to describe the electrical output. Geometry and electric specifications determine the amount of the scavenged power and the key parameters we investigated include the contact area, the thickness of electric films, and external resistance. All of which have been numerically optimized as well.

Additionally, we have developed a rotary TENGs that converts rotational motion into electric power. This device successfully generates power from renewable energy sources such as wind and waves. The fabricated device effectively works under different grating numbers, rotational speeds, and tribo-spacing values.

One significant issue with most TENGs is damage to the triboelectric layers. To overcome this issue, we propose the idea of non-contact rotary TENGs, with this design lasting longer. The temporal responses of current and voltage of the device were obtained under various working conditions.

To summarize, TENGs are the most sustainable candidate to generate power on a small scale. This technology can potentially be employed in large-scale electricity generation by means of connecting TENGs together. Future investigations will focus on bulk energy generation and hybridization of TENGs to unrestrictedly run self-powered electronics.

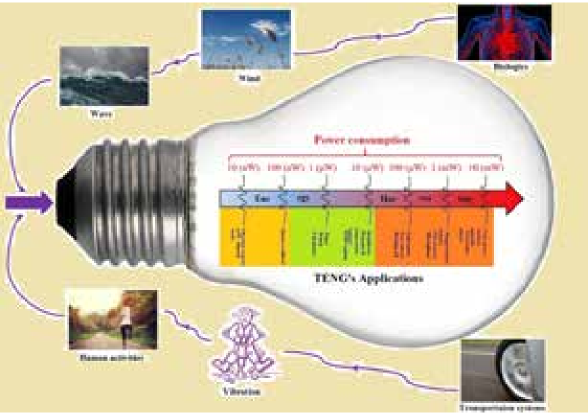


Figure 1
TENG's various applications

PHOTOCHROMIC PERFORMANCE OF DONOR ACCEPTOR STENHOUSE ADDUCTS (DASAs) IN SOLID MATRICES

Rowan McDonough, Nick Rudgley, Oskar Majewski, Ahmed Bhoyro
(Department of Defence), Richard Evans, Mike Perkins and David Lewis

Donor Acceptor Stenhouse Adducts (DASAs) are an exciting new class of photochromic dye that exhibit negative photochromism. This means that they are strongly coloured in darkness and become colourless upon light irradiation. The speed of this colour change is highly dependent on the environment surrounding the dye, with rapid switching observed in solution and much slower switching in solid matrices. To achieve rapid colour switching and desired colouration, the interactions of these photochromic dyes with their surrounding environment on the nano-scale must be understood.

The ability of DASA dyes to reversibly transition between a coloured to transparent state in response to visible light offers many applications in sensing, smart materials, textile coatings and novelty items. The rates, magnitude and stability of this colour change is highly dependent on the chemical structure of the DASA, as well as the chemical and physical properties of the surrounding environment, especially in solid polymeric matrices.

Kinetic modelling of several DASAs dyes in a range of polymeric textile binder matrices has revealed a linear dependence of the thermal re-colouration rates on the glass transition temperature (Tg) of the binder polymer. This dependence is due to the rigidity of the polymeric matrix restricting the mobility of the thermal carbon-carbon double bond rotations involved in the photo-switching reaction mechanism of the DASAs. This was demonstrated by performing the photo-switching reaction at a temperature below the Tg of the binder, resulting in almost complete restriction of the thermally driven re-colouration reaction. This Tg dependence may be over come by conjugation of low Tg polymeric tails directly to the dye structure, effectively surrounding the dye in a low Tg nano-environment, resulting in increased dye mobility, thus increased photo-switching rates.

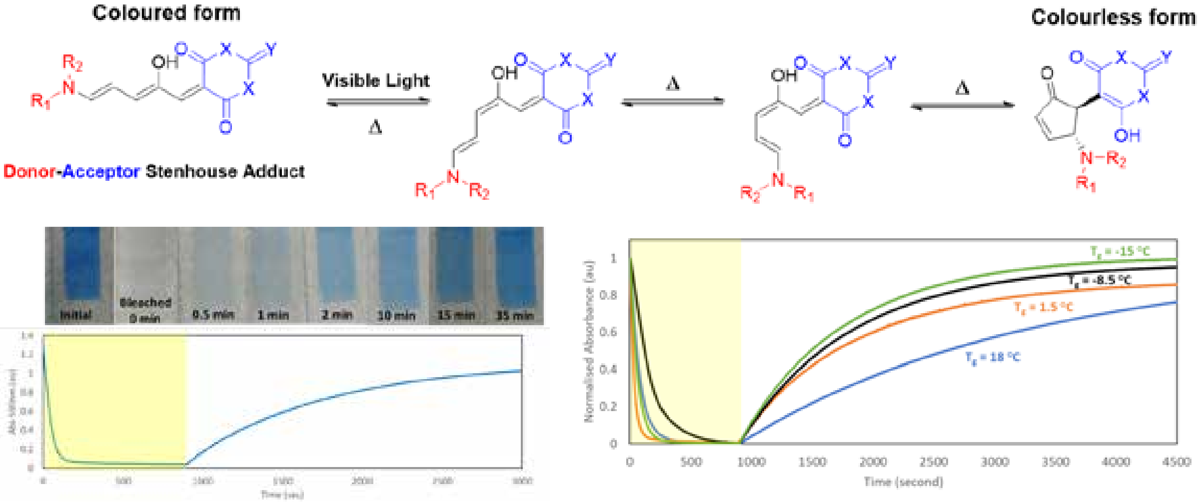


Figure 1
Top: Photo-switching mechanism of Donor Acceptor Stenhouse Adducts

Left: Coloured, photo-bleached and thermal re-colouration of a DASA in solid polymeric matrix film on glass slide.

Right: UV/Vis absorbance tracking of light activated de-colouration of DASA (yellow) and thermal re-colouration over time of a DASA within polymeric binder matrices of different glass transition temperatures (Tg).

WATER AND ALCOHOL SOLUBLE POLYMER DONORS FOR GREEN FABRICATION OF POLYMER SOLAR CELLS

Xun (Caroline) Pan, Anirudh Sharma (KAUST), Renee Kroon (Linköping University), Desta Gedefaw (The University of South Pacific), Sait Elmas, Yanting Yin, Gunther G. Andersson, David A. Lewis, Mats R. Andersson

The fabrication of organic solar cells using photoactive layers tends to use harmful halogenated solvents. The use of these solvents is the opposite to the environmentally friendly goals that solar cells claim to achieve. Our research demonstrates that water and alcohol soluble semiconducting polymers can act as the electron donor when synthesising organic solar cells resulting in the green fabrication of organic solar cells.

The performance of polymer solar cells (PSCs) has improved significantly over the past decade, demonstrated by over 18 per cent power conversion efficiency (PCE) achieved in the laboratory. Most high PCEs have active materials that need to be processed using halogenated solvents, which can potentially damage people's health and the environment. If alternatives are not available, large-scale fabrication could consume large quantities of these harmful solvents, causing additional disposal issues. We believe that these risks will be mitigated by focusing on developing green fabrication techniques that reduce or even eliminate solvents.

With this goal in mind, water and alcohol soluble conjugated polymers were designed and synthesized and used as electron donors in polymer solar cells. The basic design concept is to replace the aliphatic solubilizing side-chains in TQ1 polymeric structure with side groups having pyridine groups. In this way, a series of new polymers achieved switchable solubility in water and ethanol. The mechanism of the switchable solubility is visually shown (Figure 1). Briefly, nitrogen atoms in pyridine side groups are pronated by acid to generate pyridinium salts. This process requires a trace of volatile formic acid to protonate the polymers to offer the water/alcohol solubility. Once processed into a film, heating the film at 110 °C is used to remove the volatile acid obtaining a neutral polymer.

Our research produced functional PSCs for the first time based on pyridine side-group functionalized p-type conjugated polymers. Furthermore, the PSC performance has a strong relationship to the loading and properties of functional side-groups in the polymer structure, providing guidelines for the future design of water-soluble conjugated materials for solar cell application. This new water/ethanol processable conjugated polymers provides a pathway to the environmentally friendly fabrication of PSCs. Using side-chain modification of a conjugated structure can easily be broadened to different materials for other organic electronics applications.

Reference: Pan, X.; Sharma, A.; Kroon, R.; Gedefaw, D.; Elmas, S.; Yin, Y.; Andersson, G. G.; Lewis, D. A.; Andersson, M. R., Water/Ethanol Soluble p-Type Conjugated Polymers for the Use in Organic Photovoltaics. Frontiers in Materials 2020, 7.

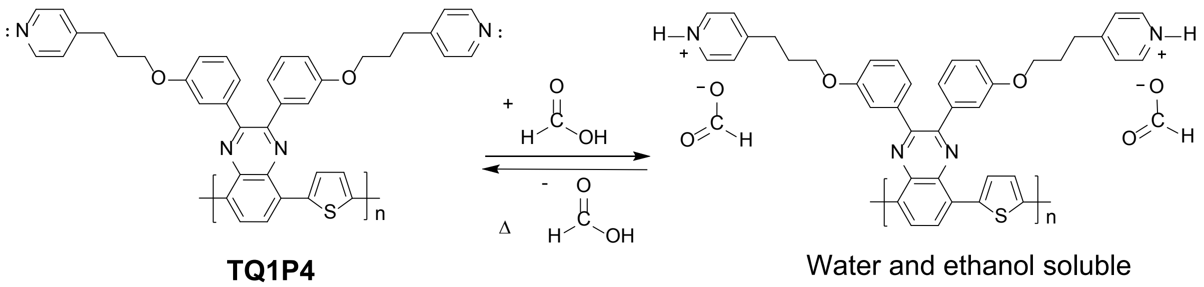


Figure 1
Protonation of pyridine-functionalized polymer TQ1P4 using formic acid and the deprotonation process to remove formic acid under heating.

IS CONCENTRATED SOLAR POWER THE FUTURE OF ENERGY?

Raihan Rumman and Gunther Andersson

Concentrated solar power (CSP) plants are designed to take advantage of renewable sources of energy, and essentially need to be exposed to harsh environmental conditions for decades, which can result in untimely failure of components within such systems. By selecting the appropriate range of alloys capable of sustaining against extreme weather and operating conditions, it is possible to not only expand the lifetime of the plants but also increase the efficiency of the system, making it a viable, long term, green energy solution. To achieve this, advanced corrosion studies of materials used in solar receivers, storage, and heat exchangers such as steel is deemed critical.

Conventional solar establishments use alloys that are operated at lower temperatures compared to CSP systems, allowing greater flexibility in terms of materials selection. However, this limits the performance and lifetime of these plants, paving way to understand these materials' behaviour, primarily related to corrosion in high temperature conditions. Recent global research indicate that Iron and Nickel based superalloys may have the capability to effectively perform in long term solar applications without compromising their intrinsic characteristics.

To understand corrosion mechanism and be able to design better alloys for CSP applications, the materials group at the Institute for Nanoscale Science and Technology of Flinders University first thermally treats a wide range of steel alloys in the labs in expedited cycles to generate layers of corrosion on the materials. These corrosion layers are formed primarily due to the materials' compositions, and their reaction to high temperature and varying chemical environments. By controlling the elemental composition, it is possible to reduce the degree the corrosion of these layers. Since Chromium and Nickel are the two most important elements in the corrosion studies of steel, 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. By choosing the right balance among these elements, it is possible to predict and limit the progression of corrosion in these alloys. It is also important to identify the conditions of reactive chemicals in the environment that can trigger certain corrosion mechanisms. Since these steels are often exposed to phase changing materials and liquid salts in real systems, the understanding of how they affect the alloys at high temperature is also a vital part of the study.

Using advanced analytical techniques such as Micro Computed Tomography (Micro CT), Scanning Electron Microscopy (SEM), X-Ray Photoelectron Spectroscopy (XPS), Scanning AUGER Microscopy (SAM), X-Ray Diffraction (XRD), the Flinders materials scientists 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.

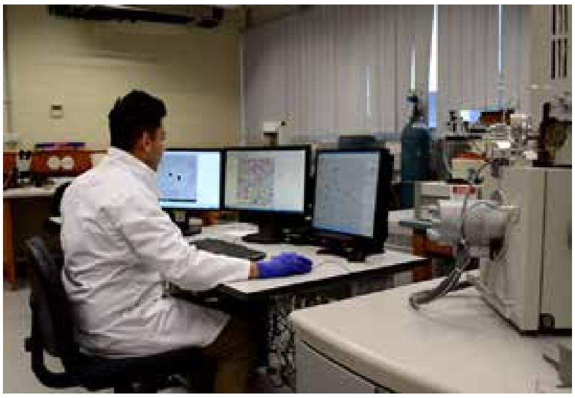


Figure 1
Using high resolution scanning electron microscopy at Flinders University to observe high-temperature corrosion behaviour in superalloys.

DEGRADATION OF STAINLESS STEEL AND SUPER ALLOYS FOR CONCENTRATED SOLAR PLANT USE SUBJECTED TO HIGH TEMPERATURE AND CORROSIVE ENVIRONMENT

Yanting Yin, Raihan Rumman, David Lewis, Gunther Andersson

Our work is focused on creating a high temperature environment, simulating the long-term use of alloys in a corrosive environment. The experiment is to correlate the field use of steels in concentrated solar thermal system. The instability such as degradation and cracks presenting on alloys are of our interest for conducting analysis. The down-selection of materials is based on their long-term stability.

Stainless steel and super alloy are considered as material candidates for storage containment and heat transfer pipes in a concentrated solar thermal plant (CSP), while phase change salts and liquid sodium are often used as heating fluid for harvesting energy from solar heat and storing energy within.

Upon the ongoing concentrated solar thermal research in ASTRI, the temperature limit in containment has been pushed to nearly 780 °C and for heat transfer it is 600 °C. Meanwhile the corrosiveness of heating fluid is noticeably presented subject to high temperature, leading to an accelerated corrosion and degradation upon alloys.

Our research is based on a small-scale simulation of the field use of CSP, where a variety selection of alloy candidates is heated at practical temperature in presence of either liquid sodium or phase change salts. Our analysis was conducted microscopy and spectroscopy apparatus to study the corrosion rate, chemical degradation, steel de-alloy pattern and crack propagation occurred on alloy surface. We provide Australian Solar Thermal Research Institute (ASTRI) with technical data and instruction for the materials down-selection process based on the outcome of long-term stability test.

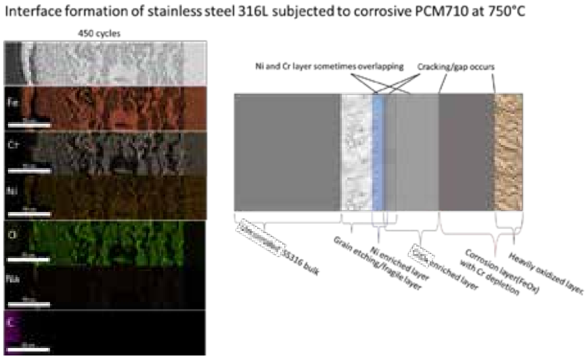


Figure 1
Left: Cross-section of steel surface indicates a formation of multi-layer structure upon the surface because of thermal corrosion.
Right: An illustration of the layer formation where metal element is distributed.

Acknowledgements
This research was supported by both the Flinders Microscopy and Microanalysis (FMMA) and Australian Solar Thermal Research Institute (ASTRI).

IMPROVING THE PERFORMANCE OF SCALABLE SLOT-DIE PRINTING OF ORGANIC SOLAR CELLS UNDER AMBIENT CONDITIONS

Bradley Peter Kirk and Mats Andersson

Large-scale printing of organic photovoltaic (OPV) devices has shown to be an effective method of manufacturing solar panels that are flexible, cost-effective and light weight. Even with these advantages, there is still a considerable performance gap between lab-based and roll-to-roll fabricated devices. This project investigated the use of different active layer materials and adjusting of printing parameters for slot-die coating of OPVs.

Large-scale printing of organic photovoltaic (OPV) devices has been a promising manufacturing method for solar panel production, allowing for the fabrication of low-cost, flexible and light-weight devices. Performance of small-scaled devices have achieved an efficiency of up to 18 per cent. Despite this, there is still a considerable gap between small-scale and roll-to-roll fabricated devices.

Our focus is improving the performance and stability of printed OPV devices fabricated via mini-roll coating with a slot-die printing technique. These devices were fabricated on flexible substrates under ambient conditions in the presence of oxygen and moisture, allowing for scalable OPV fabrication.

To construct high-performance OPVs it is critical to choose active layer materials that yield high efficiencies, are relatively stable, and cost-effective. We are replacing the TQ1 polymer with PPDT2FBT due to its potential use in large-scale OPVs. The efficiencies achieved by TQ1:PC61BM and PPDT2FBT:PC71BM were 2.9 per cent and 5.4 per cent respectively.

Another goal is to optimise the printing conditions, specifically the flow-rate and drum-speed enabling more uniform coating and defect-free films. Reducing the drum-speed and optimising the flow rate from 1.0 m/min to 0.2 m/min using PPDT2FBT:PC71BM increased the efficiency up to a maximum of 6.5 per cent. Increasing the active layer thickness by manipulating the ink flow-rate 8.1 per cent efficiency was achieved.

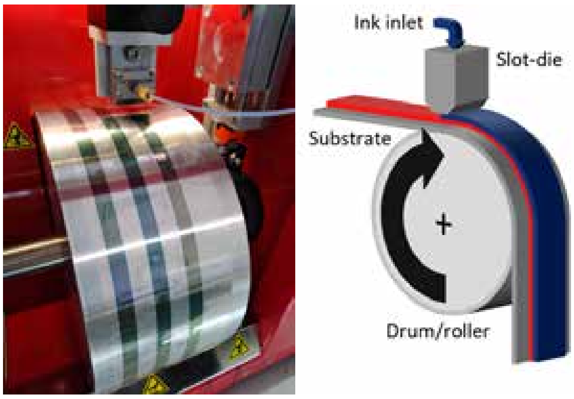


Figure 1
Mini-roll coater with slot-die attachment actual mage of device (left) and schematic (right).

SECURITY

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

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

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

DEFENCE INNOVATION PARTNERSHIP (DIP)

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

DEFENCE SCIENCE AND TECHNOLOGY GROUP (DSTG)

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

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

FORENSIC SCIENCE SA (FSSA)

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

THE AUSTRALIAN FEDERAL POLICE

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

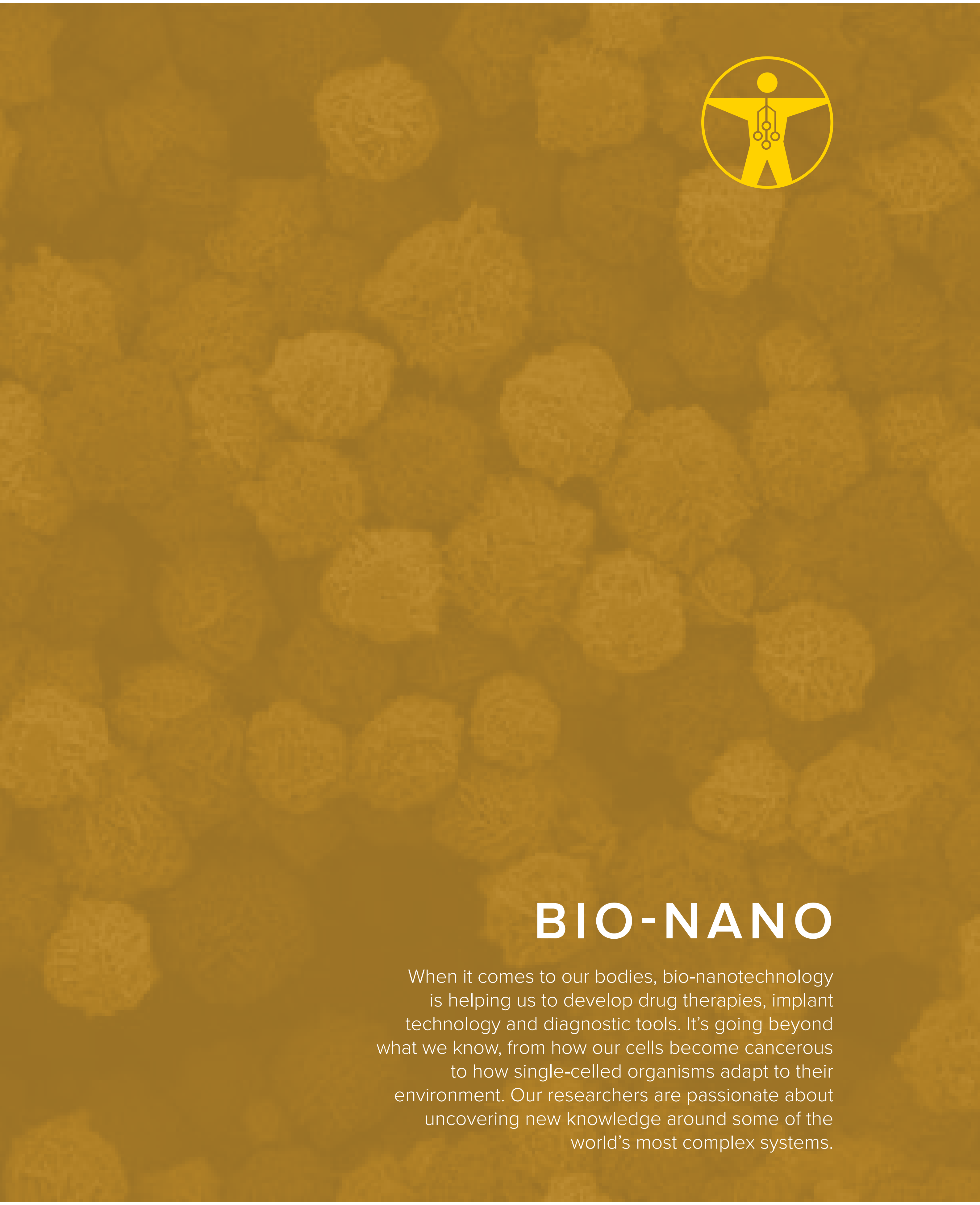
OFFICE OF NAVAL RESEARCH (ONR)

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

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

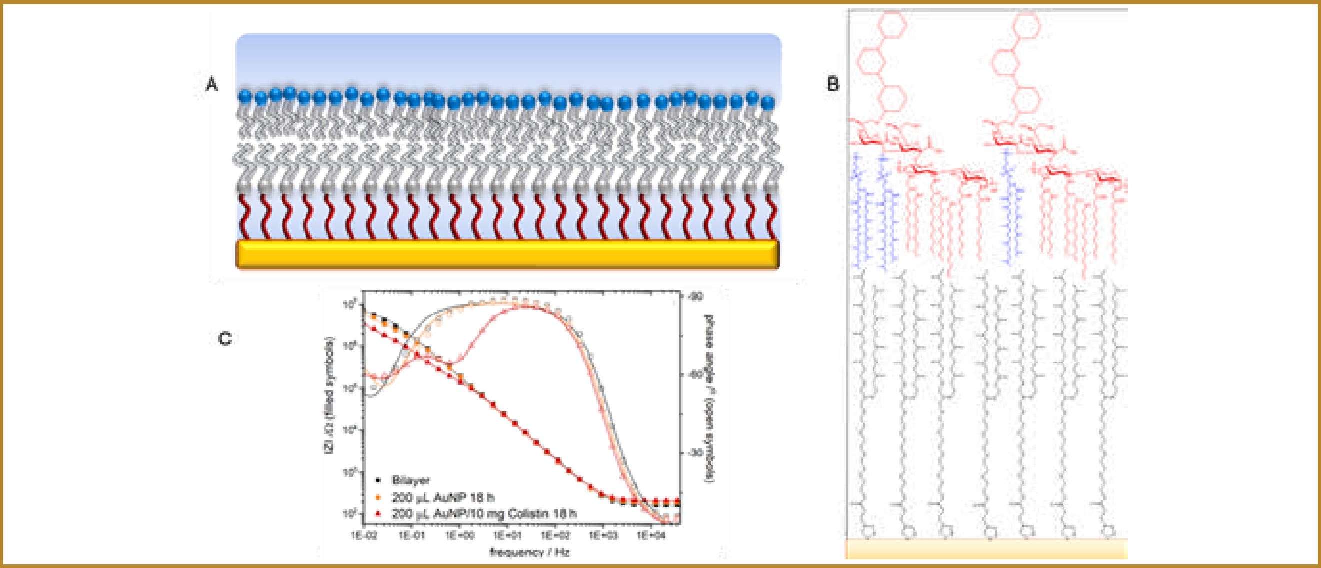
UNITED STATES DEPARTMENT OF DEFENSE – US ARMY

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



BIO-NANO

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



WORKING WITH MODEL MEMBRANES

Cell membranes are highly complex systems yet vital to the functioning of every organism. This high complexity makes systematic study extremely difficult. Internationally, many research groups are working to develop a variety of model systems to mimic cell membranes. A drawback of these, however, can be that they lack sufficient complexity. The Köper Group is working towards designing a system that more closely represents the main characteristics of a functioning cell membrane while avoiding being overly complex.

A typical cell membrane has an approximately 6 nm lipid bilayer, which encapsulates all cells and all organelles within cells. This bilayer is composed of a large variety of different types of lipids, proteins, carbohydrates and sterols. A bilayer's composition varies depending on the origin and function of the membrane.

Membranes provide a semi-permeable barrier between the inside and the outside of the cell or organelle. Proteins govern the transport of ions and molecules that make up the membrane. The membrane itself is impermeable, especially to ions. This functionality allows the build-up and maintenance of charge gradients and provides the foundation for biological processes such as cell-cell signalling.

The cause of many diseases results from the malfunctioning of these fundamental processes. Most modern therapeutic drugs target the malfunctioning of membrane proteins to cure or slow down disease processes. Understanding the concepts that govern both the structure and function of membranes and their associated membrane proteins will help create new drugs and make existing drugs more efficacious.

The sheer complexity of a typical membrane hinders systematic studies. The number of individual lipids within a single membrane varies from thousands to hundreds of thousands, with different species having unique lipid compositions and arrangements.

Over the past 60 years, researchers have created various model membranes that mimic the lipid bilayer but only using a small number of components. Model systems include vesicles or liposomes, black lipid membranes and solid supported membranes.

The development and characterisation of tethered bilayer lipid membranes (tBLMs – Figure 1A) is the focus of the Köper Group.

A tBLM is composed of a lipid bilayer, with the inner leaflet composed of anchor lipids binding the membrane to a solid substrate. In most cases, sulphur chemistry anchors the tBLM to a gold substrate. tBLMs provide a high degree of stability and high electrical sealing properties, making it possible to study functionally incorporated ion channel proteins. The solid substrates allow for the use of various surface analytical techniques.

In recent years, the Köper group has developed model membrane architectures based on tBLM's that contain more complexity and more closely resemble natural membranes by incorporate lipopolysaccharides (Figure 1B), inspired by the outer membrane of Gram-negative bacteria. The addition of more lipids into the bilayer and an asymmetric bilayer resulted in a model that mimics essential features of a bacterial membrane. This model membrane showed similar ion-dependent behaviour and susceptibility to antibiotics to the natural membrane.

We are using this system to study the effects of different drugs on membrane properties and drug combinations. We have demonstrated that the addition of small gold nanoparticles and antibiotics led to an increased disruption of the membrane architecture. (Figure 1C).

Recently the Köper group has used whole-cell bacterial extracts and fused these with a tethered monolayer. This process created a more complex tBLM containing native lipids. This model was used to study the development of antibacterial resistance and how this relates to membrane properties. By comparing tBLMs made from bacteria treated under variable conditions, we have shown the effects of various treatments on the structure and function of the bacterial membrane.

The number of applications for model membranes has increased by increasing the complexity of the systems. One such application is biosensing applications. Membrane proteins are known to have inherent sensing capabilities, often with very high sensitivity and selectivity. Embedding such proteins into a controllable model system coupled to an electronic read-out offers almost limitless sensing options.

VORTEX FLUIDIC-MEDIATED FABRICATION OF FAST GELATED SILICA HYDROGELS WITH EMBEDDED LACCASE NANOFLOWERS FOR REAL-TIME BIOSENSING UNDER FLOW

Xuan Luo, Colin Raston, Keith A. Stubbs (School of Molecular Sciences, The University of Western Australia), Peng Su (Centre for Marine Bioproducts Development, Flinders University), Gregory A. Weiss (Department of Chemistry, University of California Irvine, Irvine, California), Wei Zhang (Centre for Marine Bioproducts Development, Flinders University)

The cost and limited reusability of enzymes hinders the development of enzyme-based biosensors. Most enzymes are inactivated during the assay process and are unable to be separated for reuse. Therefore, a new technique to make cheaper and more efficient biological enzyme hybrids could have valuable applications in future water depollution, targeted drug manufacturing and other industries.

To overcome cost and limited reusability of enzymes, a new technique to make cheaper and more efficient biological enzyme hybrids - the immobilization of enzymes as hybrid protein-$Cu_3(PO_4)_2$ nanoflowers (NFs) - is investigated. The fabrication of hybrid NFs via an intermediate toroidal structure is dramatically accelerated under shear using the vortex fluidic device (VFD), which possesses a rapidly rotating angled tube.

As prepared laccase NFs (LNFs) exhibit ≈ 1.8-fold increase in catalytic activity compared to free laccase under diffusion control and can be further enhanced by ≈ 2.9-fold for catalysis under shear using the VFD.

A new LNFs immobilization platform, LNF@silica incorporated on the inner surface of a VFD tube, was subsequently developed resulting in fast gelation of LNFs along the VFD tube surface. The resulting LNFs@silica coating is highly stable and reusable showing a 16-fold increase in its efficiency compared to the non-VFD control.

This platform allows efficient assay monitoring in real-time under continuous flow conditions. By utilizing the VFD, the generation and immobilization of laccase nanoflowers into silica hydrogel has greatly simplified fabrication and saves both time and money, along with the ability to reuse the enzyme for further reactions.

This unique system demonstrates four different applications of the VFD – fabrication, immobilization, continuous flow and real-time monitoring. The next steps are to test this model system with real-world samples for example wastewater and use this system with other enzymes/proteins to determine if their efficiency is increased.

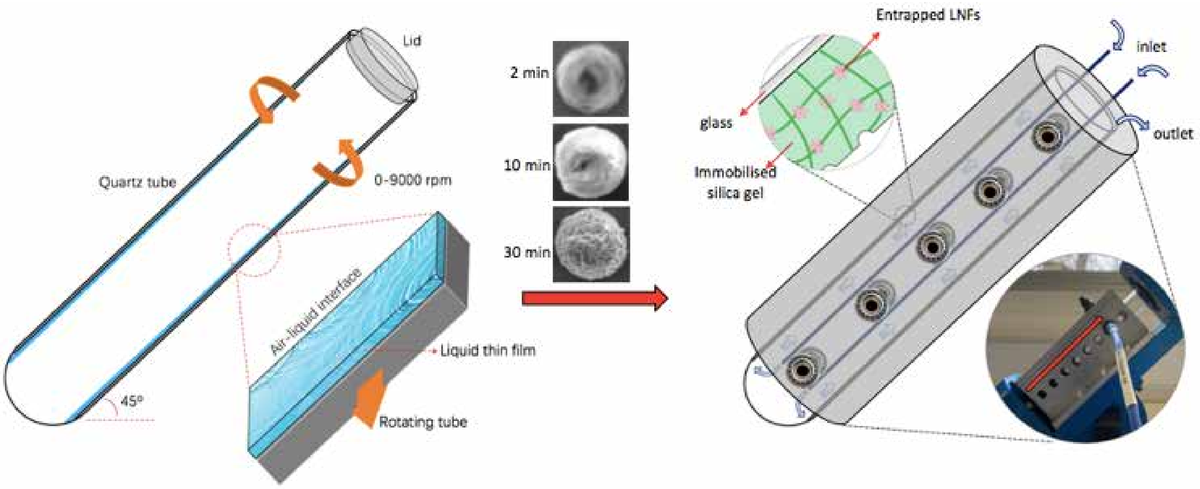


Figure 1
from ACS Appl. Mater. Interfaces 2020, 12, 51999-52007

INCREASED HEALTH BENEFICIARY LIPID DROPS IN MICROALGAE DETERMINED WITH A FAST-RESPONSE AIEGEN BIOPROBE

AHM Mohsinul Reza, Jianguang Qin, Youhong Tang

Dietary supplementations of fatty acids have been shown to have wide-reaching health benefits for humans. To increase the use and understanding of fatty acid production in microalgae, we have investigated the use of bioimaging as a non-invasive mechanism to track fatty acid production. We have successfully demonstrated that the lipid-specific aggregation-induced emission fluorogen (AIEgen), DPAS ($C_{20}H_{16}N_{20}$) can be used to visualise fatty acids in microalgae.

Dietary supplementations of fatty acids produced from microalgae have wide-reaching health benefits for humans. Bioimaging tools that allow easy, rapid and non-invasive evaluation of lipid conditions could help to boost the use of microalgae in health supplements. Additionally, the development of easy visualisation techniques of lipid droplets could be an effective approach to understand lipid dynamics within microalgae.

Our focus is on the required environmental conditions to yield lipid in the microalga, Euglena gracilis as the bio-functional component determined with a lipid-specific AIEgen, DPAS ($C_{20}H_{16}N_{20}$). Briefly, the optimum conditions for lipid biosynthesis in this species has been explored and visualized with DPAS and compared to the commercial lipid staining probe BODIPY in vivo. The presence of organic carbon in the form of glucose and deprivation of nitrogen and calcium in the cultural environment enhanced long-chain polyunsaturated fatty acid, such as omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) production in the dark. DPAS benefits from a very low background signal, and therefore is more sensitive than BODIPY for semiquantitative in vivo fluorescence measurements. Co-staining in the presence of BODIPY and chlorophyll also indicated that DPAS is suitable for multicolour imaging with red and green fluorophores.

We have demonstrated that DPAS is a highly effective biocompatible and photostable fluorophore for rapid and sensitive visualisation of lipid droplets. This novel staining method can be used to screen lipid production mechanisms in microalgae as the potential alternatives to health supplementation for humans.

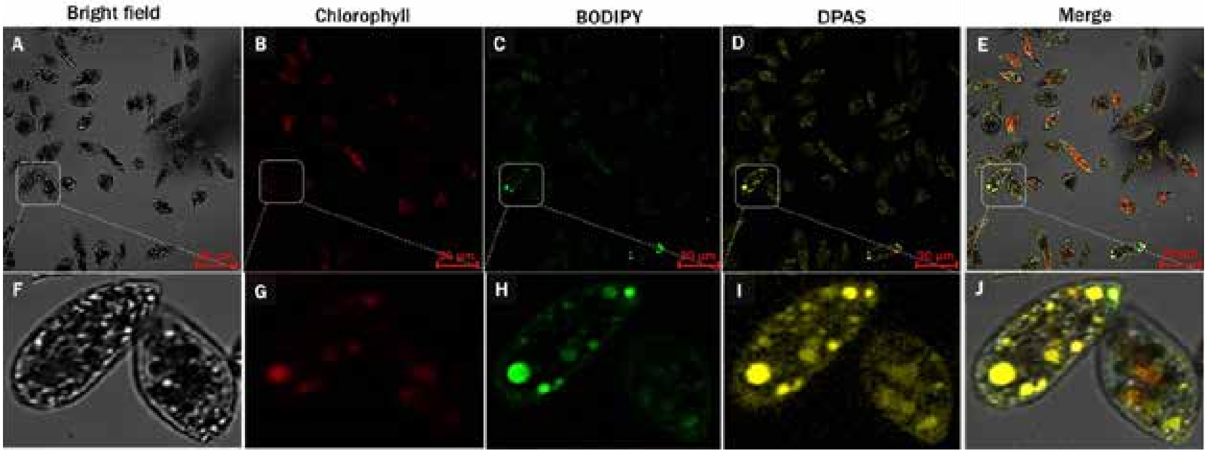


Figure 1
Images of lipid drops in Euglena gracilis cells. Cells were incubated with lipid specific aggregation induced emission (AIE) nanoprobe, DPAS ($C_{20}H_{16}N_{20}$) (D) and commercial lipid specific fluorescent probe, BODIPY (C). Bright-field image: (A); Chlorophyll: (B); Merged image: (E). F, G, H, I, and J are the enlarged regions of bright-field, chlorophyll, BODIPY, DPAS stained cells and merged image, respectively.

A POLYMER NANO-MESH FOR DRUG DELIVERY

Karuna Skipper, Ingo Köper

In an effort to reduce antibiotic side effects and increase their effectiveness following joint-replacement surgery, a new method of drug delivery was created. Antibiotics are loaded into a biodegradable mesh that is coated across the prosthetic joint. The drugs are released from the mesh, creating a high local concentration of antibiotic. This has potential to prevent the rise of antibiotic resistance.

Among other contributing factors, insufficient antibiotic is a major contributor to the rise of antibiotic resistance. This may result from an inappropriate prescription, or patients not following the recommended schedule. Either way, this may lead to the bacterial infection developing resistance to the drug, leading to further complications for the patient and potentially spreading this resistance to other bacterial colonies. Therefore, a more effective method of preventing bacterial infections is needed. We are focused on post-surgical infections following implantation of prosthetic hip and knee joints that impacts many thousands of patients annually.

We set out to create a coating for the implant prosthetics containing antibiotic drugs within its structure that gradually break down when inside the body. The breakdown would facilitate the release of the drugs delivering the antibiotics directly to the implant site. This approach has the dual benefit of creating a high localised concentration of the antibiotic, increasing its efficacy, while minimising systemic distribution, preventing negative side-effects.

Electrospinning, in which a polymer solution is passed through an electric field, pulling the polymers into a continuous thread and depositing them as a randomly oriented mesh (Figure 1), was used to create the coating. Polydioxanone, a synthetic polymer commonly used as "dissolving sutures", was found to be best suited to this process. The model antibiotic Colistin Sulphate was combined with the polymer solution and thus imbued in the resulting mesh.

This mesh coating was highly effective in preventing bacterial growth within the first twenty-four hours of exposure. The drug rapidly dissolved out of the polymer matrix, instead of staying in place until the polymer dissolved away. Therefore, while it may be effective at preventing an initial infection, this mesh does not have the long-term preventative effect desired. Future research will focus on modifying the electrospinning technique to achieve the desired long-term, zero-order release pattern.

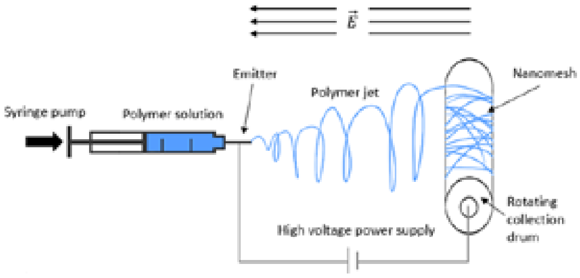


Figure 1
A general schematic of the electrospinning process.

FLUORESCENT GRAPHENE OXIDE

Javad Tavakoli and Youhong Tang

Despite superior electronic, thermal, and mechanical properties, graphene oxide (GO) significantly reduces the brightness of fluorescent dyes causing a major drawback in the design of medical sensors. Our strategy has led to the development of highly fluorescent GO with great potential to revolutionize the field.

Graphene oxide (GO) has been well recognised as an effective fluorescence (FL) quenching material that reduces the brightness of conventional fluorophores. The development of new fluorescent dyes, with aggregation induced emission (AIE) features, brought hope to change the FL property of GO/AIE. However, extensive research to develop efficient GO/AIE material just increased the final FL property by < 3 folds. Even such a small increase in the FL property has been considered effective in the development of ultrasensitive optical sensors for the detection of various biomolecules, specifically including single-strand DNA.

We prepared highly fluorescent GO/AIE (GO/TPE-2BA) materials exhibiting ~4 or ~14 folds increase in relative FL intensity compared to that of previously prepared GO/AIE materials and AIE alone, respectively. We utilised a dynamic thin-film microfluidic platform, known as a vortex fluidic device (VFD), to produce GO/AIE material with the property of high FL, which is without precedent. The simple, novel, and cost-effective method we developed involved mixing of AIE with GO under high shear mechanical stress at the micro-scale. The final FL property was found to vary based on the concentration of GO, rotation speed of the VFD, and the amount of water (water fraction; WF). WF is known to affect the size of the AIE nanoparticles during aggregation with the smaller size being brighter.

We observed that the addition of GO at the concentration of 0.0025 mg.mL−1 to the TPE-2BA solution resulted in brighter particles for WF > 70% with a 13-fold greater FL relative intensity at WF = 80% compared to that at WF = 50%. Compared to the TPE-2BA alone, the GO/TPE-2BA produced at WF = 80% was brighter, with 110% enhancement in the FL relative intensities, respectively.

When a VFD was utilised, TPE-2BA (100 µM) was added to the GO solution (0.0025 mg mL−1) in a rapidly rotating VFD tube (1000–5000 rpm) tilted at 45° relative to the horizontal position, at WF = 80%, an increase (60 times) in the relative FL intensity of GO/TPE-2BA was observed. The method affords highly bright GO/AIE material with >1400% increase in the relative FL intensity compared to that of AIE alone. Increasing the rotation speed from 0 to 3000 rpm and then from 3000 to 5000 rpm resulted in enhancement and quenching of the FL intensity, respectively. At WF = 80%, a 400% enhancement in the FL relative intensity of the GO/TPE-2BA, compared to that of 0 rpm, was observed when the rotation speed was 1500 rpm. However, the GO quenched the FL property of the complex at rotation speeds >3000 rpm, with 15%, 75% and 90% reduction in the FL relative intensity, compared to that at 0 rpm, occurring at 3000, 4000 and 5000 rpm, respectively (Fig 1).

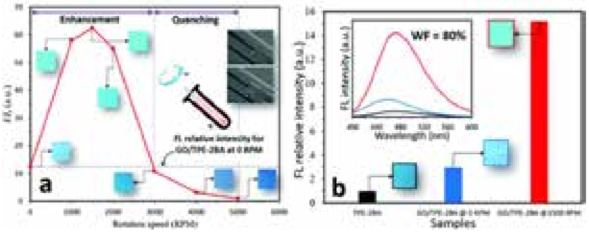


Figure 1
(a) Change in relative FL intensity of GO/TPE-2BA probe as a function of VFD tube rotational speed at the excitation wavelength of 310 nm and WF = 80%, θ = 45°. The concentrations of GO and TPE-2BA were 0.0025 mg mL−1 and 100 µM, respectively. (b) Change in relative FL intensity of different samples. Insets: Camera images of GO/TPE-2BA solutions at different rotational speed captured under a UV light at the excitation wavelength of 365 nm, high-speed camera images (12 600 fps) representing the injection of TPE-2BA solution into the GO solution in a rotating VFD tube, and schematic drawing of the VFD with rotational speed and tilt angle of the VFD tube denoted by ω and θ, respectively.

BIOMARKER DETECTION BY AGGREGATION-INDUCED EMISSION LUMINOGENS

Xinyi Zhang and Youhong Tang

Biomarker detection in non-invasively collected biofluids is an easy and rapid method of medical diagnostics. A novel group of bio-probes with aggregation-induced emission (AIE) properties is being developed for monitoring analytes in biofluids. Several applications for these bio-probes, such as point-of-care (PoC) devices, are being developed. These low-cost and highly reliable AIE bio-probes are beneficial for the early detection of disease and chronic disease management. These uses are applicable in rural locations and would facilitate greater involvement of consumers in managing their own health care needs.

We are employing aggregation-induced emission luminogens (AIEgens) for different biomedical applications and have been successfully employed for biomarker detection in body fluid such as urine, saliva and sweat. We tested and optimised conditions for detecting albumin in human urine by using existing AIEgen bio-probes and developing an associated portable device.

Chronic kidney disease (CKD) describes the gradual loss of kidney function. A person who suffers from severe CKD may require a kidney transplant or dialysis to survive. Urine albumin is the biomarker for CKD screening and treatment. Usually, people use urine test strips to monitor albumin, which is qualitative or semi-quantitative. Only hospitals can do these tests, which are expensive and take a long time.

Human serum albumin (HSA) can reach 35–50 g/L in blood plasma but less than 30 mg/L in urine because of renal filtration. Hence, albuminuria can be used as a diagnostic index for chronic kidney disease. We have evaluated TPE-4TA in a clinical situation and developed a Standard Operation Procedure for detecting albumin in human urine through both fluorescent spectrophotometer and medical device prototype (Fig 1).

Optimising operating conditions and testing procedures including fluorescent bio-probe concentration, urine to water dilution ratio, reaction time, reagent addition order, type of dilution solution and urine sample age. Our work will apply these parameters to support PoC device development and optimise the specifications of the prototype.

The bio-probe industry is expected to experience rapid growth due to the increasing awareness of early detection and fast screening of diseases. The direct results obtainable from using simple sensing processes provides convenient and low-cost packaging making use of smartphone data capture and analysis, and data cloud storage. High selectivity and sensitivity of AIE bio-probes integrated with portable devices will enable affordable and reliable biofluid detection in rural locations and developing countries.

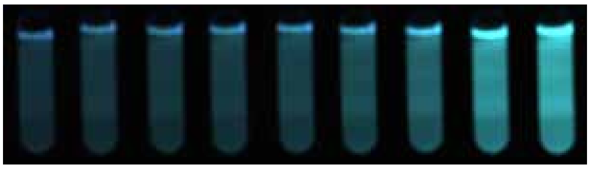
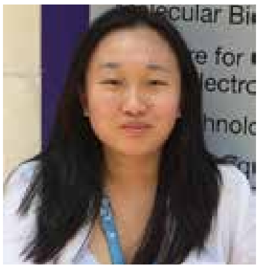


Figure 1
Enlightening human urine contained different levels of albumin using an aggregation-induced emission biosensor, TPE-4TA.



3D PRINTING WITH DUAL-CURE RESINS

Kay Chen, Jon Campbell and David Lewis

3D printing offers enormous potential to produce on-demand complex objects that are otherwise impossible with traditional manufacturing methods. This has the potential to create a paradigm shift in current manufacturing processes. However, fundamental barriers of limited material selection and poor material performance such as weak mechanical strength and structural integrity, currently prevent the transition from prototyping to practical applications of 3D printed parts.

3D printing is a layer-by-layer manufacturing process used to construct 3D objects from a computer aided design model. The main attractions of 3D printing are the high degree of customisation, rapid prototyping, and ability to produce complex geometric structures that are otherwise impossible with traditional manufacturing methods.

One approach to combat this challenge is the use of dual-cure resins. Dual-cure resins can facilitate the incorporation of new materials and chemistries to 3D printing, and the ability to polymerise a second network within the first after the photocuring step may facilitate 3D printed parts with improved interfacial adhesion due to the sequential formation of an interpenetrating polymer network (IPN).

IPNs are comprised of two or more polymer networks entangled on a molecular level but not covalently bonded to each other. The advantage of IPNs is the ability to combine two polymers with mismatched properties (i.e rubbery and brittle) and polymerisation mechanisms to produce a system with enhanced properties such as greater mechanical strength surpassing those of polymer blends.

Figure 1
3D printed structures using dual-cure resins.

INVESTIGATING THE STRUCTURE OF ARTIFICIAL CELL MEMBRANE IN THE PRESENCE OF ORGANIC LIQUID BY ION SCATTERING SPECTROSCOPY

Ahlam Alharbi, Gunther Andersson, and Ingo Köper

Although artificial cell membranes have been studied using different tools, there is still a lack of understanding of the overall structure of these membranes. Applying surface analytical techniques will give a greater understanding of the structure and the molecular arrangement of the phospholipids. Having more knowledge of the structure will help in further development and adjustment of the structure of artificial membranes to mimic real membrane, thus, using them in drug delivery and sensing applications.

Natural cell membranes are hugely complex structures as they contain more than a hundred types of biological molecules e.g. proteins, fats, carbohydrates, etc. Glycerol-based phospholipids equate for approximately 40% to 60% of the total amount of lipids contents of bio-membranes. Therefore, artificially synthesised phospholipids were needed to enable scientists to study the biological processes on the cellular membrane. Tethered bilayer lipid membranes (tBLMs) are solid supported membranes, where the solid substrate is separated from the bilayers by tethering group, e.g. DPhyTL. TBLMs are the most promising class of artificial phospholipid bilayers as they resemble some of the fundamental features of bio-membranes, such as membrane fluidity.

They also allow for the incorporation of proteins within the bilayers. Investigating the membrane with surface analytical tools would give a more precise result which will lead to having a broad understanding of the characteristic and properties of the membrane. Neutral impact collision ion scattering spectroscopy NICISS is a technique that is employed for determining the elemental composition of the outermost layer and the composition of the bulk near to the surface. It has been successfully applied to study the structure of liquid surfaces. NICISS employs helium ions to penetrate through the target, collide with the atoms, lose some energy, and then backscattered from the target.

Finally, the neutralised atoms will be detected by time-of-flight TOF analyser to determine the concentration depth profiles of elements at soft-matter surfaces. For generating liquid surfaces in NICISS, the most used method is the rotating disc method. In this technique, a flat rotating disc holding the target is immersed into the liquid in a closed box. The closed box has a small aperture to help the flow of the gas phase and to allow the ion beam to hit the target and backscattered from the target to the detector. The thickness of the solvent film depends basically on the wheel's speed of rotation. NICISS will help in understanding the structure of tBLMs which would lead to developing their structure to become even more mimicable to real membranes, thus, using them in drug delivery and sensing applications.

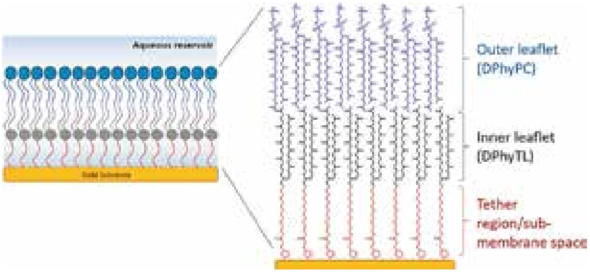
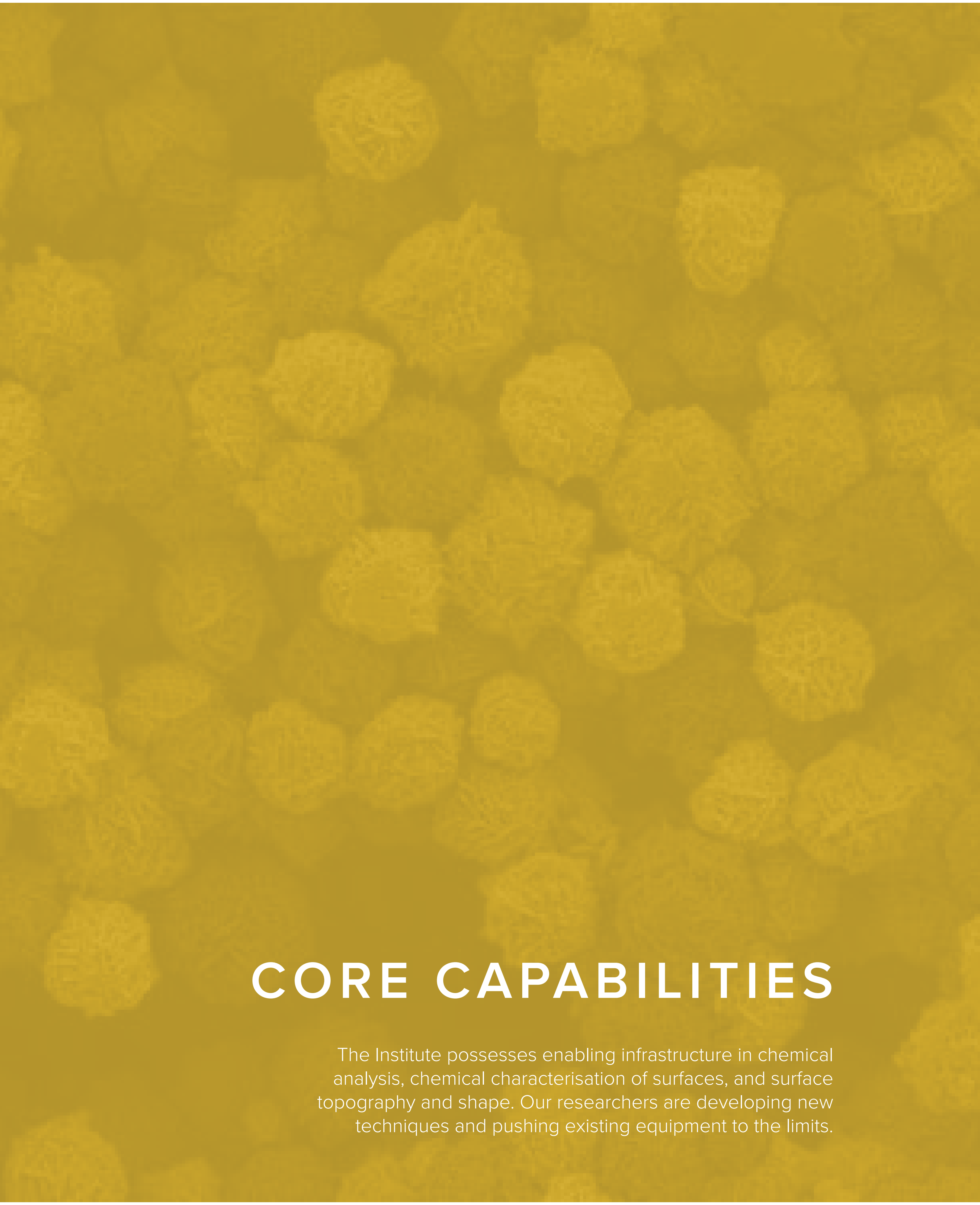


Figure 1
Schematic diagram of a DPhyTL-based tBLM (1).



CORE CAPABILITIES

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

MICROSTRUCTURAL CHARACTERISATION OF COLDSPRAY 3D PRINTED METAL ALLOYS

The Additive Manufacturing Alliance (Dr Rebecca Murray and Dr Rebecca Adamson) based at the Charles Darwin University has developed a strong collaboration with SPEE3D, an Australian company at the forefront of cold-spray 3D printing. They are working closely with the Australian Army to trial additive manufacturing at the point of need. In 2020, the Quinton lab was approached to join this collaboration and have begun providing characterise and validation services to ensure their printed components are of the utmost quality.

A rapidly emerging area of advanced manufacturing is 3D printing. While people are now familiar with the 3D printing of plastic, we are now seeing the emergence and rise of a range of other materials that are now 3D printed, including concrete, biomaterials and even chocolate. Perhaps the most challenging material of all when it comes to 3D printing are metals. The ability to manufacture metals and alloys through 3D printing brings a promise of revolutionising the manufacturing world and permanently change the way we fabricate building and transport material components. 3D printing has the potential to produce materials in small amounts, minimising waste and create complex structures that are difficult to fabricate through conventional machining and can also allow components to be made at the point of need rather than require storage of spare components in large warehouses.

The 3D printing of metal is in its infancy, and one of the main issues being that the properties that 3D printed metals possess are very different from those of their ingot counterparts. Research has shown that the properties of printed components are dependent on the material, method of manufacture, prevailing atmosphere, thermal properties and the thermal behaviour at the surface where the printing takes place, which itself is dependent on the geometry of the component. The current variability associated with 3D printing technology has created a challenging problem and further research is required to develop appropriate standards and component validation to ensure products are uniform and up to safety standards.

Metal 3D printing can occur via different methods such as powder-bed fusion or direct-energy deposition. The Additive Manufacturing Alliance are currently trialling 3D printing using cold spray technology. This method utilises high-pressure spraying of microscopic particles of the desired material that are propelled and directed at the growing surface at ballistic speeds without any additional energy. The particles arrive at the surface of the component with sufficient energy that they fuse to the surface. This method was first perfected with copper, but in recent years the materials of interest have widened to include alloys of aluminium, titanium, nickel and steel.

Members of the Quinton lab (Raihan Rumman, Dr Ruby Sims and Professor Quinton) visited Charles Darwin University to initiate a collaboration and assist with validating materials that had been cold spray 3D printing. The two groups have complementary skills in manufacturing capability and advanced characterisation. The Quinton labs capabilities are using spectromicroscopy to observe the microscopic features of the printed material. The first aim is to understand and optimise the printing process. Ultimately the goal is to create via 3D printing materials with known, desired properties with repeatability and ease at point of need.

This project demonstrates the strength of collaboration through Australia's central corridor and offers many opportunities for future regional technical and economic development.

FLINDERS MICROSCOPY AND MICROANALYSIS

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

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

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

Our instruments:

- Scanning electron microscopy (FEI Inspect F50)
- Scanning auger nanoprobe (PHI-710 AES)
- Large-volume micro-CT (Nikon XT H 225ST CT Scanner)
- Neutral impact collision ion scattering Spectroscopy (NICISS- Custom built)
- Metastable induced electron spectroscopy - custom built and includes ultraviolet photoelectron spectroscopy, inverse photoemission spectroscopy and x-ray photoelectron spectroscopy, NICISS
- Atomic force microscopy (Multimode 8 AFM with Nanoscope V Controller and Dimension FastScan AFM with Nanoscope V Controller)
- Tip enhanced raman spectroscopy (Nanionics TERS with XplorRA Horiba Scientific confocal Raman microscope)
- Confocal raman microscopy (WiTec alpha 300R confocal Raman microscope)
- Confocal fluorescence microscopy (Zeiss LSM 880 Fast Airyscan confocal microscope; Olympus FluoView 1000 laser scanning confocal microscope; Leica TCS SP5 laser scanning confocal microscope)
- X-ray Diffraction (Bruker D8 Advance Eco)

To learn more, visit www.flinders.edu.au/microscopy. 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.

MATERIALS PROPERTIES

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

POLYMER CHARACTERISATION

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

ADVANCED MATERIAL LABORATORY — TONSLEY INNOVATION PRECINCT

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

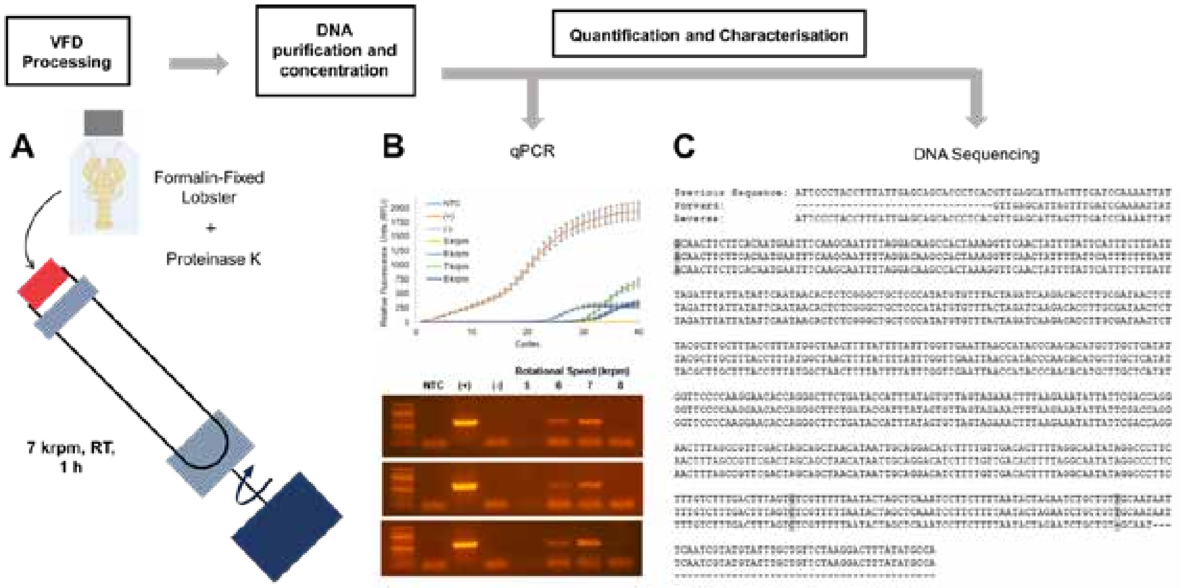
- The Advanced Materials laboratory is shared with the materials engineering group. This space houses an FTIR spectrophotometer, tensile and impact testing machines, salt spray durability test, ovens and 6 fume cabinets for chemical synthesis research.
- A clean room, used for fabrication of electronic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

NATIONAL RESEARCH FACILITIES

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

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

COLLABORATION



VORTEX FLUIDICS-MEDIATED DNA RESCUE FROM FORMALIN-FIXED MUSEUM SPECIMENS

For over 150 years, museums have used formalin as the preferred chemical to preserve tissues, which includes species that are now extinct. The DNA from such specimens tends to become cross-linked and is slow and difficult to rescue. By using the mechanical energy generated by the vortex fluid device housing, a rapidly rotating tube tilted at 45°, this issue can be overcome and the DNA from extinct species recovered.

The ability to rescue DNA from formalin preserved specimens has exciting potential for exploring the DNA from millions of historical and even extinct species housed in museums worldwide. Enzymatic processing using proteinase K to digest crosslinked proteins generated during the preservation process is slow with low DNA recovery rates.

Previous studies have established that the vortex fluidic device can dramatically accelerate enzymatic reactions. The mechanism is due to pressure fluctuations associated with Faraday waves generated in the thin film microfluidic platform. These Faraday waves generate eddies within the thin film, along the rapidly rotating 20 mm diameter tube tilted at 45°. This mechanical energy and high mass transfer occur at a thickness of 200 nm within the film. Applying these fundamental findings dramatically reduced the processing time and proved effective in rescuing DNA from a lobster species with the proteinase K enzymatic reaction accelerated in the vortex fluidic device.

Collaborators: University of California, Irvine, Harvard University, with Flinders University PhD candidate Jessica Philips.

AUSTRALIAN NUCLEAR SCIENCE AND TECHNOLOGY ORGANISATION (ANSTO)

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

AUSTRALIAN SOLAR THERMAL RESEARCH INITIATIVE (ASTRI)

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

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (CSIRO)

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

NATIONAL INSTITUTE FOR MATERIALS SCIENCE (NIMS), JAPAN

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

DEFENCE SCIENCE AND TECHNOLOGY GROUP (DSTG)

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

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

THE AUSTRIAN INSTITUTE OF TECHNOLOGY (AIT)

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

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

3RT

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

The development of 3Wood$^{\text{TM}}$ is all thanks to 3RT's partnership with the Institute for Nanoscale Science and Technology and its Director Professor David Lewis. 3Wood$^{\text{TM}}$ is environmentally sustainable and uses a non-toxic resin in its production. Further work with Flinders University is aiming to look at other improvements including UV light and water resistance.

2D FLUIDICS

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

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

MICRO-X

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

PUBLICATIONS

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