MICROSCOPY AUSTRALIA RESEARCH HIGHLIGHTS 2018

We invite you to explore how our collaborative research infrastructure empowers discovery and innovation. See how this new knowledge can deliver a healthier and more prosperous Australia.

CONTENTS

NEWS FROM THE TEAM	2
STATS	4
NETWORK	6
EQUIPMENT & EXPERTISE	8
TECHNIQUE DEVELOPMENT	10
AUSTRALIAN NANOTECH – BUILDING BUSINESS	12
SUPPORTING MEDTECH & PHARMA	14
STORIES AND STRUCTURES – NEW CONNECTIONS	16
IMC19	18
GLOBAL BIOIMAGING – EXCHANGE OF EXPERIENCE	20
FUTURE DIRECTIONS	21
RESEARCH OUTCOMES & SOCIAL IMPACT	22 – 43
CONTACTS	44

Image: Electron backscatter diffraction of a high entropy alloy. Dr Mehdi Eizadjou, Lena Frommeyer, Prof. Simon Ringer and Prof. Gerhard Wildetoo.

Cover image: Autofluorescent confocal image of a living Melaleuca (paperbark) leaf. Area is approximately 1mm across. Paul Rigby.

NEWS FROM THE TEAM

MINISTER

Senator the Hon. Dan Tehan,
Minister for Education and Training

I want to congratulate Microscopy Australia on what has been a busy and successful year.

The Morrison Government is committed to supporting industry, business and the research sector as it drives innovation across Australia.

Microscopy Australia continues to empower research for social impact that is vital to our future economic prosperity. You produce leading edge research across a wide variety of fields, while launching your new name and branding and exploring new and exciting ways to share your successes – both here in Australia and around the world.

Your collaboration with the Powerhouse Museum for the *Stories and Structures – New Connections* exhibition, as part of the 2018 Vivid Ideas program, explored an interesting link between the world of art and the world of research.

I wish Microscopy Australia every success in 2019 and beyond. Keep up the good work.

CHAIR

Dr Gregory R. Smith
Chair of Board

2018 has been a very significant year for this organisation. Most notably it has involved a name change with the former Australian Microscopy and Microanalysis Research Facility becoming the more user-friendly, simpler-named Microscopy Australia.

The 19th International Microscopy Congress (IMC) came to Sydney in 2018. This four-yearly event is effectively a global Olympics of Microscopy. Since 2010, a local organising committee had sought to win the IMC for Australia. It made very strong submissions both in Rio de Janeiro (2010) and in Prague (2014), at which time the Sydney bid for 2018 was successful. Ultimately, a very highly regarded international conference and exhibition was run in Sydney last September with over 2,000 participants. Microscopy Australia played a significant part at this IMC event.

As part of our international partnership with Global Bio-Imaging (GBI), Microscopy Australia worked with GBI and the National Imaging Facility to organise and host three highly successful workshops in Sydney after the IMC. These brought bioimaging managers and staff together from around the world to share their knowledge, experience and best practices.

Microscopy Australia proudly launched its *Stories and Structures – New Connections* exhibition this year. The event was introduced to the public during Sydney's 2018 Vivid Ideas festival. It has since commenced a tour of the country. By contrasting high resolution microscopy images with traditional forms of imagery produced by noted Aboriginal artists, the exhibition provides a unique event that is attracting wide interest.

Very pleasingly, the inclusion of Microscopy Australia in the Federal Government's NCRIS 2018 budget round was announced before the last financial year ended. A multi-year co-investment strategy now enables the acquisition of major new instruments at various Microscopy Australia nodes. These new microscopy techniques and related capabilities will permit Microscopy Australia to continue supporting a world-leading position in technologies including geoscience, medical, biological, materials, and horticulture. Most critically, this NCRIS round has also funded the inclusion of a new Victorian node to join the Microscopy Australia partnership. Monash University has been selected and will be brought on board in 2019.

CEO

Prof. Julie Cairney
Chief Executive Officer

Our users rely heavily on access to our sophisticated microscopy facilities to do world-leading research. With surveys indicating that more than 90% of users are satisfied with our services, it is with some trepidation that we have changed our long-established 'AMMRF' brand to Microscopy Australia. The new name is simple and descriptive and we feel that it clearly conveys our vision and purpose. The response amongst our stakeholders and users alike has been overwhelmingly positive and I am confident that it will serve us well into the future.

As we approach the end of 2018, we reflect on a very significant year. Along with our name change, other highlights include our participation in the organisation of the 19th International Microscopy Congress in Sydney in September, the launch of the *Stories and Structures – New Connections* exhibition and associated Vivid Ideas event, and of course, good news in the May budget.

This budget provided a welcome investment in our National Collaborative Research Infrastructure Strategy, including $15M above business as usual for Microscopy Australia. This investment, in conjunction with substantial co-investment from our host universities and state governments, will support our new five-year investment strategy.

This plan includes much-needed investment in important emerging microscopy technologies including atomic-scale microscopy, cryo-electron microscopy and high-sensitivity microanalytical tools. Access to these capabilities and the associated expertise is crucial for Australia to maintain a world-leading position in geoscience, medical, biological, materials, plant and nano sciences. A small increase in our federal operational funding has also provided an opportunity for us to expand the national network by supporting open access to infrastructure and technical experts at a new partner facility in Victoria. As we expand into Victoria, we think our new name reflects the wider reach of our national facility.

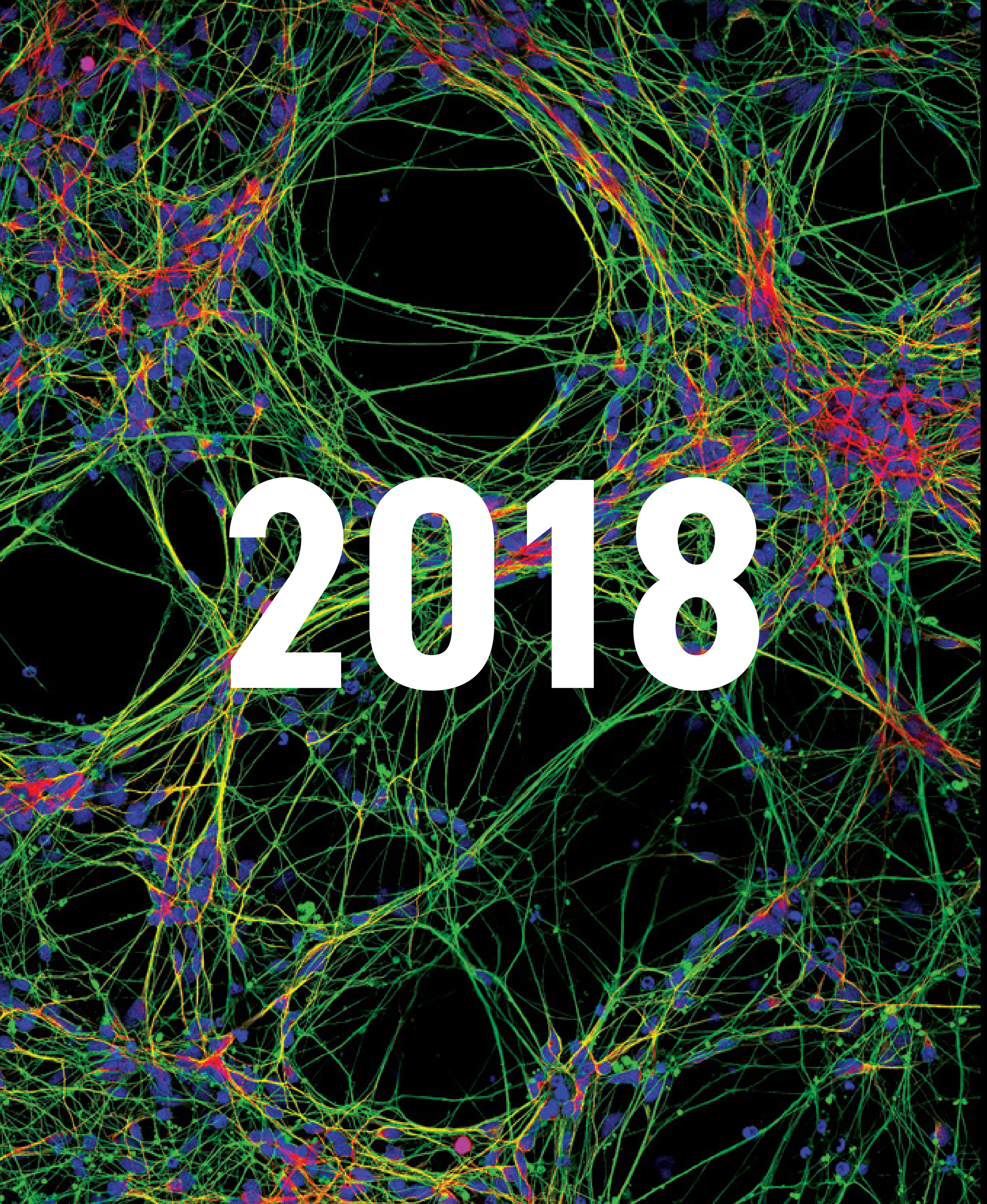


Image: Neurons from Stem Cells - Confocal | Jianyun Gao

STATS

233
INSTRUMENTS

3,900
USERS

120+
INDUSTRY CLIENTS

268,000
HRS BEAMTIME

160,000
MYSCOPE USERS

1,400+
PUBLICATIONS

50% PHYSICAL & MATERIALS
34% BIOMEDICAL
16% GEOSCIENCE & ENVIRONMENT

41% MANUFACTURING
22% BIOMEDICAL
37% RESOURCES & ENVIRONMENT

BIG NEWS

This year's standout achievements include:

- Launch of our rebrand with a focus on research outcomes and the idea "There is so much more to see".
- Five years of certainty around operational funding + $15M on top of business as usual funding.
- Launched some of Australia's highest resolution microscopes.
- *Stories and Structures – New Connections* exhibition, juxtaposing micrographs with Indigenous art was launched and is now touring Australia.
- Our team made major contributions to the Australian microscopy community at IMC19 – the world's largest microscopy conference.
- Hosted and helped organise three Global BioImaging workshops in Sydney.
- Amazing new experts have joined the team.
- Launched new modules and content on MyScope, our online learning resource: www.myscope.training.
- Selection of Monash University as our new Victorian facility.
- Continued to enable great research – check out this year's inspiring highlights pg 22 – 43.

SPECIALISTS

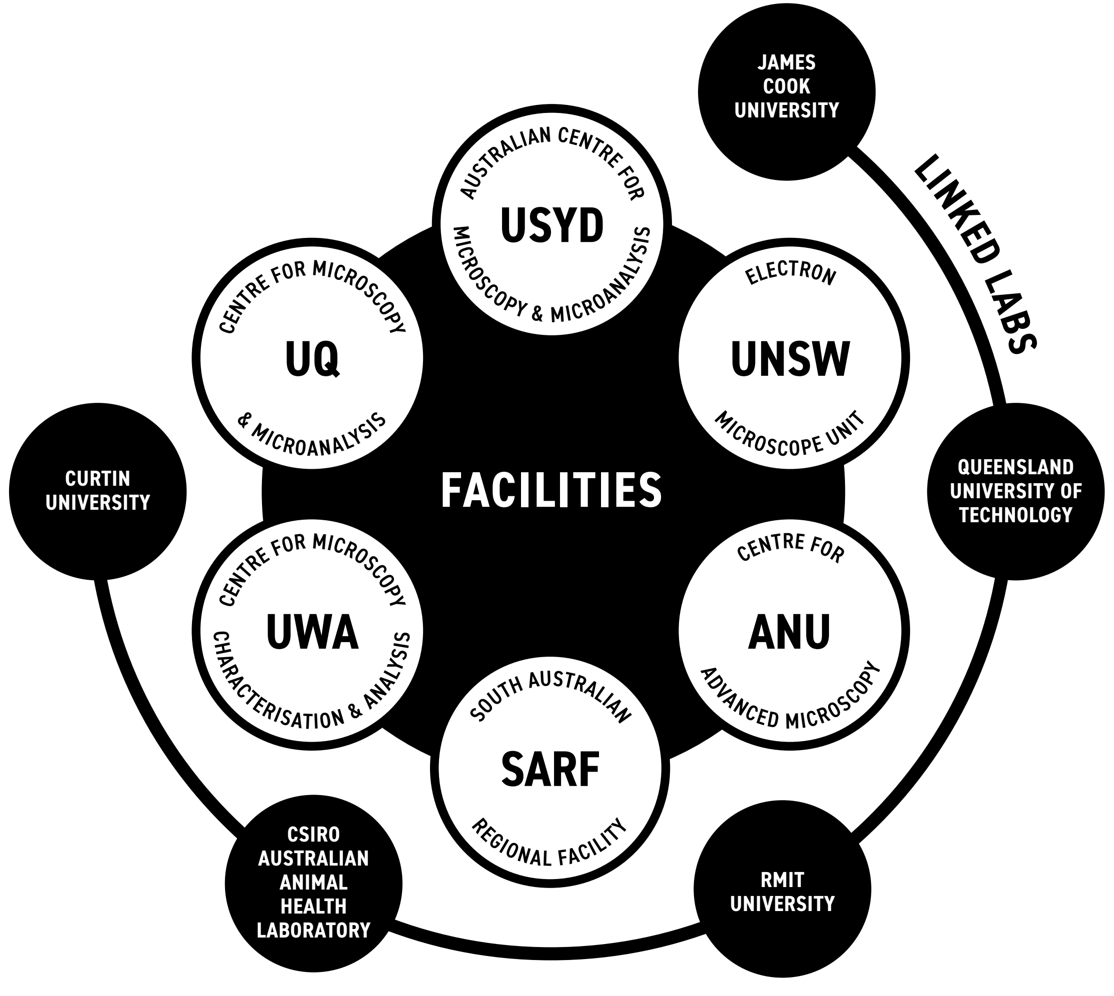
TEAM

Our people are the driving force of Microscopy Australia. A team of skilled specialists are keen to share their knowledge, offering personalised support and training. These are just a few of our team photographed at various events. Thanks to all of you.

RESEARCHERS

TRAINERS

NETWORK



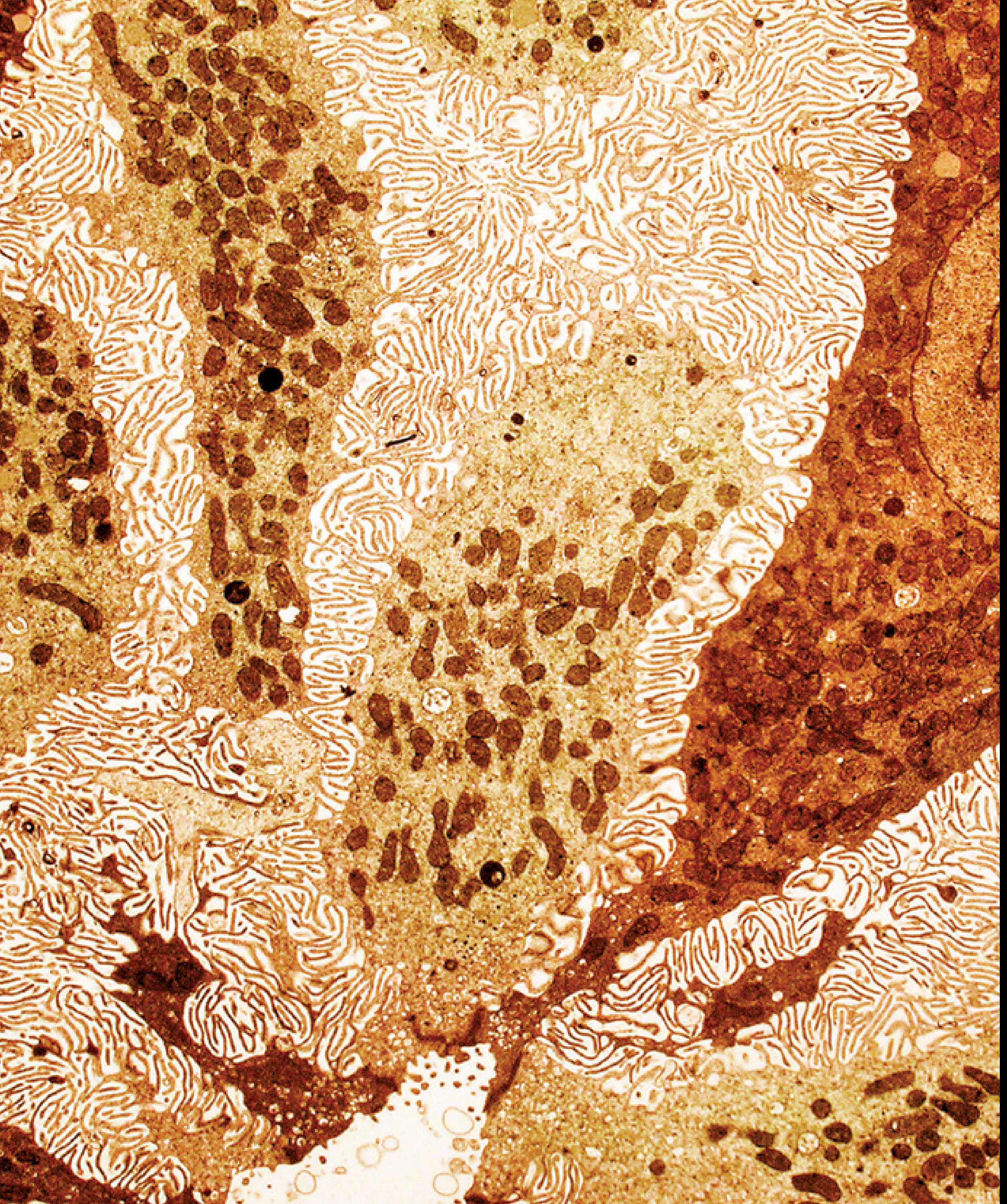


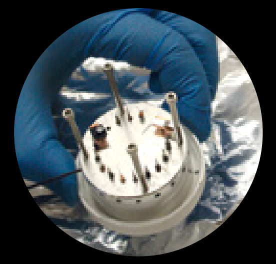
Image: Colour-enhanced TEM of a crocodile salt gland

EQUIPMENT AND EXPERTISE

Microscopy Australia empowers research by providing open access to sophisticated instruments and expertise for researchers around the country. Our dedicated staff ensure that researchers collect high quality data. Our range of specialised techniques is summarised here.

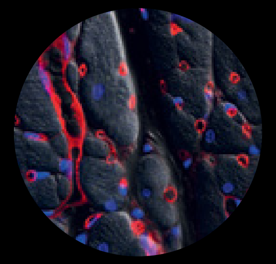
Our online microscopy training tools are also openly accessible with over 160,000 users worldwide in the last year alone.

With the nation's largest range of high-end microscopes and specialists, we also support business across a wide range of industry sectors. Companies of all sizes, from start-ups to multi-nationals, benefit from our services, training and R&D partnerships.



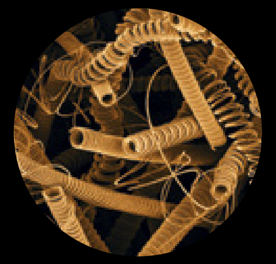
SPECIMEN PREPARATION

- Biological & Materials
- Cell Culturing & Molecular Preparation
- Thermomechanical Processing
- Ion Milling & Machining
- Ion Implantation



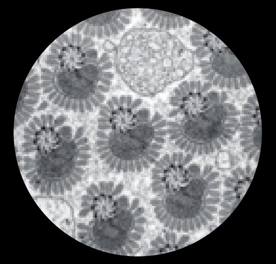
LIGHT & LASER TECHNIQUES

- Fluorescence, Confocal & Multiphoton Microscopy
- Super Resolution Microscopy
- Analytical Spectroscopy
- Flow Cytometry
- Laser Microdissection



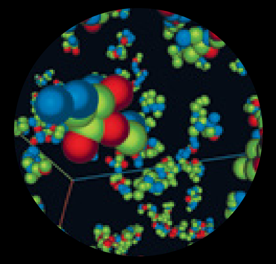
SCANNING ELECTRON MICROSCOPY

- Imaging & Analytical Spectroscopy
- In-situ Imaging & Testing
- Cathodoluminescence
- Electron Backscatter Diffraction



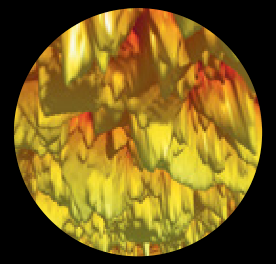
TRANSMISSION ELECTRON MICROSCOPY

- Imaging & Analytical Spectroscopy
- Cryo-techniques & Tomography
- Phase & Z-contrast Imaging
- Electron Diffraction



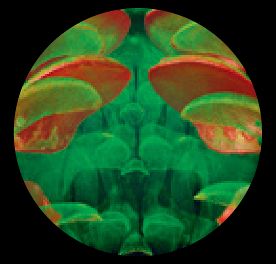
ION & SPECTROSCOPY PLATFORMS

- Secondary Ion Mass Spectroscopy
- Imaging Mass Spectroscopy
- Atom Probe
- LA-ICP-MS



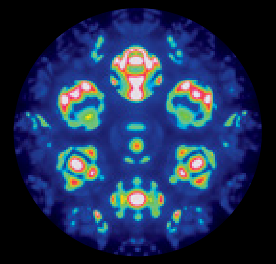
SCANNED PROBE TECHNIQUES

- Atomic Force Microscopy
- Scanning Tunneling Microscopy
- Near-field Scanning Optical Microscopy



X-RAY TECHNOLOGIES

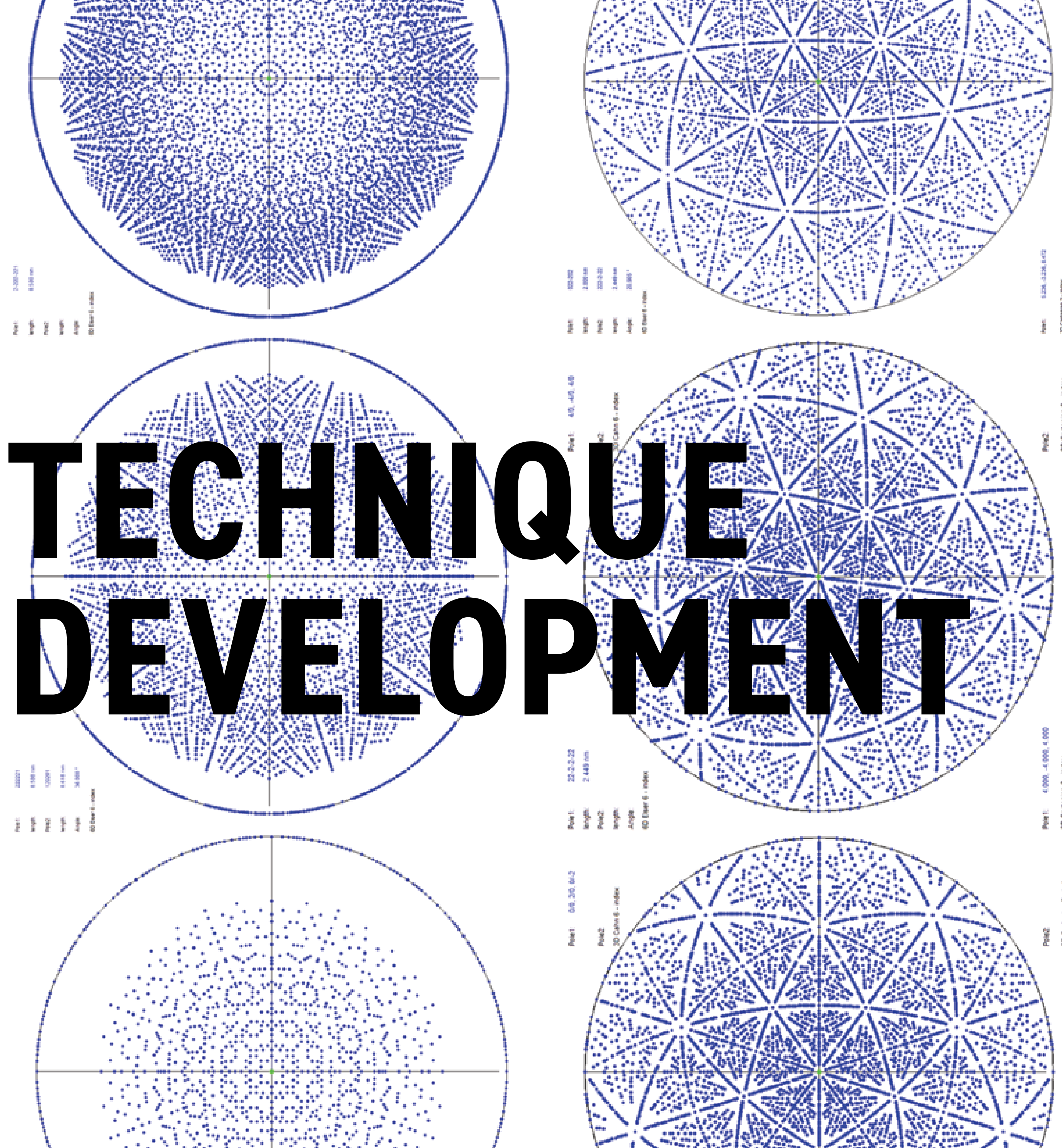
- X-ray Diffraction
- X-ray Fluorescence
- X-ray Micro & Nanotomography



VISUALISATION & SIMULATION

- Computed Spectroscopy
- Computed Diffraction
- Image Simulation & Analysis
- Data Mining

TECHNIQUE DEVELOPMENT



SYDNEY – ATOMIC-SCALE STUDY OF QUASICRYSTALS

Quasicrystals have an ordered structure, as do 'conventional' crystals. However, the pattern of atoms doesn't keep repeating itself in the same way as it would in a normal crystal. Quasicrystals were discovered by Dan Shechtmen in 1982 and were considered very contentious at the time, causing ridicule of him as a scientist. But his expertise in transmission electron microscopy (TEM), and his persistence and tenacity, meant that he was able to prove the existence of quasicrystals.

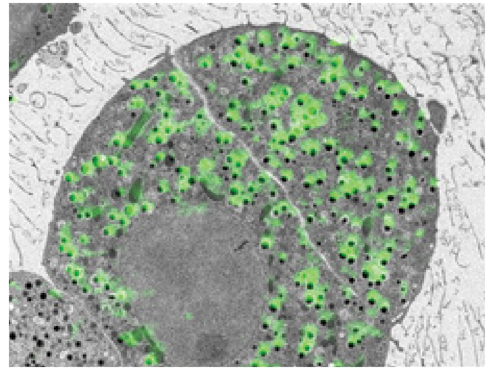
In 1991 the International Union of Crystallography rewrote the definition of 'crystal' to:

"any solid having an essentially discrete diffraction diagram". Quasicrystals are now a popular field of study in materials science and engineering.

Quasicrystals can exist alongside 'conventional' crystals in various different materials but to date there has been no coherent approach to the analysis of both structural types in a single sample. The analytical expertise of Drs Anna Ceguerra, Hongwei Liu and Magnus Garbrecht at Microscopy Australia's University of Sydney facility, has focused on developing a calculation method that simplifies analysis of the relationships between quasi- and conventional crystals. This enables exploration of the relative orientations of the crystals and can shed light on the behaviour and properties of these materials.

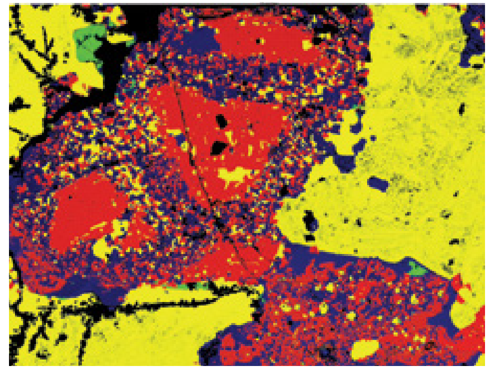
The team's 'crystallographic calculator' allows the structures and orientation of all the crystals in a sample to be understood from both TEM and atom probe data. This improves the current analysis methods and supports research into new and complex areas of materials science using our advanced microscopes.

A snapshot of the technique development work by our expert staff – providing Australian researchers with constantly improving tools. All these advances were presented at IMC19.



ANU

Optimising automated systems for correlative light and electron microscopy for studies into diabetes, malaria and cancer.

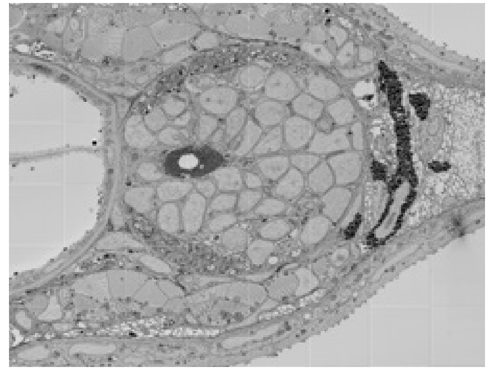


ANU

Testing traditional assumptions to find the most practical and efficient approach to elemental analysis.

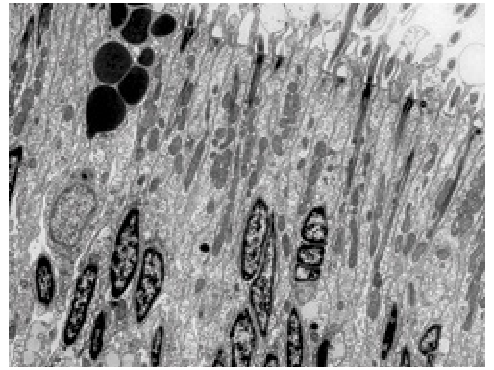
SYDNEY

Working out atom probe parameters to enable analysis of complex biomineralised samples like bone and shell.



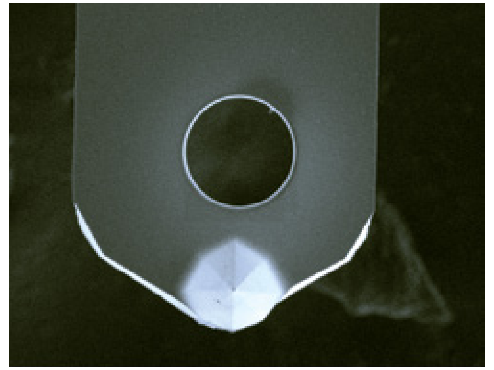
UQ

Repurposing electron beam lithography instruments to enable precision scanning electron microscopy (SEM) imaging of large areas.



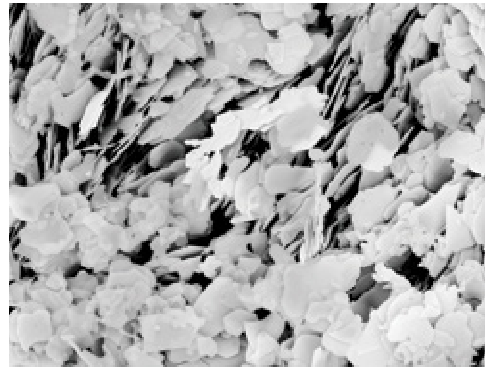
UQ

Discovering how microwave radiation improves sample preparation procedures.



FLINDERS

Developing an internet-based initiative for atomic force microscopy (AFM) calibration across three countries; enabling direct comparison of AFM data from researchers around the world.



CURTIN

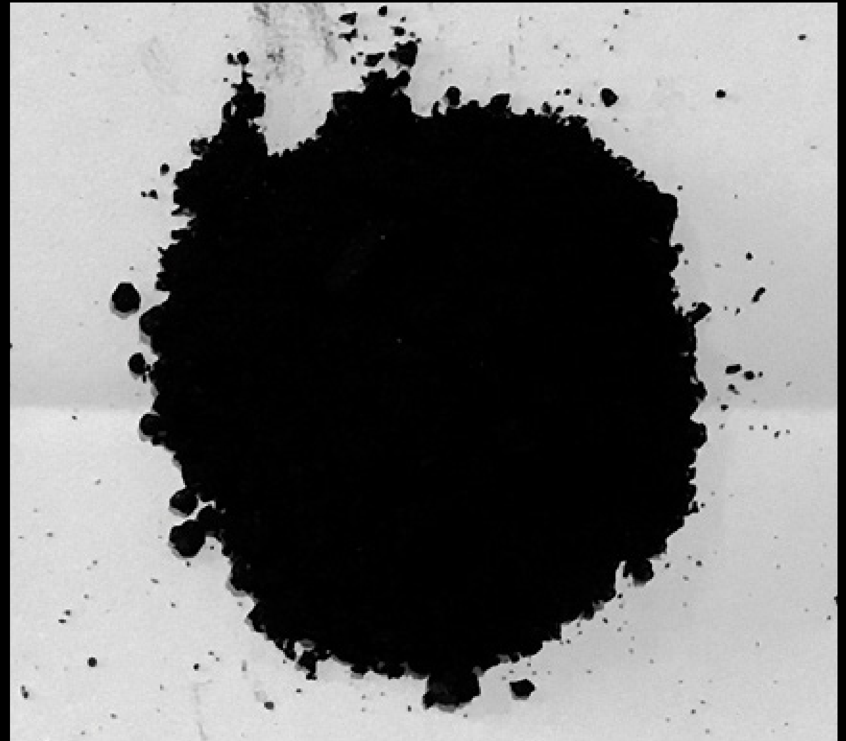
Relating particle morphology to automated X-ray diffraction (XRD) specimen preparation parameters for optimal results.

AUSTRALIAN NANOTECH – BUILDING BUSINESS

Graphene is a single sheet form of carbon that is only one atomic layer thick. It is the strongest material ever tested and efficiently conducts heat and electricity.

Graphene Manufacturing Group

Competitor's (above) vs GMG's Graphene (below)



The Graphene Manufacturing Group (GMG) is an award-winning Brisbane-based global technology business empowering innovation across industries through the bulk supply of graphene. GMG began operations in August 2016 from their pilot plant, realising their vision to unlock the incredible variety of applications for graphene, that until now, have been restricted to research labs.

The team at GMG have engineered a unique and flexible continuous process that delivers high quality graphene at a fraction of the cost of existing production methods. The process can be tailored to precisely align with GMG's clients' needs for their different applications.

"Our innovative production process is world-leading, so it is essential to understand exactly what we are manufacturing.

The analysis done for us at Microscopy Australia's University of Sydney facility has been instrumental in both the process and product design of our graphene. It allows us to streamline improvements before and during production as well as confirming post-production efficacy.

Via scanning and transmission electron microscopy, Microscopy Australia has enabled us to understand our graphene by providing:

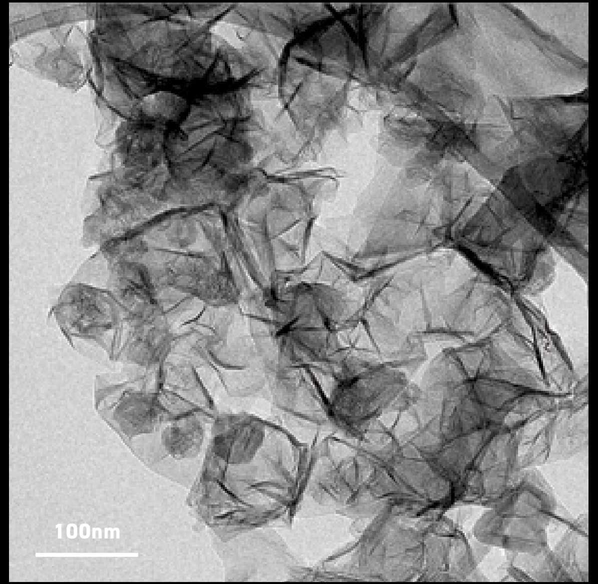
- sizes and morphology of the carbon structures we were producing
- quantifying our graphene layers (along with Raman analysis from Sydney Analytical)
- confirmation of the crystalline structure of our graphene.

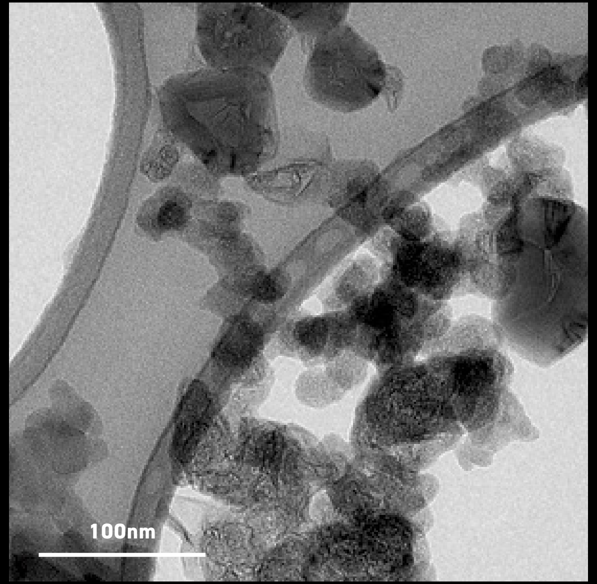
This enables us to adjust operating windows during our manufacturing process and directly link the characteristics of our graphene with tangible customer outcomes.

This independent analysis is also essential for us in building successful relationships with our current and future customers and with our investors.

We now have confidence to better understand the improvement mechanisms required for multiple applications of the wonderous product we produce." Craig Nicol, Founder, Managing Director and CEO.

GMG's success sees them constructing of one of the largest graphene plants in the world in early 2019.





TEM images of two GMG graphene samples

CLIENT BASE & PRODUCT APPLICATIONS INCLUDE:

CONCRETE

EPOXY RESIN

MEDICAL DEVICES

BITUMEN

POLYMERS

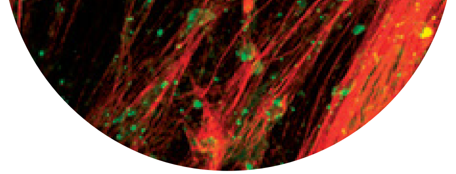
BATTERIES FOR ELECTRIC VEHICLES

DEFENCE MATERIALS

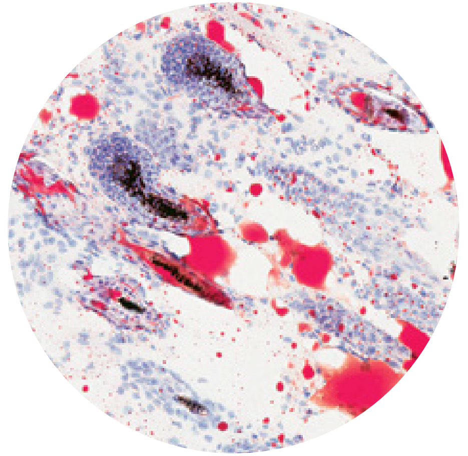
COATINGS

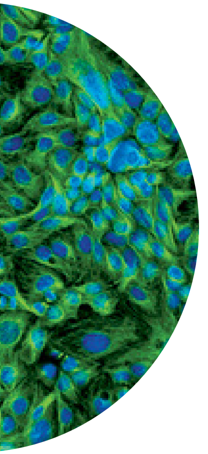
SOLAR CELLS

METALS



SUPPORTING MEDTECH & PHARMA





LAUNCHED 2018

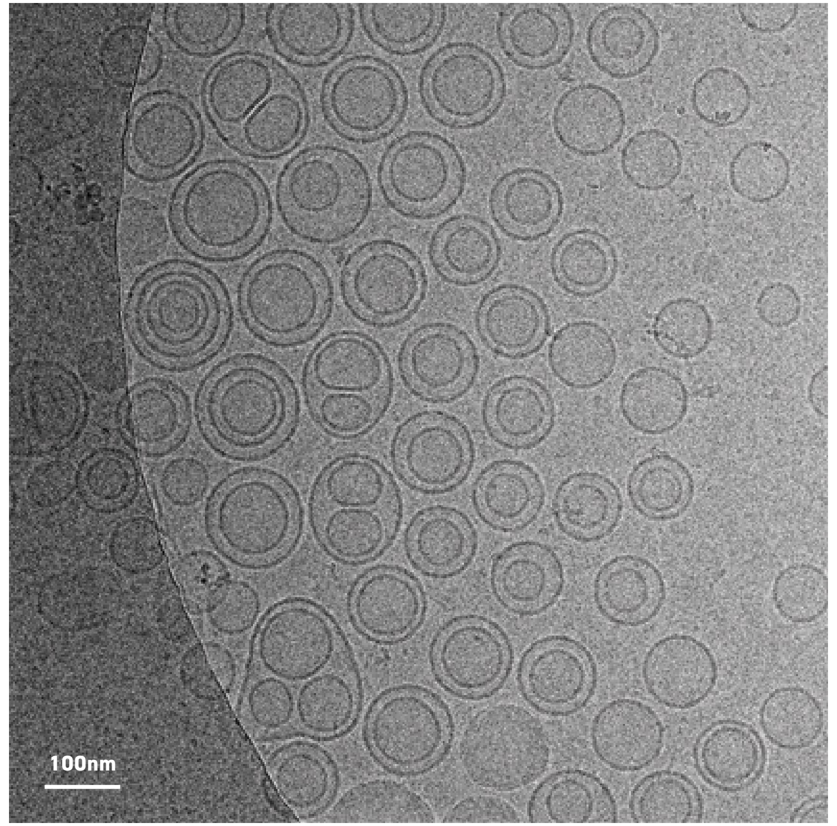
MICROSCOPY AUSTRALIA TECHNICAL VOUCHER FUND

The Microscopy Australia Technical Voucher Fund has been established with the support of MTPConnect, the Industry Growth Centre for medtech and pharma. The scheme aims to provide easy, discounted access to our sophisticated instruments and expert technical help for this important industry. It is designed to reduce barriers and provide industry with access to analytical tools and experts with problem-solving capabilities. Solutions can be tailored to the specific research needs of both SME and large companies.

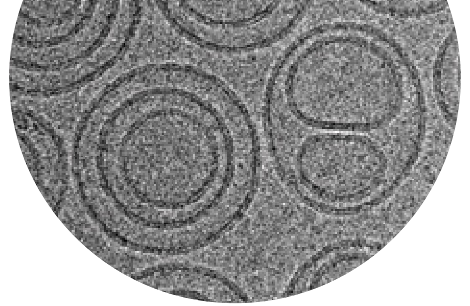
Our wide-ranging techniques can help medtech industries understand the structure, function and properties of molecules, cells and materials whether they are structural proteins, antibodies, drugs, drug delivery systems, biomaterials, alloys, ceramics, nanoparticles or polymers.

ammrf.org.au/industry-services

(Microscopy Australia website in progress)



Cryo EM image of cannabinoid-containing liposomes



AN INTERVIEW WITH LG PHARMA

Little Green Pharma (LGP) is a privately held pharmaceutical start-up founded in 2016 in Perth, WA. After securing the necessary permits and establishing manufacturing partnerships in 2017, LGP became the first company to produce and bring 100% Australian-made pharmaceutical-grade medicinal cannabis formula to the Australian market.

"While ensuring supply of our currently available formula (to prescribing physicians for patients who meet the criteria set out by their state health authority regulations and via the TGA's Special Access Scheme B) we are also committed to developing new pharmaceutical-grade medicinal cannabis formulations of quality and efficacy for Australians with unmet clinical needs."

Fleta Solomon, CEO

"We are currently producing our LGP Classic 10:10 oil oral liquid formulation, where each mL contains 10mg THC and 10mg CBD derived from medicinal cannabis whole plant extract. THC and CBD in a 1:1 ratio is a common starting point for practitioners. We are also continuing to expand and improve our range of available formulas by engaging with academic and other partners to conduct pre-clinical and clinical development R&D work with new medicinal cannabis formulations, including many for which we have secured IP protection."

Damian Wood,
Head of Pharmaceuticals

"Engaging with Microscopy Australia, through their facility at UNSW, we have been able to validate the physical makeup of some of our novel investigational formulas. This work, supported by a Microscopy Australia Technical Voucher, was very timely, as we were able to use world-class resources, including the new Talos Arctica cryo-EM instrument to image our samples."

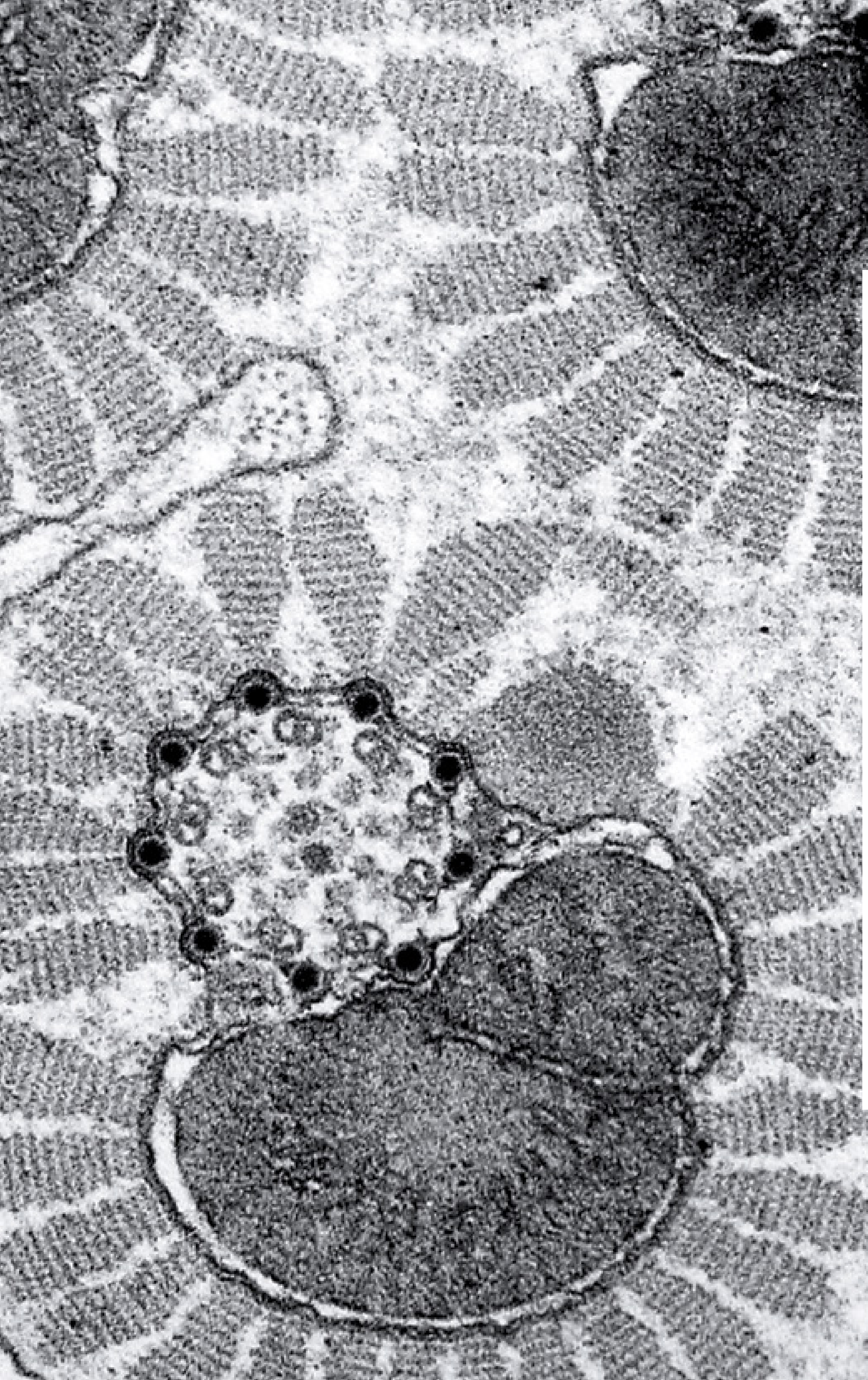
Lilly Bojarski,
Medical Science Liaison (NSW)

"We have subsequently been granted another voucher to continue our research. This will enable LGP to monitor our formulas for any degradation during various storage conditions."

Damian Wood,
Head of Pharmaceuticals

"LGP is continuing to engage with academic research partners to develop novel approaches to delivering cannabinoid-containing formulas as efficiently as possible for maximum clinical effect. We intend to maintain our association with Microscopy Australia as we are committed to continuing R&D in the medicinal cannabis space."

Lilly Bojarski,
Medical Science Liaison, (NSW)



STORIES & STRUCTURES

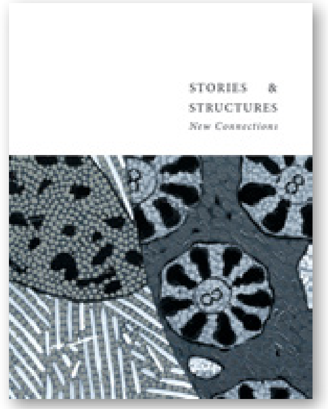
New Connections

60,000 YEARS OF TRADITION MEET THE MICROSCOPIC WORLD

We recently created a touring exhibition of micrographs and associated Aboriginal and Torres Strait Islander artworks. Funded by external sponsorship and curated by Microscopy Australia, it aims to engage all Australians with science and Indigenous cultures in new ways.

This exhibition explores images that pass on knowledge and shape our understanding of the world. Rich visual parallels between the representations seen in many Indigenous artworks and the microscopic structures hidden in the natural world, reveal unexpected and intriguing similarities. This delivers a new vision of our country and its stories. We hope that these images will open conversations and provide opportunities to make new and lasting connections across disciplines and across cultures.

Images: Sperm Growing in a Moth Testis | Greg Rouse
Witchetty Grub Dreaming | Jennifer Napaljarri Lewis



Visit the website to view the full exhibition, tour dates and hosting information. Download the exhibition book at: **micro.org.au/storiesandstructures**

IMC19

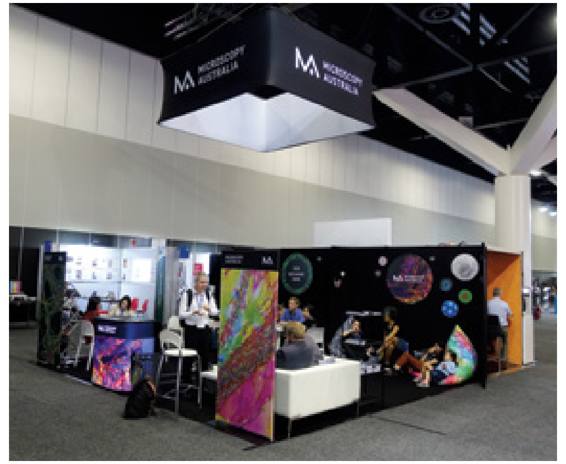
The Australian Microscopy & Microanalysis Society (AMMS) hosted the 19th International Microscopy Congress (IMC19) in September at the International Convention Centre, Sydney. Microscopy Australia staff were heavily involved in getting the Congress to Australia, organising the meeting and its diverse scientic program.

2,100+ DELEGATES FROM 48 COUNTRIES
2,000+ PRESENTATIONS
150 INVITED TALKS
450 ORAL PRESENTATIONS
800 POSTERS
2 NOBEL LAUREATES
70 COMPANIES IN TRADE EXHIBITION
INTRODUCED DIGITAL POSTERS

MICROSCOPY AUSTRALIA – RECHARGE LOUNGE

The new Microscopy Australia identity was launched at IMC19. Our Recharge Lounge was very popular with delegates and recognition of the new name grew quickly as our branded bags and notebooks flew off the shelves.

With 125 of our staff gathered from around the nation, collaborations and knowledge exchange blossomed. Most gave talks or poster presentations to the international assembly. Many also volunteered to share the wonders of microscopy with school groups from around New South Wales.



STEM OUTREACH AREA

The Learning Space was a free, four-day school science program at the Congress, initiated by the corporate members of AMMS and supported by a bevvy of volunteers from microscopy vendors, universities, the Australian Science Teachers Association and museums around Darling Harbour. As a corporate member of AMMS, Microscopy Australia contributed both volunteers and organisers to the Learning Space.

570 students from 19 schools were enthralled by hands-on experience with microscopes, a 3D virtual reality visualisation of the inside of a cell, and 3D printer demonstrations.

Congratulations to the outreach team jointly coordinated by Benjamin Pace and Eleanor Kable with a bunch of amazing volunteers keen to share their knowledge. It was great to see so many people come together to make this happen at the IMC19 event, inspiring future microscopists.

The students were excited to continue exploring micrcopy at **myscopeoutreach.org**

4 DAYS
25+ VOLUNTEERS
19 SCHOOLS
570 STUDENTS
4 SEM'S
20 LIGHT MICROSCOPES
VR
3D PRINTING

Equipment and demonstrations were supported by Microscopy Australia, ZEISS, Leica, AXT, Keepad Interactive, NewSpec, ATA, Coherent, Me3D and UNSW Art and Design, VR: Prof. John McGhee.

INDIGENOUS CULTURE

Microscopy Australia enriched the IMC19 visitor experience with Australian Indigenous culture, live art and music.

The *Stories and Structures – New Connections* exhibition brings 60,000 years of visual tradition and storytelling into dialogue with scientific imaging and was on show at the Congress. One of the exhibition artists, Kurun Warun, attended the IMC trade show at the invitation of Microscopy Australia. He used this unique international platform to share his art and culture live onsite.

For more on *Stories and Structures – New Connections* visit the website:

micro.org.au/storiesandstructures

RESPONSE

"Innovations in microscopy enable us to extend our understanding of ourselves and the world around us. IMC19 brought together leaders in both the development and the application of microscopy in a huge range of disciplines"

Prof. Simon Ringer
Congress Chair

"An investment in this field (microscopy) is an investment in nanoparticles that target such things as a drug directly to malignant cells; 3D printed lattices that act like tiny factories for T-cells; vital in the new generation of cancer immunotherapies and more. Without Microscopy, there is no modern science – end of story."

Dr Alan Finkel
Australia's Chief Scientist
IMC19 opening address

"This was a great STEM initiative by IMC19 and an amazing experience for the students who came. We don't have these microscopes at our school and without the IMC19 Outreach Program, most of our students wouldn't be able to use this equipment. Our students are learning directly from experts."

Mrs Diane Fairweather
Head of Science,
Riverstone High School

CONGRATULATIONS TO EVERYONE INVOLVED IN MAKING IMC19 A GREAT SUCCESS.
THE EVENT RECENTLY WON THE INTERNATIONAL IAPCO COLLABORATION AWARD.

GLOBAL BIOIMAGING – EXCHANGE OF EXPERIENCE

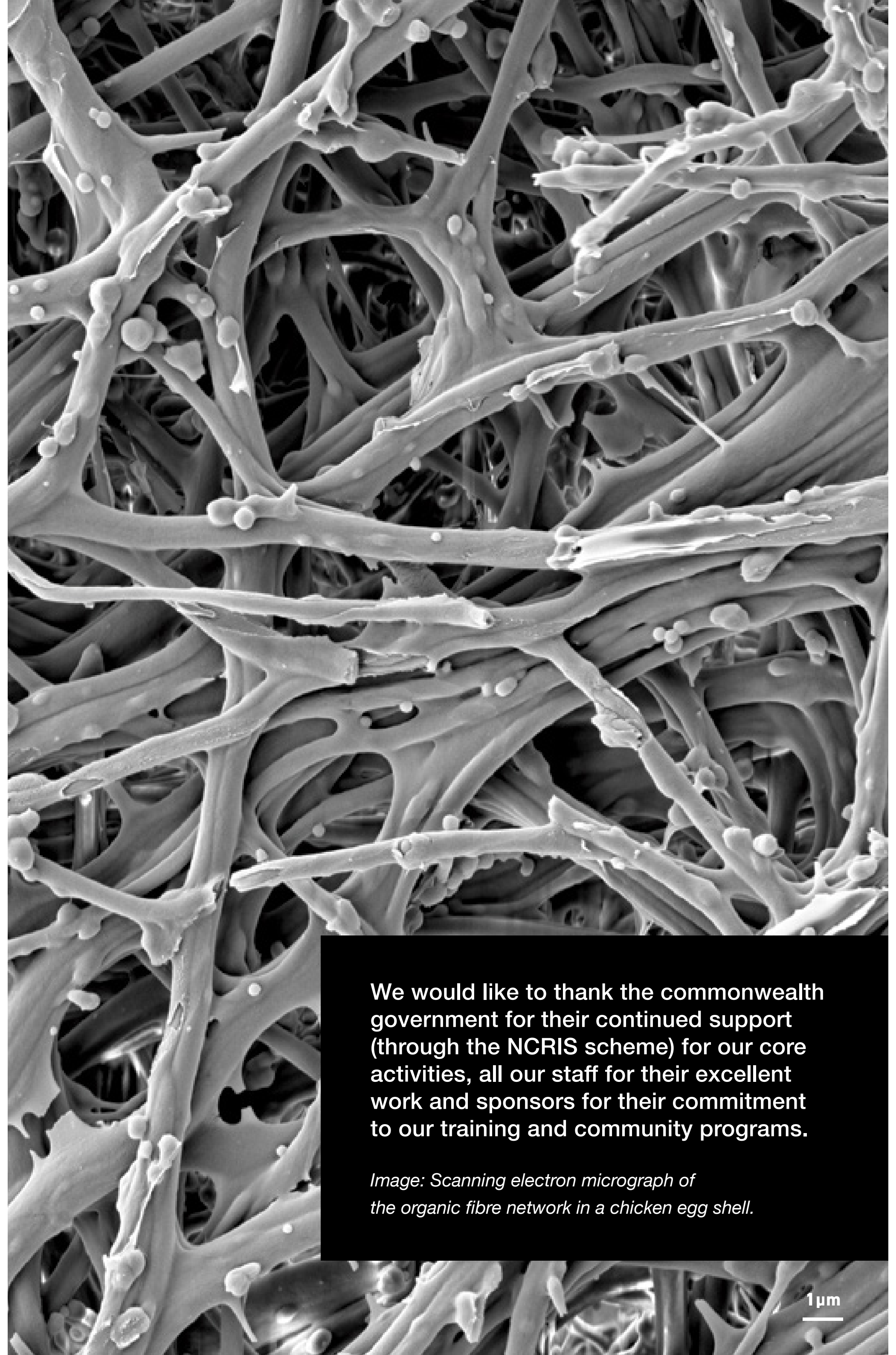
EoE III deligates at the Charles Perkins Centre – The University of Sydney

In September 2018 Microscopy Australia, working with the National Imaging Facility, were proud to host three Global BioImaging (GBI) events. An Exchange of Experience brought together 64 bioimaging facility managers from 18 countries. They tackled big questions about creating a sustainable future for international collaboration and the development of frameworks to ensure quality of research, service standards and data management. Microscopy Australia shared our experience as a national open access research infrastructure and the value it brings, not just to researchers, but Australia as a whole.

The next event, the second International Training Course on the Management and Operation of Imaging Core Facilities, provided the opportunity for visitors to learn from an international panel of experts about the nitty gritty of running a world class facility. This included topics from delivering durable, reliable and high-quality image data, to managing difficult clients.

This was followed by the second International Training Course on Challenges in Image Data Management and Analysis. This is an area that benefits enormously from knowledge sharing as microscopists around the world seek the best solutions to getting the most from the large datasets that microscopy now generates.

Feedback from both events was overwhelmingly positive, further projecting Microscopy Australia into the global consciousness as a world leader in advanced imaging.



We would like to thank the commonwealth government for their continued support (through the NCRIS scheme) for our core activities, all our staff for their excellent work and sponsors for their commitment to our training and community programs.

Image: Scanning electron micrograph of the organic fibre network in a chicken egg shell.

FUTURE DIRECTIONS

INSTRUMENTS & EXPERTISE

Australian researchers need access to emerging microscopy and microanalysis technologies to take their research successfully into the future. We will provide access to new technologies in three key areas: atomic-scale microscopy, cryo-electron microscopy and high sensitivity microanalytical tools. These new tools will be supported by experts to help researchers in both materials and biological sciences produce world leading research.

DATA SOLUTIONS

Researchers are producing ever-larger and multi-dimensional data sets and are increasingly using multiple instruments as part of a single study. They need harmonised data analysis, transfer and storage solutions to turn the data into new discoveries. We are finding synergies with other organisations who have similar data requirements and are working with them to implement systems to meet these challenges. Microscopy Australia will fund a network of dedicated staff around Australia to deploy these systems and to interface between researchers, instrument scientists and the data and analytics solutions.

TOOL DEVELOPMENT

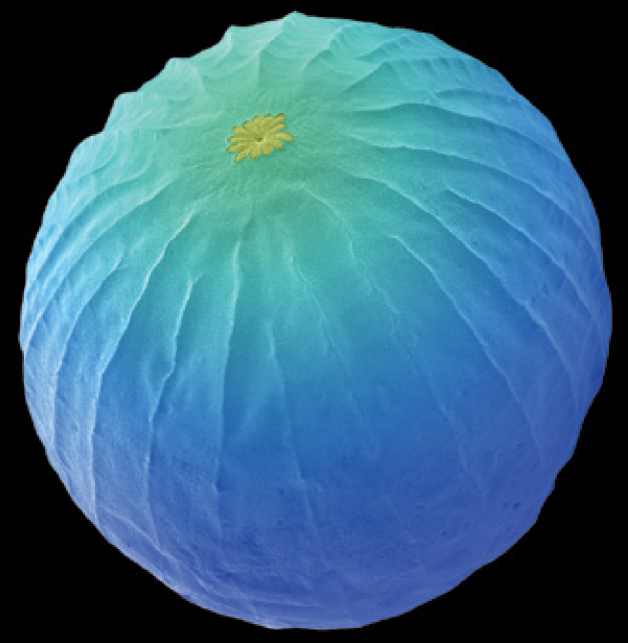
We will give Australian science the edge by developing new instruments and analytical techniques. Dedicated staff will be employed specifically to develop innovative and useful new solutions: hardware, software and methods to take our capabilities into the future.

INDUSTRY ENGAGEMENT

We will continue to work with industry, particularly with SMEs, through programs such the Industry Growth Centres and our MTPConnect-funded Technical Voucher scheme. This brings subsidised access to microscopy to industries both large and small.

TRAINING & COMMUNITY

We will continue to expand our world-leading MyScope training platform to add modules covering techniques with high demand or high knowledge requirements. The *Stories and Structures – New Connections* exhibition (see pg 16) will tour Australia to make new and lasting connections, encouraging interest in STEM, particularly amongst Australia's Indigenous youth.



MyScope

Explore our online platforms to train in advanced microscopy:

myscope.training

Introduce your family to microscopy with our engaging simmulator activities:

myscopeoutreach.org

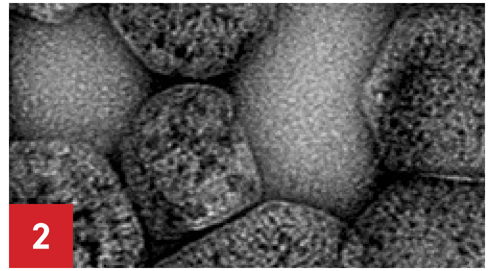
Image: Colour enhanced scanning electron micrograph of a moth egg

RESEARCH OUTCOMES & SOCIAL IMPACT

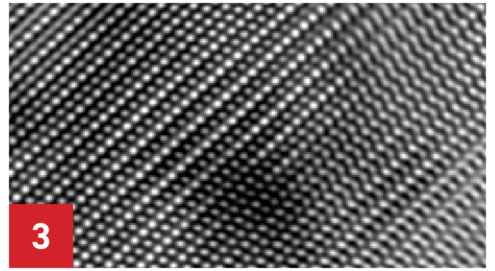
Take a closer look at this year's research highlights – all enabled by Microscopy Australia. With over 3,900 researchers annually, here are just a few of our recent stories.

2018

PILBARA ROCKS POINT TO PAST LIFE ON MARS

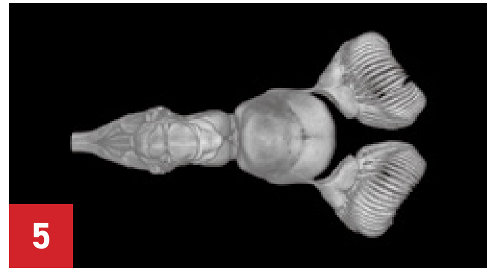


GENETIC ENGINEERING FOR FOOD SECURITY

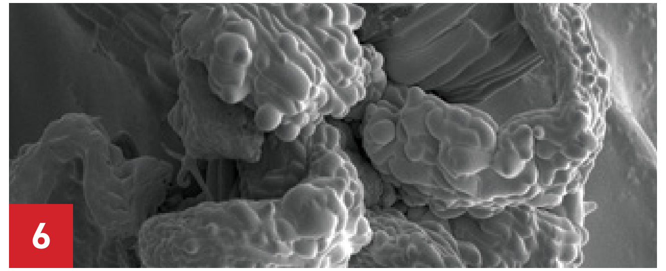


MAGNESIUM PLASTICITY GAINS

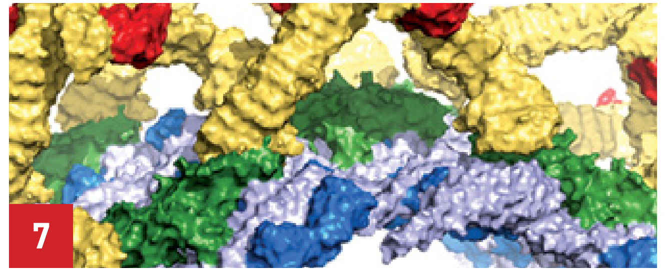
A SOLAR FUTURE



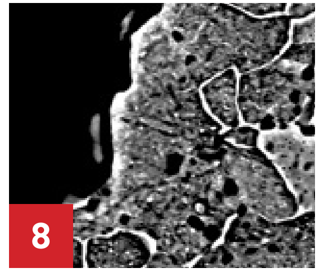
FISH SMELL



BECOMING A FLOWER

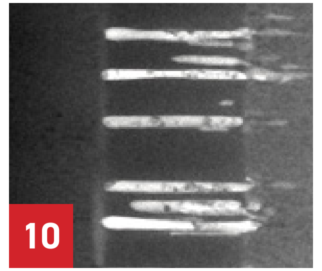


INSIGHTS INTO PARKINSON'S DISEASE

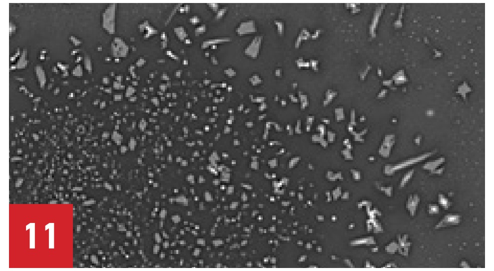


FROM AUTOMOTIVE WASTE TO ROBUST COATED STEEL

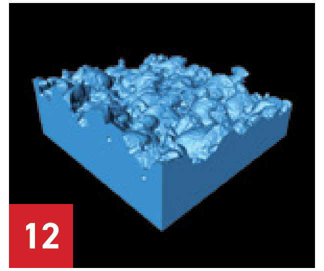
VIRTUAL LEAF



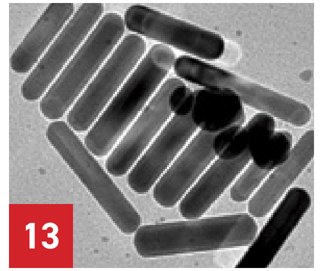
CONCENTRATING SUNLIGHT IN SOLAR CELLS



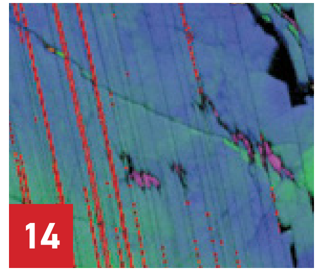
SUPPORTING INDUSTRY – AURUBIS



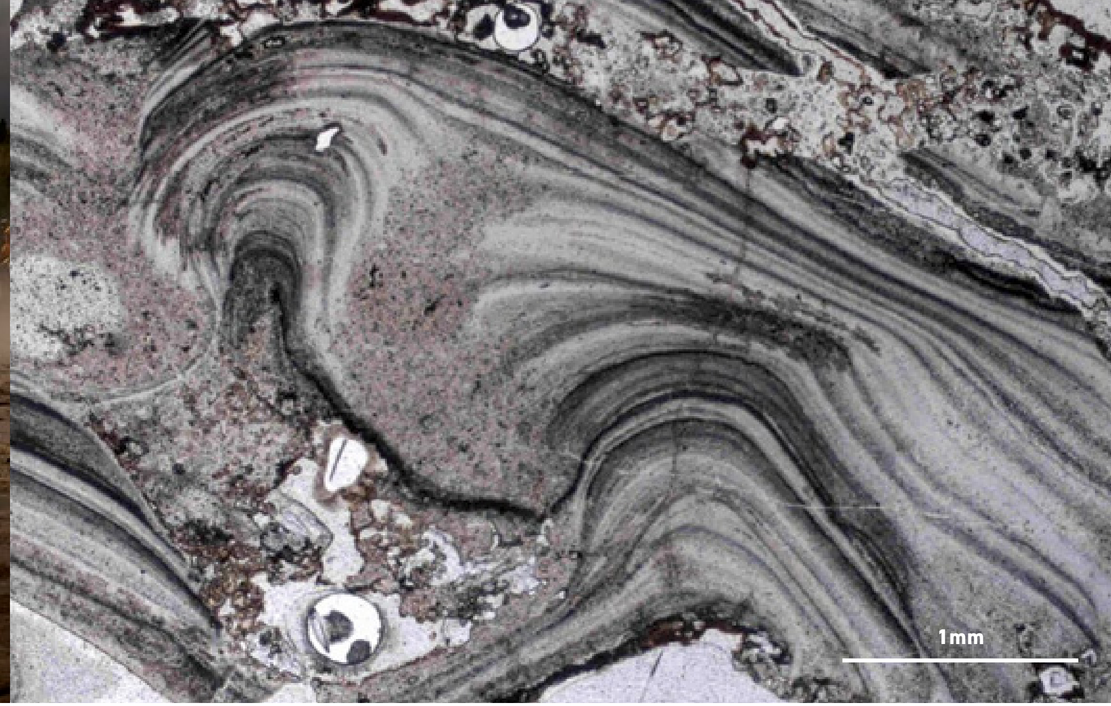
BACTERIA LIKE IT ROUGH



GOLDEN EFFECTS ON CELLS



RARE MINERAL REVEALS HUGE IMPACT CRATER



Images: Pilbara region of north Western Australia
Mars, NASA
Geyser in an Icelandic hot spring field
Section of geyserite showing the dark and light banding

1

PILBARA ROCKS POINT TO PAST LIFE ON MARS

Signs of life – 3.5 billion years ago

CHALLENGE

The serious search for life elsewhere in the Universe is a rather infant endeavour for humanity. How do we formulate a search strategy and what questions do we ask? Since life on Earth was microbial for its first three billion years, we can begin with a deeper understanding of the history of life on this planet.

'Extremophile' microbes living on Earth today thrive in extreme conditions – hyper-hot, cold, salty, acidic – conditions too harsh to support more complex plant and animal life. Although we see no sign of complex life elsewhere in our solar system, we know of active and ancient environments that could support extremophiles. Mars is one example, as well as the moons of Jupiter and Saturn; Europa and Enceladus.

RESEARCH

Rocks in the Pilbara region of north Western Australia preserve the oldest known fossilised life on the planet. Some of these are stromatolites – rock structures built by communities of micro-organisms. In the late 1970s geologists were excited to discover the oldest known stromatolites on Earth in a group of rocks called the Dresser Formation, located in the east Pilbara. Geologists continued investigating to interpret the ancient environment that supported these microbes.

Initial research suggested a quiet shallow-water marine setting such as the modern-day Shark Bay, WA. Later work by Prof. Martin Van Kranendonk's research group at UNSW Sydney suggested it was actually a dynamic volcanic setting with large volumes of circulating volcanically heated water. This model raised interesting questions. Were the ancient microbes surviving in volcanically heated water, or were they simply growing in the quiet areas of the system, unrelated to hydrothermal activity?

The answer unfolded when Tara Djokic, working with Prof. Van Kranendonk and Prof. Malcolm Walter at UNSW, discovered the presence of geyserite directly interlayered with the stromatolites. Geyserite is a rock type that only forms at the edges of hot spring pools such as those seen today in Yellowstone National Park.

Electron microscopy in the Microscopy Australia facility at UNSW Sydney showed that very fine light and dark layers in the rock sample were composed of titanium dioxide and clays. These minerals aided in identifying the geyserite as they are known to precipitate from modern hot spring pools. The proximity of geyserite and fossil life allowed the researchers to conclude that life was flourishing in and around the edges of hot spring pools, approximately 3.5 billion years ago. The discovery of geyserite in the Dresser formation also showed that land-based hot springs were present on Earth around 3 billion years earlier than previously known.

IMPACT

The finding of 3.5 billion-year-old-life inhabiting land-based hot springs on Earth suggests a good place to start looking for signs of life on Mars would be around ancient hot spring rocks. In fact, many of the rocks on Mars are the same age as the Dresser formation and evidence of ancient hot springs has already been identified on the red planet.

Ref: Djokic et al., 2017, Nature Communications, 8, 15263

2 GENETIC ENGINEERING FOR FOOD SECURITY

Future food security is vital in the face of growing populations and environmental uncertainty. Genetic engineering could hold the key to increased crop yields.

There are three major groups of plants with respect to how they collect and use carbon dioxide (CO_2). C_3 plants use CO_2 directly from the air whereas C_4 and crassulacean acid metabolism (CAM) plants first convert it to an acid called malate. Malate allows CO_2 to be stored and concentrated around RuBisCO, the enzyme that starts CO_2's conversion into sugars. C_3 plants are most efficient in fertile, moist and temperate conditions while C_4 plants are more efficient in hot and arid conditions.

RuBisCO works very slowly and in C_3 crops it is a major limiting factor for their photosynthetic performance and yield.

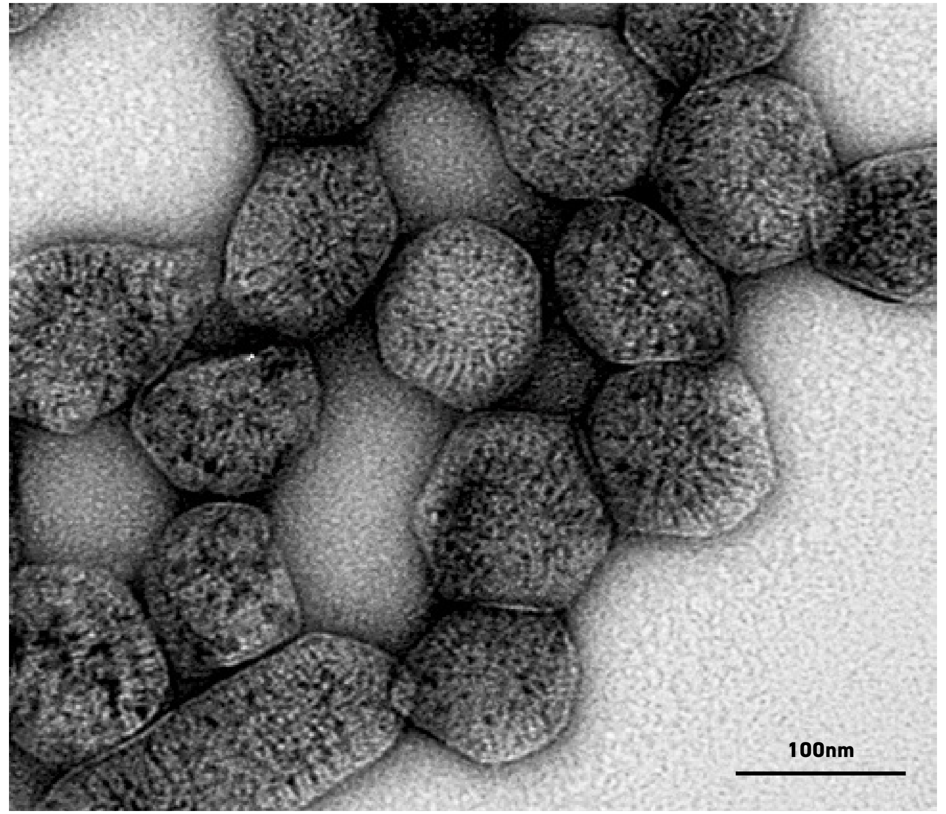
Cyanobacteria use a different version of RuBisCO. This enzyme, along with other components that concentrate CO_2 around it, is held in micro-compartments called carboxysomes, enabling it to work much faster than plant RuBisCO.

Mathematical modelling shows that crop yield could be increased by up to 60% if the C_3 plant RuBisCO could be replaced with Cyanobacteria RuBisCO and the rest of the CO_2 concentrating components in functional carboxysomes.

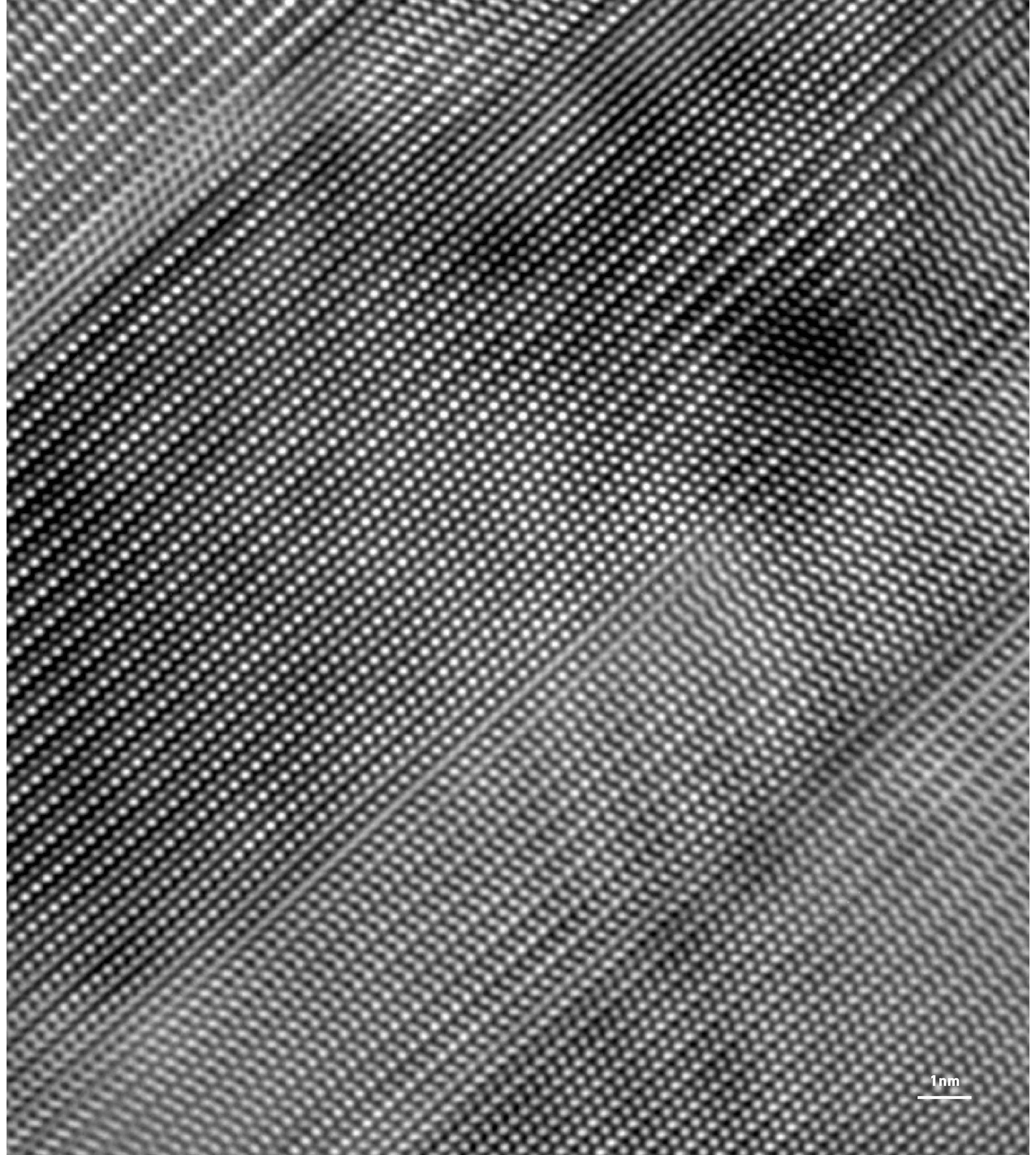
Drs Ben Long, Wei Yih Hee and Prof. Dean Price from the Australian National University (ANU), have used tobacco as a model plant. Using just four of the necessary genes from cyanobacteria, they have successfully engineered tobacco chloroplasts to make basic carboxysomes. Transmission electron microscopy in the Microscopy Australia facilities at ANU showed these carboxysomes to be full of RuBisCO and around 100 nanometres in diameter, the same size as those that naturally occur in cyanobacteria.

This success provides a critical step toward the construction of fully functional carboxysomes in plants incorporating a complete cyanobacterial suite of CO_2 concentrating components. This promises stronger crop yields, while improving use of both nitrogen fertiliser and water across a wide range of environmental conditions.

Ref. B. Long et al. 2018 Nature Communications, 9:3570 | DOI: 10.1038/s41467-018-06044-0



TEM image of plant carboxysomes encapsulating RuBisCO enzymes.



3 MAGNESIUM PLASTICITY GAINS

Materials science aims to improve economically valuable metal alloy properties such as lightness, strength and plasticity. Plasticity is the property of material to be shaped without breaking. As the lightest metals available for structural engineering, magnesium alloys are the focus of much research, and new processing methods continue to be developed. Improving the plasticity of these alloys is a challenge due to the crystal structure of magnesium.

Dr Suqin Zhu has worked extensively on these alloys and developed a process called high strain-rate rolling (HSRR) that is strikingly effective at producing high quality magnesium alloy sheets that are strong and easy to work. Dr Zhu is now working with Prof. Simon Ringer at the University of Sydney and uses Microscopy Australia instruments to understand, at a microscopic scale, how HSRR increases strength and plasticity.

Transmission Kikuchi diffraction and atomic-scale transmission electron microscopy (TEM) revealed that HSRR alloys have a very high density of a particular kind of distortion, known as a stacking fault. These distortions are created in the alloy's crystal lattice early in the HSRR process. These don't allow the lattice planes to slide past each other. However, as the process continues at higher strain, these stacking faults transform into a different kind of distortion, known as perfect dislocation, that slides easily.

Through this series of structural reactions, HSRR makes two significant changes to the structure of the alloy. Firstly, perfect dislocations greatly increase plasticity because they allow the crystal lattice planes to slide. Secondly, HSRR makes smaller crystals, which make the modified alloy stronger and tougher than it was before the HSRR.

Microscopy is essential to the atomic-scale engineering of alloys. If the HSRR process can be scaled to industrial production and commercialised, these innovative magnesium alloys will have great economic potential. They will have applications in vehicles, from trains and planes to cars and bikes, and in electronic and biomedical devices.

Ref: S.Q. Zhu & S.P. Ringer, 2018, Acta Materialia, 144, 365

Image: TEM image showing stacking faults and dislocations in a Mg alloy.

200,000TW OF SOLAR ENERGY FALLS ON EARTH EACH YEAR

TOTAL GLOBAL ENERGY DEMAND PER YEAR = 20TW

Image: Morning sun seen from the Apollo 7 spacecraft, NASA.

4

A SOLAR FUTURE

CHALLENGE

In a world in need of cheaper, sustainable and clean energy solutions, solar is an obvious option. However, the cost and efficiency issues of different solar cell technologies continue to challenge researchers.

The solar cells on our roofs today use crystalline silicon. These are reasonably efficient but remain expensive and require a lot of energy to manufacture. Physical inflexibility also limits their applications. Several cheaper, more adaptable and easier-to-manufacture alternatives are being seriously investigated.

Two of these alternative cells are:

- **based on carbon nanotubes and silicon: the main challenge with these cells is efficiency.**
- **dye-sensitised solar cells (DSSC): thin-film, semi-flexible, translucent and simple to make, but use costly components such as platinum and ruthenium. Although they are not currently as efficient as crystalline silicon cells, they have a wider range of applications.**

RESEARCH

Phosphorene is a 2D form of phosphorus only a few atoms thick. Researchers at Flinders University considered that its properties could increase the efficiency of a variety of different solar cell types. Their approach was to include a layer of ultra-thin phosphorene nanoflakes into these next-generation solar cells.

The research team led by Prof. Joe Shapter and Dr Munkhbayar Batmunkh developed a quick and simple way to make thin flakes of phosphorene with microwaves.

Black phosphorus is immersed in the common organic solvent, N-Methyl-2-pyrrolidone (NMP), and exposed to microwaves for just 10 minutes. This contrasts to previous methods involving 15 hours of treatment with sound waves. By using Microscopy Australia facilities in South Australia for a wide range of visualisation and analytical techniques, the team was able to demonstrate the ultra-thin phosphorene nanoflake structure and high quality of their phosphorene flakes.

These flakes were then incorporated into both dye-sensitised and carbon nanotube–silicon solar cells to act as the electrocatalysts in these systems. This fabrication was supported by the Australian National Fabrication Facility in Adelaide.

The DSSC–phosphorene cells showed superior photovoltaic efficiency of 8.31% which outperforms expensive platinum-based DSSC.

The carbon nanotube–silicon–phosphorene solar cells gave a 25% improvement in power conversion over the carbon nanotube–silicon alone.

IMPACT

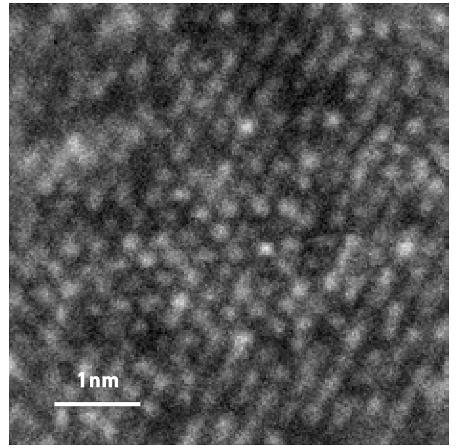
- This new microwave method for producing phosphorene will contribute significantly to the field of phosphorene research.
- Efficiency gains in a range of cheap, easy-to-make and efficient solar cells without the need for platinum.
- Greater uptake of solar energy as a viable and sustainable option for power generation.

"With these promising early results, further studies with the microwave technique and other solvents will help improve stability and durability of phosphorene and allow us to look at ways to produce larger amounts for possible commercial applications"
Dr Christopher Gibson

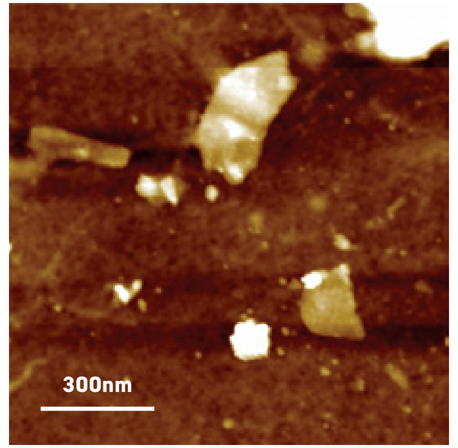
Refs: M Bat-Erdene et al. 2017, Small Methods 1, 1700260

M Bat-Erdene et al. 2017, Adv. Funct. Mater. 27, 1704488

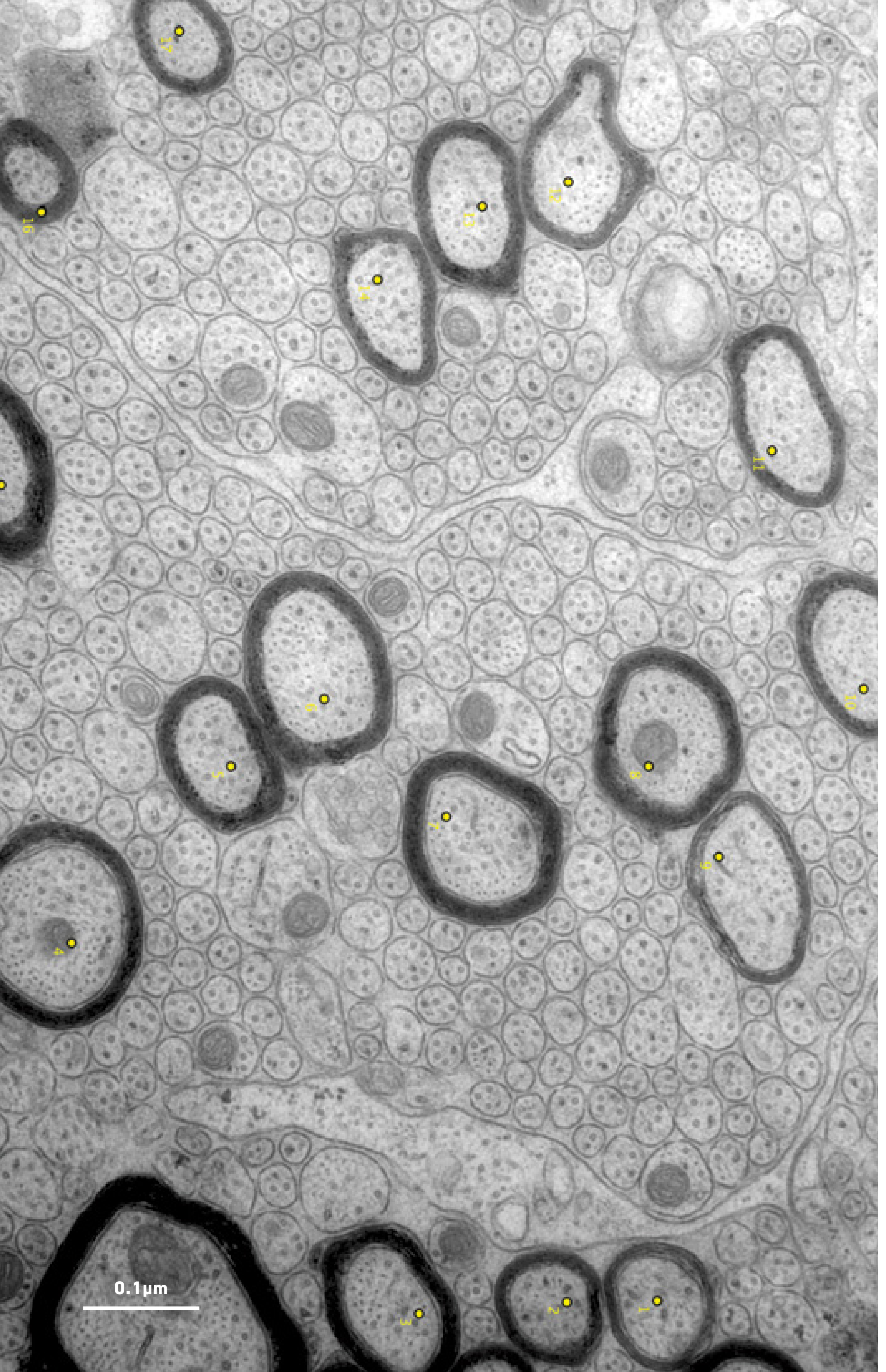
M. Batmunkh et al. 2018, Angew. Chem. Int. Ed. 57, 2644 –2647



Transmission electron micrograph of atoms in a phosphorene flake.



Atomic force microscopy image of a flake of phosphorene.



5 FISH SMELL

Some fishes, especially sharks, are believed to have an acute sense of smell to help them detect food, mates or predators. Although a lot is known about bony fishes, data is still lacking for cartilaginous fishes such as sharks, skates and rays. The relative size of the olfactory bulbs (OBs) in the brains of animals, including fish, can be used to predict olfactory abilities, but it is not clear whether this is the best measure for sensitivity.

Ms Victoria Camilieri-Asch, working with Prof. Shaun Collin at the University of Western Australia (UWA) has used a number of microscopy techniques at Microscopy Australia at UWA to discover more. By using iodine-based stains to enhance contrast for X-ray computed tomography (CT), she has visualised the brain and olfactory system of two model species; the brown-banded bamboo shark (right) and the common goldfish. This has generated accurate 3D models that she used to calculate the volume of the olfactory system. In collaboration with the VascLab at UWA and the PAWSEY Supercomputing Centre, these models are being used to study the water pressure and flow in the nasal cavities of these species.

Ms Camilieri-Asch has also used transmission electron microscopy to count the number of nerve cells taking signals into and out of the OBs (left). She found huge differences: for one nerve cell coming out of the OB, the shark has 200 times more nerve cells going to it, suggesting that the shark is much more sensitive to olfactory information than the goldfish.
Ms Camilieri-Asch is also using confocal microscopy to look at the distribution of different receptor cells in the olfactory cavities of sharks.

Although cartilaginous fishes are considered evolutionarily primitive, they are certainly more complex than was initially thought. Studying their olfactory abilities is contributing to a better understanding of their behaviour.

The brain is 30mm long

6 BECOMING A FLOWER

How plants trigger their cells to develop into flowers has long confounded researchers.

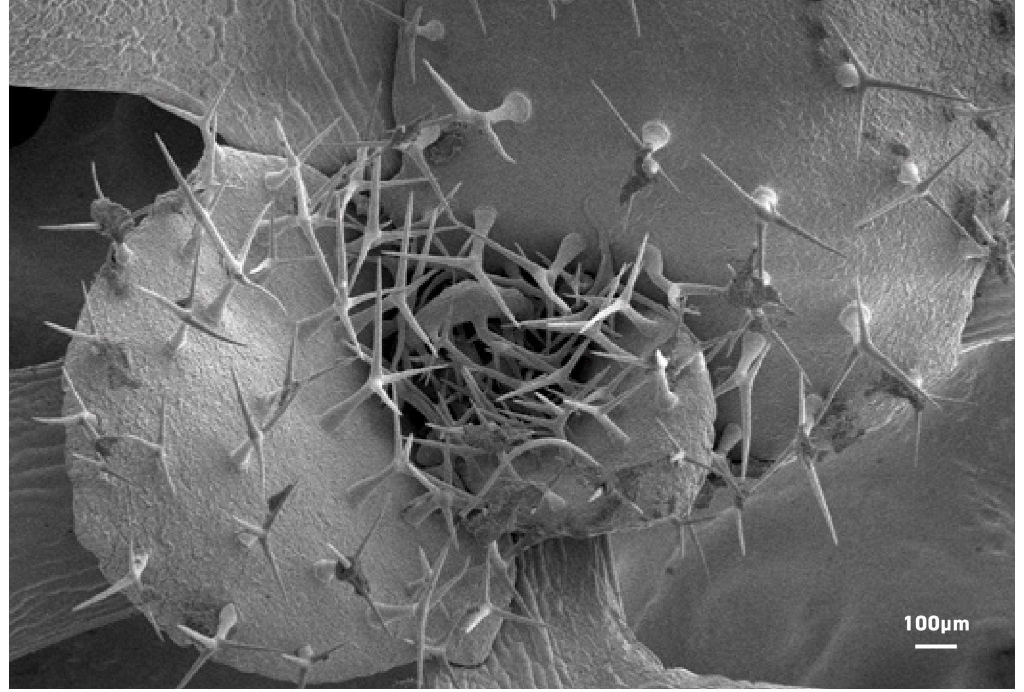
However, a new class of signalling molecules called apocarotenoids may hold the answer. Plant biologists have recently shown that apocarotenoid signals (ACS) give plants essential cues for root, leaf, and flower development, as well as protecting them from adverse environmental conditions. How they do this is being investigated by Dr Ryan McQuinn and Prof. Barry Pogson at the ARC Centre of Excellence for Plant Energy Biology at the Australian National University (ANU) in collaboration with Prof. Patricia Leon at the National Autonomous University of Mexico (UNAM).

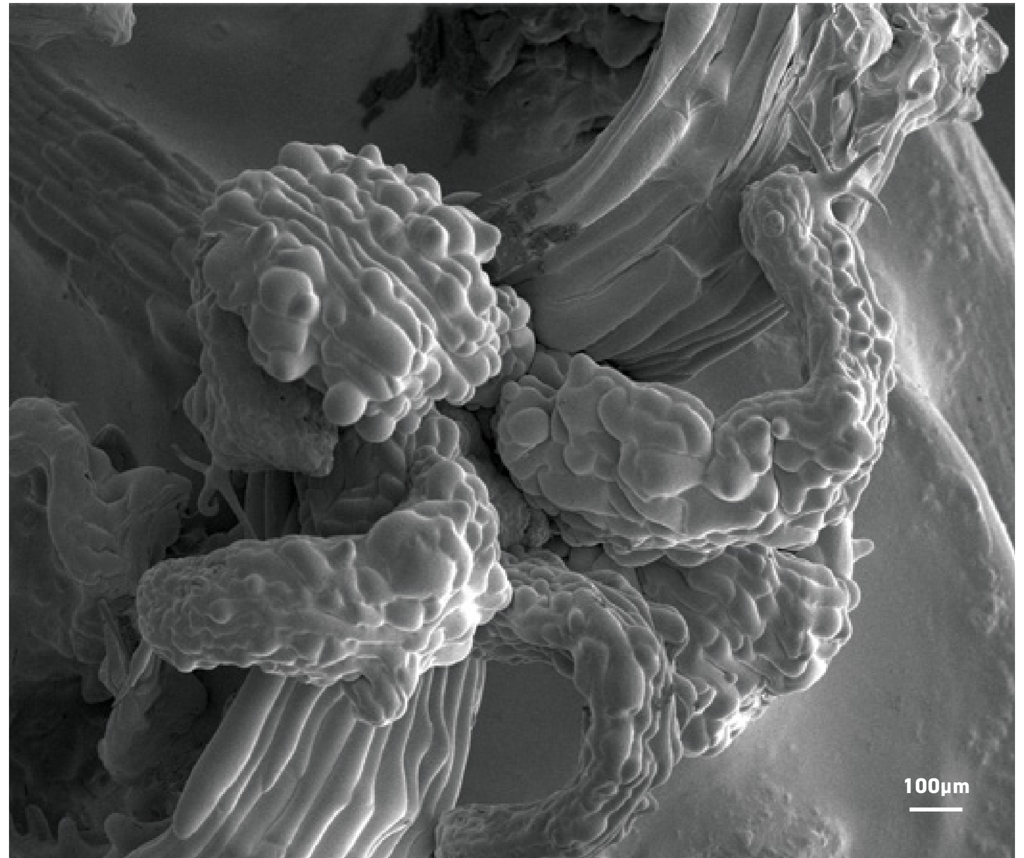
In an experimental plant strain one of these molecules, called ACS1, accumulates to well above normal levels, disrupting normal plant growth. Prof. Leon's group found that the pattern of gene activity in these plants suggests that ACS1 promotes flower development.

To explore this possibility, Dr McQuinn analysed the plant architecture and leaf structure by using cryo scanning electron microscopy at Microscopy Australia's facility at the ANU and compared them to normal plants.

Leaves usually develop in a spiral pattern (top), with an abundance of spiky hairs. The experimental plants (bottom) lack the spiral leaf arrangement and hairs. Instead, the surface is much bumpier with cells more closely resembling the part of a flower where pollen attaches for pollination. This was confirmed when pollen came in contact with the lumpy cells of the experimental plant, "inflating" like it would during pollination.

ACS1 appears to be the first chemical signal discovered that triggers flower formation. Elucidating this previously enigmatic process opens up potential new ways to control flowering with significant implications for agriculture and future food security.





7 INSIGHTS INTO PARKINSON'S DISEASE

Just as your parcels are packaged and delivered to your doorstep, so your body has molecular machines responsible for packaging cellular cargo and ensuring it gets to the correct location within the cell. However, just as parcel delivery can go wrong, so it can in your body. Misdelivered cellular cargo can lead to devastating neurodegenerative diseases such as Parkinson's disease.

An international team led by A/Prof. Brett Collins from the University of Queensland (UQ), Dr John Briggs at MRC Laboratory of Molecular Biology (LMB), UK, and Prof. David Owen at Cambridge Institute for Medical Research, UK have joined with collaborators at the Max Planck Institute of Biochemistry, Germany, to solve the structure of retromer, the molecular machine responsible for ensuring the safe and efficient transport of cellular cargo.

Retromer consists of four proteins bound to the membrane surrounding a cellular compartment called an endosome. It is found in species from baker's yeast to humans and controls molecular sorting – redirecting incoming molecules to where they need to go.

Recently, the team determined the 3D structure of the entire yeast retromer complex in its assembled, membrane-bound state. Cryo-electron microscopy on frozen samples enabled the intricate details of the protein structures to be elucidated.

A number of microscopy techniques in Microscopy Australia's UQ facility complimented other results from the LMB. Results revealed that three of the retromer proteins form a supportive network of arches that are docking points for control proteins. In cooperation with membrane-associated sorting proteins, they cause the membrane to bend and form tubules. It is these tubules that deliver the cargo around the cell. The structure shows that a mutation known to cause Parkinson's disease might interfere with how the arches interact with each other.

This work will allow scientists to better understand how mutations in retromer lead to neurodegeneration and potentially provide a basis for designing drugs to help treat the disease.

Ref.: Oleksiy Kovtun et al. 2018, Nature 561, 561–564

View the video: Structure of the membrane-assembled retromer coat by cryo-electron tomography. Oleksiy Kovtun & John Briggs.

www.youtube.com/watch?time_continue=7&v=nEuG2-FLAHA

Scan for Video

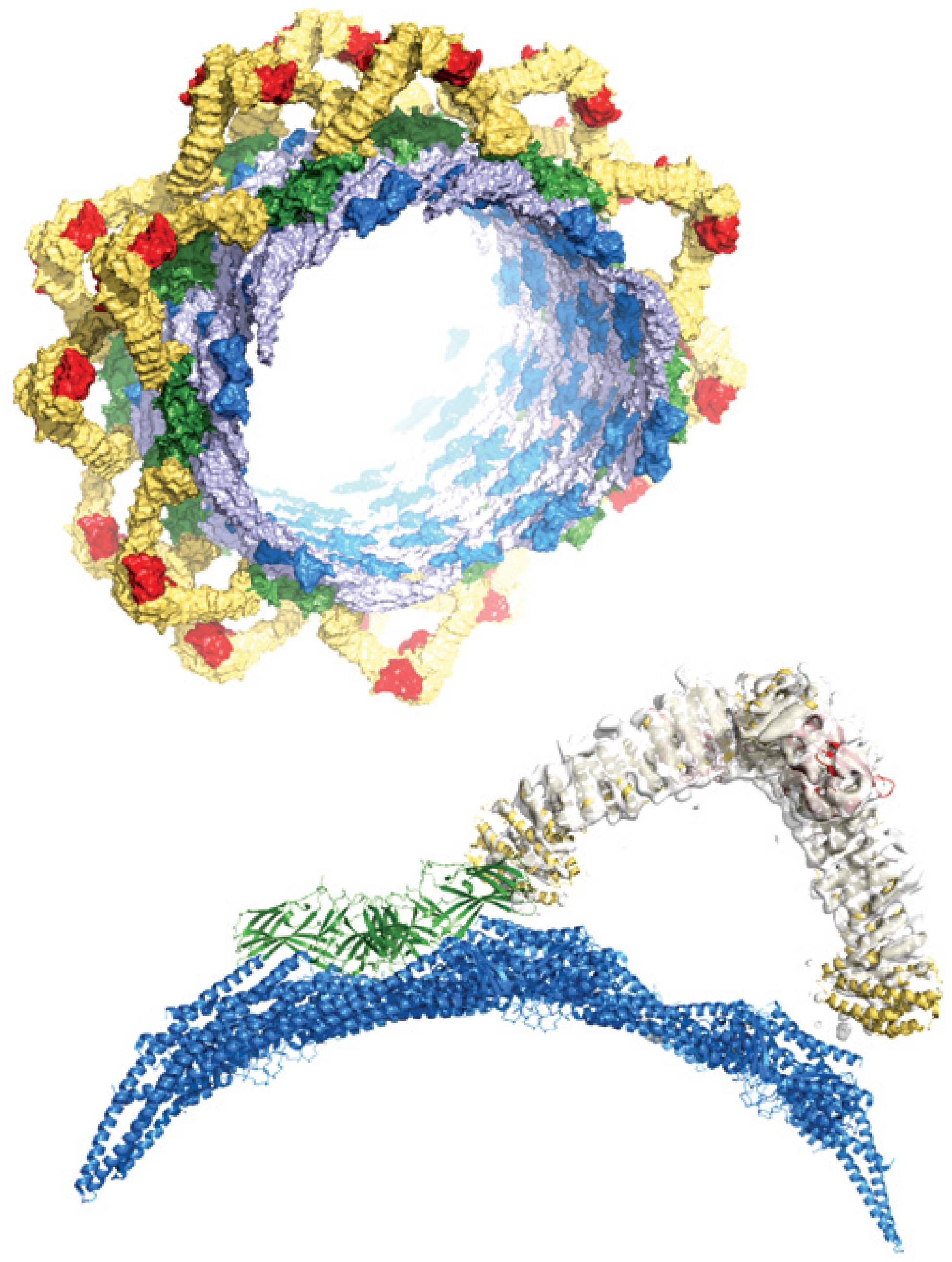


Image: Cryo-electron tomography of tubules showing the retromer arches.

8

FROM AUTOMOTIVE WASTE TO ROBUST COATED STEEL

SILICON FROM GLASS

NITROGEN AND CARBON FROM PLASTICS

TITANIUM FROM PAINTS

CHALLENGE

1. **The heterogeneous nature of complex industrial waste makes it difficult to sort and recycle, so much of it ends up in landfill.**
2. **Steels and hybrid steels that have high abrasion and corrosion resistance are highly valued for industrial applications. However, they are costly and difficult to produce.**

An opportunity exists for innovation in complex industrial waste management and steel production. A combined solution could have a global impact on productivity and sustainability.

RESEARCH

ARC Laureate Professor at UNSW Sydney, Veena Sahajwalla, has developed a process to use complex automotive waste as an input stream to modify and toughen steel. Titanium from paints, pigments and UV protection; silicon from glass, and nitrogen and carbon from plastics are transformed by using a precisely controlled, high-temperature procedure. They react to form titanium nitride and silicon nitride, ceramics that become chemically bonded to the surface of normal carbon steel. Carbides also form under these surface coatings. Both the nitrides and carbides increase hardness and improve resistance of the steel to corrosion and abrasion. The process is cost effective and can be modified to customise the surface to suit the intended application of the material.

Prof. Sahajwalla and her team use Microscopy Australia at UNSW to monitor and modify their processes to arrive at the most effective coatings.

Prof. Sahajwalla is working in recycling science to enable global industries to safely utilise toxic and complex waste as low-cost alternatives to virgin raw materials and fossil fuels.

She has already developed and commercialised 'green steel' technology, which uses old rubber tyres and waste plastics to fuel steel making. This innovation delivers zero-waste recycling because the rubber and plastics are completely consumed. It also significantly reduces the amount of coal and coke used to fuel the furnaces.

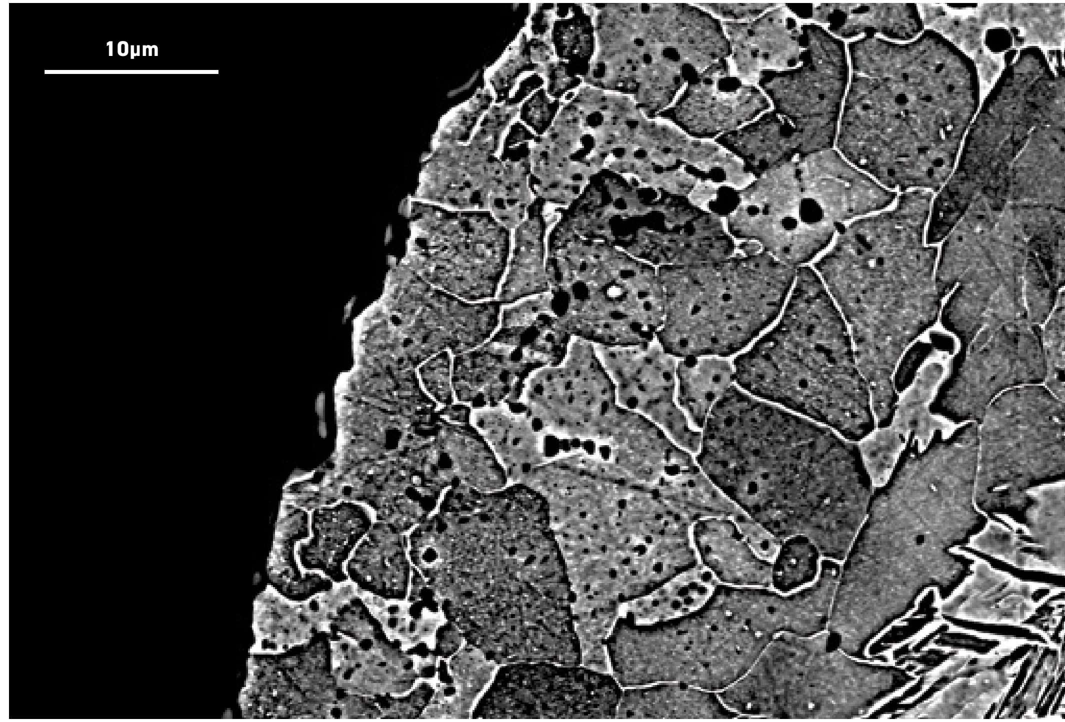
IMPACT

- Provides durable steel products for industry's demanding applications
- Reuses valuable resources – towards zero waste
- Saves raw, virgin materials – more sustainable industry

Ref: Farshid Pahlevani, et al. 2016, Scientific Reports, 6:38740

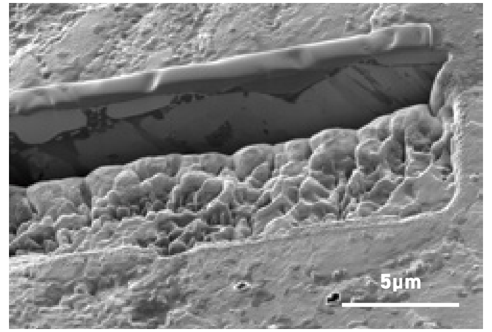
This work has been supported by ARC industrial Transformation Hub – Green Manufacturing.

[Prof. Sahajwalla's 'green steel' technology was named on the US Society for Manufacturing Engineers' 2012 list of 'innovations that could change the way we manufacture'.]



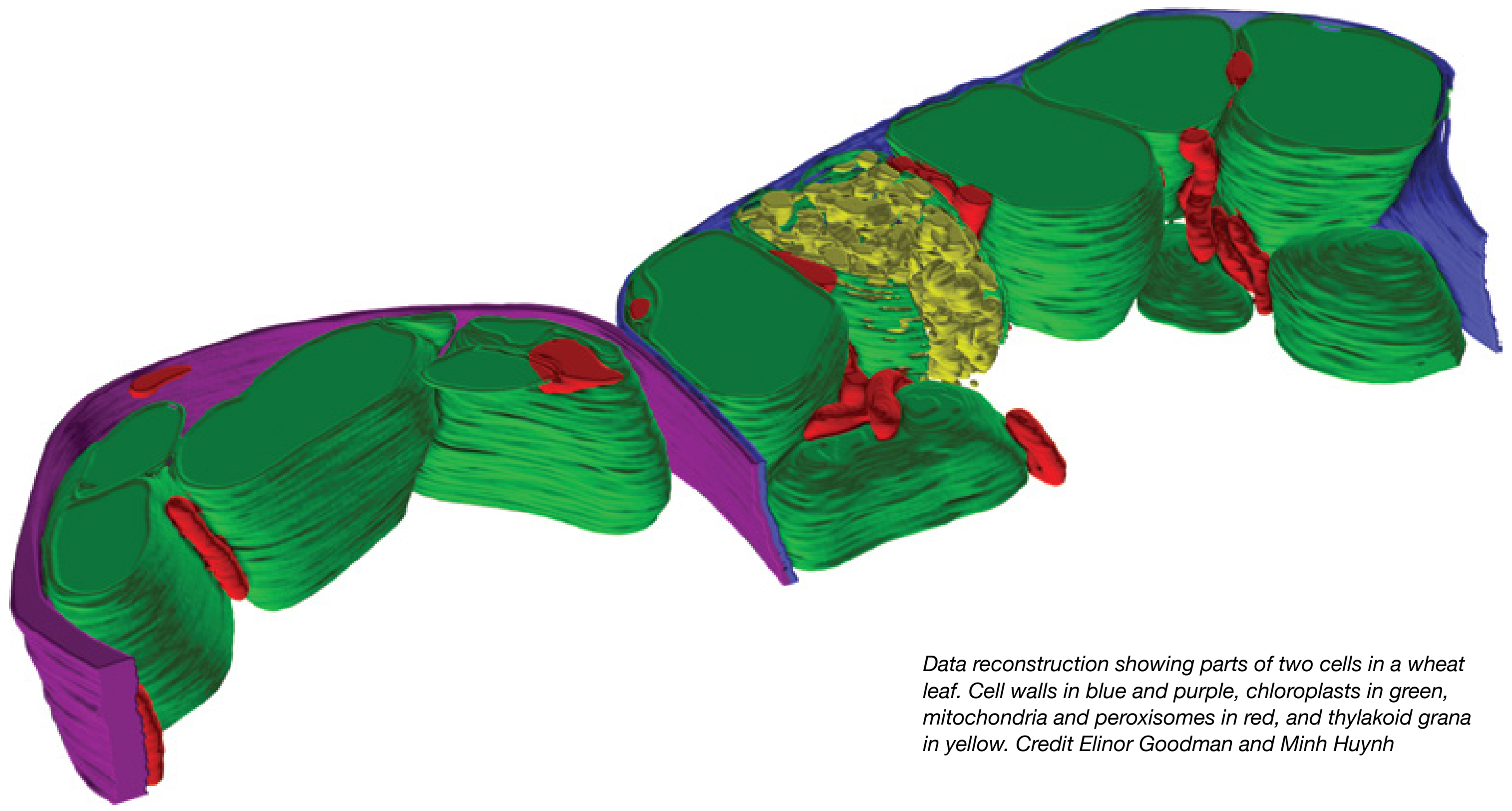
Scanning electron micrograph showing the microstructure of the ultrahard ceramic layer derived from waste materials.

Prof. Sahajwalla at the furnace



The cross-sectional microstructure of the ultrahard surface layer exposed using a focused ion beam microscope.

SECURING CROP PRODUCTIVITY IN FUTURE CLIMATES



Data reconstruction showing parts of two cells in a wheat leaf. Cell walls in blue and purple, chloroplasts in green, mitochondria and peroxisomes in red, and thylakoid grana in yellow. Credit Elinor Goodman and Minh Huynh

9

VIRTUAL LEAF

CHALLENGE

Leaves are the pivotal points for the exchange of water, carbon, and energy between the biosphere and the atmosphere. So far, it has been difficult to measure these processes within the leaf at a microscopic scale. Plant biologists have resorted to highly simplified 2D imaging methods and 1D models to study 3D leaf processes. Measurements within leaves in 3D would enable a consensus framework to be established so leaf processes, such as photosynthesis and water transport, can be accurately modelled through simulations.

RESEARCH

Prof. Margaret Barbour from the University of Sydney (UoS) won a Sydney Research Excellence Initiative 2020 grant from the University to bring together the world's leading plant biologists working in this area to review the current state of knowledge and define priorities for future research.

The resulting workshop spawned an international collaboration across three continents including researchers from Harvard, Yale, the University of California Davis, the University of Queensland and the Australian National University. This led to a landmark paper published in *Trends in Plant Science* in October 2018. It showed how recent advances in imaging and computational technology are enabling a data-rich scientific pipeline that integrates 3D leaf measurement, anatomical modelling, and biophysical simulation from the sub-cellular to the tissue level and beyond. Imaging techniques, including serial block face imaging, conducted at Microscopy Australia's UoS facility, were fundamental to this visualisation, providing high-resolution images of internal cellular anatomy.

IMPACT

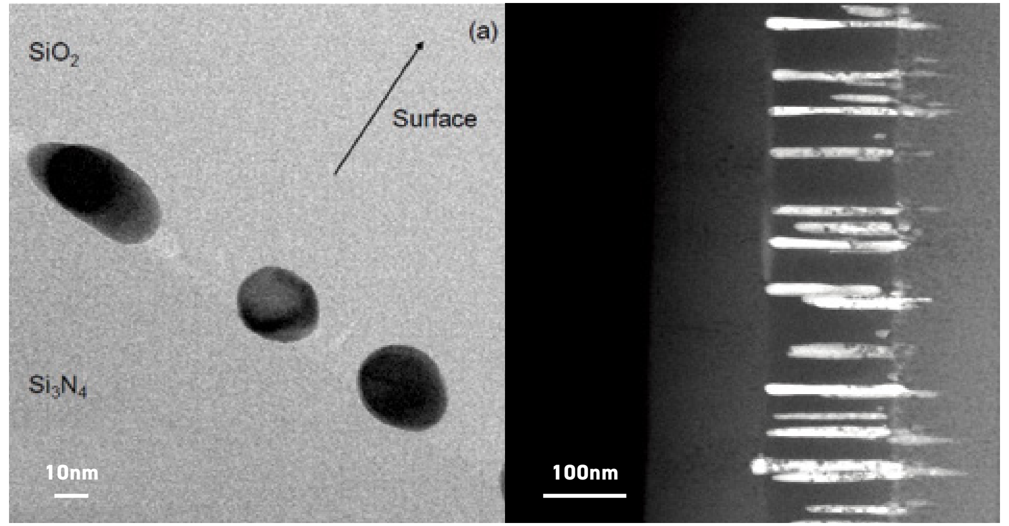
The proposed 3D virtual leaf will substantially improve our understanding of the many nuances of leaf anatomy and function.

It will deliver fundamental insights into:

- movement of carbon dioxide and water within leaves over multiple scales
- relationships between leaf anatomical diversity and functional diversity
- designing the most productive leaves for our major crop plants

The group's goal for the next decade is to pursue a coordinated, collaborative study of detailed leaf anatomy for several model species representing a range of plant types. They can then apply the resulting data to model key 3D leaf processes including photosynthesis, respiration and water transport.

10 CONCENTRATING SUNLIGHT IN SOLAR CELLS



Photovoltaic cells convert light from the Sun into electricity and are the main components of the solar panels placed on rooftops to harvest energy. If solar panels could be made cheaper and more efficient they would be more widely used. One way to increase their efficiency is to concentrate light coming into the cell. This can be achieved by adding a thin transparent layer filled with small metal particles that help direct light that would otherwise be reflected or scattered, into the solar cell.

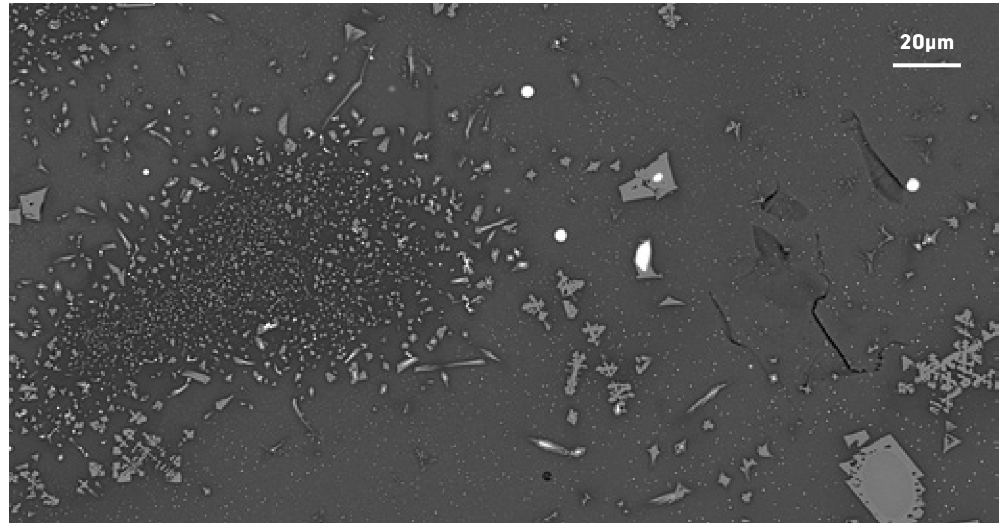
Optimised cell performance will depend on the size, shape and density of metallic particles in the added layer. Pablo Mota-Santiago and A/Prof. Patrick Kluth from the Australian National University (ANU) are collaborating with researchers in France and have focused on ways to control the size of elongated gold particles deposited on a silicon wafer.

The researchers first lay down a continuous layer of gold on the silicon, surrounded above and below by two barrier layers to restrict the particle elongation process. The system was heated to make the gold form into spheres and then irradiated with various doses of high energy gold ions in order to cause controlled elongation of the round particles.

At the Microscopy Australia facility at ANU, the researchers used transmission electron microscopy (TEM) to examine the features produced in their process. High dose irradiation led to a dense array of elongated gold particles forming in the middle layer. Further studies to evaluate the effectiveness of the different particles in concentrating light can now take place.

Image: TEM images of the spheres (left) and elongated gold particles (right)

11 SUPPORTING INDUSTRY – AURUBIS



Aurubis AG, with its headquarters in Germany, is one of the world's major copper producers. Their Research, Development and Innovation (RDI) team is always seeking ways to increase efficiency in processing more and more complex raw materials.

"Knowledge of the behaviour of feed/product materials at various process stages provides important guidance for any modification or new design of the process flow", says Dr Ata Fallah, Senior Manager of Pyrometallurgical Process Characterisation, RDI at Aurubis AG. "Careful characterisation of materials produced in these stages is one of the first steps towards building the knowledge base."

Microscopy Australia at the Australian National University has provided microscopic level analysis by using electron microprobe and QEMSCAN analysis to characterize Aurubis's materials during the copper smelting process.

Images from this commercial work are confidential, so the example above comes from an unrelated copper smelter. The image shows the complex microstructure and mineralogy of some waste material. The bright spherical particles are valuable copper remaining in the slag after "extraction". Microanalysis like this helps plant engineers to make informed decisions on how to minimise copper loss in the smelting processes.

More accurate information on metal loss and element behaviour can be obtained using these microanalysis techniques than by the bulk analysis methods conventionally used at metallurgical processing plants. Microscopy Australia's advanced micro-imaging and microanalysis facilities empower problem-solving at the industrial level, letting Aurubis maximise value from its processes.

12 BACTERIA LIKE IT ROUGH

Breast implants consist of an outer shell and a filler material. One of the many risks of breast implant surgery is the formation of scar tissue around the implant in response to this foreign object in the body. Known as capsular contracture, the scar tissue can squeeze the implant and cause distortion and hardening of the breast tissue.

Textured surfaces on breast implants were developed in the 1960s to improve tissue incorporation and reduce capsular contracture. While textured surfaces can achieve this aim, they do promote more bacterial growth in the lab, and it seems, in the body. As well as causing infection, this bacterial growth can, in itself, encourage capsular contracture. This complex area calls for a combination of laboratory and clinical research.

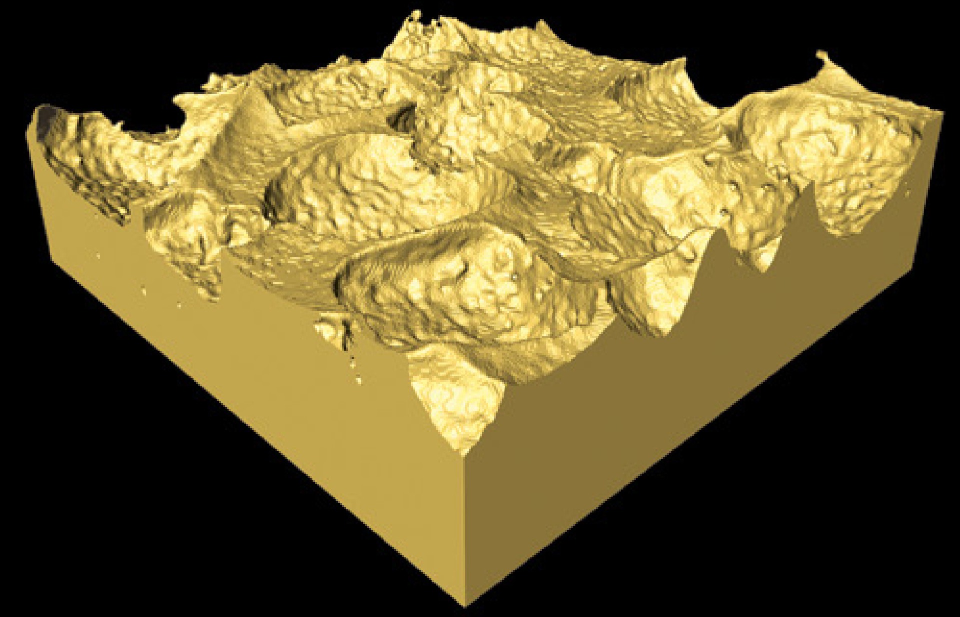
Many types of implants are available with surfaces ranging from very smooth to highly textured. Prof. Anand Deva, and his team at Macquarie University aimed to investigate these different surfaces to systematically study the relationship between surface area, roughness, and capacity for bacterial attachment and growth in the lab.

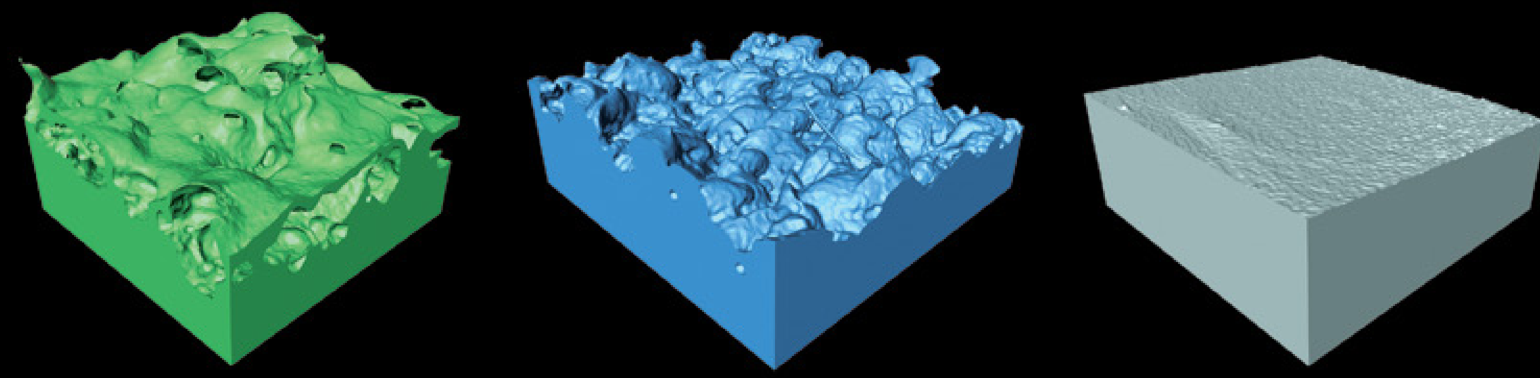
They used X-ray microtomography in the Microscopy Australia facility at the University of Sydney to collect highly accurate 3D data on the surface area and roughness of 11 available implants. These measurements enable unprecedented precision in the modelling and classification of the various implants. The researchers also tested these implant shells to relate surface roughness to bacterial attachment and growth.

The team's research showed a significant linear relationship between surface area and bacterial attachment/growth. For smoother implants there was some variation between the species of bacteria that preferred to grow on the individual types.

These measurements provide a vastly improved system to enable surgeons to better correlate objective measurement with functional outcomes.

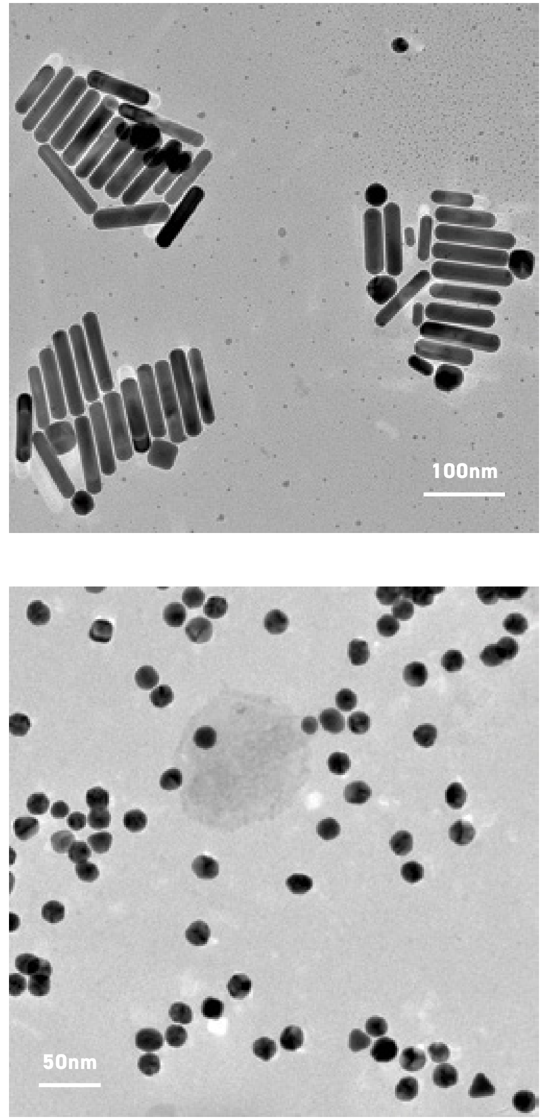
Ref: P. Jones, et al. 2018, Plast. Reconstr. Surg., 142, 4, 837-849



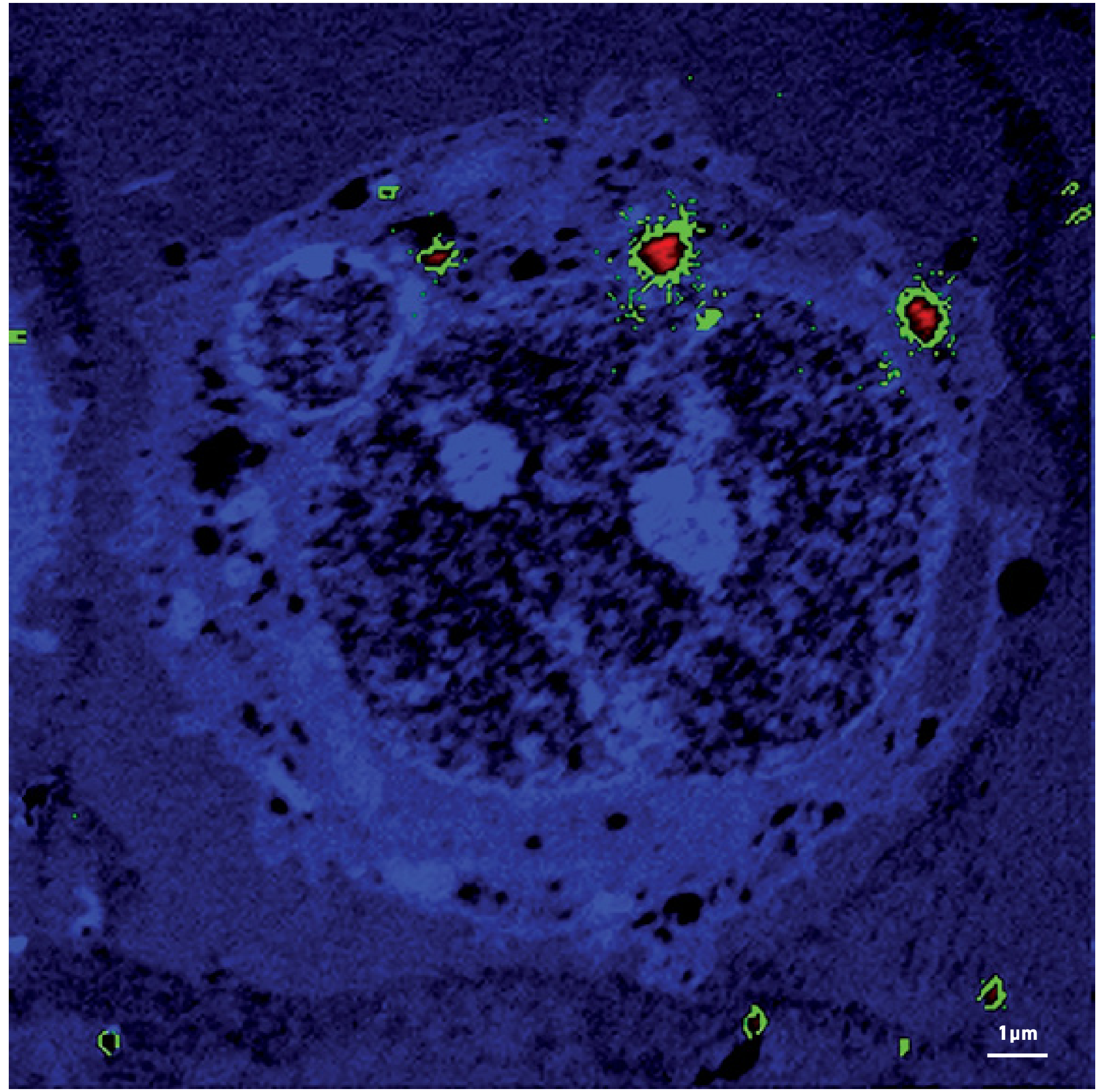


X-ray microtomography images of a selection of implant shells showing surface roughness.

Each sample is 1.4mm square.



Transmission electron micrographs of gold nanorods (top) and nanoparticles (bottom)



NanoSIMS image of a cell containing gold nanorods and showing the concentration of gold represented by a colour gradient with red being very concentrated and green being less concentrated. Blue areas contain no gold. The large, round, dark area in the center is the nucleus and some gold can be seen inside it.

13

GOLDEN EFFECTS ON CELLS

CHALLENGE

Nanoparticles are being widely investigated for diverse roles in medicine, including as carriers to deliver drug molecules into cells, and as components of diagnostic tests and sensors. Lots of work is being done to understand how cells respond to nanoparticles and to determine whether they are a safe new treatment strategy. Gold nanoparticles and nanorods are two of the most studied inorganic nanoparticles. They are known not to be toxic when introduced into cells, but some studies have reported changes in gene activity following exposure to gold nanorods. This could have major implications for health. Genes are switched on and off in the cell's nucleus but gold nanorods don't enter the nucleus. How then are genes being affected?

RESEARCH

An international group of researchers led by Prof. Swaminathan Iyer and Dr Nicole Smith at the University of Western Australia (UWA) have targeted this question. Chemical processes are used to attach other molecules, such as drugs, to the gold nanorods and nanoparticles. These processes were explored as possible culprits. The chemically modified nanorods and particles were introduced into cells and analysed by NanoSIMS, transmission electron microscopy and X-ray photoelectron spectroscopy in the Microscopy Australia facility at UWA.

Results showed that soluble (ionic) gold can diffuse off the ends of the chemically modified gold nanorods much more readily than it does off similarly modified round gold nanoparticles. While the modified nanorods are inert when they are produced in the lab, their chemistry changes into a more reactive form once they get inside the cells. These reactive nanorods release soluble gold that travels to the nucleus. Once inside, the gold induces the DNA to form what are called DNA G-quadruplex structures. Positively charged ions like gold are known to stabilise these structures. DNA G-quadruplexes appear to be involved in many DNA functions including switching genes on and off, replicating DNA and rearranging genes.

IMPACT

These results provide:

- a mechanism to explain the changes in gene activity seen in cells treated with gold nanorods.
- a warning to those developing translatable technologies using nanomaterials that they need to explore in-situ chemical changes within the genomic environment in detail, beyond the traditional coarse cytotoxicity evaluation.

14

RARE MINERAL REVEALS HUGE IMPACT CRATER

CHALLENGE

When meteorites hit the Earth, a crater forms violently and very fast, lifting deep-seated rocks from the centre of the impact area to the surface in seconds. Measuring the consequent geological deformation at different scales in these complex impact structures is tricky. If microscale mineral deformation can be correlated with macroscale crater-formation processes, we can better understand how the Earth's surface behaves during meteorite impact.

RESEARCH

The Woodleigh crater near Shark Bay, WA was created by a meteorite impact about 360 million years ago. It is buried below younger sedimentary rocks that obscure its macroscale features, including its size. Estimates of the crater diameter vary between 60 and 120km. Research student Morgan Cox from Curtin University, under the supervision of Dr Aaron Cavosie, is studying core samples from the Woodleigh crater. The samples were collected by the Geological Survey of Western Australia from 300m below what is thought to be the centre of the crater.

Electron microscopy, including electron backscatter diffraction analysis, in the Microscopy Australia Linked Lab at Curtin, revealed tiny areas of a mineral named reidite. This extremely rare mineral only occurs in rocks subjected to the incredible pressure created when space rocks slam into the Earth's crust. Reidite forms when the common mineral zircon is transformed during the massive pressure of impact.

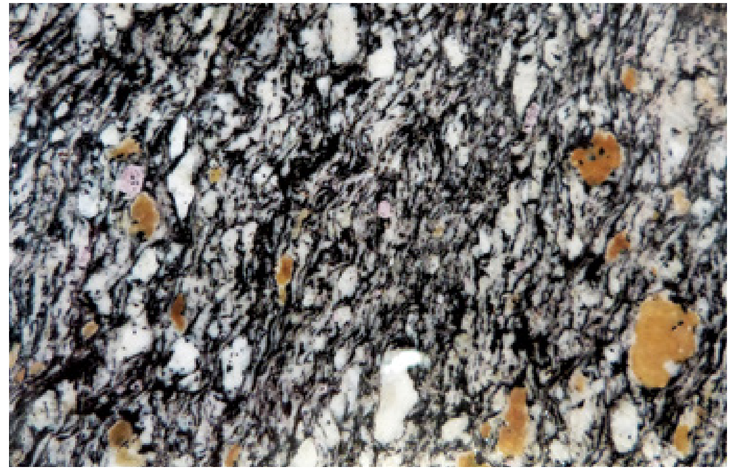
The researchers also found microscopic structures called deformation twins that only form in zircon grains shocked by impact. Analysis revealed that reidite formed first during the initial shock-compression stage. The twins then formed during the post-compression stage, when a lower pressure shock wave lifted the formerly compressed crust rapidly upwards.

The discovery of reidite near the base of the core suggests a relatively large crater. The research team is now using numerical modelling to refine the size of Woodleigh. If its diameter is greater than 100km, as now seems likely, it will be the largest-known impact crater in Australia, and the fourth largest known on Earth. The third largest is the Mexican crater (Chicxulub, largely underwater), formed by the meteorite impact that led to the extinction of the dinosaurs.

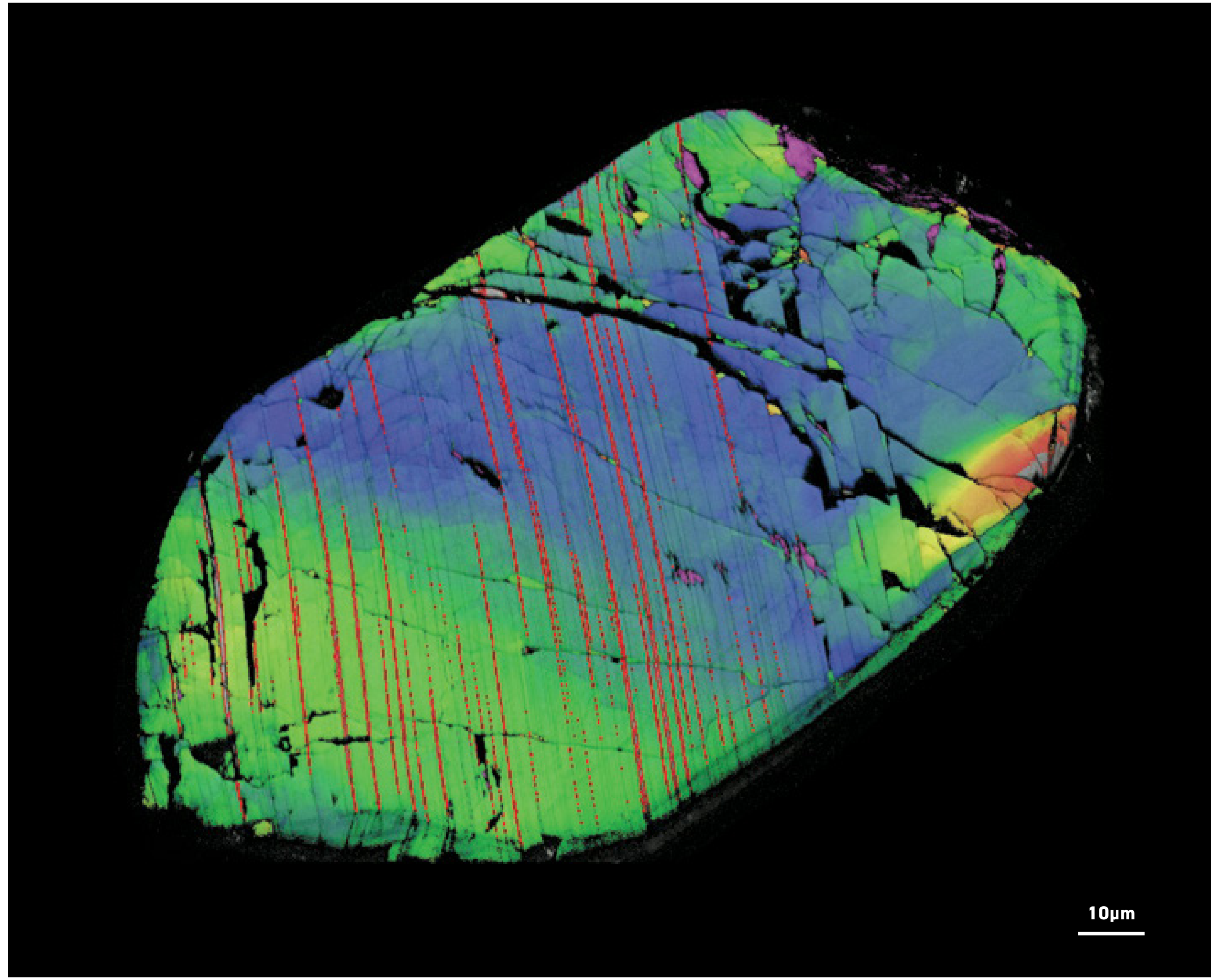
IMPACT

- First physical evidence that links different cratering stages to the predicted theoretical and numerical models of crater formation.
- This analysis provides a new benchmark against which other craters can be analysed.
- Large economic mineral deposits are currently being mined close to the surface in impact craters: gold at the world's largest impact crater in South Africa (half the worlds's gold ever mined has come from here); and huge nickel deposits at the world's second largest impact crater in Canada. It is not currently known if such deposits are present at Woodleigh.
- Shock-twinned zircons from Apollo mission lunar impact samples may now be linked to central uplift regions of complex craters and/or impact basins on the Moon.
- Presence of reidite indicates the crater's size and is therefore a measure of the resulting environmental catastrophe. This impact is likely to have been an extinction-level event, even though it is smaller than the impact that caused the dinosaurs to be wiped out.
- The rare presence of reidite enables investigation of its properties and evaluation of its potential as a new material for future technologies.

Ref: M. A. Cox, et al., 2018, Geology, 46, 983–986.



Morgan Cox in the field.
Drill core from the central uplift of the Woodleigh crater.



Electron diffraction image of a shocked zircon that was partially transformed to reidite. Red lines are deformation twins; reidite is shown in purple.

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