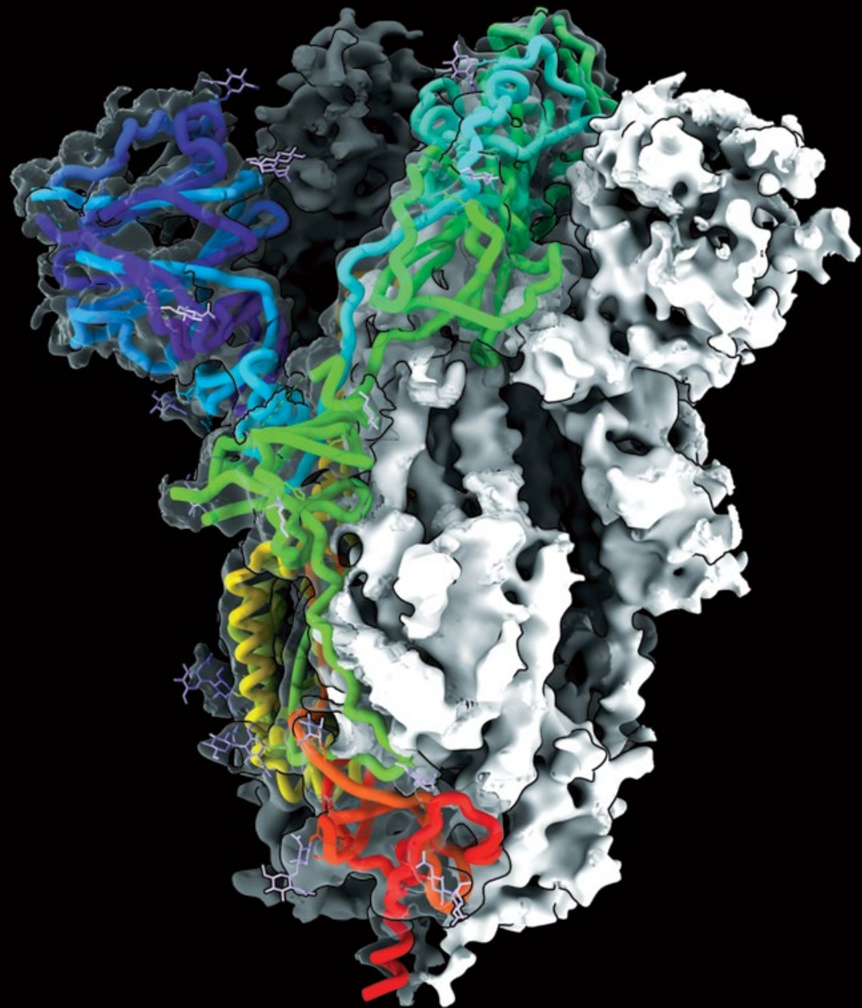
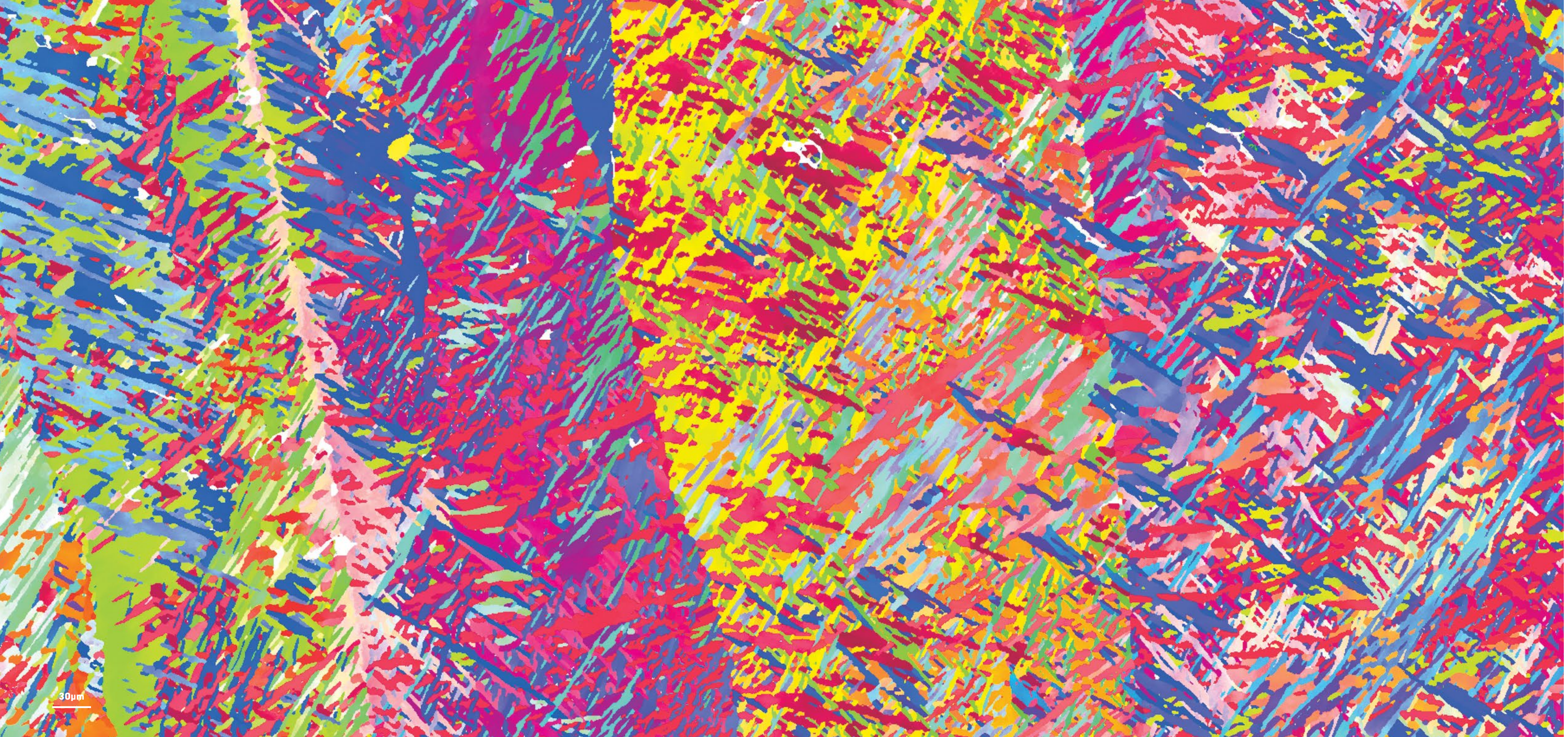
MICROSCOPY AUSTRALIA RESEARCH HIGHLIGHTS 2020





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

CONTENTS

COVER: THE UNIVERSITY OF QUEENSLAND'S COVID-19 VACCINE CANDIDATE – THE SCLAMP PROTEIN – RECONSTRUCTED FROM CRYO-TEM DATA

Left: EBSD map showing columnar grains produced by additive manufacture of Ti-4Al-4V by Will Davids at our University of Sydney facility.

NEWS FROM THE TEAM

MINISTER

Senator the Hon. Dan Tehan,
Minister for Education

Congratulations on another year of excellence and achievements. Microscopy Australia's work is an important part of Australia's economic recovery from COVID-19, and our future innovation. The importance of this is reflected in the Australian Government's $4.5 million funding boost to Microscopy Australia through the 2020 Research Infrastructure Investment Plan.

More than 3,500 researchers from universities and industry use Microscopy Australia instruments and expertise every year. More than 150,000 trainee microscopists around the world use your training tools. These are impressive numbers.

Microscopy Australia supports and enables diverse research that leads to economic, environmental, social and health benefits for Australians. Your work is vital in helping to ensure Australians learn the skills needed to succeed in the jobs that will power our COVID-19 economic recovery.

I applaud your willingness and ability to pivot quickly to support national priorities, especially in response to COVID-19. The breadth and depth of research on vaccines and diagnostics you enabled in 2020 demonstrates how your world-leading microscopes and expertise keeps Australia at the forefront of global research. Thank you for all that you do. I look forward to seeing your continued success next year.

CHAIR

Dr Gregory R. Smith
Chair of Board

Microscopy Australia has managed surprisingly well through the prolonged trials of the COVID-19 shut-downs and the limits that were placed on its laboratory operations. Finalisation of some co-funding support from several state government sources was delayed which has slowed some planned instrument purchases, however, a majority of the planned equipment has been acquired, or is progressing, with important capabilities now about to come online.

Monash University is now clearly a core member of the group. Four new linked labs came onboard in 2020 as well. Even during 2020, Microscopy Australia has continued to operate as a very well-coordinated, collaborative national model that optimises capital utilisation, people interaction and research productivity

Microscopy Australia's international standing continues to be reinforced at its annual Scientific Advisory Committee (SAC) meetings. The most recent SAC videoconference had an expanded attendance and its members discussed emerging trends in microscopy, new equipment and techniques, computational methods for data analysis, unattended microscopy automation and remote access (a very timely expanded capability in 2020), and how to access global best practices. Microscopy leaders from USA and Europe continue their wish to further increase the level of their interactions with Microscopy Australia.

During these trying times, the Board of Microscopy Australia wants to formally acknowledge the essential efforts of the organisation's world-class platform scientists. Despite the need to considerably limit physical access to the facilities, the team has maintained a surprisingly high level of output and research support, including to the UQ vaccine development group.

Microscopy Australia's endeavours to attract all the required state government co-investment is a continuing priority. While much of the organisation's next-generation equipment is being installed now, the financial shortfalls have tested management and the Board. Nonetheless, it is expected that Microscopy Australia will be able to deliver on its Five-Year Plan, even if a few of its major equipment purchases are delayed.

CEO

Prof. Julie Cairney
Chief Executive Officer

What a year 2020 has been. Between bushfires, hailstorms and pandemics, it's been an exercise in resilience. All of us have been affected in some way and some of our labs have needed to close twice, in response to two separate disasters!

The facilities and staff at Microscopy Australia have shown tremendous resolve and perseverance, and it has been wonderful to see how we were able to operate most of our facilities in a safe operating mode, even during the most severe stages of lockdown. This allowed us to continue critical research, including on COVID-19 vaccine development, and the development of Australian-made PPE for our hospitals and emergency workers.

In this year's research highlights, we have placed an emphasis on how our facilities support disaster preparedness, something that has been in the forefront of our minds this year. I hope you enjoy reading about the incredible work for which the users of our facilities depend on us.

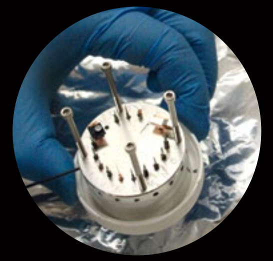
Robyn Chapman at our University of Queensland facility using a serial block-face SEM.

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.

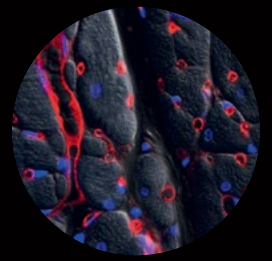
Our online microscopy training tools are also openly accessible with over 120,000 users worldwide in the last year alone.

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

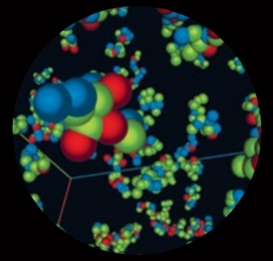
- Fluorescence, Confocal & Multiphoton Microscopy
- Super Resolution Microscopy
- Analytical Spectroscopy
- Flow Cytometry
- Laser Microdissection

SCANNING ELECTRON MICROSCOPY

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

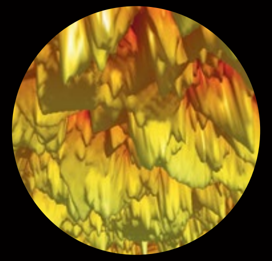
TRANSMISSION ELECTRON MICROSCOPY

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



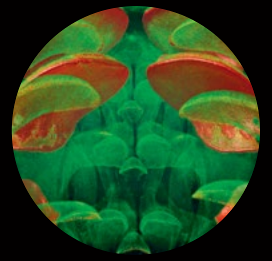
ION & SPECTROSCOPY PLATFORMS

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



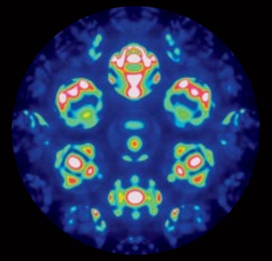
SCANNED PROBE TECHNIQUES

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



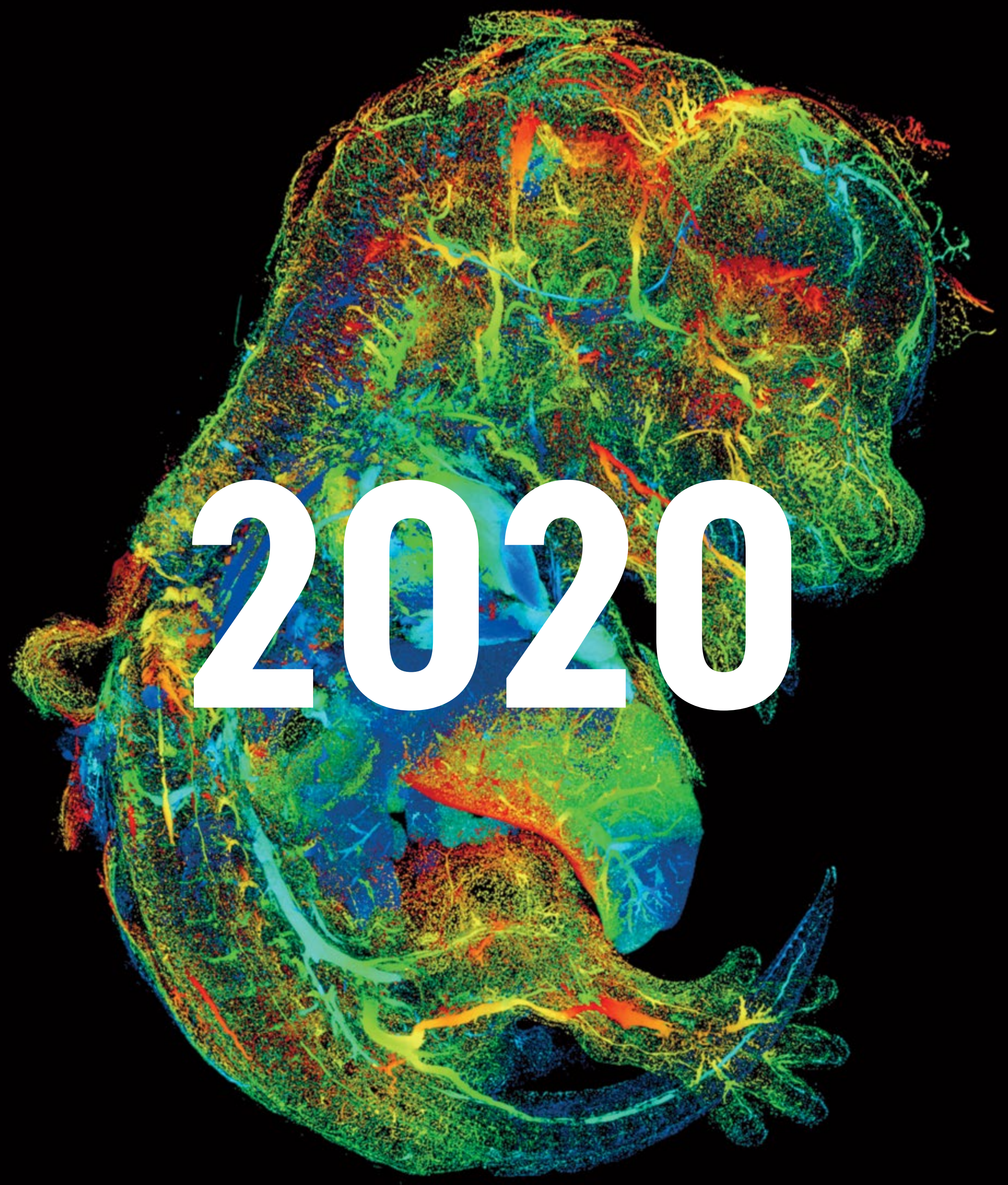
X-RAY TECHNOLOGIES

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



VISUALISATION & SIMULATION

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



Data from March 2020 collection. Left: Autofluorescence image of blood vessels in a developing mouse embryo by Howard Vindin

252
INSTRUMENTS

149
EXPERTS

3,780
USERS

179
INDUSTRY CLIENTS

294,959
HRS BEAMTIME

121,921
MYSCOPE USERS

1,433
PUBLICATIONS

51% PHYSICAL & MATERIALS
37% BIOLOGICAL & MEDICAL
12% GEOSCIENCE & ENVIRONMENT

42% MANUFACTURING
17% BIOMEDICAL
40% RESOURCES & ENVIRONMENT

OPEN TO ALL

Established in 2007 Microscopy Australia is a consortium of open-access microscopy facilities and linked laboratories based at universities around the country. These facilities are open to all, regardless of institution, whether in academia or industry. Microscopy Australia was formed under the National Collaborative Research Infrastructure Strategy (NCRIS) to support strategic investment into research infrastructure.

This year's standout achievements include:

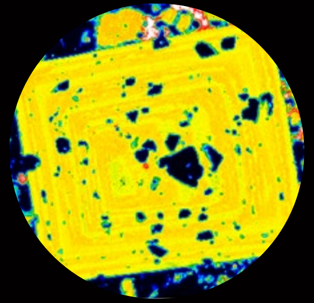
- new NCRIS-supported instruments began to arrive at several facilities
- we increased our online presence to support users and facility staff with webinars, a new YouTube channel and technique-specific catch ups called MicroChats
- new modules for MyScope Training were released: *www.myscope.training*
- four new linked laboratories were welcomed – see pg 8
- despite the challenging year, user satisfaction remained high and 98% of our users would recommend our facilities to a colleague
- Microscopy Australia increased support for research data management and became a founding member of the Australian Characterisation Commons at Scale project
- a broad range of research into natural disasters was supported – see pg 12
- three out of five of the PM's Prizes for Science were awarded to researchers who rely on our facilities.

WELCOME TO FOUR NEW LINKED LABS

We are excited to announce four new centres have joined Microscopy Australia as linked laboratories.

With the world in the process of tackling one of the greatest challenges of our generation, it is more important than ever to come together to share resources and expertise. The new capabilities and knowledge that these linked laboratories will bring to Microscopy Australia could not have come at a more crucial time and we look forward to having them on board.

> *On behalf of Microscopy Australia, I am delighted to welcome the new linked labs. We look forward to learning and sharing with the staff at these facilities, through meetings, masterclasses, online workshops and eventually meeting in person at annual workshops and through staff exchange visits*
>
> *– Microscopy Australia CEO Prof. Julie Cairney*

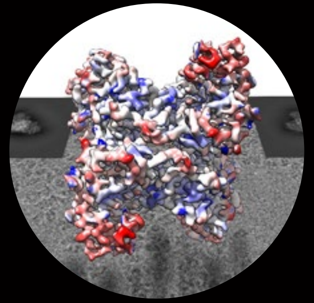


UNIVERSITY OF TASMANIA

CENTRAL SCIENCE LABORATORY MICROSCOPY & MICROANALYSIS FACILITIES

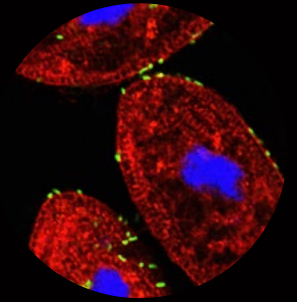
DEAKIN UNIVERSITY

DEAKIN ADVANCED CHARACTERISATION FACILITY



UNIVERSITY OF WOLLONGONG

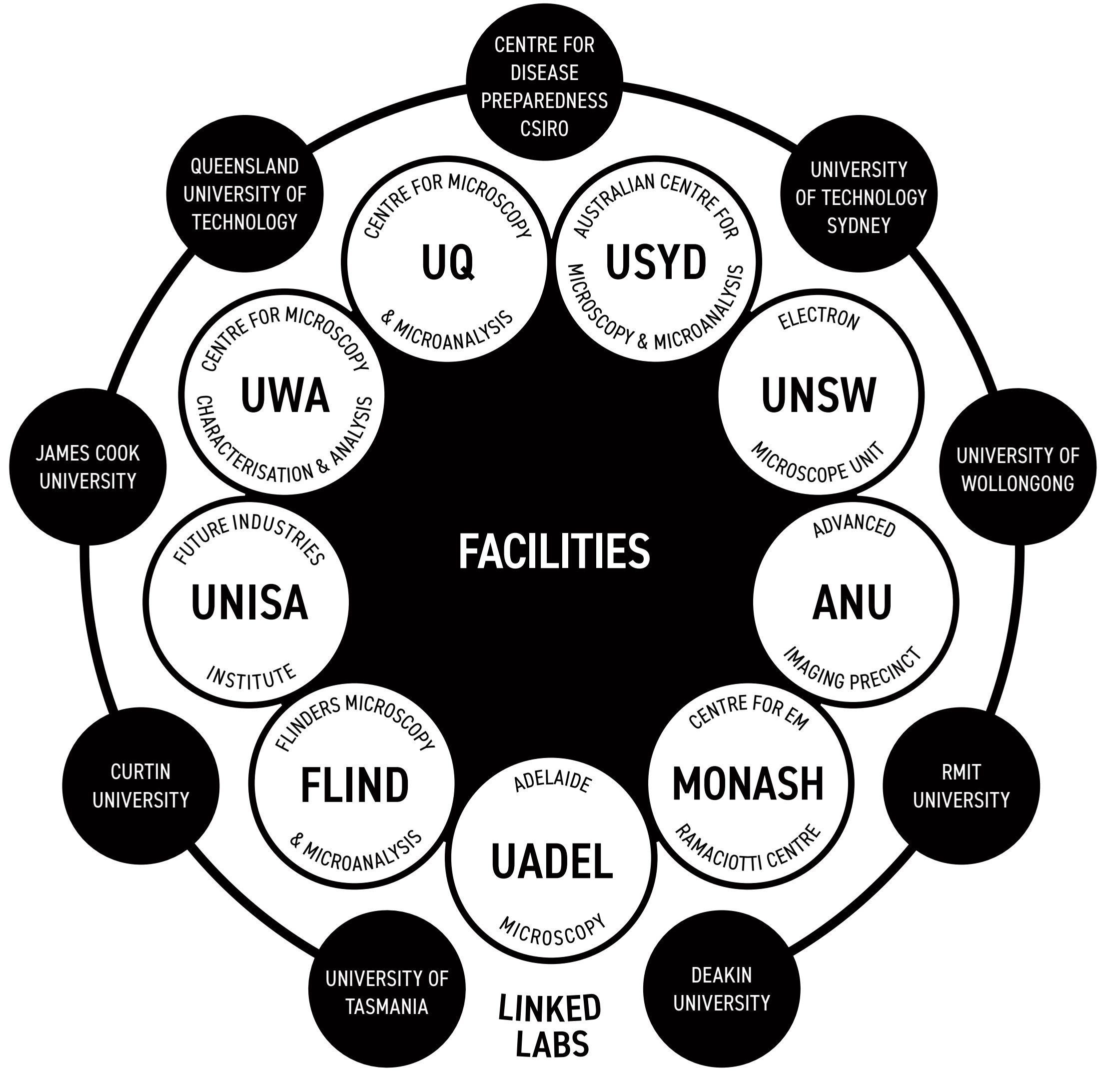
ELECTRON MICROSCOPY FACILITY & CRYO-EM FACILITY

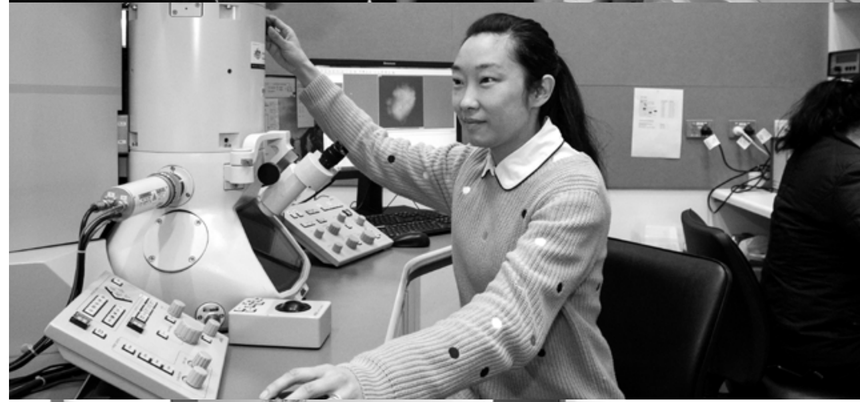


UNIVERSITY OF TECHNOLOGY SYDNEY

MICROBIAL IMAGING FACILITY

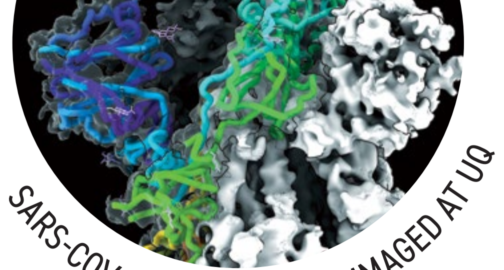
OUR NETWORK



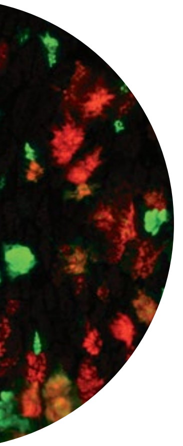


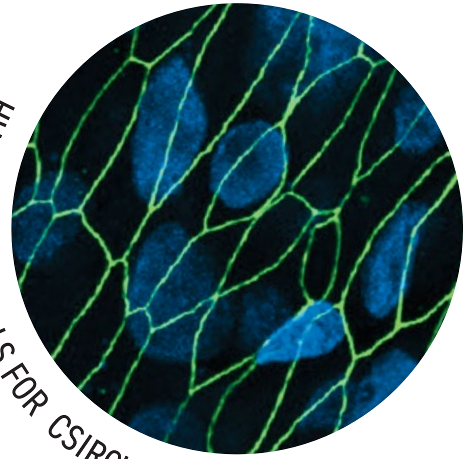
LOU BRILLAULT OPERATING THE CRYO-EM AT UQ

WEAROPTIMO'S REAL TIME BIO-SENSOR

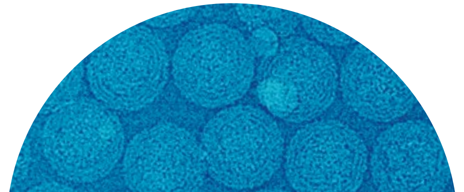


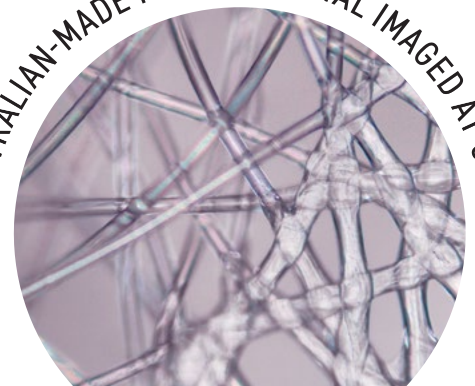
SARS-COV-2 SPIKE PROTEIN IMAGED AT UQ





HUMAN LUNG CELLS FOR CSIRO'S AIRWAY MODEL





AUSTRALIAN-MADE MASK MATERIAL IMAGED AT UNISA

COVID-19 RESPONSE

MICROSCOPY AUSTRALIA'S FACILITIES AROUND THE COUNTRY HAVE BEEN SUPPORTING THE NATION'S RESPONSE TO COVID-19. THESE ARE JUST A FEW EXAMPLES OF THE INCREDIBLE WORK BEING UNDERTAKEN BY RESEARCHERS.

VACCINE

Vaccines against the SARS-Cov-2 virus are the best hope to overcoming the current COVID-19 pandemic. Two of the important candidates being developed in Australia; one from the University of Queensland (supported by CEPI) and another from Adelaide-based company Vaxine, have both relied on Microscopy Australia to provide microscopy and expertise in support of their programs – see the full story on p20

BIO-SENSORS

WearOptimo is developing ‘sticker-like’ sensors, that rapidly measure levels of the inflammatory cytokine biomarker IL-6 levels through the skin, to help in the fight against COVID-19. A rapid rise in IL-6 predicts the onset of a dangerous ‘cytokine storm’ a few days before it occurs. Detecting and monitoring IL-6 allows resources such as intensive care and ventilator access to be prioritised for these patients. Lab-based measurement of IL-6 from blood draws is labour intensive and takes many critical hours. Therefore, it is uncommonly measured in COVID-19 patients for logistical reasons. The WearOptimo sensor can give a result in minutes and can continue to monitor a patient throughout the time they are in hospital. The detection of IL-6 using the WearOptimo technology has been demonstrated and we are now rapidly developing this sensor for evaluation in clinical trials, with the aim of deploying the sensor to hospitals.

ADJUVANT

Advax™, an adjuvant that enhances the immune response to a vaccine, was developed using our Flinders University facility and licensed to Vaxine Pty Ltd. This adjuvant is being incorporated into Vaxine's COVID-19 vaccine, COVAX-19®, currently in clinical trials in Adelaide – more on p14

AIRWAY MODEL

Using confocal microscopy, our linked lab at the Australian Centre for Disease Preparedness at CSIRO has developed a realistic model system of human airway cells. This will be used to study how viruses like SARS-CoV-2 infects the lungs.

PPE TESTING

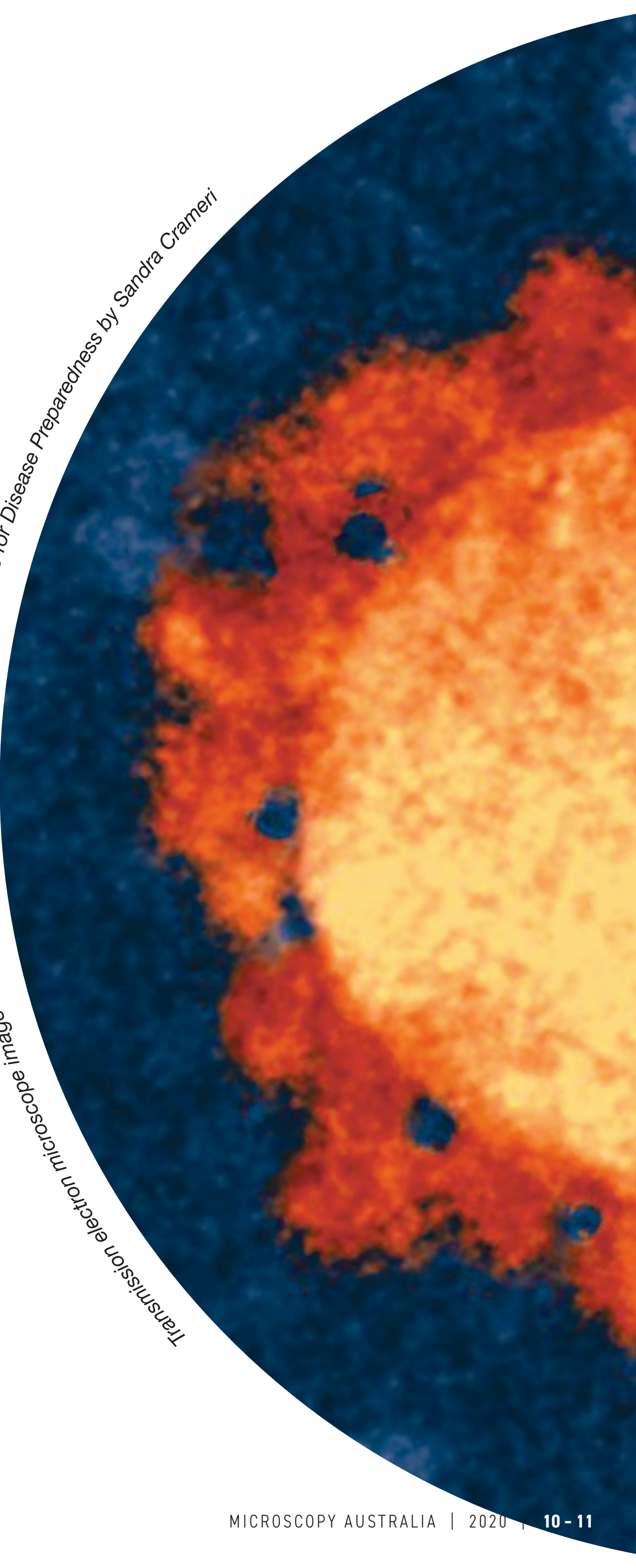
Staff expertise at the University of South Australia has been used to develop methodologies, bespoke equipment and to test the quality and effectiveness of locally manufactured personal protective equipment. Optical microscopy shows a mask material in development.

TEST KITS & DIAGNOSTICS

Electron microscopes at our Monash and Adelaide University facilities have been used to study materials being developed for use in different COVID-19 test kits.

INTERNATIONAL SECURITY

The International Atomic Energy Agency has sent additional samples to our UWA facility to analyse on the ion probe as access to the their European Network of Analytical Labs was significantly reduced due to COVID-19 shutdowns.



Transmission electron microscope image of SARS-CoV-2 from CSIRO's Australian Centre for Disease Preparedness by Sandra Crameri

DISASTER PREPAREDNESS & RESPONSE

Microscopy Australia is supporting innovation and the development of sovereign capability to help us respond to disasters and keep Australians safe. This is a selection of the research enabled by our facilities.

BUSHFIRES

Supporting ongoing bushfire impact investigations – **multiple**

Understanding when to conduct hazard reduction burns to reduce the impact on sensitive native plants – **RMIT**

Development of fire resistant building materials from waste and fungus – **RMIT**

Creating fire-retardant paints now sold around the world – **UAdel for First Graphene**

Understanding the impact of bushfire ash on lung disease – **UNSW**

Testing cell therapy to treat smoke inhalation – **USyd**

INFECTIOUS DISEASE

Two COVID-19 vaccines in clinical trials – **UQ/CSL & Vaxine/Sypharma/Merck**

Broad spectrum flu and pneumococcal vaccines – **Gamma Vaccines and GPN Vaccines**

More effective, non-inflammatory adjuvant to enhance a wide range of vaccines – **Vaxine**

Nanopatch revolutionary dry-coated vaccine delivery patch heading into production – **Vaxxas**

Cryo-TEM, along with other methods, is helping to find new approaches to beating antibiotic resistance – **multiple**

EMERGENCY MEDICINE

MeTro, a modified elastin glue which is a faster, bio-compatible alternative to stitches for surgery and emergency medicine – **USyd**

Worlds smallest mobile X-ray units – easily transportable to emergency situations – **Micro-X**

Anti-bacterial and anti-inflammatory, anti-oxidant-coated bandages – **UniSA**

Helping industries pivot to making masks (Detmold) and developing new mask materials – **UniSA & QUT**

Wearable, disposable micro-sensors for real-time monitoring of seriously ill COVID-19 patients that are cheaper and faster than current methods, in clinical trials – **WearOptimo**

SAFE WATER

Using metal-organic frameworks and sunlight to transform brackish water and sea water into safe, clean drinking water – **Monash**

Polymers made from waste can remove heavy metal and oil contaminants to clean up water and soil – **Flinders**

Reduced graphene oxide sponge to absorb water contaminants – **ARC GEIT at UAdel**

Nanostructured surfaces for oil/water separation – **USyd**

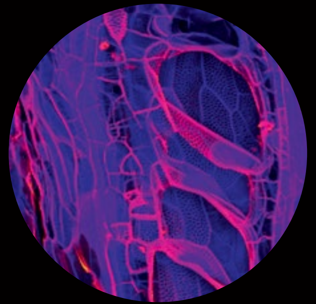
DROUGHT & PESTS

Revealing how plants protect themselves during drought and how they rehydrate afterwards – **ANU**

Improving water retention and crop yield using waste biomass as biochar – **UNSW**

Developing technology to improve ironstone gravel soils to increase crop yields – **GRDC**

Understanding how parasitic nematodes hijack water and nutrients in wheat roots – improving crop yields – **UAdel**



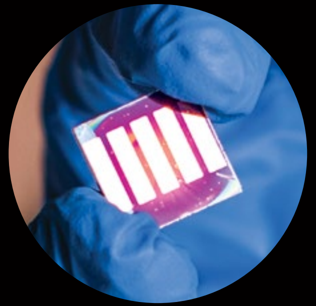
EMERGENCY POWER

Supercapitors made form jackfruit for more efficient, eco friendly batteries that could be used for emergency power supply – **USyd**

Flexible, transparent solar film that can be applied to many surfaces to produce energy even in low light – **UQ**

Multiple projects working to extract more energy from sunlight for more efficient solar – **ANU & UNSW**

Wearable flexible electronics that are powered by the body's movement – **RMIT**



PROVIDING SERVICES TO OVER

100

COMPANIES EACH YEAR

SUPPORTING INNOVATION & INDUSTRY

Microscopy Australia provides critical infrastructure to enable all stages of the innovation pathway, from feed-in research through to commercialisation and long-established industries.

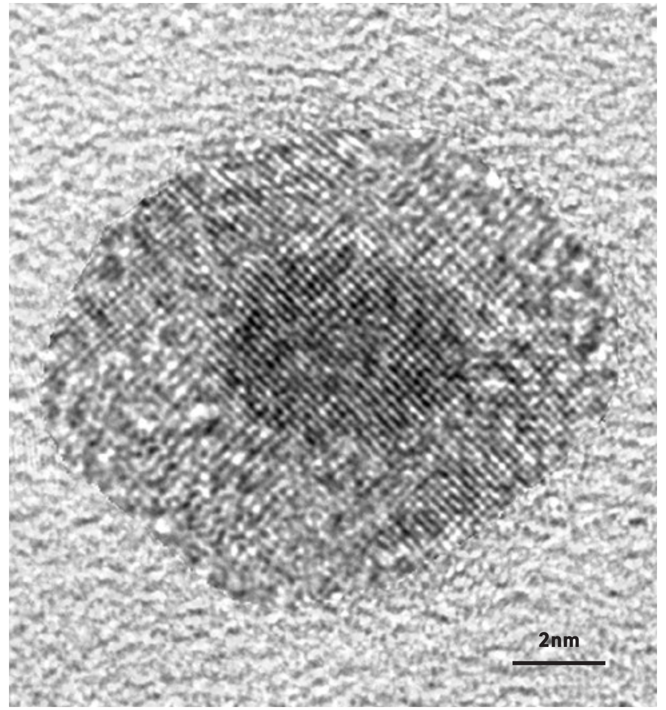
VAXINE & THE COVAX-19 VACCINE
SPIN OUT

Vaccine formulations generally consist of an antigen that mimics part of the infectious agent, mixed with a compound called an adjuvant that helps stimulate a strong immune response against the antigen.

A vaccine development company in Adelaide called Vaxine Pty Ltd, founded by Flinders University Professor of Medicine, Nikolai Petrovsky (above), has developed an exciting new non-inflammatory adjuvant called Advax™, made from a crystallised form of inulin.

Advax™ has stronger immune-enhancing properties than previous adjuvants, attracting the interest and support of the US National Institutes of Health. Advax™ development has relied on an microscopy at our Flinders University facility to understand its detailed molecular structure and mechanism of crystallisation. Advax™ is being incorporated into many vaccines being tested around the world, most recently in Vaxine's own COVID-19 vaccine, called COVAX-19®, currently in clinical trials in Adelaide.

VAXINE'S COVID-19 VACCINE IS IN CLINICAL TRIALS IN ADELAIDE

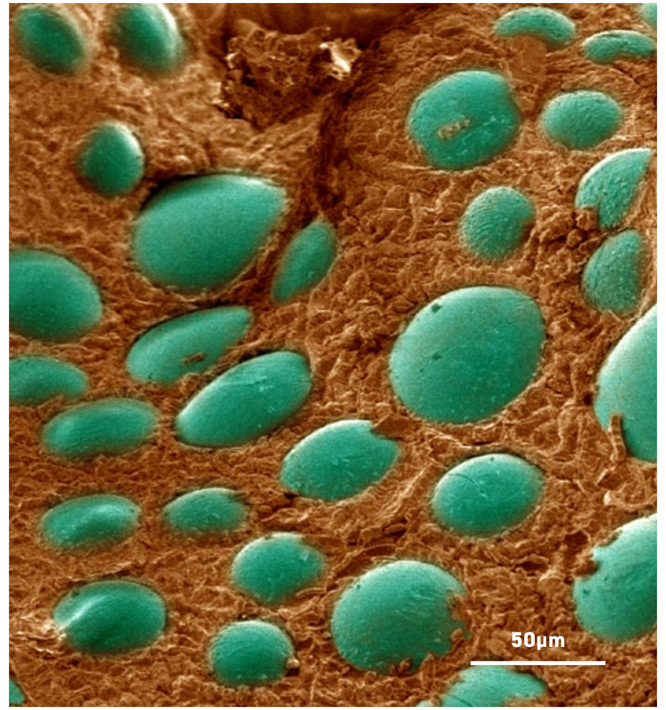


FERRONOVA
SPIN OUT

Ferronova is a medical device company founded in 2016 producing magnetic nanoparticles currently in human trials for use in cancer cell tracing.

Spun out of the University of South Australia and Victoria University of Wellington, it licenses IP from the University of Sydney. Their nanoparticles are detectable with a handheld device for use during cancer surgery to highlight lymph nodes in complex areas around head and neck, prostate and colorectal cancers. They will facilitate biopsies while avoiding critical surrounding structures such as arteries.

Research partners at UniSA and UNSW Sydney use transmission electron microscopy in the optimisation of the nanoparticles. The SA Government and BioMedTech Horizons along with seed investors have provided funding.

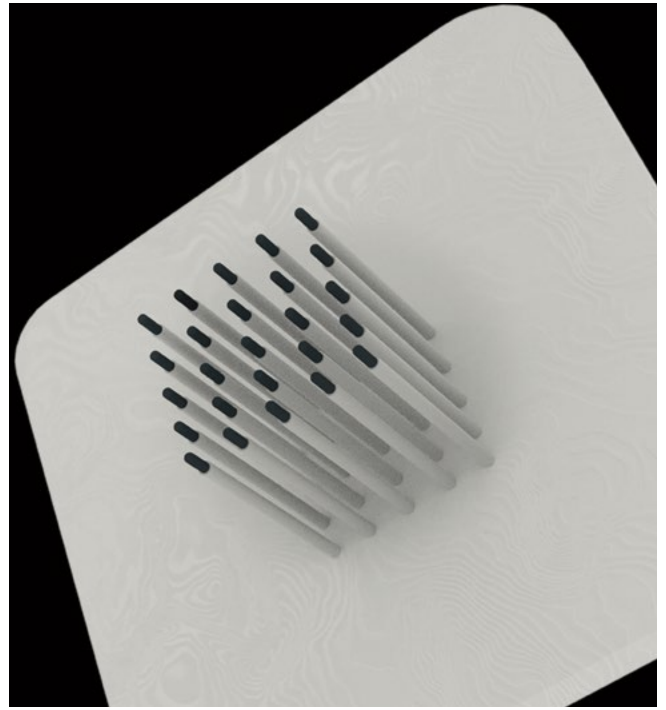


CLEAN EARTH TECHNOLOGIES
COMMERCIALISATION

The wonder polymers developed at Flinders University by A/Prof. Justin Chalker and his team, that can bind and remove mercury and oil from the environment, have recently also been shown to bind the toxic PFAS chemicals.

The patents for these polymers have been bought by Clean Earth Technologies (CET). CET is making the production equipment in Adelaide where they will then use it to manufacture the polysulfide, also at a plant in Adelaide. This has already started to create a number of new green manufacturing jobs.

A/Prof. Chalker won the New Innovators category in the 2020 Prime Minister's Prizes for Science.

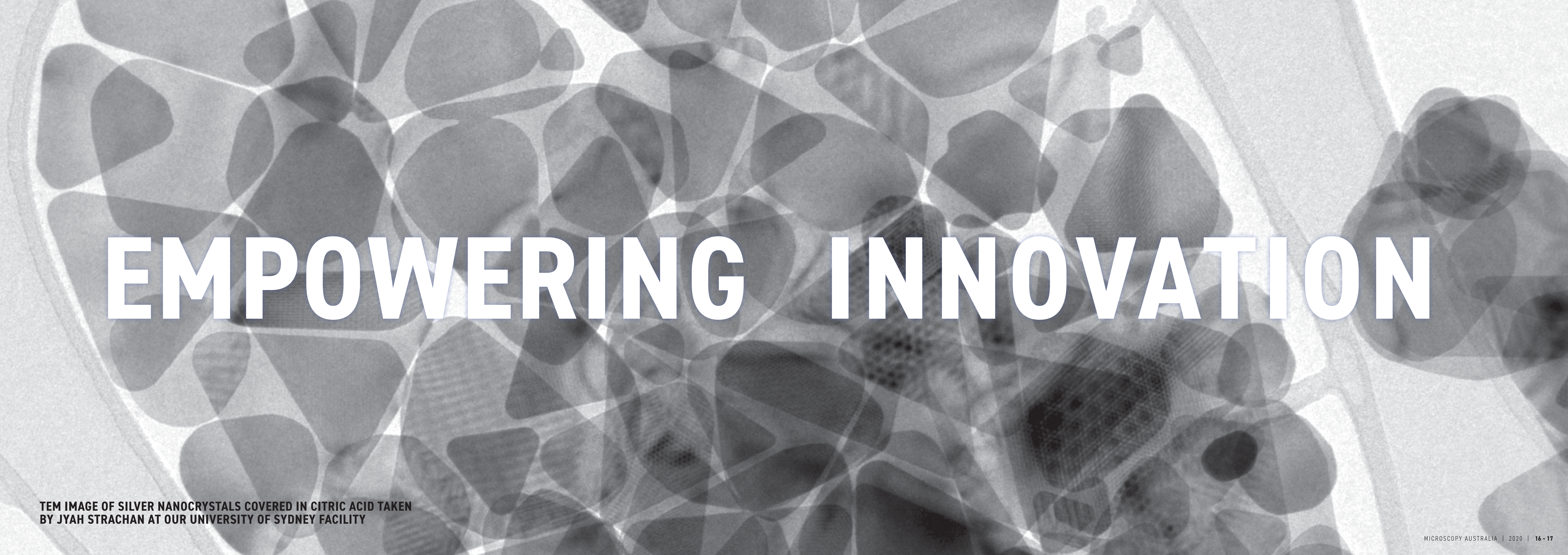


CARBON CYBERNETICS
SPIN OUT

Carbon Cybernetics was founded in 2018 to commercialise innovative carbon-fibre-based nanotechnology developed at RMIT and the University of Melbourne, which predicts epileptic seizures with a higher density of recording electrodes than anything currently available on the market.

With funding from the BioMedTech Horizon's grant, Carbon Cybernetics is set to test the feasibility of their device as a permanent brain implant and plan to begin human trials in 2023.

This device will hopefully provide improved planning for how and when to administer treatments, more independence and confidence for patients, and improved career prospects, social engagement and mental health outcomes.

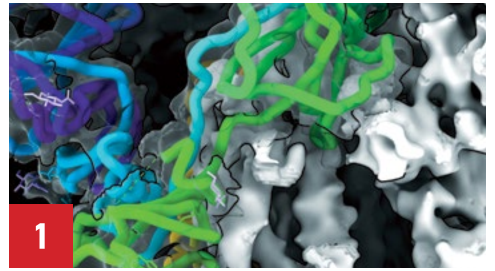


EMPOWERING INNOVATION

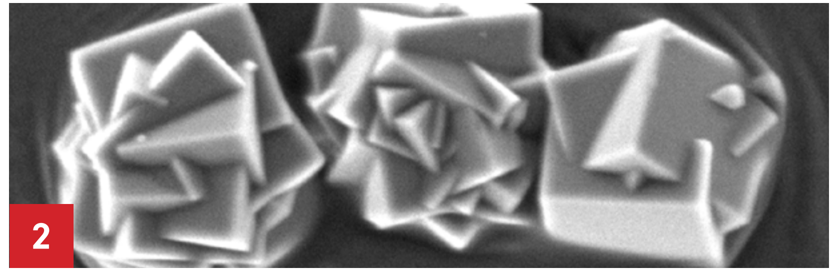
TEM IMAGE OF SILVER NANOCRYSTALS COVERED IN CITRIC ACID TAKEN BY JYAH STRACHAN AT OUR UNIVERSITY OF SYDNEY FACILITY

RESEARCH OUTCOMES & SOCIAL IMPACT

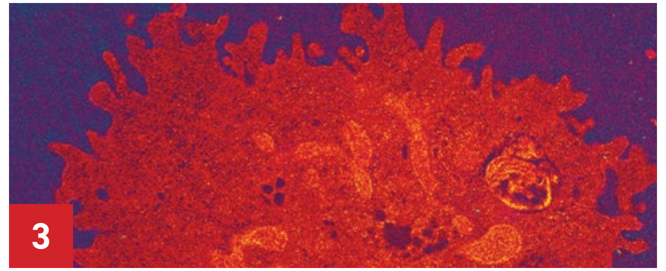
Take a closer look at this year's research highlights – all enabled by Microscopy Australia. With over 3,000 researchers annually, here are just a few of our recent outcomes.



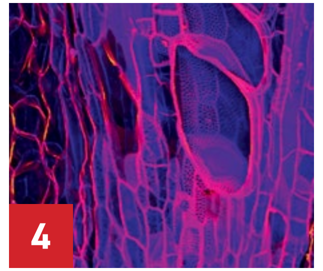
1 CRYO-TEM INSTRUMENTAL IN UQ COVID-19 VACCINE



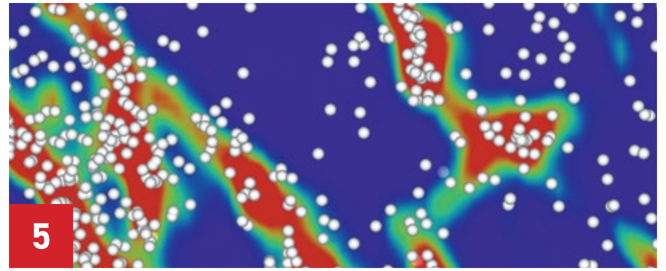
2 MANUFACTURING INNOVATION PARTNERSHIP



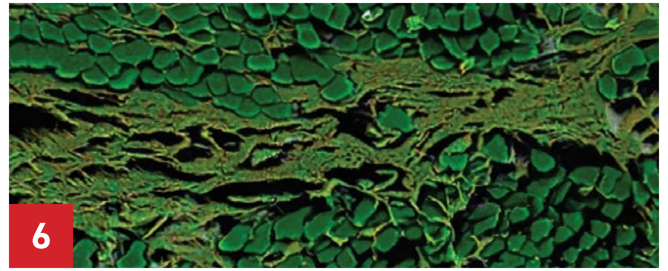
3 COMMON DRUG IMPROVES CANCER OUTCOMES



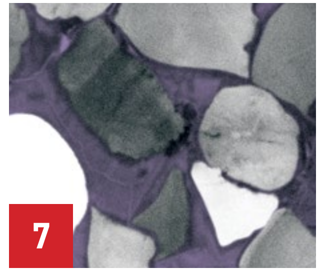
4 NEMATODE INFECTION OF WHEAT



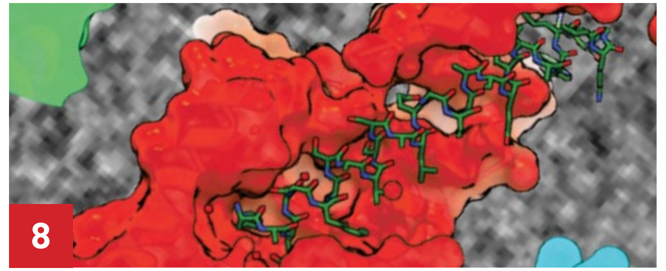
5 PREPARING FOR THE HYDROGEN ECONOMY



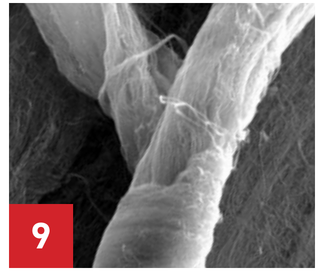
6 SYNTHETIC SCAFFOLDS FOR TENDON AND LIGAMENT REPAIR



7 IMPROVING DEEP-WATER OIL EXPLORATION

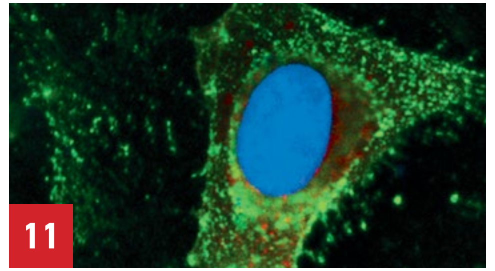


8 DIABETES DRUG ACTION VISUALISED

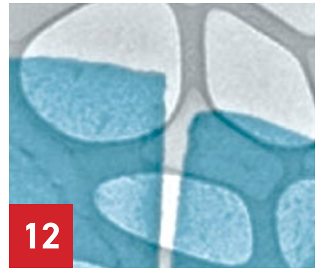


9 A NEW ERA IN X-RAY TECHNOLOGY

10 SUNLIGHT-RESPONSIVE NANOTECH FOR DESALINATION

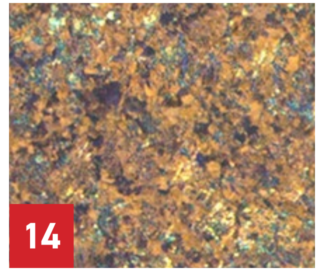


11 BEE VENOM FOUND TO KILL AGGRESSIVE BREAST CANCER

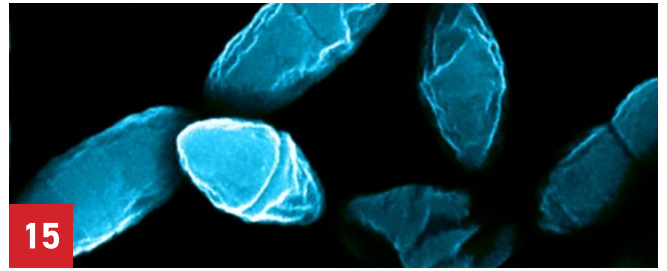


12 ATOMICALLY THIN FLEXIBLE ELECTRONICS

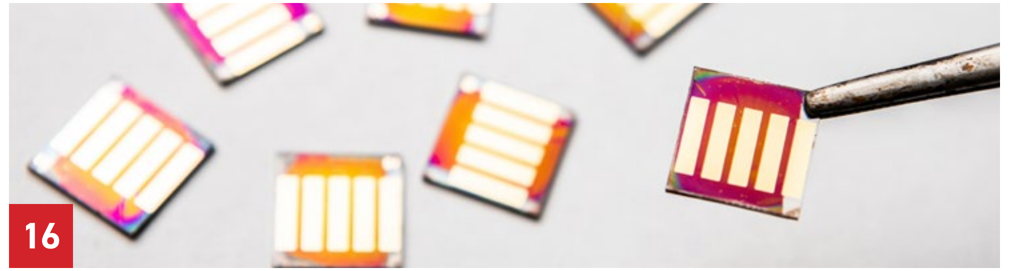
13 BANDAGES FOR CHRONIC WOUND TREATMENT



14 NOVEL TITANIUM ALLOY FOR 3D-PRINTING



15 FIGHTING THE BIGGEST INFECTIOUS KILLERS



16 RECORD EFFICIENCIES IN NEXT-GEN SOLAR TECH

2020

1

CRYO-TEM INSTRUMENTAL IN UQ COVID-19 VACCINE

COVID-19 IS RESPONSIBLE FOR 1.17 MILLION DEATHS TO OCTOBER 2020

CHALLENGE

Controlling the COVID-19 pandemic by development of a safe and effective vaccine is a major global challenge. This is the third coronavirus outbreak in the past 20 years and is causing unprecedented morbidity, mortality, and economic disruption.

In early 2020, through their existing partnership with the Coalition for Epidemic Preparedness Innovations (CEPI), the University of Queensland (UQ) vaccine development team, lead by Prof. Paul Young, A/Prof. Keith Chappell, Dr Dan Watterson and Project Director Prof. Trent Munro, was tasked with the rapid generation of a vaccine to halt the COVID-19 pandemic.

RESEARCH

The UQ team used the system they had already developed known as the Molecular Clamp. This enables the production of stable synthetic proteins that copy important surface proteins from viruses. The system was designed to enable the rapid production of vaccine candidates to prevent the spread of newly emerging viruses – exactly what was needed to tackle COVID-19.

SARS-CoV-2 is the virus that causes COVID-19. Each virus particle is spherical and is covered with proteins called spikes. These spikes latch onto human cells and then change shape to allow the viral membrane to fuse with the cell membrane and deliver the viral genes into the host cell. They are then copied to produce more viruses. To create an effective immune response that prevents infection, the body must react to the spike protein in its pre-fusion state.

The molecular clamp system is designed to lock the spike protein into this pre-fusion state to produce a stable and effective vaccine.

Through January and February, the team developed a large panel of Spike-clamp (Sclamp) vaccine candidates and used transmission electron microscopy at our UQ facility to help identify lead constructs. By mid-February a single candidate had been selected for further development. Images of Sclamp were collected on the new cryo-TEMs at our UQ facility, and single particle analysis carried out. This work revealed the shape of the vaccine candidate at near-atomic resolution and confirmed that it mimics the pre-fusion form found on the virus.

The UQ vaccine is currently in its first clinical trials and UQ and CEPI have signed an agreement with CSL to produce the vaccine in Victoria.

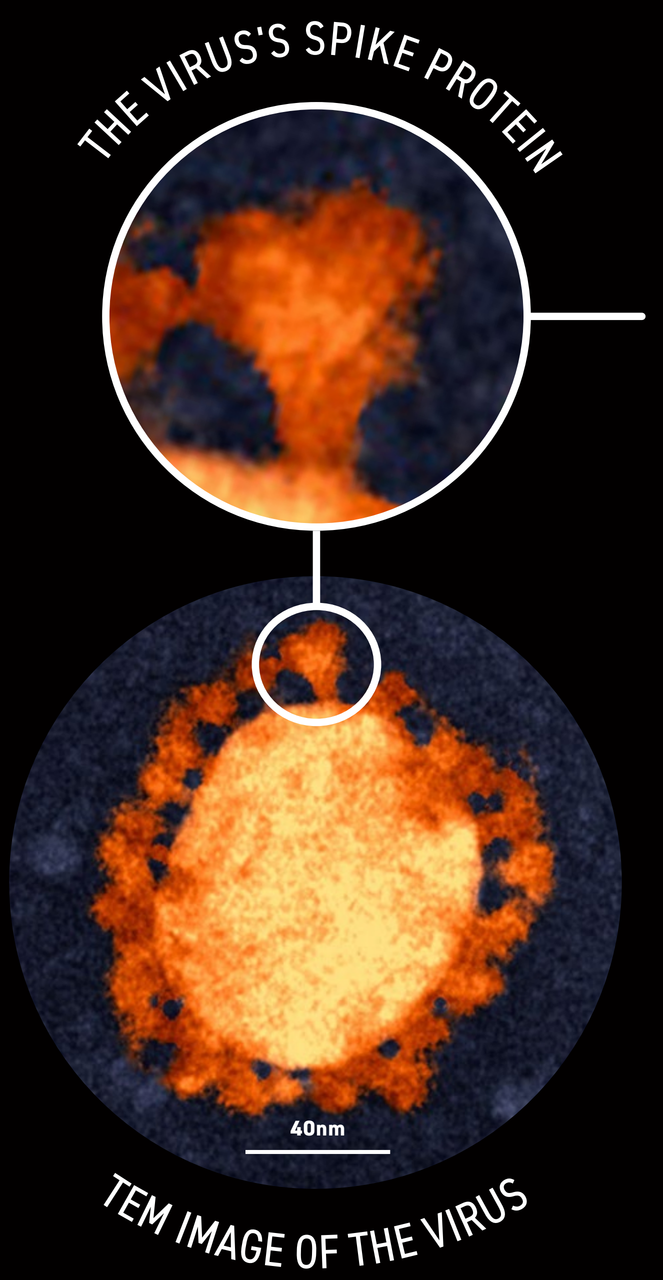
IMPACT

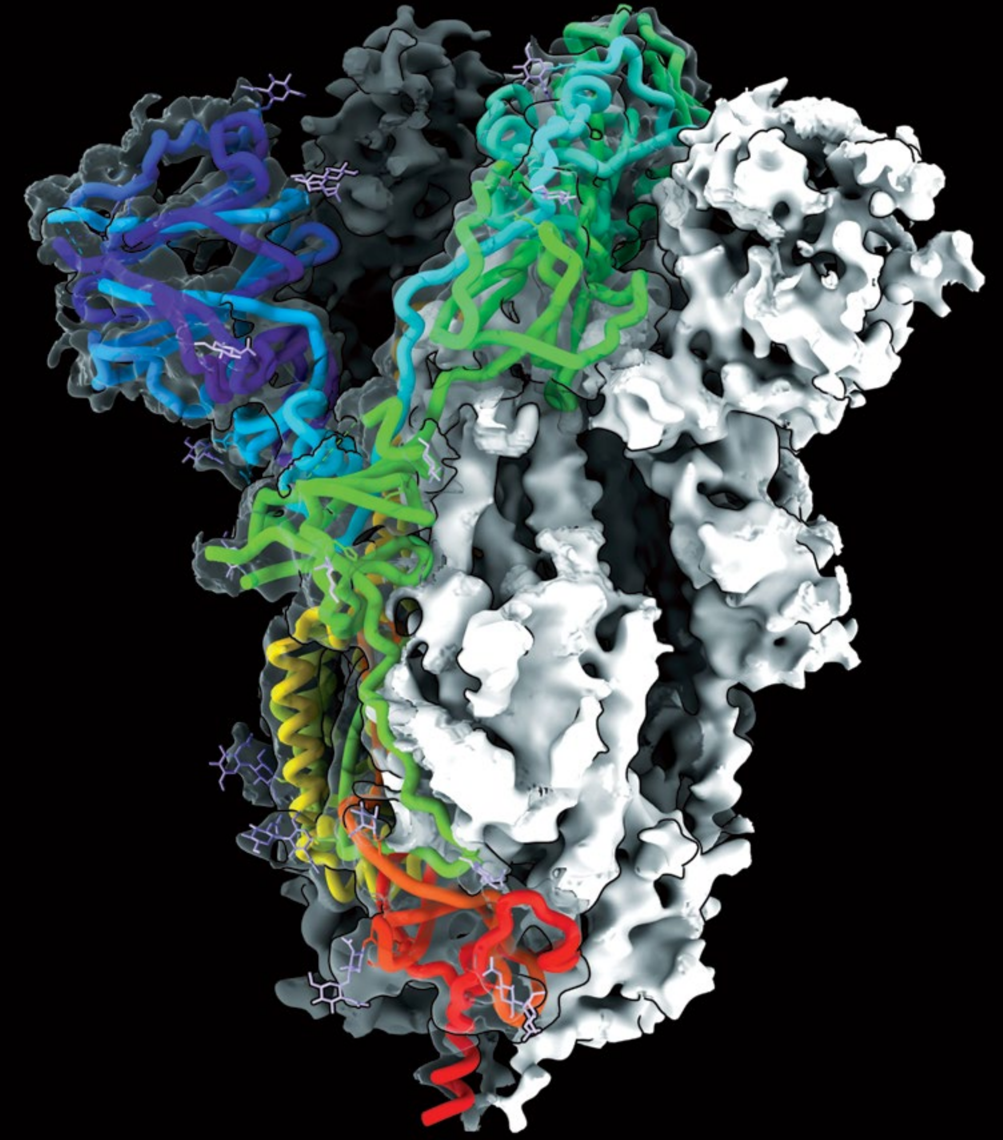
A safe and effective vaccine to prevent COVID-19 will:

- save millions of lives
- prevent losses due to illness and any long-term health effects of infection
- enable the return of normal social interactions
- help to rejuvenate the global economy

Left: Transmission electron microscope image of SARS-CoV-2 from our linked lab CSIRO's Australian Centre for Disease Preparedness by Sandra Crameri

Right: Cryo-TEM reconstruction of the Sclamp vaccine candidate by Naphak Modhiran, Daniel Watterson and Lou Brillault





STRUCTURE OF THE SCLAMP PROTEIN RECONSTRUCTED FROM CRYO-TEM DATA

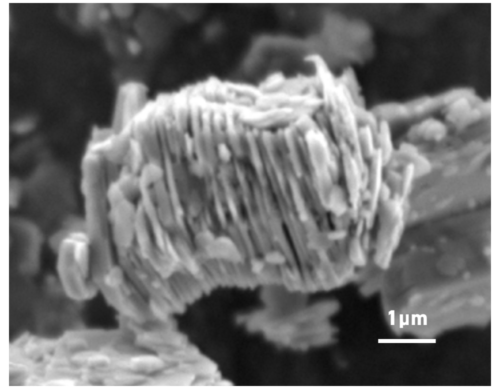
2 MANUFACTURING INNOVATION PARTNERSHIP

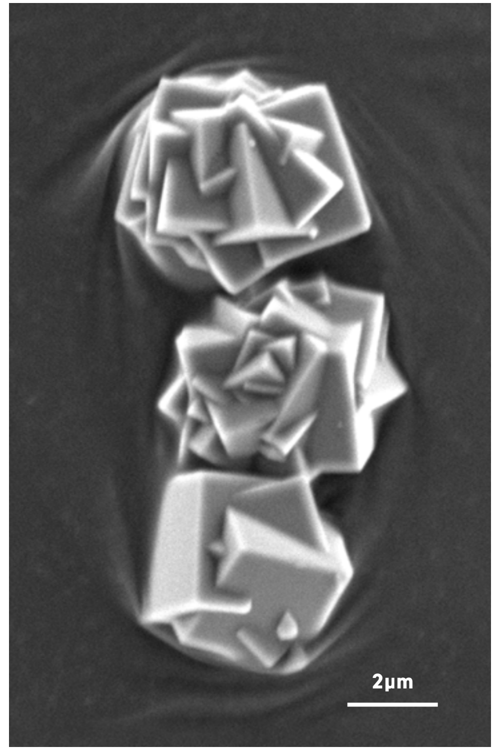
A mineral processing technology developed at The University of Queensland (UQ) has been licensed to ASX-listed industrial kaolin and mineral technology company Metalsearch Limited (ASX:MSE) through UniQuest. Metalsearch is commercialising this innovation, supported by a research agreement with UQ. Scanning electron microscopy (SEM) from our UQ facility was instrumental in cementing this partnership.

Researchers, A/Prof. James Vaughan and Dr Hong (Marco) Peng developed the new, quicker, energy-efficient and greener approach to producing synthetic zeolites. Zeolites are produced from the clay mineral kaolin and play an important role in a cleaner and safer environment. They are an effective substitute for harmful phosphates in powder detergent. Phosphates are banned in many parts of the world because of blue-green algae toxicity in waterways. As catalysts, zeolites increase process efficiencies, decreasing energy consumption and, as redox catalysts, sorbent zeolites can help remove exhaust gases. Their adsorbent capabilities see them widely used in water treatment, for example, in the removal of heavy metals produced by nuclear fission.

The technology gives Metalsearch a unique commercial edge in capitalising on the kaolin from their Abercorn Project – a large-scale kaolin mine near Monto in central Queensland. The technology also provides a potential commercial remediation solution to the mining industry by using mine tailings as a zero-cost feed stock in the production of high value zeolites. The 2019 global synthetic zeolite market was estimated at USD $5.64 billion.

Synthetic zeolites are commonly known as molecular sieves because of their sponge-like structure and tiny pores. This can be visualised by SEM, which was used extensively during the development of the new process.





SEM images of kaolin source material (top) and the manufactured zeolite (below).

3 COMMON DRUG IMPROVES CANCER OUTCOMES

The anti-nausea and anti-psychotic drug, prochlorperazine (Stemetil), could be repurposed to make antibody treatment of tumours more effective. The research team from the Universities of Queensland, Sydney and Newcastle, and the Princess Alexandra Hospital is led by A/Prof. Fiona Simpson.

Antibodies designed to attack cancers stick to particular proteins on the surface of the tumour cells and cause these cells to die. This occurs via a process called natural killer cell-mediated antibody-dependent cellular cytotoxicity (ADCC). The more protein molecules there are on the surface of the cell, the more places there are for the antibodies to stick, making the treatment more effective.

These protein molecules normally carry signals from the outside of the cell to the inside. Prochlorperazine was found to temporarily block the movement of these proteins into the cells leaving more on the surface where they can stick to the antibodies resulting in increased cell death. By combining antibodies and prochlorperazine, the researchers have also shown that the current variations in treatment effectiveness can be overcome.

Transmission electron microscopy conducted by Prof. Rob Parton and James Rae at our facilities at the University of Queensland was used to show the changes in movement of surface proteins into the cell.

Prochlorperazine, combined with existing cancer drugs like cetuximab, trastuzumab (Herceptin) and avelumab, was studied on tumours from head and neck, breast and metastatic colorectal cancers in mice. This treatment resulted in the disappearance of all the tumours from ten mice with head and neck cancer.

Dr Simpson was curious to see what would happen if she re-introduced the same cancer back into the mice four weeks later.

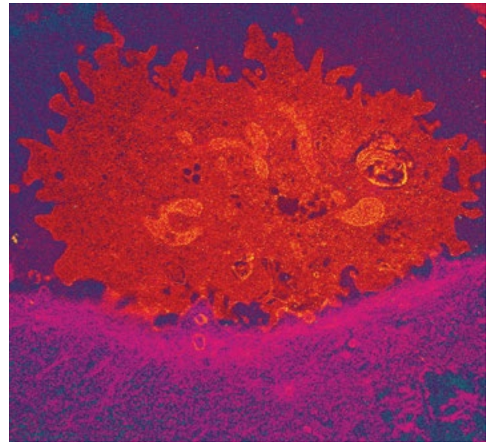
"The anti-nausea drug works by changing the surface of the tumour cells so that existing cancer drugs which target tumours are better able to interact with the immune system," Dr Simpson said.

"The result is that cancer cells become sitting targets that can no longer escape the immune system. We observed a process we haven't seen before and which increased the natural killer immune cells' ability to attach to, and kill the cancer. It is almost as if the killer cells become zipped to the tumour cells."

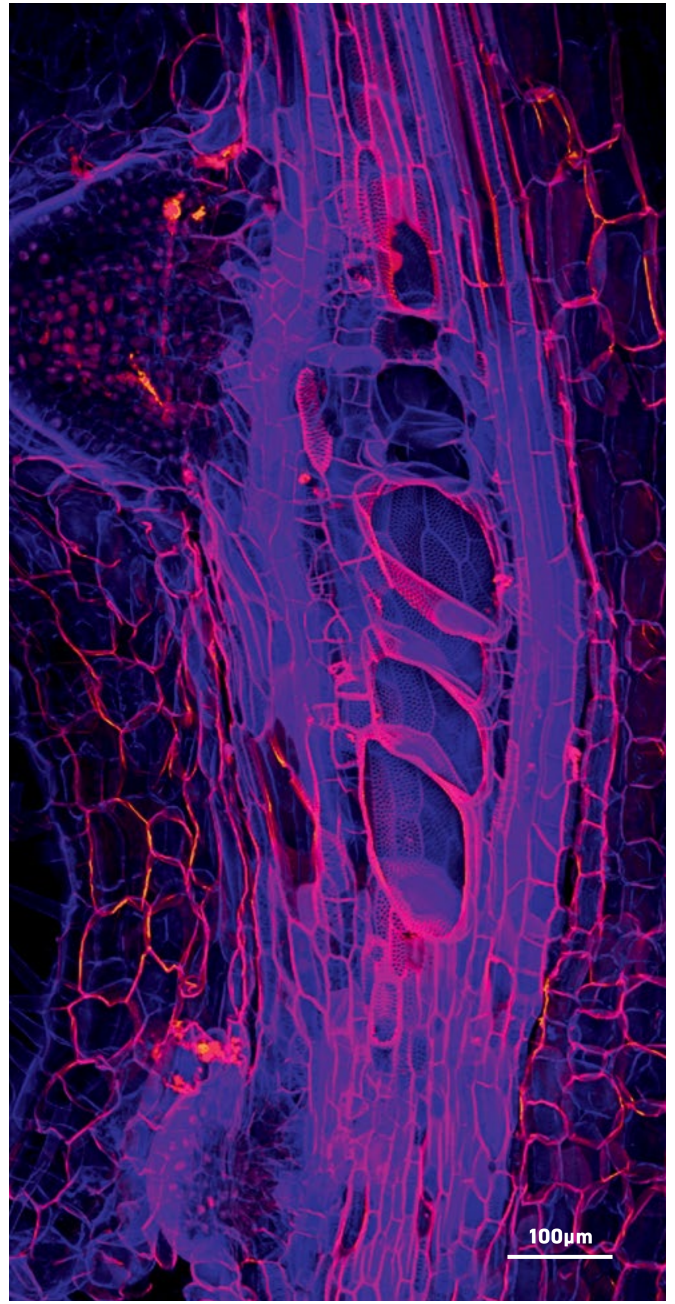
"Amazingly, their cancer was rapidly eliminated – as if the new combination, in addition to being more effective, was also able to teach the immune system how to better recognise cancer cells," Dr Simpson said.

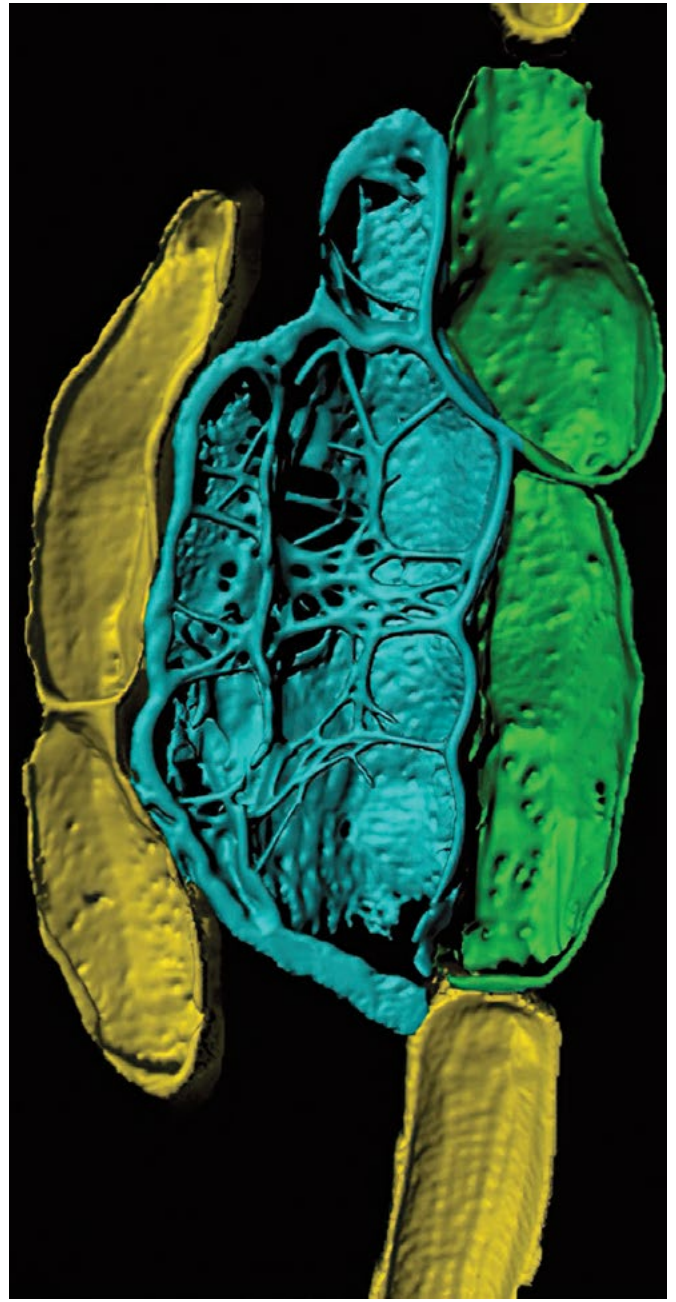
The team's long-term vision is to use this approach to not only clear a patient's cancer in the immediate term, but to prevent their cancer coming back in the future by establishing protective 'immune memory'.

H. Y. Chew et al. 2020, Cell 180, 5, P895-914.e27



Colour-enhanced TEM image of a killer cell (red) attaching to a cancer cell (pink).





4 ROOT CAUSE OF NEMATODE INFECTION OF WHEAT

Cereal cyst nematodes (CCN) infect plant roots and are capable of causing devastating yield loss of wheat crops. Despite significant research it still wasn't clear how these parasites interfere with root development and crop yield. PhD student Kara Levin, working at University of Adelaide's Waite Research Institute, used their Microscopy Australia facilities to combine novel specimen preparation, confocal microscopy and high-resolution 3D imaging to reveal how cereal cyst nematodes hijack water and nutrients in wheat roots.

Comprehensive microscopic investigation of nematode feeding sites is complicated by their variable size, shape and depth within root tissue. The techniques used by Ms Levin in her research, and published in the journal *Scientific Reports*, allowed her to look deep within CCN-infected wheat roots and generate 3D models of nematodes and their effects on plant tissues. Rotational videos provided clear views of the unique anatomy of feeding sites, with sufficient resolution to reveal cellular-level spatial relationships among nematodes, feeding sites and the host vascular tissues that transport water and mineral nutrients. This approach revealed striking and previously unreported remodelling of developing water transport vessels, known as xylem, after infection by CCN. By hijacking the classical developmental pathway leading to programmed cell death of some cells, xylem vessels can be kept alive for use by the parasite.

Ms Levin says that although microscopy has been used to investigate this system for decades, this 3D approach is the first to show that xylem cells in infected roots become short and fat 'bubbles' rather than long and narrow 'tubes'. This is likely to impede water transport within the roots. Her supervisor, Prof. Diane Mather says this information is "important in determining resistance mechanisms in wheat that could be exploited in breeding programs".

A. Levin et al. 2020, Scientific Reports 10, 9025

Left: Confocal image showing a longitudinal section through a nematode feeding site in a wheat root.

Right: 3D data reconstruction showing a feeding site (aqua), central xylem 'invaded' by the feeding site (green), and enlarged central xylem (yellow).

5

PREPARING FOR THE HYDROGEN ECONOMY

CHALLENGE

When steels are exposed to hydrogen, they can become brittle, leading to catastrophic failures. In many conditions this is not too much of an issue as hydrogen levels in the atmosphere are quite low. However, as we move towards a more hydrogen-fuelled future, with pipelines and tanks needed to transport and store hydrogen fuel, this problem becomes one of the major obstacles for the realisation of the hydrogen economy.

It is also a significant limitation to the uptake of ultra-high strength steels, which are particularly susceptible to hydrogen embrittlement. This currently prevents their use in the development of lighter, stronger vehicles of the future. Working in partnership with CITIC Metals, researchers at the University of Sydney set out to understand hydrogen embrittlement at the atomic level and to find ways of introducing microstructural traps to lock the hydrogen that gets absorbed during the life of the steel.

RESEARCH

The origin of this effect involves complicated interactions of hydrogen with defects in the metal at many length scales. However, understanding these interactions is limited by the fact that it is experimentally challenging to measure the precise location of hydrogen atoms at the atomic scale: hydrogen being the smallest and lightest of the elements. Although macroscale techniques can identify hydrogen retention in metals, they do not allow the measurement of the relative contributions of different types of microstructural features.

Dr Yi-Sheng Chen, working with Prof. Julie Cairney, used the state-of-the-art cryogenic atom probe in the Microscopy Australia facility to directly observe hydrogen (in the form of deuterium) at specific microstructural features in steels, such as dislocations. This technique was first prototyped by Prof. Roger Wepf, director of our University of Queensland facility, then developed and implemented in partnership with instrument developer, Microscopy Solutions, in Sydney.

Using this system, Dr Chen found that hydrogen accumulates at dislocations weakening the steel along these features. These observations provided the critical information to validate models of how hydrogen causes embrittlement

In addition to these observations, Dr Chen also found the first direct evidence that clusters of niobium carbide, and the boundaries between different steel crystals, trap hydrogen in such a way that it can't readily move to the dislocations to cause embrittlement. These microstructural features could be the key to the informed design of embrittlement-resistant steels.

Left: visualisation of atom probe data, collected by Dr Chen, showing the hydrogen atoms (white) collecting at dislocations (red). Visualisation by Dr Andrew Breen.

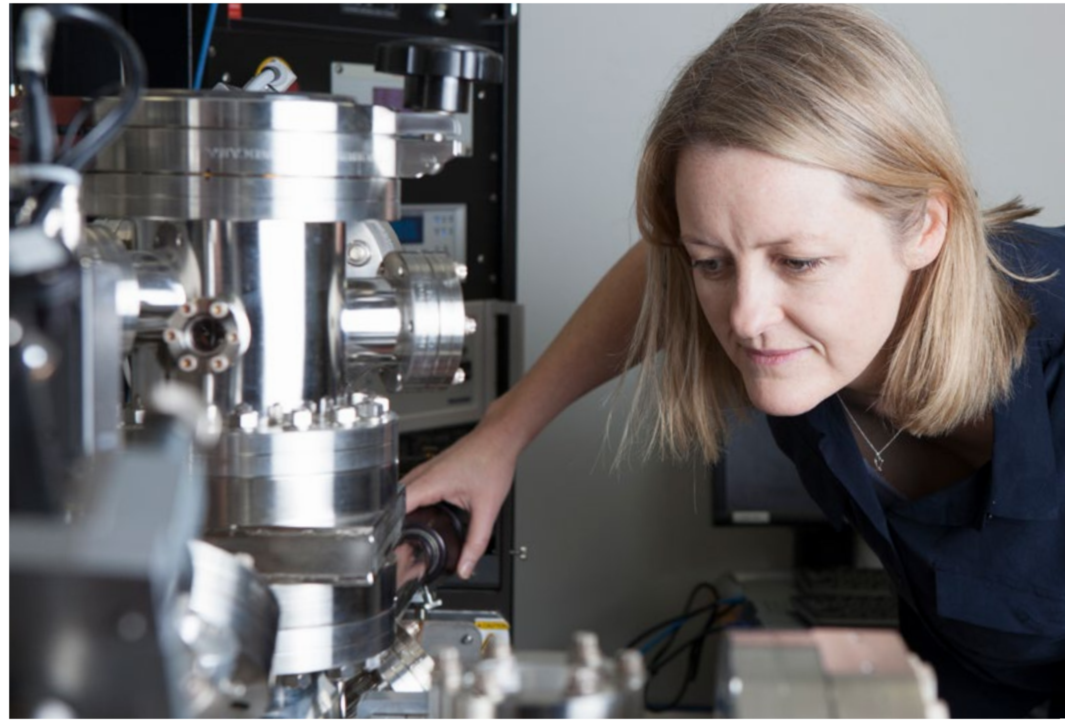
IMPACT

– **Expanding Australia's hydrogen economy:** Safe production, use, storage and transport of hydrogen.

– **Fuel efficient transport vehicles:** Ability to use embrittlement-resistant ultra-high strength steels in lighter, safer, more fuel-efficient vehicles of the future.

– **Clean fuel solutions:** Positive progress towards implementing clean fuels to assist with the global decarbonisation scheme.

Y-S Chen et al. 2020, Science 367 (6474), 171-175.



Prof. Julie Cairney using an atom probe. Her team developed cryogenic atom probe tomography, a world-first technique for imaging hydrogen atoms in steel.

SUPPORTING AUSTRALIA'S NATIONAL HYDROGEN STRATEGY FOR CLEAN FUEL SOLUTIONS

6 SYNTHETIC SCAFFOLDS FOR TENDON AND LIGAMENT REPAIR

A team of biomedical engineering researchers from the University of Sydney, working with international collaborators, are hoping to improve the outcomes of tendon and ligament repair by developing a new synthetic scaffold for their regeneration.

Australia's love of sport means it has one of the highest rates of knee anterior cruciate ligament (ACL) injury and reconstruction in the world. Nearly 200,000 ACL reconstructions were performed in Australia between 2000 and 2015. In 2014, the total direct hospital costs of ACL reconstruction surgery in Australia were estimated to be $142 million. Worldwide, the costs of tendon and ligament rupture repair and surgery revision are worth tens of billions of dollars of the clinical orthopaedic market.

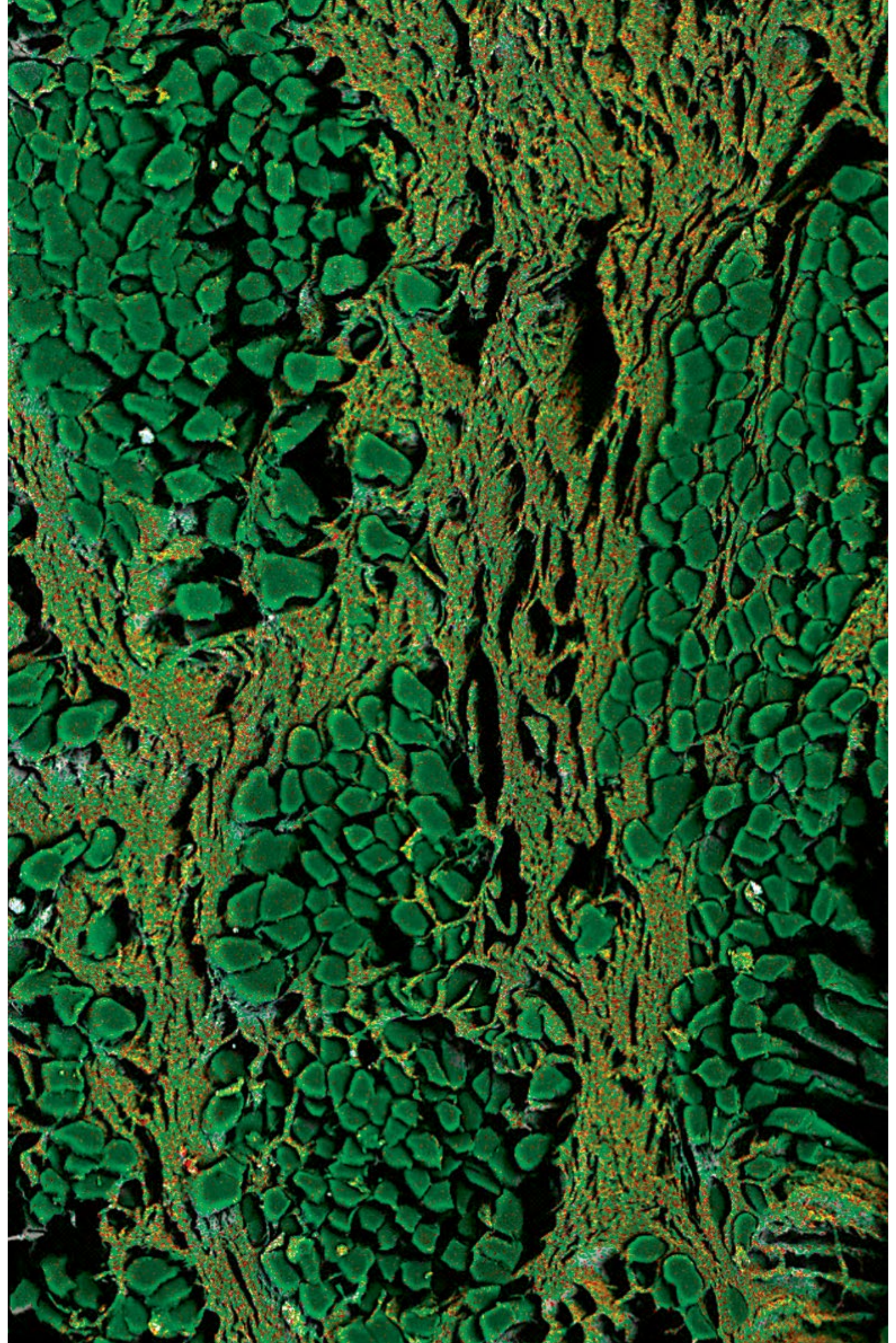
Led by Prof. Hala Zreiqat, working with postdoctoral researcher Dr Young No, the researchers are the first to develop and patent novel fibre-reinforced hydrogel scaffolds, a synthetic substance that has the ability to mimic and replace human tendon and ligament tissue. Tested on patellar tendon models in rats, the synthetic scaffold has been developed with a stress resistance and water volume similar to natural tendons and ligaments, allowing for improved in-growth of collagen tissue.

Scanning electron microscopy (SEM) at our University of Sydney facility was used to examine the surface, and cross section, of the scaffold. The team also conducted elemental mapping (EDS) on the SEM to visualise how elements like zinc, silicon and carbon, dispersed throughout the scaffold might aid ligament and tendon growth. They found that incorporating bioactive strontium hardystonite ceramic particles in the bone end of the artificial tendon could encourage bone attachment. Its absence promoted muscle tissue ingrowth.

"For synthetic scaffolds to be accepted by the body, their physical and chemical architecture must align with human tendons and ligaments. Our technology hopes to fast-track the restoration of tendons' and ligaments' mechanical function and support the growth of collagen tissue, without compromising the body's biological response." said Prof. Zreiqat.

Y. J. No et al. 2020, ACS Biomater 6(4), 1887–1898

Image: SEM/EDS image of the cross section of a freeze-dried synthetic fibre-reinforced hydrogel. The 'soft' porous hydrogel phase is light green and the 'hard' fibre phase is dark green by Dr Young No.



7 IMPROVING DEEP-WATER OIL EXPLORATION

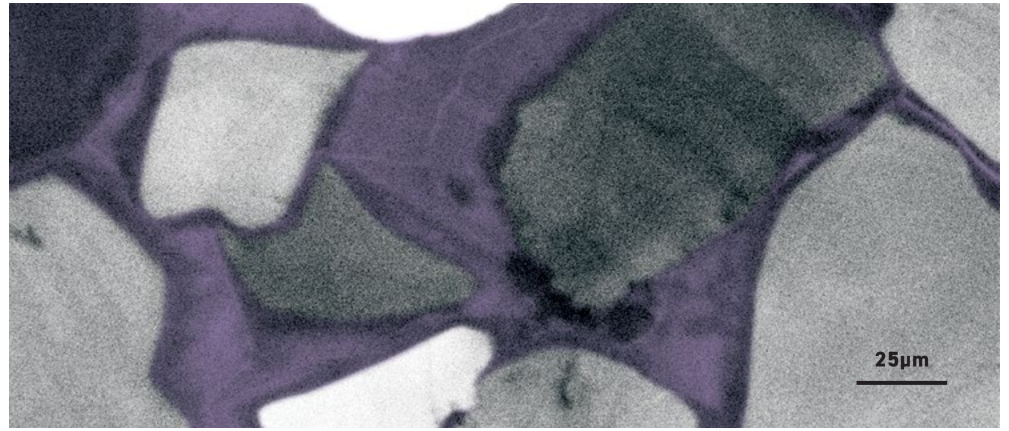
Off the coast of Western Australia abundance of oil and gas discoveries in the Exmouth Sub-Basin have made it an attractive region for deep-water oil exploration. However, deep-water exploration is very expensive, and of the 74 exploration holes drilled up until 2001, only 22% struck oil. Research that allows oil companies to better target their exploration in the area could provide significant cost savings.

In order to better target exploration, a team composed of George Mills and Stephen Molyneux from Carnarvon Petroleum, Julien Bourdet from CSIRO and Laure Martin and Matvei Aleshin from the University of Western Australia (UWA) have been exploring reservoir rocks laid down in the Basin during the late Triassic. During that period the large Mungaroo Delta opened onto the Exmouth Sub-Basin providing the organic-rich sediments needed for oil and gas formation and sands that can host the hydrocarbon accumulations. This makes these Triassic rocks particularly interesting to oil and gas companies. Despite this, it was found that at particular locations reservoir rocks had poor porosity and could not hold much gas.

The team used scanning electron microscopy with a cathodoluminescence filter to see what was filling the pore spaces in the reservoir rock. They discovered that quartz had formed in the spaces between the grains in the rock forming a cement, leaving no room for hydrocarbons to be trapped. In-situ oxygen isotope composition in the quartz performed using the SIMS Cameca 1280 at our UWA facility, combined with fluid inclusion analysis at CSIRO, suggested they formed in response to a mineral-laden fluid from deep in the earth.

The researchers knew that the South part of the Exmouth Basin is affected by a complex network of deep faults, or cracks, in the Earth's crust. These would allow for hot, mineral-laden water, heated by magma deeper in the earth, to travel up to the reservoir rocks. This is important because it means that rocks close to these faults are likely to be affected by quartz filling the pore spaces. By knowing this, companies can target their exploration away from these regions allowing them to make informed decisions about where to explore.

SEM cathodoluminescence image shows grains bound together with the quartz cement (purple).



8 DIABETES DRUG ACTION VISUALISED

The glucagon-like peptide-1 receptor (GLP-1R) is important in regulating the body's glucose and energy balance making it a valuable target for diabetes and obesity treatments.

The receptor is normally activated by the binding of a peptide hormone called GLP-1. Peptide drugs that mimic the action of GLP-1 by binding to the receptor are among the most important agents used to treat type 2 diabetes. However, as they are peptides, they are easily broken-down during digestion. They therefore need to be injected, which is not ideal for long-term patient compliance and convenience. Attempts to develop non-peptide drugs that can be taken orally and that will bind to, and activate GLP-1R, have had only limited success. However, that is now changing with three non-peptide drugs currently in clinical trials.

An international collaboration, led by A/Prof. Denise Wooten and Prof. Patrick Sexton at Monash University, has studied how these new non-peptide drugs bind to GLP-1R.

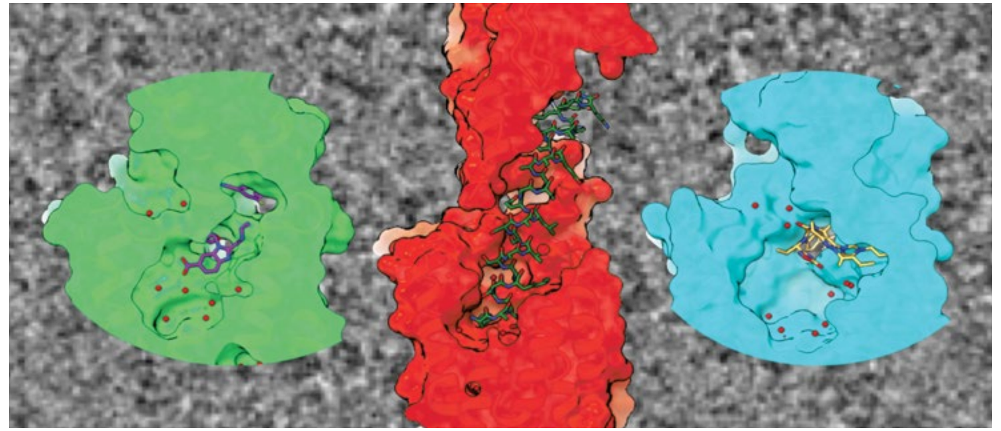
In work published in a series of high impact papers, the team used high resolution cryo-electron microscopy (cryo-EM) at our Monash University facility and showed that each of the non-peptide drugs binds to a different place on the receptor, with each having distinct ways of activating GLP-1R compared to the current peptide drugs.

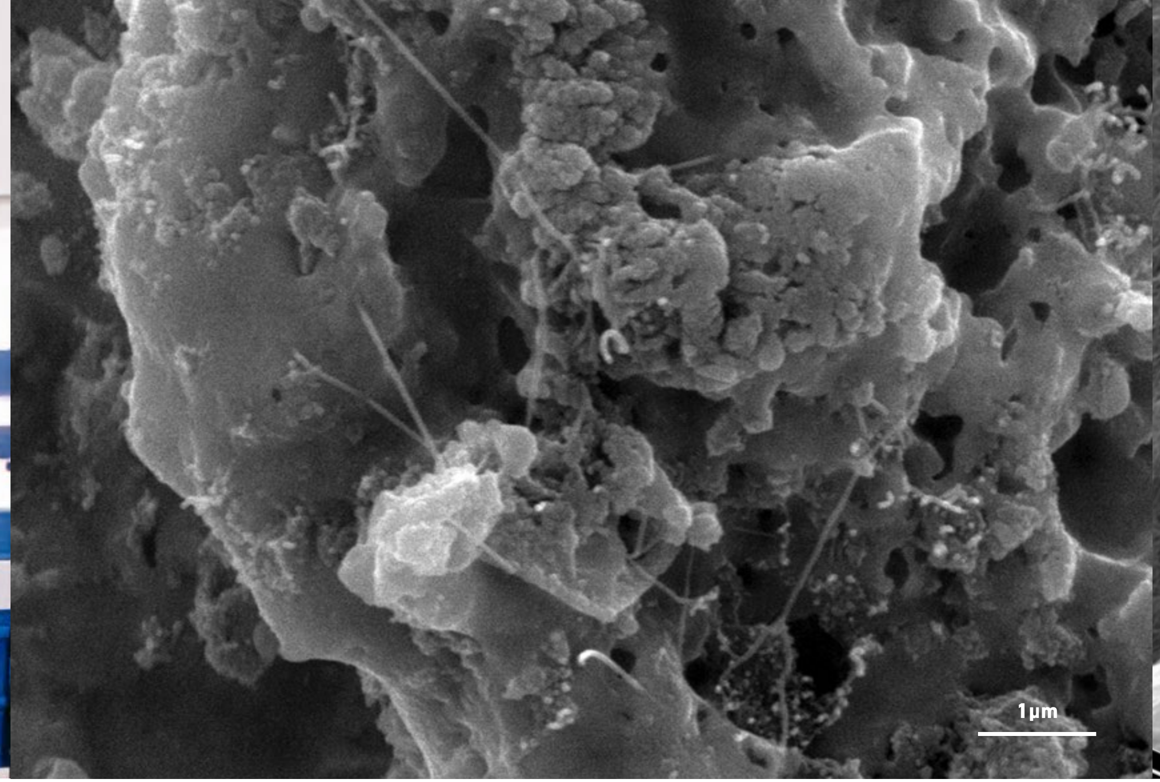
One of these drugs recently demonstrated excellent efficacy in reducing both the blood sugar and weight of type 2 diabetic patients. Unlike the other non-peptide drugs, it could closely mimic the signalling and regulation of the native GLP-1 peptide. High-resolution cryo-EM revealed unprecedented structural detail of the binding sites within the receptor, providing molecular understanding of how the drugs work.

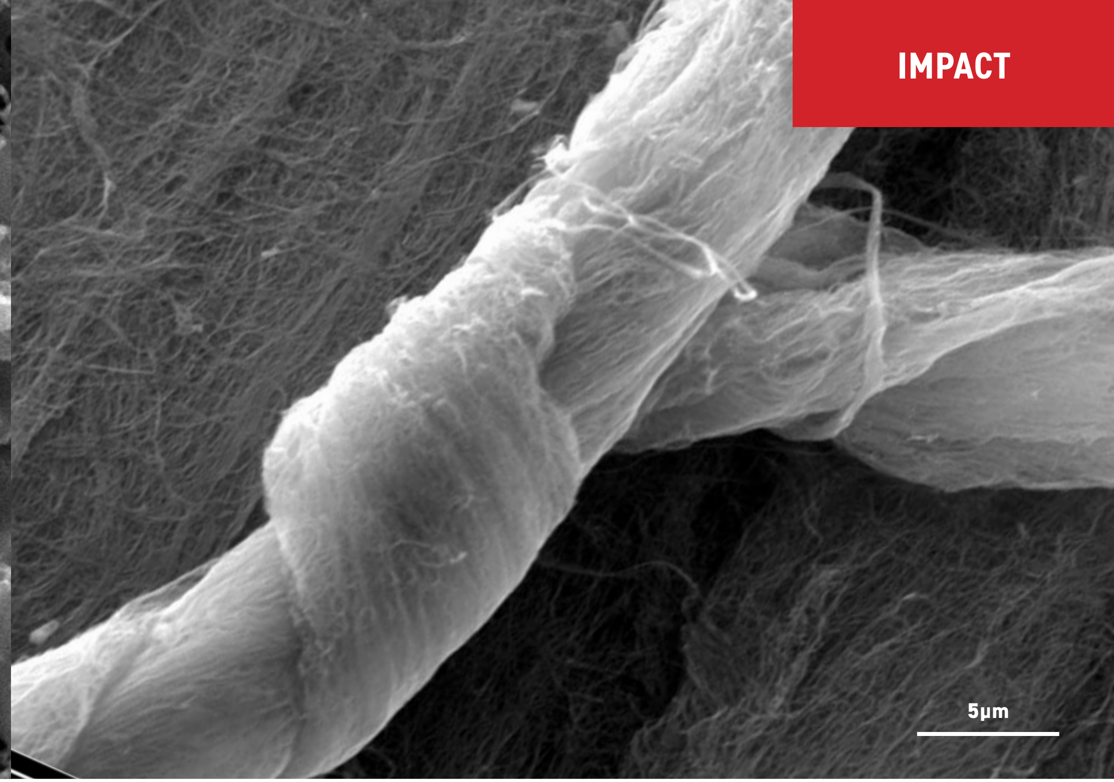
Their discoveries pave the way to unpicking how the different drugs activate different subsets of the many signalling pathways controlled by GLP-1R. This will lead to new knowledge that can be directed to improving oral diabetes drugs to give greater efficacy, potency and tolerability.

P. Zhao et al., 2020, Nature 577, 432–436 and X. Zhang et al. 2020, Molecular Cell DOI: 10.1016/j.molcel.2020.09.020

Cross sections of cryo-TEM-derived structures of GLP-1R binding to GLP-1 in the centre, and the two drugs on the left and right.







9

A NEW ERA IN X-RAY TECHNOLOGY

WORLD LEADING TECHNOLOGY DESIGNED & MANUFACTURED IN SOUTH AUSTRALIA

CHALLENGE

X-rays are being used in increasingly varied applications creating demand for a variety of smaller, portable, higher resolution, high throughput devices. These include machines for medical and inspection techniques, such as radiotherapy, CT scans, breast cancer screening, security inspection and high throughput manufacturing.

Above: SEM images of sputtered carbon nanotubes (left) and a carbon nanotube bundle (right).

Left: Engineers at Micro-X's Adelaide factory assemble the 'Carestream DRX Revolution Nano' portable X-ray unit.

RESEARCH

Micro-X Ltd has collaborated with researchers from Flinders University and the University of Adelaide, with help from a grant from the Department of Innovation Science and Technology, and developed and patented an innovative, electronic X-ray tube that uses carbon nanotubes (CNT) to miniaturise the X-ray generation components.

This X-ray tube is the key to reducing size, weight, heat and power and produce truly portable X-ray machines. Their proprietary CNT emitter is now manufactured in Adelaide and will form the basis for all Micro-X's X-ray products. Micro-X is the first company to commercialise CNT-based X-ray tubes.

Microscopy at our Flinders University facility provided Micro-X with a better understanding of their systems and manufacturing processes.

IMPACT

Micro-X's in-house, local manufacture provides substantial benefits in reduced costs, reduced cycle time, improved quality, increased scalability and independence in the supply chain.

Micro-X designed and now manufactures the DRX-Revolution Nano for Carestream Health, which won a 2018 Good Design Award. Nano is now installed in an increasing number of Australian and international hospitals. Production was increased in response to COVID-19.

Micro-X has completed two contracts with the Australian Defence Force for a mobile backscatter imager to detect IEDs and an ultra-lightweight, digital, mobile X-ray unit for deployed military medical facilities, with potential applications in humanitarian aid and disaster relief.

Micro-X has completed one, and is operating a second, contract with the UK Department for Transport's Future Aviation Security team to develop an imager to detect small amounts of explosive materials concealed in electronics within passengers' carry-on luggage.

In conjunction with the Australian Stroke Alliance, Micro-X has also produced preliminary designs for a brain CT device that can be mounted into road and air ambulances to diagnose stoke victims prior to transfer to hospital.

Micro-X has committed to developing, sourcing and manufacturing components locally, supporting Australian manufacturing and creating jobs in South Australia. Over 85% of the Nano's components are domestically sourced.

10

SUNLIGHT-RESPONSIVE NANOTECH FOR DESALINATION

CHALLENGE

Desalination has been used to address escalating water shortages globally. Due to the availability of brackish water and seawater, and because desalination processes are reliable, treated water can be integrated within existing water systems with minimal health risks. However, thermal desalination processes by evaporation are energy-intensive, and other technologies, such as reverse osmosis, have a number of drawbacks, including high energy consumption and chemical usage in membrane cleaning and dechlorination. Harnessing sunlight to facilitate desalination could reduce these costs making desalination a more energy-efficient and environmentally sustainable solution for water security.

SOLUTION

Dr Huanting Wang and his group at Monash University have now developed a composite material that can adsorb a high concentration of ions and release them on exposure to sunlight, providing a low-cost and environmentally friendly water desalination solution.

The metal–organic framework (MOF) ion adsorber is made of molecules that flip between a charged and an uncharged form depending on whether it is in the dark (charged) or in the light (uncharged). This behaviour forms the basis of the rechargeable desalination technology. In dark conditions, the molecule, called merocyanine, has both positive and negative charges that pull ions out of salty or contaminated water in just 30 minutes. When exposed to sunlight, the molecule flips to its alternative structure, called spiropyran, losing its charge and releasing the ions that were bound. This sunlight-mediated release can occur in just four minutes.

On its own, this light-sensitive molecule accumulates damage from repeated exposure cycles of light and dark. However, the researchers found that if it is attached to a MOF support that has a high surface area, its stability and performance greatly improves. Scanning electron microscopy at the Microscopy Australia facility at Monash was used to visualise the steps in the development and testing process.

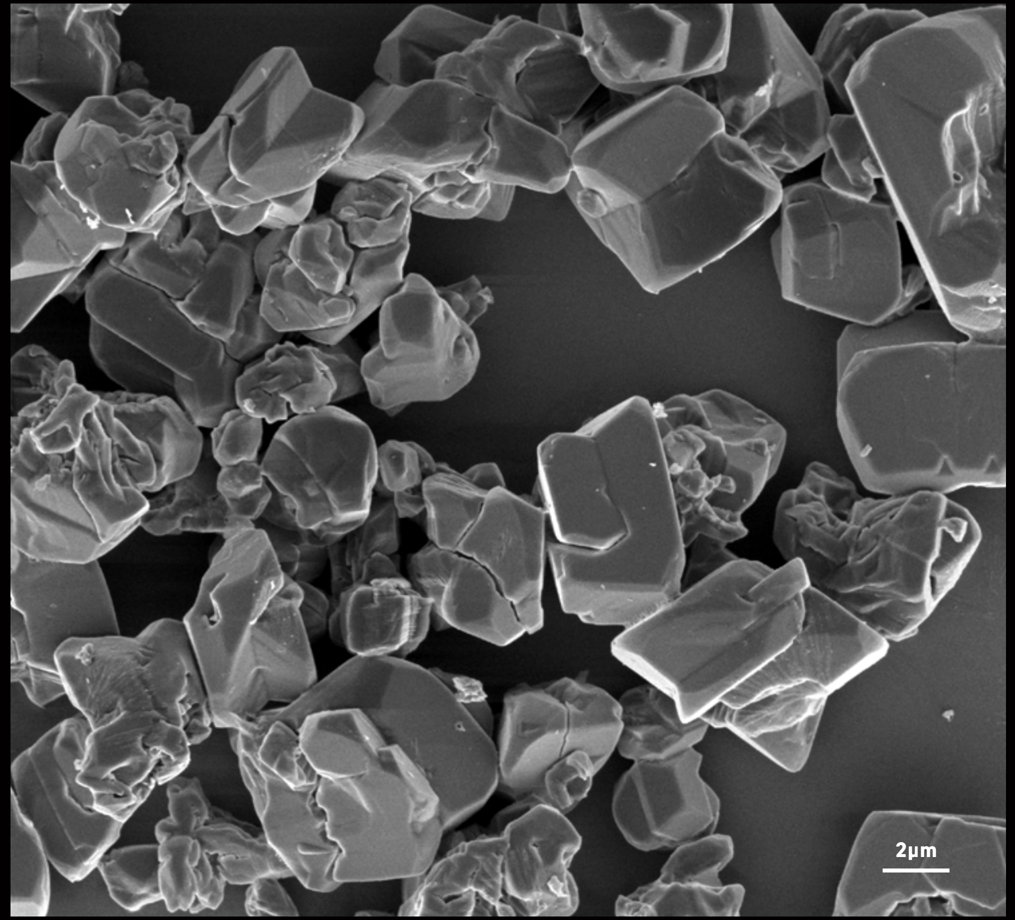
The research team tested the system to show that it is both efficient at desalination and cost effective, making use of natural sunlight to keep the system producing clean water. The system can generate 139.5 litres of clean water per kilogram of MOF per day in a more energy-efficient manner than current methods.

IMPACT

The World Health Organization says that good quality drinking water should have a total dissolved solid (TDS) of <600 parts per million (ppm). This research team was able to achieve a TDS of <500 ppm in just 30 minutes.

This new desalination solution has advantages for deployment across the world where grid energy is unavailable, including remote and rural regions, and emergency situations where safe drinking water can be difficult or impossible to obtain by traditional means.

R. Ou et al. 2020, Nature Sustainability doi:10.1038/s41893-020-0590-x



4 BILLION PEOPLE FACE SEVERE WATER SCARCITY EACH YEAR

SEM image of the MOF ion adsorbing material.
Statistic: M. Mekonnen et al. 2016, Science Advances 2, 2, e1500323

11 BEE VENOM FOUND TO KILL AGGRESSIVE BREAST CANCER

Breast cancer is the most commonly diagnosed cancer in Australian women with one in seven diagnosed by the age of 85. Honeybee venom's major constituent, a short protein called melittin, has been found to selectively kill various types of cancer cells. However, it has not been investigated for breast cancer and the way it works has not really been known.

Now, Pilar Blancafort's team at the University of Western Australia has tested melittin on a range of breast cancer cell types using a wide range of complementary techniques including live-cell confocal microscopy and scanning electron microscopy at our University of Western Australia facility. They found that melittin was able to substantially reduce the chemical messages that drive cancer cell proliferation without damaging normal cells. This effect was strongest in the most aggressive and hardest to treat forms of breast cancer: triple-negative and HER2-enriched breast cancers.

The researchers found that one end of the melittin molecule mediates the cancer killing properties by forming pores in the cancer cells' outer membranes. This disrupts and remodels the membranes. Keeping this pore-forming activity at one end of the melittin molecule, the researchers introduced an additional amino-acid sequence at the other end, which causes the melittin to attach specifically to breast cancer cells, further enhancing melittin's specificity.

Melittin was also found to have another remarkable effect: enhancing the effectiveness of some current drugs used against breast cancer, possibly by facilitating entry to the cells through the melittin-generated pores.

"We found that melittin could be used with small molecules or chemotherapies, such as docetaxel, to treat highly-aggressive types of breast cancer. The combination of melittin and docetaxel was extremely efficient in reducing tumour growth in mice" said lead researcher Dr Ciara Duffy.

C. Duffy et al. 2020, npj Precision Oncology 4, 24
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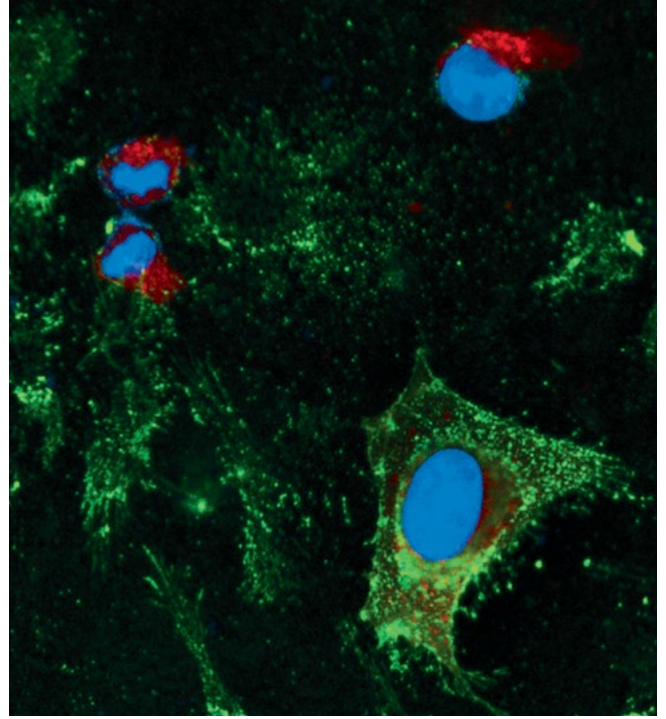
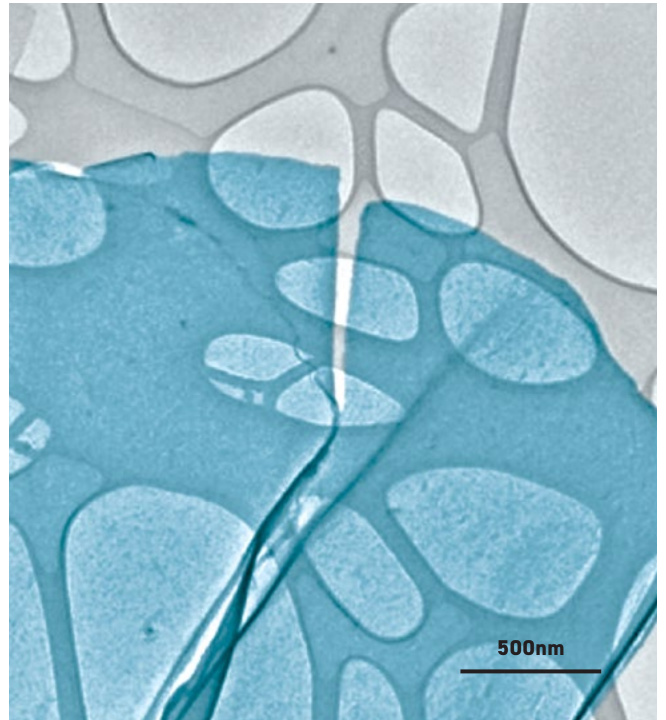
Top: Confocal image of triple-negative breast cancer cells treated with melittin.





12 ATOMICALLY THIN FLEXIBLE ELECTRONICS

An RMIT–UNSW collaboration has made a big step towards future flexible, wearable electronics, and biosensors that draw their power from the body's movements.

Atomically-thin tin monosulfide exhibits strong piezoelectric properties, converting mechanical forces, or movement, into electrical energy. Along with its inherent flexibility, this property has long made it a good candidate for developing flexible nanogenerators that could harvest movement to power wearable electronics or internal, self-powered biosensors.

However, the material has strong interactions between the layers, making production of useable quantities of single, atomically-thin layers of tin monosulphide extremely difficult. A new liquid metal technique developed by Profs Yongxiang Li and Kourosh Kalantar-Zadeh and their team at the FLEET Centre of Excellence at RMIT University, has enabled the production of large scale, homogenous monolayers of tin monosulfide with minimal grain boundaries that achieve record output power from a tin-monosulphide piezoelectric. The stable and flexible sheets can be implemented into a variety of systems for efficient energy harvesting, bringing us one step closer to flexible, wearable electronics.

At our linked laboratory, the RMIT Microscopy and Microanalysis Facility, optical microscopy and high resolution scanning electron microscopy were used to examine the tin-monsulphide sheets during the development of the technique and transmission electron microscopy (TEM) was used to confirm the atomic-scale structure and thinness of the sheets.

H. Kahn et al. 2020, Nature Communications 11, 3449 (2020)

Bottom: Colour-enhanced TEM image of an atomically thin tin sulfide nanosheet (blue).

13

BANDAGES FOR CHRONIC WOUND TREATMENT

World-first, active, coated bandages with the power to attack infection and inflammation could revolutionise the treatment of chronic wounds such as pressure, diabetic or vascular ulcers that won't heal on their own.

The team lead by Dr Thomas Michl from University of South Australia developed the novel coating, by attaching a special antioxidant called TEMPO, to bandages by using plasma polymerisation technology. TEMPO is a stable nitroxide radical that can be applied to any wound dressing so that when the TEMPO-coated bandages meet the wet wound, nitroxides leach out and exert their effects. These nitroxides were found to simultaneously reduce wound inflammation and break up infection to help the wound repair process.

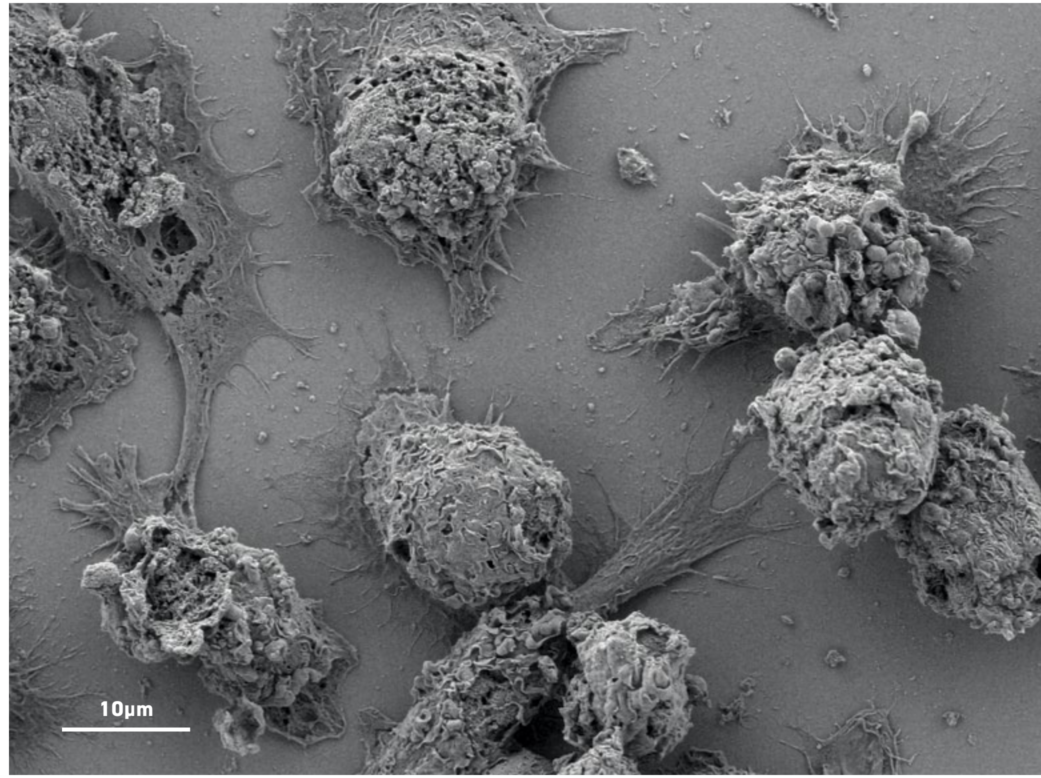
Dr Michl's team used atomic force microscopy, scanning electron microscopy and X-ray photoelectron spectroscopy at our University of South Australia facility to demonstrate that TEMPO could be turned into smooth coatings and to monitor their structure and cellular interactions. The technology is highly scalable and sustainable, making it a viable option for broad application worldwide.

In Australia, nearly half a million people suffer from chronic wounds, costing the health system an estimated AU$3 billion each year. It's a similar picture around the world with more than 5.7 million people suffering from chronic wounds in the United States and more than 2 million in the UK. This is hugely costly to the economy – an estimated US$20 billion per year in the US and £5 billion in the UK.

With growing rates of global obesity, diabetes and an ageing population, chronic wounds are increasingly common, yet until this breakthrough discovery, few treatments have shown such positive results.

"Upgrading current dressings with this state-of-the-art coating will promote effective healing on chronic wounds and reduce patient suffering. Proper care for chronic wounds requires frequent changes of dressings but currently, these wound dressings are passive actors in wound management. Our novel coatings change this, turning any wound dressing into an active participant in the healing process – not only covering and protecting the wound, but also knocking down excessive inflammation and infection. No other method so far has achieved this." Dr Michl says.

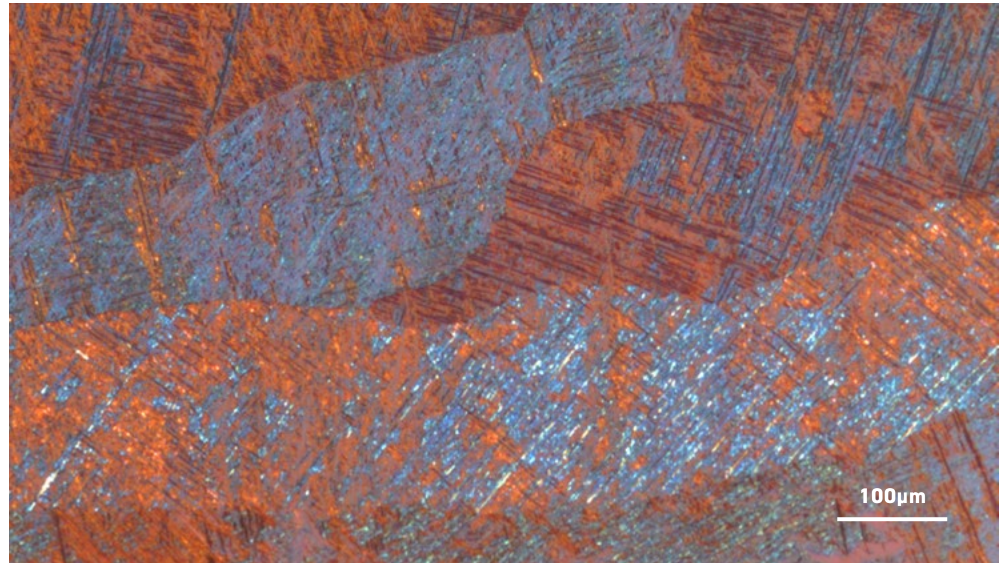
T. Michl et al. 2020, RSC Advances 10, 7368-7376



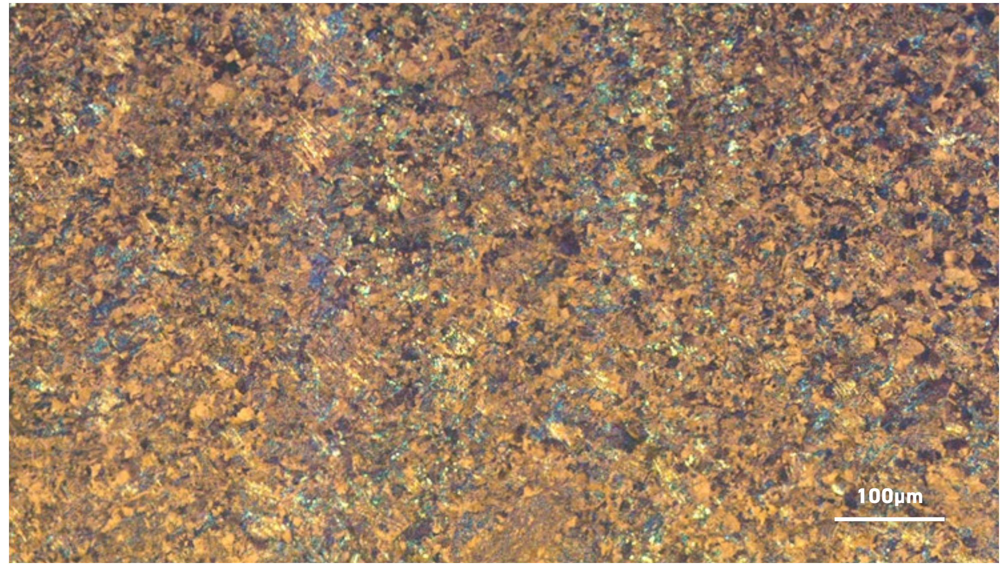
SEM image shows that the immune cells remain unchanged after treatment with TEMPO coating.

14

NOVEL TITANIUM ALLOY FOR 3D-PRINTING



3D printed titanium aluminium alloy.



3D printed novel titanium copper alloy.

CHALLENGE

Additive manufacturing, also known as 3D printing, has been called the third wave of manufacturing and is leading the trend towards mass customisation of manufactured parts. Titanium (Ti) is an exciting material for this kind of fabrication. It is one of the strongest metals in the world, is resistant to rust and corrosion yet remains ductile. It's also expensive. This requires it to have excellent mechanical properties to make it worth using.

Current Ti alloys used in 3D printing cool into column-shaped grains. This leads to different mechanical behaviours in different directions. This can lead to processing difficulties in some alloys, including cracking and distortion.

Left: 3D-printed titanium-copper bars.

RESEARCH

To solve this problem, a team lead by Prof. Mark Easton at RMIT University in collaboration with others at CSIRO, the University of Queensland and Ohio State University has developed titanium–copper (Ti–Cu) alloys that have an ultra fine grain size. The copper facilitates the seeding of new crystals leading to fine grains that grow equally in all directions. This results in a structure that has more homogeneous properties and better processability than current alloys.

Items printed with this new Ti–Cu alloy are as strong or stronger than those produced from current titanium alloys by using traditional manufacturing. The copper is also relatively cheap and easy to use in alloy production and brings antibacterial properties and biocompatibility that could ideally position this alloy for use in bespoke 3D-printed medical implants.

Scanning and transmission electron microscopy along with elemental mapping and light microscopy were used to assess the micro- and nano-structures within the alloys throughout the research process. This was conducted at RMIT Microscopy and Microanalysis Facility, a linked lab of Microscopy Australia and the results have been published in *Nature*.

IMPACT

Strong and more cost-effective titanium alloys will make 3D printing a viable manufacturing method for:

- aerospace and defence applications such as turbine blades, hydraulic systems, armour plating, naval ships, spacecraft, and missiles
- industrial applications such as rotors, compressor blades, hydraulic system components and nacelles
- MRI and CT compatible medical devices and implants, dental implants, surgical tools and wheelchair components
- consumer goods such as sporting equipment, motorcycles, cars, and architectural components.

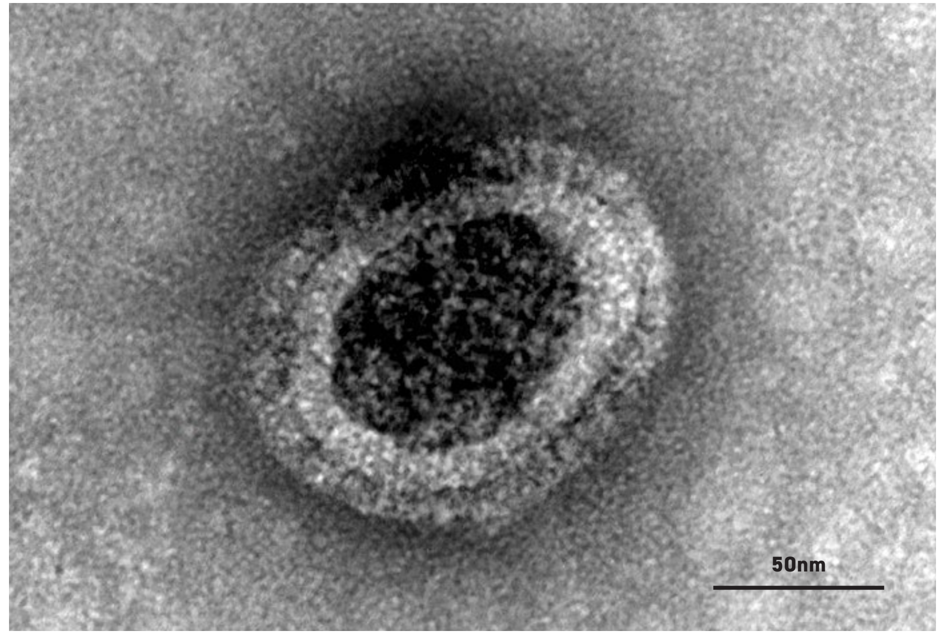
D. Zhang et al. 2019, Nature 576, 91-95

PNEUMOCOCCUS IS THE WORLD'S BIGGEST BACTERIAL KILLER CAUSING MILLIONS OF DEATHS EACH YEAR

Colour-enhanced scanning electron micrograph of pneumococcus, the bacteria that cause pneumococcal pneumonia by Dr Shannon David.

15

FIGHTING THE BIGGEST INFECTIOUS KILLERS



TEM image of an irradiated influenza vaccine particle showing its structure is maintained after inactivation treatment.

CHALLENGE

Streptococcus pneumoniae, or pneumococcus, is the biggest bacterial killer on the planet and accounts for an estimated 1-2 million deaths a year. It's the main cause of pneumonia, meningitis, sepsis, and sinus and ear infections. These are treated with antibiotics, which in turn contribute to antibiotic resistance, one of the biggest threats to global health. Current pneumococcal vaccines only protect against a small subset of the 100 known strains.

Influenza predisposes patients to pneumococcal disease, with very high mortality rates. The influenza virus and pneumococcus worked together to cause up to 100 million deaths during the 'Spanish flu' pandemic of 1918-1919. Despite this well-known synergism, current vaccination strategies continue to target the individual pathogens.

RESEARCH

Dr Mohammed Alsharifi, previously at the Australian National University and now at the University of Adelaide, discovered the potential of gamma-irradiated influenza viruses as universal flu vaccines. Gamma Vaccines Pty Ltd was formed to commercialise this technology, which gives broader protection than the current annual flu vaccines.

In collaboration with Prof. James Paton, the Gamma Vaccines team then developed a gamma-irradiated pneumococcal vaccine that is designed to protect against all 100 pneumococcal strains. GPN Vaccines, a subsidiary of Gamma Vaccines, was established to commercialise this vaccine. Existing pneumococcal vaccines target the outside coat of complex carbohydrates that are unique to each pneumococcal strain. The GPN Vaccines team removed this coat to expose the underlying surface proteins, common to all pneumococcal strains. GPN Vaccines has completed successful preclinical trials and scaled up to clinical grade manufacture of the vaccine ready for a Phase 1 clinical trial in 2021.

Working together, these researchers are continuing to explore the most effective approaches to vaccination and have tested the simultaneous delivery of the influenza and pneumococcal vaccines. In preclinical studies, they found that giving a combination of the two vaccines enhanced the effectiveness of both.

Transmission and scanning electron microscopy (TEM and SEM) at our University of Adelaide facility enabled this work.

IMPACT

- **Building business:** Two companies formed – Gamma Vaccines Pty Ltd in 2009 to commercialise GammaFlu®, and GPN Vaccines Ltd in 2017 to commercialise the broad-spectrum pneumococcal vaccine. GPN Vaccines has raised $7 million in a Series 2 investment round and received a $1 million grant from the SA State Government's Research, Commercialisation and Startup Fund for clinical trials.
- **Creating jobs:** expanding local research and development and supporting Australia's biotechnology ecosystem.
- **Healthier populations:** cost savings to the public healthcare system and reducing the need for antibiotics, and therefore the risk of antibiotic resistance.

S. David et al. 2019, Nature Micro. 4, 1316–1327

16

RECORD EFFICIENCIES IN NEXT-GEN SOLAR TECH

CHALLENGE

The start of 2020 was marred by extreme bushfires and drought. It was a visceral reminder of the future we face if we fail to reduce our carbon emissions. Electricity production is Australia's single largest source of emissions, and also one of the easiest to reduce. We are a country blessed by sun. However, until solar technology becomes more competitive in cost and efficiency it will be hard to justify replacing existing energy infrastructure and the jobs associated with it.

RESEARCH

Australian Universities are leading the world in technical innovation in solar, making it increasingly viable. Here are just three of the many solar projects around the country supported by our microscopy over the past year. The researchers have produced record solar efficiencies using novel technologies.

A research team led by Prof. Lianzhou Wang at the University of Queensland has set a world record for the conversion of solar energy to electricity by using nanoparticles called 'quantum dots'. Unlike the stiff and brittle silicone wafers that are used in common household solar panels today, quantum dots are both flexible and printable. This gives them the potential to be made into transparent films that could be applied to everything from cars, planes and buildings to wearable electronics. They also have greatly improved performance compared to traditional solar cells in cloudy, wet and low light conditions, even indoors.

Squeezing more energy out of sunlight is another approach to increasing the efficiency of solar cells. In a world first, researchers led by Prof. Tim Schmidt from UNSW Sydney, along with global collaborators, have been able to 'upconvert' low energy light into higher energy light by using oxygen and quantum dots. Currently, silicon solar cells can only capture frequencies of near infrared or higher. The research team used semiconductor quantum dots to absorb the lower energy light, and molecular oxygen to transfer that energy to organic molecules, where it accumulates and can then be re-emitted in the visible spectrum where it can be captured by the silicon. This discovery could significantly improve the efficiency of silicon solar cells, the most widespread solar cell type in production. It would also improve charge-coupled device cameras and photodiodes.

Researchers at the Australian National University and Flinders University, led by Prof. Kylie Catchpole have also set a world record for the capturing more of the sun's energy, this time by using perovskite–silicon 'tandem solar cells'. These stack newer generation perovskite solar cells on top of silicon solar cells. Perovskite is efficient at converting the blue portion of sunlight into electricity while silicon converts mostly the red portion. This achieves significantly higher efficiency than either cell could achieve on its own. They achieved an efficiency of 27.7%. At the moment, typical solar panels being installed on rooftops have an efficiency of 20%.

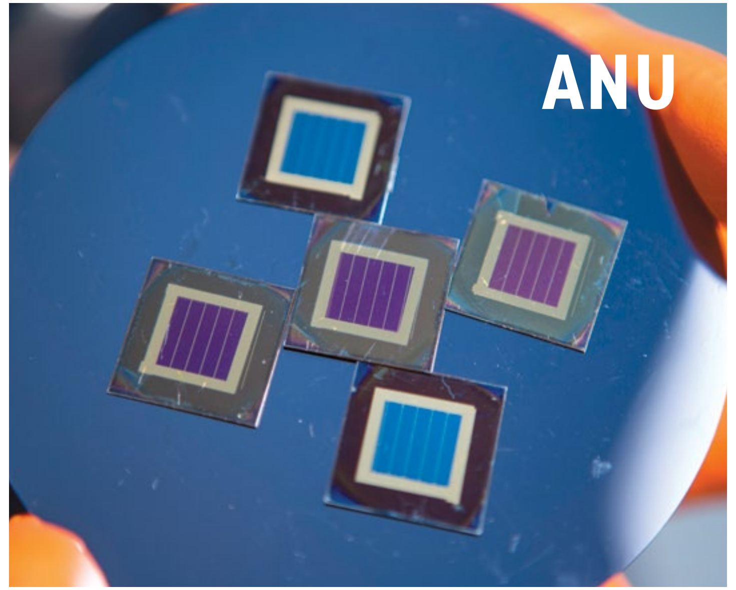
IMPACT

- Reduced carbon emissions
- Increased solar reliability and efficiency – production of electricity in low light makes solar an increasingly viable option for large scale energy production
- Reduced energy transport costs – transparent, flexible solar skins significantly increase the amount surface area available for energy production, particularly in cities

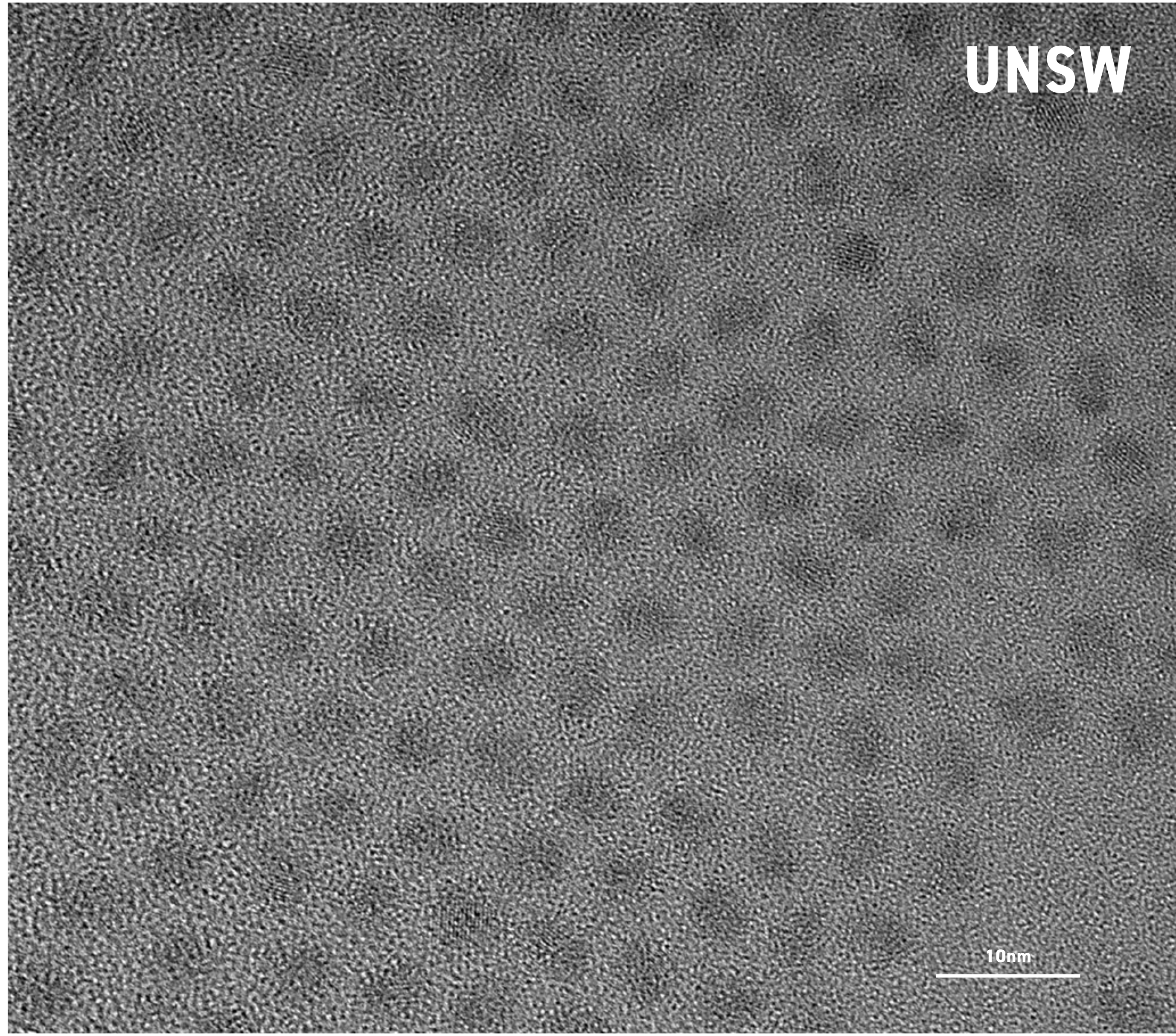
M. Hao et al. 2020, Nature Energy 5, 79–88(2020)

E. M. Gholizadeh et al. 2020, Nature Photonics 14, 585–590

T. Duong et al. 2020, Advanced Energy Materials 10, 9, 1903553



Top: Prof. Lianzhou Wang with the solution of quantum dots.
Bottom: Perovskite–silicon tandem solar cells.



Tranmission electron microscope image of quantum dots taken at our UNSW Sydney facility by Dr Soshan Cheong.

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Right: Scanning electron micrograph of the anther of an Arabidopsis flower by Ryan P. McQuinn assisted by Dr Hua Chen at our Australian National Univeristy facility.

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