ammrf
Australian
Microscopy & Microanalysis
Research Facility

PROFILE

2012

expertise
excellence
efficiency

Our vision

The AMMRF is Australia's peak research facility for the characterisation of materials through macro, meso, nano and atomic length scales by means of advanced microscopy and microanalysis.

Our mission

The AMMRF is a user-focused, interdisciplinary organisation that employs microscopy and microanalysis to explore structure–function relationships of materials in the physical, chemical and biological sciences and their technologies. Accessible to all Australian researchers, the facility provides a quality user experience enabled through the provision of world-class research services, research training and research programs.

FOUNDING NODES

The University of Sydney

UNSW The University of New South Wales

Australian National University

The University of Western Australia — Achieve International Excellence

The University of Queensland Australia

SOUTH AUSTRALIAN REGIONAL FACILITY (SARF)

The University of Adelaide

University of South Australia

Flinders University

FUNDED BY

An Australian Government Initiative

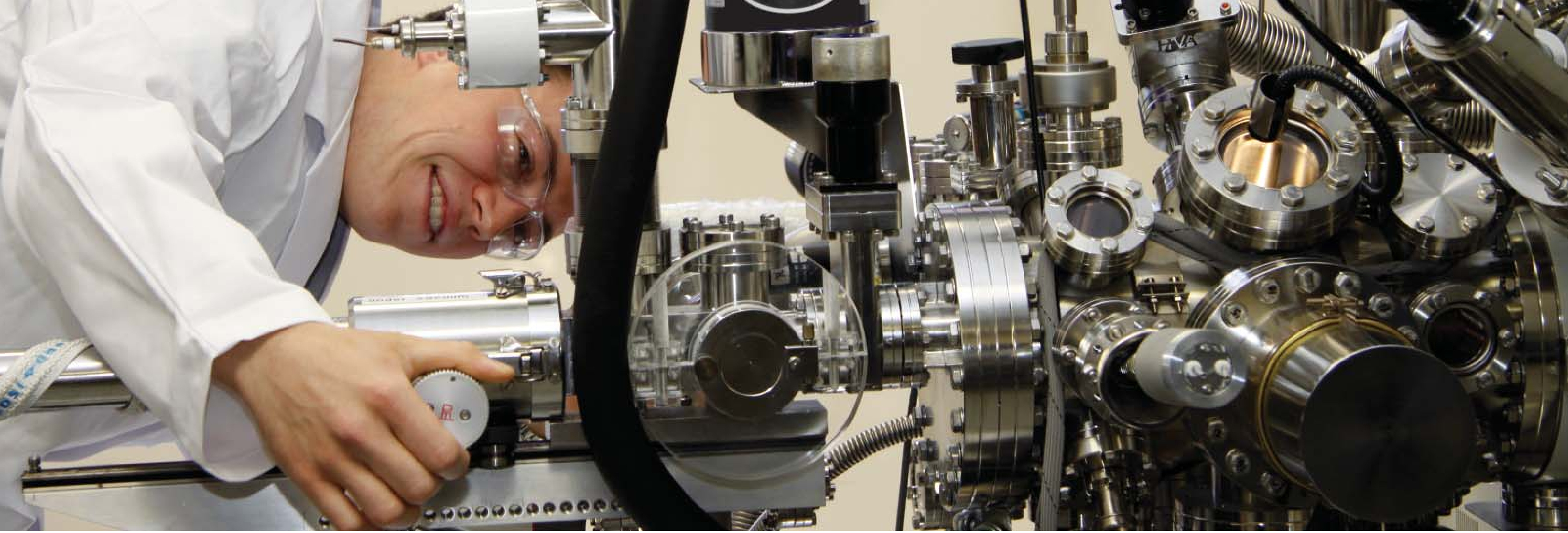
National Collaborative Research Infrastructure Strategy

NSW Government

Queensland Government

Government of South Australia

The Government of Western Australia



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Australian
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from the minister

The Gillard Government recognises the value of research and its role in keeping Australia competitive and innovative.

Australian researchers and scientists are behind some of the world's most well known scientific developments – the GPS, WiFi, penicillin, the cochlear implant. Research done here at home can have a huge impact right around the globe.

The AMMRF is a fundamental part of our national research effort. This vital collaborative facility is driving discovery through microscopy and microanalysis – technology that underlies much of Australia's scientific and industrial research.

The facility enables our researchers to find innovative answers to important global challenges and seize technological opportunities. I have no doubt that the results emerging from the AMMRF will continue to drive innovation for the benefit of the broader economy and the nation as a whole.

Senator the Hon. Chris Evans

Minister for Science and Research

from the chair

In June the AMMRF completed its fifth year of operation. Combined with its predecessor, the NANO Major National Research Facility, the milestone marks ten years of national and collaborative microscopy and microanalysis research infrastructure. The Board and I are proud of the achievements of the AMMRF as it continues to enable excellent research outcomes for more than 3000 users annually.

Our international networks are also expanding. Formal links are now in place with Euro-BioImaging and with EMBL Australia. These connections provide opportunities for sharing the success of our collaborative structure with other countries where these concepts often exist only as a sought-after ideal. International visitors are invariably impressed with our thriving infrastructure and the efficiencies that it brings to Australian science.

Our research and technical expertise remains at the forefront of the global microscopy community and contributes to the advancement of sophisticated characterisation techniques. These provide an important driver to progress in new and pressing academic and industrial research areas. For example, the AMMRF's ion probe capability at the University of Western Australia has recently joined the Network of Analytical Laboratories of the International Atomic Energy Agency allowing it to play a key role in regional and world security.

As custodians of this national resource, demonstrating to the Australian public our impact on research is an important aspect of our outreach. Incredible Inner Space continues its journey around Australia, exhibiting 28 images created using AMMRF instruments. I hope you get to see it soon.

I am enthusiastic about our impact on the Australian research landscape and hope that you will be too as you read these pages.

Dr Gregory R. Smith
Chair of Board

from the ceo

I take great pride in the substantial impact that the AMMRF is having on research in this country. You only need to read the pages of this Profile to see the scope of the projects enabled by our infrastructure. The AMMRF continues to support research through the provision of sophisticated microscopy, microanalysis and expertise and aims to meet the needs of Australian researchers into the future in their ever-growing portfolio of projects.

Long-term projects are going from strength to strength on the basis of access to our fundamental enabling infrastructure. These span the academic and industry spheres and you will see some examples highlighted in this Profile. Prof. Rob Parton's work on caveolae and the development and success of spin-off company Digitalcore illustrate how bodies of work develop and blossom over years, the more so for having our supportive infrastructure behind them. Many would not be at the forefront of world research without the AMMRF capability.

Additional stories provide snapshots of research projects studying ways of improving food and tools, measuring environmental impacts, addressing water contamination and finding more effective ways of delivering drug treatments. There will certainly be innovative developments in new stroke treatments and in art conservation to save precious paintings. BlueScope Steel's Linkage project is another long-term success with progress and outcomes reported in these pages.

The breadth of research that relies on microscopy and microanalysis can be hard to imagine and I hope that this Profile helps to illuminate some of this diversity.

Prof. Simon P. Ringer
Executive Director & CEO

collaboration

Our Organisational Structure

Established under the Commonwealth Government's National Collaborative Research Infrastructure Strategy (NCRIS), the AMMRF is a national grid of equipment, instrumentation and expertise in microscopy and microanalysis that makes nanostructural characterisation capabilities and services available to the entire Australian research community.

Activities of the AMMRF are overseen by a board composed of an independent chair and the deputy vice-chancellors in charge of research (or their nominees) from the participating universities, plus the AMMRF Executive Director and CEO. The operations team, comprising the node directors and General Manager, meets regularly and reports to the board.

NODES

Nodes are major university-based microscopy and microanalysis centres collaborating to form the core of the AMMRF. They have a wide range of overlapping and complimentary instrument types and expertise, collectively providing infrastructure for high-demand and cutting-edge techniques.

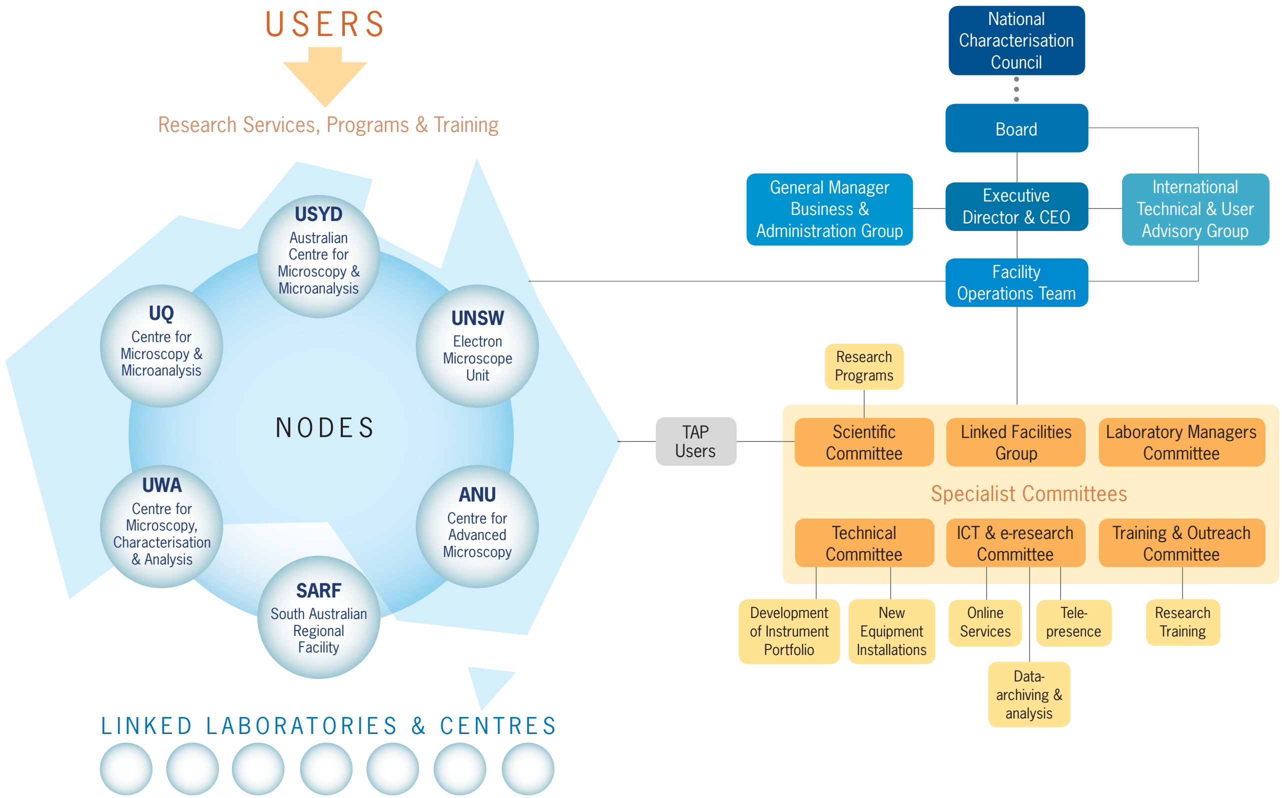
LINKED LABORATORIES

A Linked Lab provides access to specialist instruments within the university sector or within a publicly funded research agency.

LINKED CENTRES

A Linked Centre is established in conjunction with a concentration of specialist users based at a major research centre. Each centre has a dedicated microscopist.

For a full list of node, lab and centre contact details please see p.36 or visit our website: ammrf.org.au



BOARD MEMBERS

Dr Gregory R. Smith, Chair

Prof. Alan Lawson
University of Queensland

Prof. Jill Trewhella
University of Sydney

Prof. Laurent Rivory (acting)
University of New South Wales

Prof. Jim Williams
Australian National University

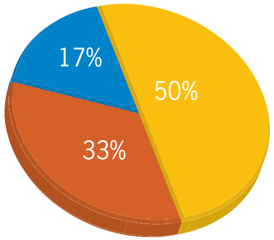
Prof. Tony O'Donnell
University of Western Australia

Prof. David Day
Flinders University

Prof. Simon Ringer
University of Sydney

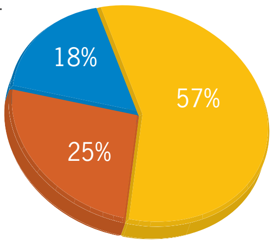
AMMRF 2011–12

TOTAL USERS
Total: 3083
By discipline:

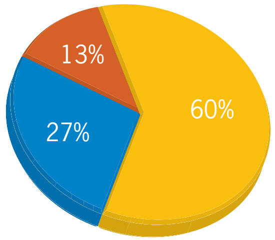


Physical/Materials Science
Biological/Medical Science
Environmental Science/Geoscience

INSTRUMENT HOURS
Total: 222 471
By discipline:



USERS FROM INDUSTRY
Total: 88
By sector:

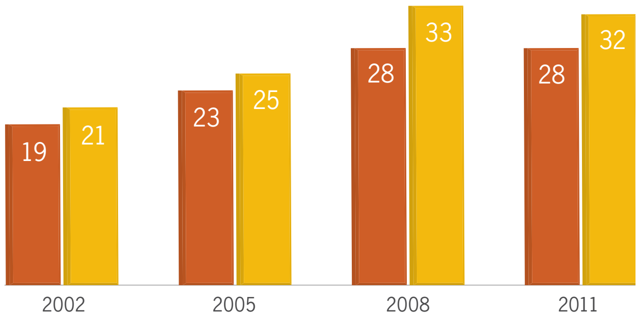


Manufacturing
Biomedical
Environmental/Resources

A decade of research excellence

% OF USER PUBLICATIONS in journals ranked A* or A
according to the ERA 2010 analysis

A* Journals
A Journals



Ten years of investment in national microscopy and microanalysis infrastructure has increased the quality of resulting publications.

International Connections

Mr Herman Nackaerts, Deputy Director General of the IAEA, signing the agreement with UWA (represented by the Vice Chancellor, Prof. Paul Johnson)

Strategic international connections ensure that we maintain a leading position in world microscopy. They allow us to understand developing technical trends and how they can be best used to address emerging global issues in research. A practical way to keep up to date in these areas is through our International Technical and User Advisory Group (ITUAG), a panel of the world's leading microscopists.

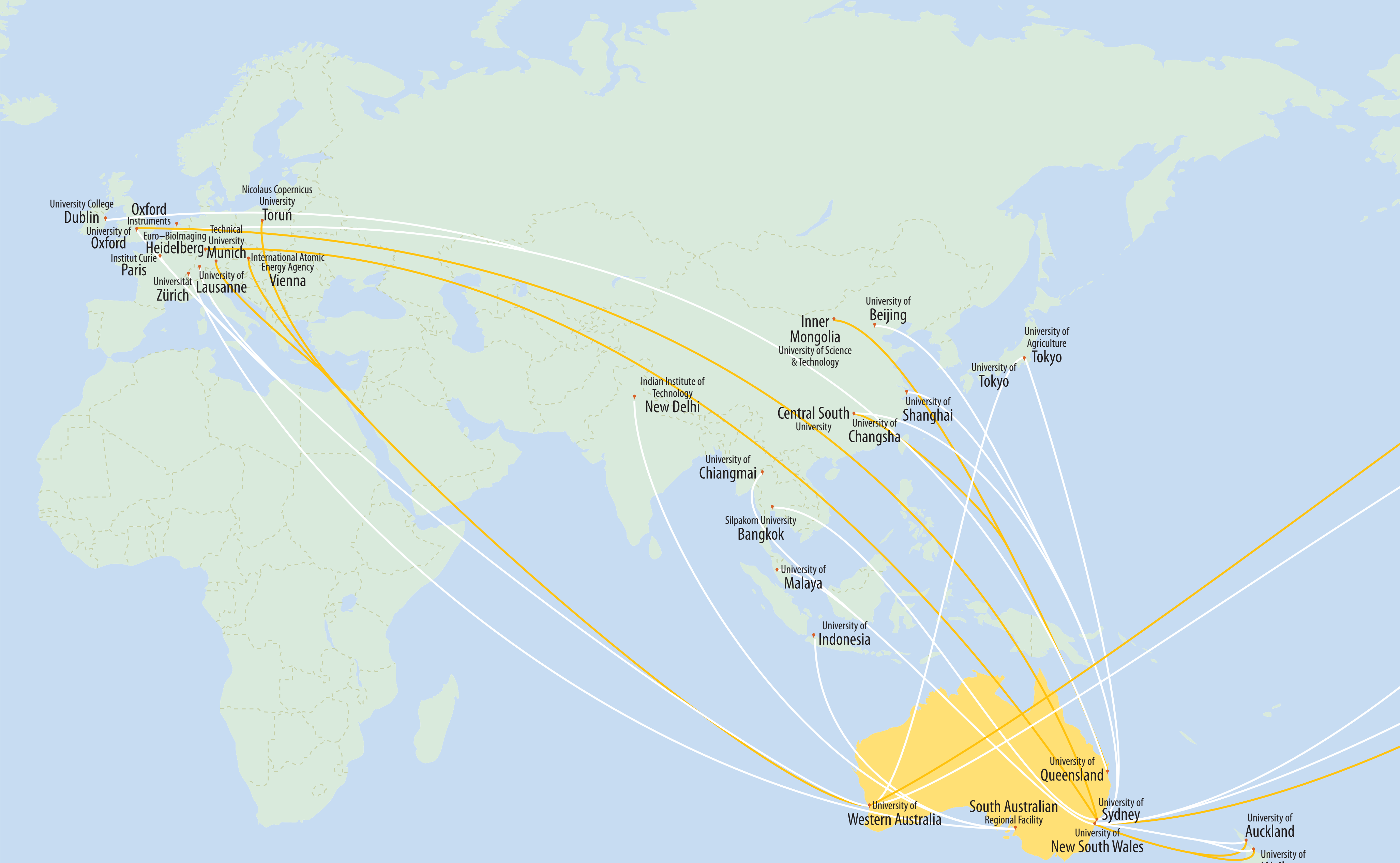
Formal frameworks are now in place with Euro-BioImaging and the European Molecular Biology Laboratory (EMBL) Australia. As Euro-BioImaging, a large, pan-European network of microscopy and imaging facilities, continues in its preparatory phase, the AMMRF is able to provide valuable guidance and experience about the creation and operation of collaborative research infrastructure networks. AMMRF users in Australia will benefit from access to enhanced bioimaging capability in Europe and Australia.

The International Atomic Energy Agency (IAEA) maintains a network of analytical labs that monitor samples from areas suspected of undisclosed use of nuclear materials from the nuclear fuel cycle. After stringent testing and certification the Flagship 1280 ion probe capability at the University of Western Australia has recently become a part of this network and will begin to play its part in monitoring global nuclear safeguards.

EURO-BIOIMAGING

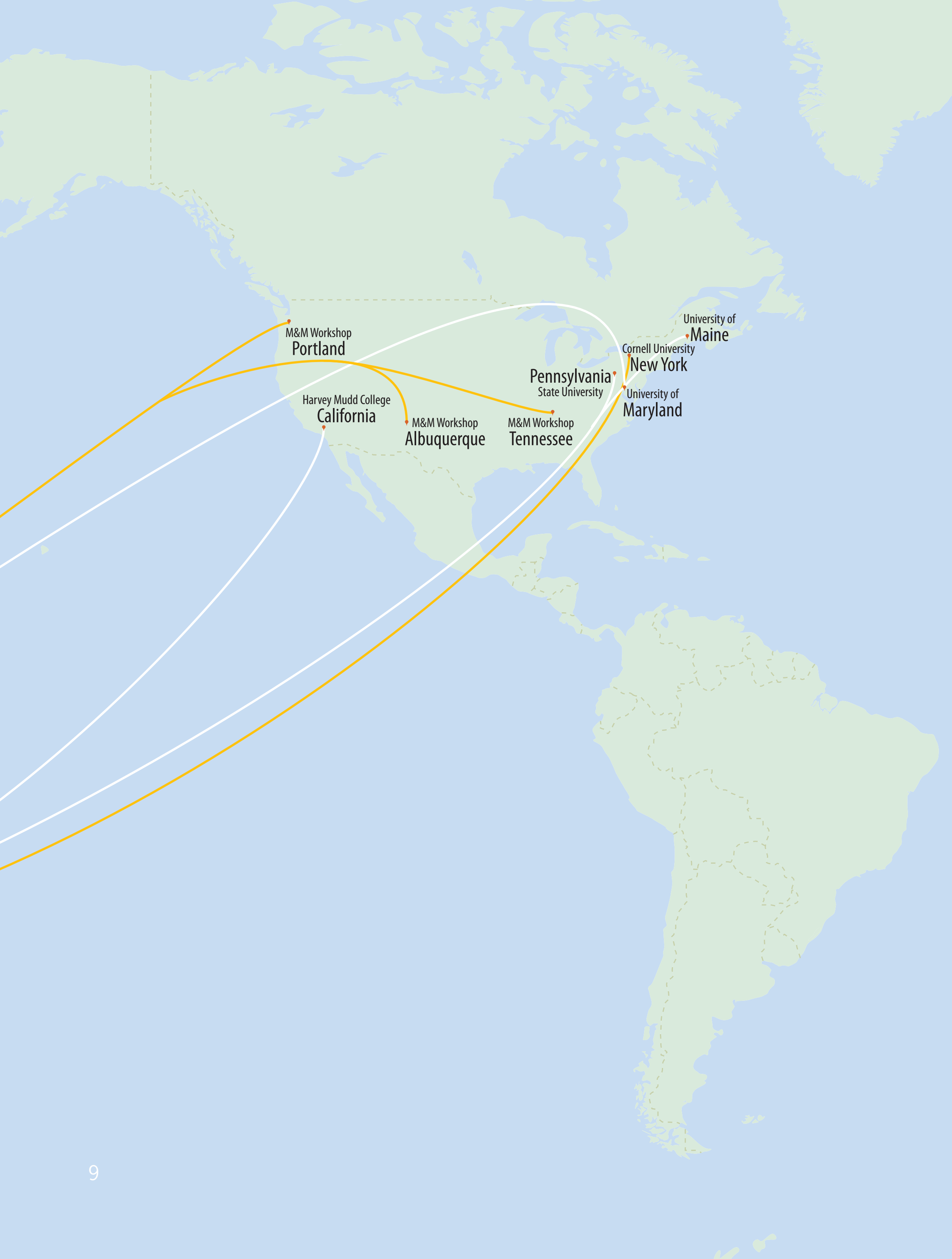
EMBL Australia

collaboration



EXPERTISE IN DEMAND

- Visitors welcomed to learn from the AMMRF
- AMMRF staff invited to share expertise



International Impact

More than a collection of instruments, the AMMRF is a well of expertise that is in high demand. Global infrastructure collaboration often underlies scientific discovery, just as the outcomes often have global impact.

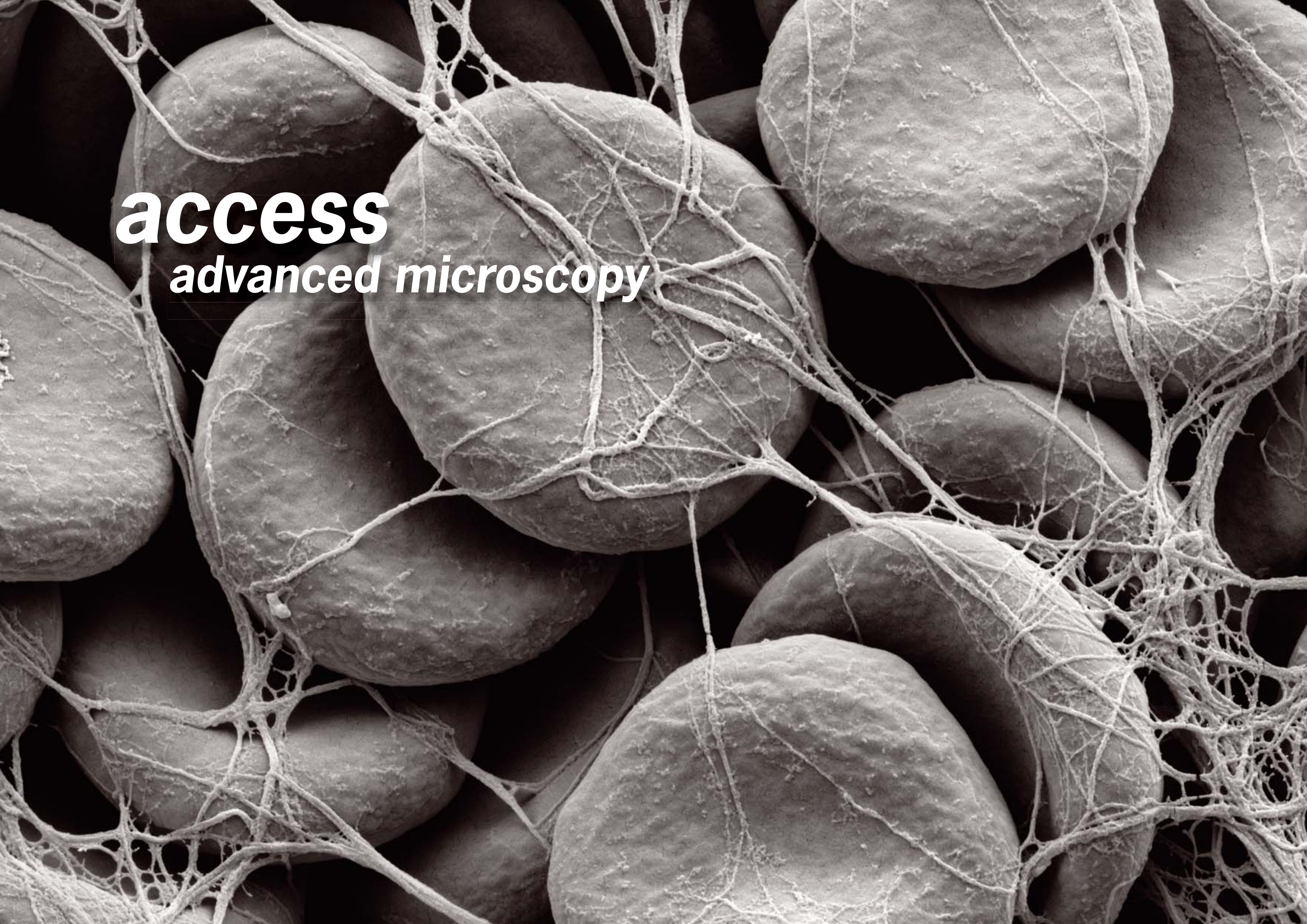
Visitors seeking expertise at our nodes are shown in white lines on the map. AMMRF experts invited to share their knowledge are shown in gold. Our staff also work with instrument manufacturers to develop new commercially available technologies, enabling scientific research worldwide. We highlight more detailed examples below:

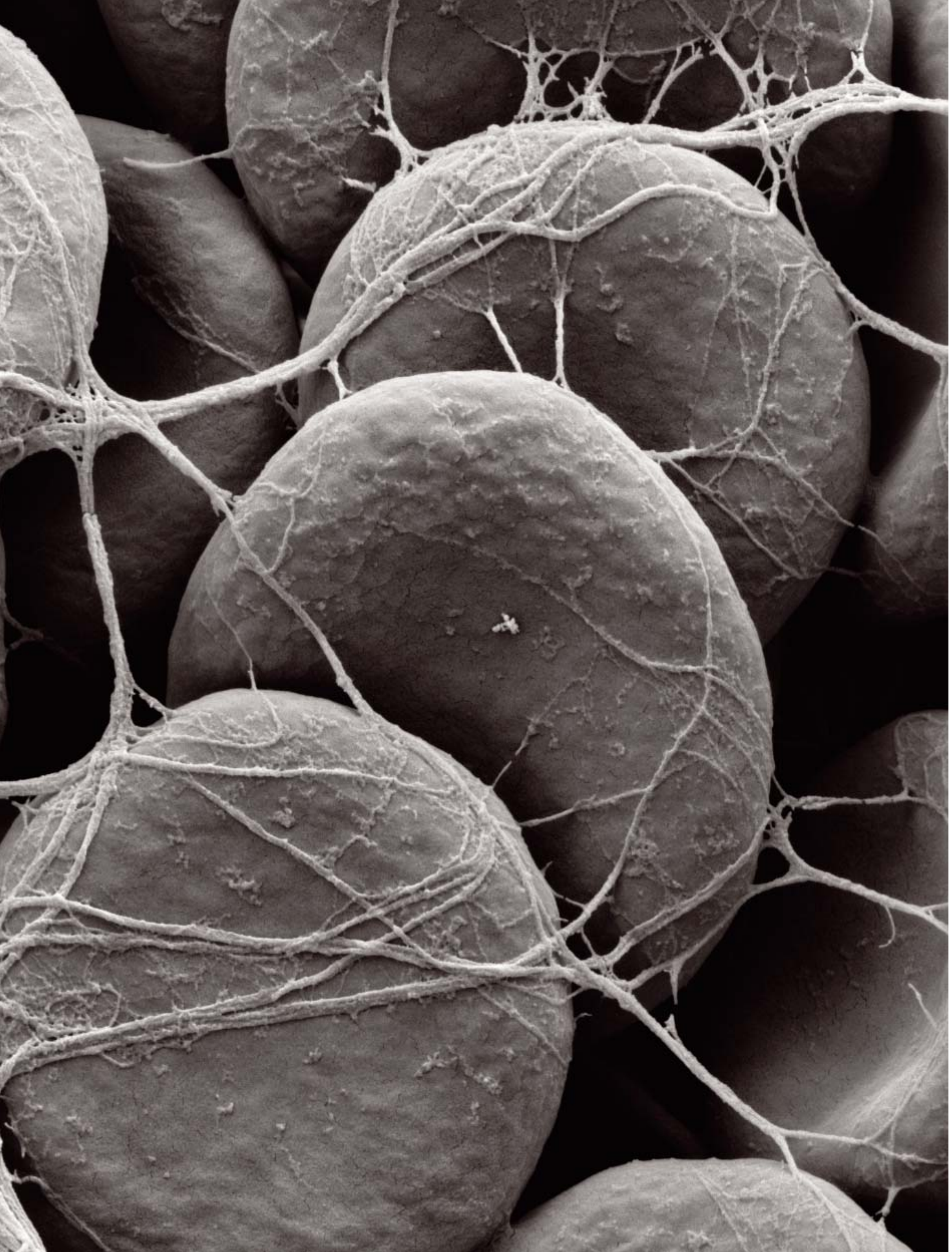
Dr Ian Reid, University College Dublin is setting up a cryo-electron microscopy lab in Ireland. He won a travel fellowship to visit the University of Queensland node and learn firsthand about what is required to manage, optimise and maintain such a facility.

Dr Ken-ichi Kobayashi, Tokyo University of Agriculture came to the University of Sydney node for a year to learn correlative light and electron microscopy techniques.

Prof. Paul Munroe, University of New South Wales has been appointed as a visiting professor at the University of Malaya where he has taught courses on nanometric characterisation using transmission electron microscopy.

Dr Patrick Trimby, University of Sydney was invited to assist Oxford Instruments in the development of software for EBSD, specifically for transmission Kikuchi diffraction in the SEM.


access
advanced microscopy



Australian
Microscopy & Microanalysis
Research Facility

Our facility comprises nearly 300 instruments run by expert staff supporting over 60 different microscopy techniques. They enable finely tailored experimental approaches to diverse research questions.

Our users are supported through all aspects of their project, from the original idea to planning, training, data collection and analysis, through to writing papers and grant applications.

Available to all Australian researchers on the basis of merit, our facility also enables innovation through partnerships with industry and through international collaborations.

advanced microscopy

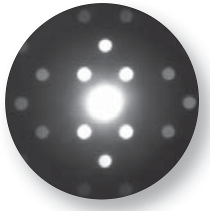
EXPERTISE, EFFICIENCY, EXCELLENCE

Our collaborative facility brings together specialised resources efficiently. The range of our instruments and techniques expands in response to the demands of the Australian research community and international technological trends.

New instruments, research environments and techniques help researchers address issues of our time such as obesity, cancer, sustainable energy and clean water.

Techniques developed as a direct result of our expertise continue to emerge. Through incorporation into commercially available instruments and services, these innovations bring benefits to researchers worldwide.

At the heart of our collaborative infrastructure are flagship instruments. These are world-class platforms, many of which are unique in Australia, and each is supported by a dedicated engineer. Research outcomes from these instruments are flagged.

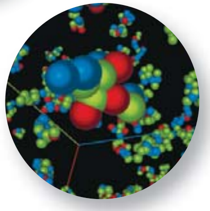


Transmission Electron Microscopy

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

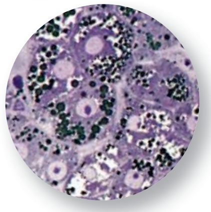
Specimen Preparation

Biological & Materials
Cell Culturing & Molecular Preparation
Thermomechanical Processing



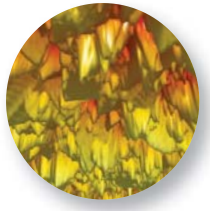
Advanced Ion Platforms

Nanoscale Mass Spectroscopy
Atom Probe Tomography
Ion Milling & Machining
Ion Implantation



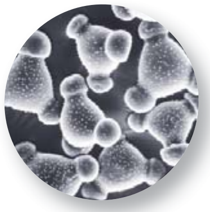
Light and Laser Optics

Confocal, Fluorescence & Optical Microscopy
Flow Cytometry & Cell Sorting
Live-cell Imaging
Vibrational & Laser Spectroscopy
Laser Microdissection



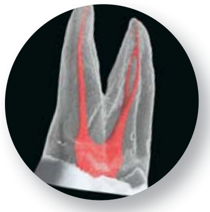
Scanned Probe Techniques

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



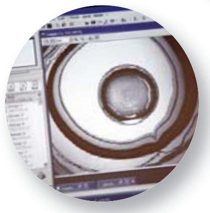
Scanning Electron Microscopy

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



X-ray Technologies

X-ray Diffraction
X-ray Fluorescence
X-ray Micro- and Nanotomography



Visualisation and Simulation

Computed Spectroscopy
Computed Diffraction
Image Simulation & Analysis
Data Mining

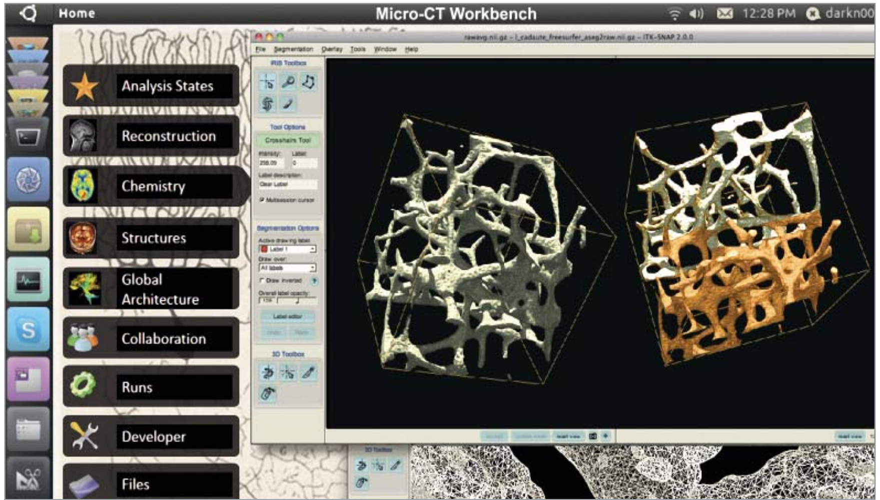
e-research

FUTURE TOOLS: CHARACTERISATION VIRTUAL LABORATORY (CVL)

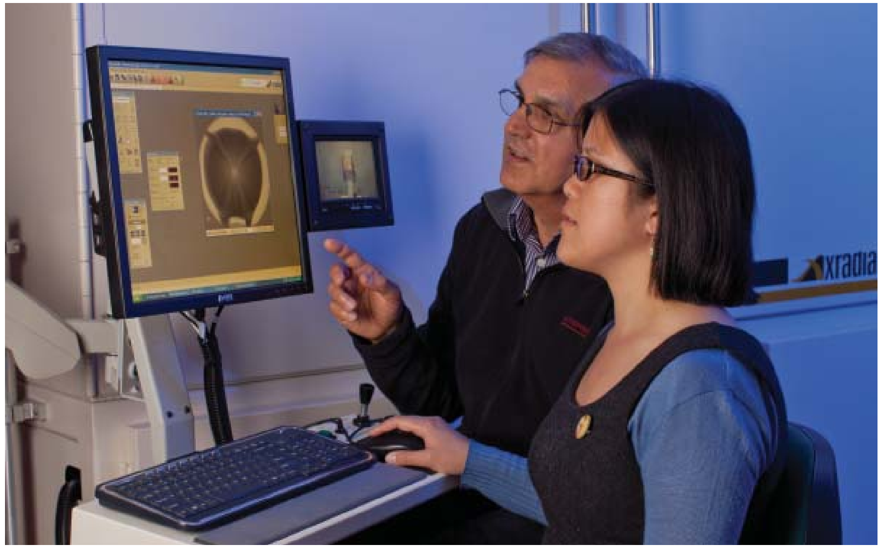
The CVL will be a cloud-based eResearch environment for analysis and visualisation of multi-modal and multi-scale data. It is being driven largely by the fields of neuroimaging, structural biology and energy materials. By integrating existing analysis and visualisation tools with high-performance computing and data storage facilities, it will facilitate research collaborations.

Development of the CVL has begun with the AMMRF developing specialised 'workbenches' in the areas of atom probe tomography and X-ray microtomography. These virtual workbenches will allow users to analyse, visualise and manage their data.

Our nodes at the Australian National University and the University of Sydney have partnered with Monash University and several other institutions to develop the CVL as part of the National eResearch Collaboration Tools & Resources (NeCTAR) project. NeCTAR is part of the Super Science initiative and financed by the Education Investment Fund (EIF).



Above: draft user interface design for the CVL workbench currently under development.



TECHNIQUE FINDER

An online tool to help you identify the appropriate microscopy techniques, instrument location and staff to answer your research questions. Our experts will guide you through the planning, training, data collection and interpretation stages of your experiment.

MYSCOPE

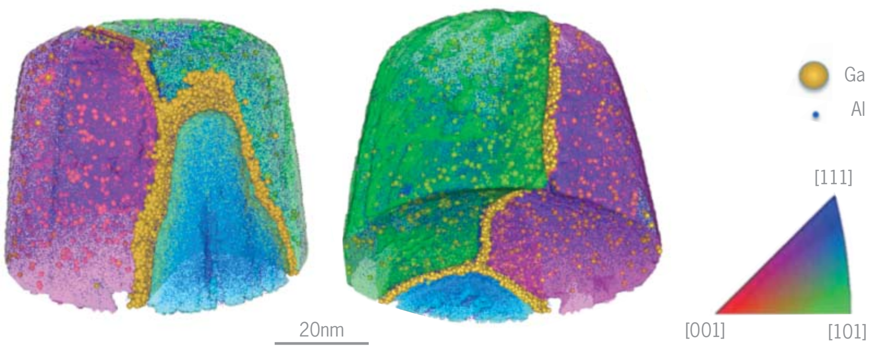
This innovation in training for advanced research provides e-learning modules that help new users progress on our sophisticated instruments.

Integrating with traditional learning environments, each module has an interactive virtual instrument, step-by-step instructions and a range of additional resources. This provides a flexible, individual learning path that prepares trainees for intensive one-on-one instruction. Better-prepared trainees improve efficiency and access to the instruments in the AMMRF nodes.

MyScope is available 24/7 online, free of charge to everyone. It enhances the wide range of training opportunities offered by the AMMRF.

To access our online tools and explore our new website, visit ammrf.org.au

ATOMIC-SCALE 3-D ORIENTATION MAPPING IN THE ATOM PROBE



A reconstructed volume of a nanocrystalline aluminium sample with gallium atoms (gold spheres) segregated to the interfaces. The colours of the grains represent the crystal orientation according to the pole figure provided.

A/Prof. Julie Cairney and Mr Vic Araullo-Peters in the AMMRF at the University of Sydney have demonstrated for the first time a powerful new technique to measure and map the orientation of the crystalline structure of matter at the nanoscale in 3-D by using atom probe microscopy.

Directional differences in spatial resolution of atom probe data have made orientation difficult. However, modern detectors now make it possible to distinguish at least three crystallographic planes due to density variations in atom probe data. This is sufficient information to determine the orientation of the grain. 3-D Hough transforms coupled with fast Fourier transforms are used to obtain crystallographic plane orientations. This technique is highly automated, with the potential to examine large datasets rapidly.

This combination of quantitative 3-D measurement of composition and crystal orientation at the atomic scale is a powerful new tool in materials science.

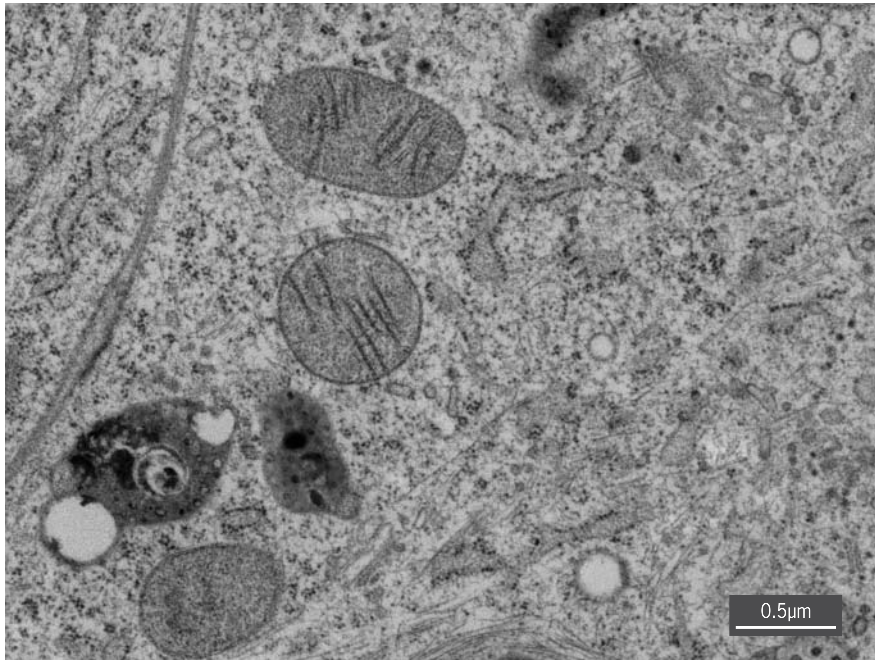
Vicente Araullo-Peters et al., *Scripta Materialia*, 66 (11), 2012

FASTER PREPARATION OF BIOLOGICAL SAMPLES FOR ELECTRON MICROSCOPY

Low temperature techniques are used in order to prevent the structural artefacts that occur with standard fixation and dehydration during biological sample preparation for electron microscopy (EM). A widely used technique involves rapid freezing of the sample in a high-pressure freezer and subsequent freeze substitution. This involves leaving the sample in a solvent at low temperatures, usually –80°C to –90°C for several days. It was assumed that this was necessary for the solvent, usually acetone, to fully replace the ice within the sample.

Mr Rick Webb from the AMMRF at the University of Queensland and Dr Kent McDonald from the University of California, Berkeley, have been working together to shorten this procedure. Their new protocols can be completed in less than three hours or even 90 minutes in the case of single-celled samples, such as bacteria and tissue culture cells. Extensive testing has shown that the new protocols are likely to work for all biological samples. In some cases results may actually be better than from the longer procedures. Combined with subsequent processing in a microwave oven it is now possible to complete the full processing of a biological sample for EM within one day, compared to a week or more previously.

The technique is now commercialised as a kit by Electron Microscopy Sciences, probably the biggest EM supply company in the world.

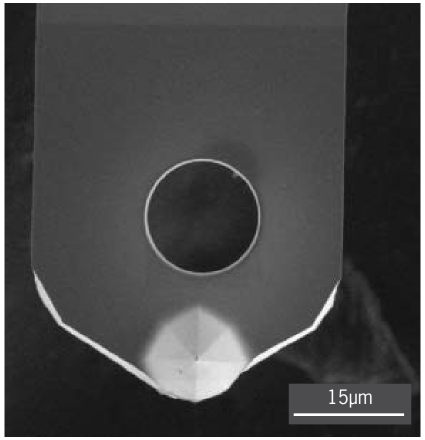


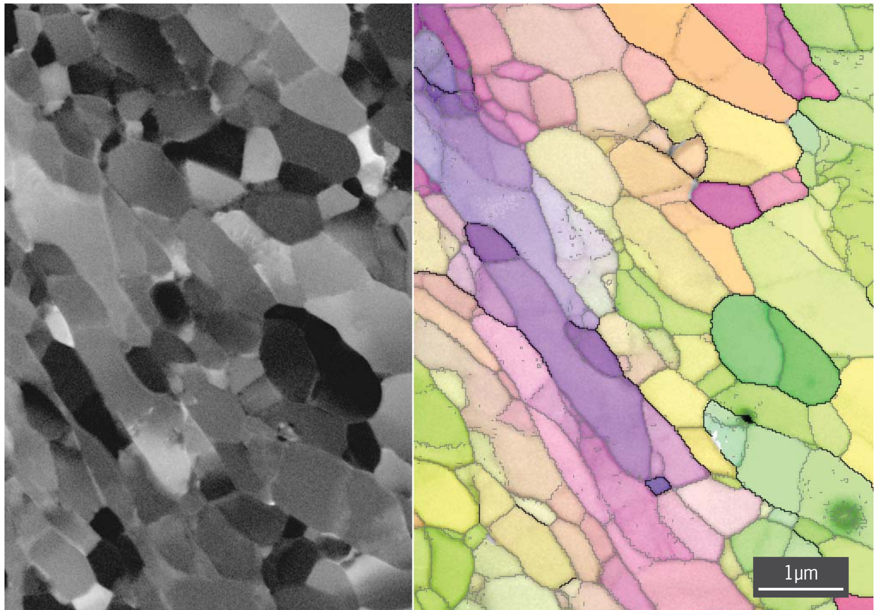
TEM image of a cultured kidney cell prepared using the new, quick technique.

MORE ACCURATE AFM

Accurate knowledge of the cantilever spring constant in atomic force microscopy (AFM) is critical in determining adhesive forces, mechanical properties of samples and in the reliable reproduction of measurements. Manufacturers' values are a guide only having errors of up to 50%. Calibration of the spring constant is difficult due to the small size of AFM cantilevers; they are only 80 to 200 micrometres in length. One approach to calibration involves loading the cantilever with micrometre-sized spheres and measuring the natural resonant frequency of the cantilever before and after the sphere's addition. The major disadvantage of this technique is that it is destructive since the sphere usually has to be glued to the cantilever. Dr Chris Gibson and colleagues in the AMMRF at Flinders University developed an improved technique where small, defined volumes of material are removed from the cantilever by using focused ion beam microscopy, in this case in the AMMRF at the University of Adelaide. The advantage of their method is that as long as the mass removed was small then the mechanical properties of the cantilever were not changed and the probe remains functional. They also showed that this method is one of the most accurate available, greatly improving the accuracy of AFM measurements.

Ashley Slattery et al. *Nanotechnology* 23, 2012





Oriented dark field technique of a deformed Al-Sc alloy collected using a conventional EBSD forescatter detector (left) and SEM-TKD orientation map (right).The field of view is approximately 5 um across and in the SEM-TKD image, the step size is 20nm. Sample and data courtesy of Katja Eder.

TRANSMISSION KIKUCHI DIFFRACTION IN THE SEM (SEM-TDK)

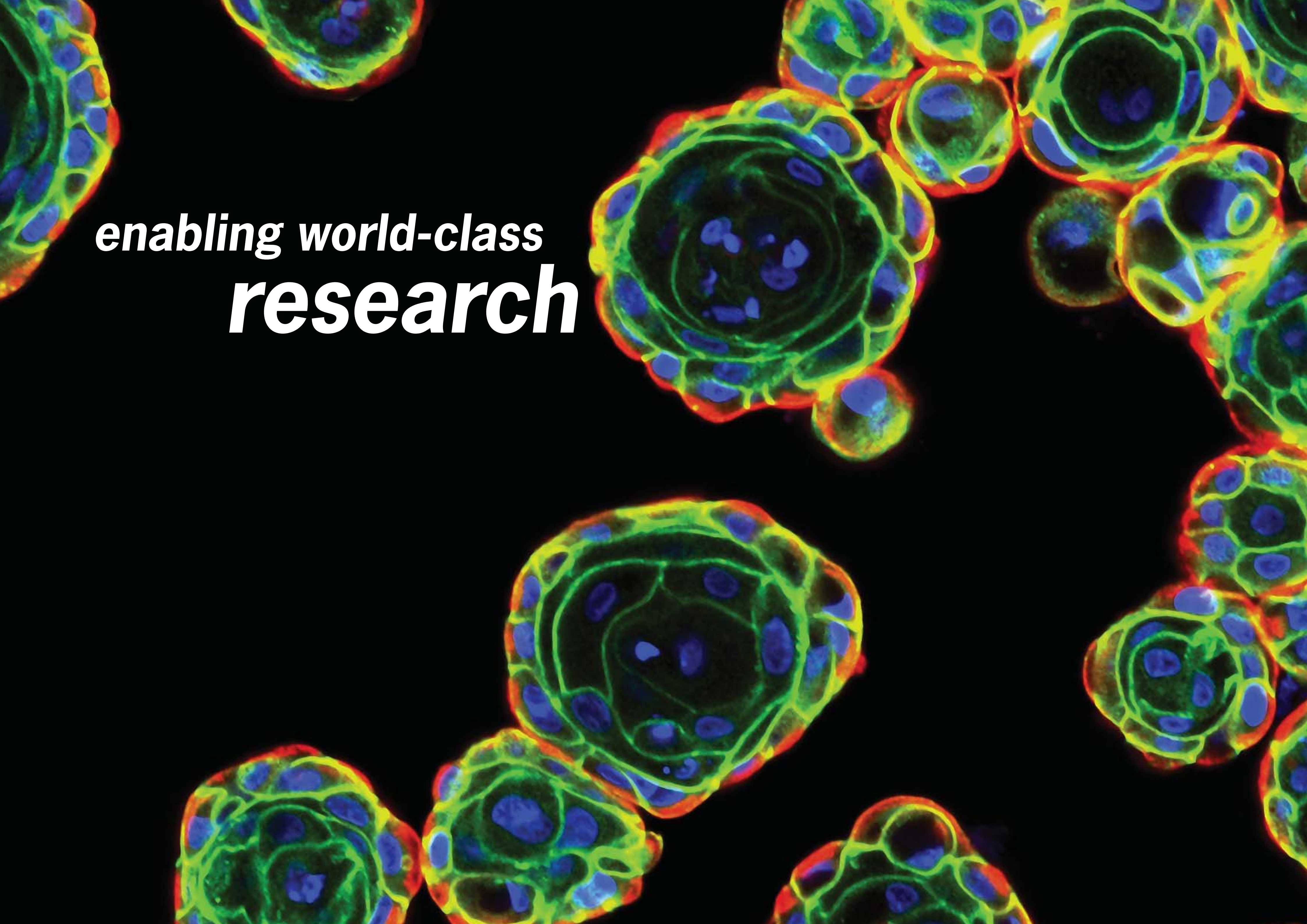
Dr Pat Trimby in the AMMRF at the University of Sydney has developed a practical technique for nanoscale electron backscatter diffraction (EBSD) based on work published earlier this year showing how a conventional EBSD system in the SEM could be used to measure diffraction patterns from electron-transparent TEM samples. The new technique, Transmission Kikuchi Diffraction in the SEM (SEM-TDK), now takes EBSD down to the nanoscale, enabling rapid characterisation of nanostructure and nanotexture in the SEM. It is now being routinely used to characterise a wide range of very fine-grained nanomaterials at high speed and with spatial resolution well below 10nm. Acquisition times of only 10–25ms, enable orientation mapping of over 100 μm^2 with measurement spacing in the 2–20nm range.

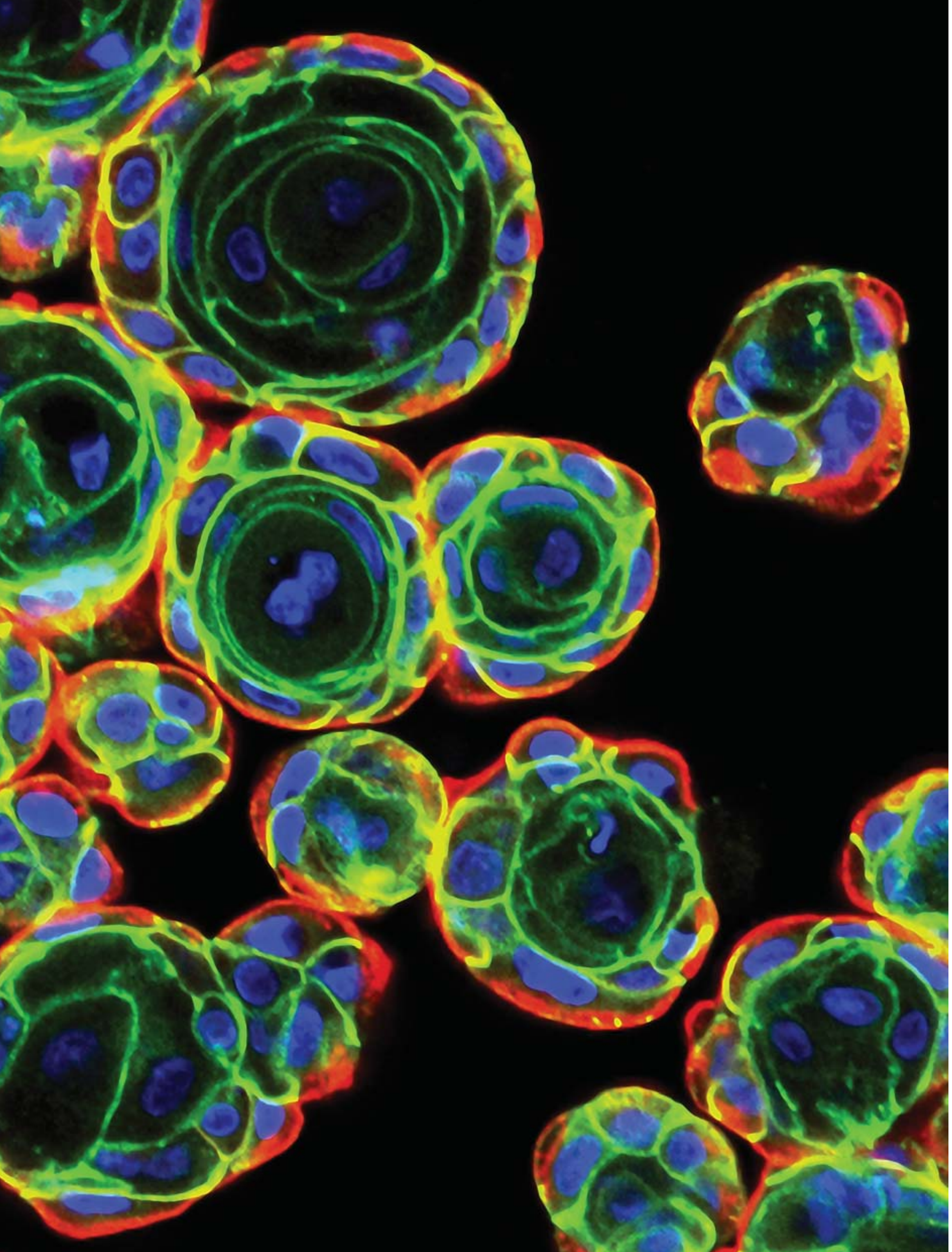
The technique can also simultaneously measure chemistry, using EDS, and capture a high-quality dark-field image by using forescatter detectors mounted on the EBSD detector. This will quickly become a commonplace characterisation technique for all researchers involved with nanomaterials.

Dr Trimby has been working with Oxford Instruments to optimise their software and enable further progress in this area.

Patrick Trimby, *Ultramicroscopy* 120, 2012

enabling world-class research





ammrf
Australian
Microscopy & Microanalysis
Research Facility

Our primary purpose is to support Australian research, generating new knowledge and feeding innovation in the academic and industrial sectors. Our instrumentation and expertise extend the range of inspirational and world-class research outcomes from Australian science.

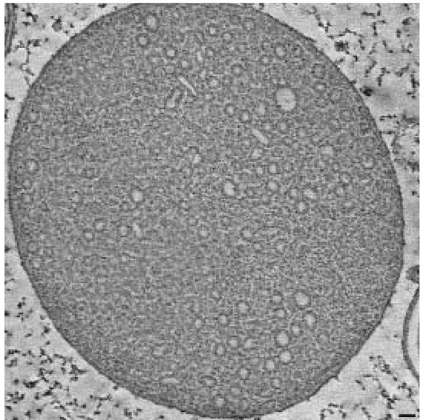
The reports on the following pages document some of our contributions to Australia's National Research Priorities, as indicated by these icons:

Frontier Technologies	Good Health	Sustainable Australia	Safeguarding Australia	Cultures & Communities

growing success

The social, economic and scientific value of collaborative research infrastructure grows over a period of years. We report regularly on research enabled by the AMMRF, but these two timeline case studies take a longer view. From little seeds of knowledge, mighty trees grow…

A world expert on cell membranes, Prof. Rob Parton uses microscopy to understand the structure and behaviour of small vesicles called caveolae. He is developing nano-scale, targeted drug delivery systems from these important structures. The AMMRF flagship electron tomography platform at the University of Queensland has enabled significant leaps forward in his research. Access to this instrument has enabled a landmark study showing how to engineer caveolae with a coating that allows the vesicles to deliver a package of drugs to target cells. Targeted delivery reduces side-effects by putting the drugs only in the cells where they are needed.



A single slice from an electron tomogram of a bacterial cell full of caveolae. Scale bar = 100nm

2008 Prof. Parton discovers a protein called caveolin that is essential for the formation of caveolae, and that they have a direct connection with the intra-cellular skeleton and communication network. Caveolar dysfunction is shown to be involved in various diseases such as cancer and muscular dystrophy. His group subsequently discovers a new group of proteins that associate with caveolae in muscle, possibly with a regulatory function. Disruption of these proteins may cause disease.

2009 Prof. Parton:

- patents ideas for the use of engineered caveolae as potential drug-delivery vehicles.
- is awarded an Australia Fellowship to further explore the ideas in his patent.
- is elected to the Australian Academy of Science.
- wins the NHMRC Achievement Award for the highest ranked project grant.

2011 Wins the Australia & New Zealand Society for Cell and Developmental Biology President's Medal.

2012 Experimental results from Prof. Parton's group, especially from PhD student Mr Nick Ariotti and postdoc Dr Piers Walser, were published in the extremely high-ranking peer-reviewed journal *Cell*: the characterisation of a customisable, cost-effective nanoscale drug-targeting system with the potential to incorporate a large and diverse range of therapeutic molecules.

For the efficient exploitation of oil and gas reserves and for the development of carbon dioxide sequestration solutions, understanding the porosity of rock is vital.

This case study shows how university research grew into an award-winning enterprise and industry consortium of 14 of the world's largest oil and gas companies.

From left to right: Andrew Kingston (ANU), Christoph Arns (UNSW), Victor Pantano (Digitalcore), John McGagh (CEO of prize sponsor, Rio Tinto), Tim Senden (ANU), Val Princzewski (UNSW) and Tim Sawkins (ANU)

2008 Researchers in the AMMRF at the Australian National University and at the University of New South Wales use a combination of advanced X-ray microtomography and serial sectioning with a focused ion beam to generate multiscale images of pores in oil-bearing rocks. They also develop software to integrate the images and model the spaces.

2009 A spin-off company, Digitalcore Pty Ltd is formed to commercialise technologies based on the fundamental imaging work. Their optimisation and image registration technologies include the proprietary VoxelPerfect™ and Heliscan™.

2010 Digitalcore wins the ENI Award for Frontier Technology in the Hydrocarbon Industry, regarded as the Nobel Prize for energy. Digitalcore continues to work with the AMMRF to optimise their proprietary imaging technologies. Digitalcore attracts an impressive list of clients in the oil and gas industries and in carbon dioxide sequestration.

2012 (August) Digitalcore wins the Eureka Prize for the Commercialisation of Innovation.

(October) Digitalcore announced their merger with the Norwegian company Numerical Rocks and Lithicon was born. The new company combines Digitalcore's unique core imaging and processing expertise with Numerical Rocks's multiphase flow modelling capabilities. In its new guise as Lithicon, Digitalcore is even more firmly established at the forefront of revolutionary digital rock analysis.

research

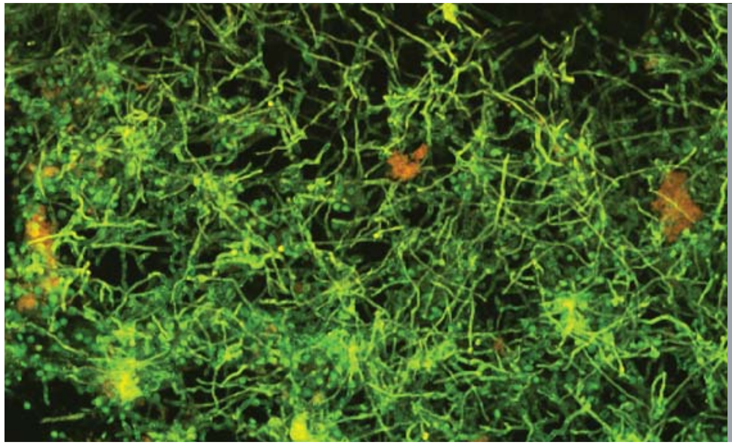
BACTERIA AND FUNGI – AN INFLAMMATORY COMBINATION

Chronic rhinosinusitis (CRS) is a common inflammatory disease of the nose and sinuses and affects around 10% of Australians. CRS is very detrimental to the sufferer's quality of life. It is difficult to treat and is associated with significant direct and indirect healthcare costs. Previous data wasn't clear as to the microbial composition in diseased and healthy sinuses. It appeared that fungi played a role in some forms of CRS but it was not clear how. Dr Sam Boase and Prof. PJ Wormald from the University of Adelaide (UoA) set out to investigate.

In a sheep model, Dr Boase attempted to establish biofilms with specific compositions. Confocal microscopy in the AMMRF at UoA was used to detect the different species of bacteria and fungi that grew in these biofilms. He showed that microbes are normally present in the sinuses and that the species composition and population density are critical factors in determining the development of CRS. However, even when an animal was hypersensitve to fungi, fungal biofilms would not become established unless bacteria, especially *Staphylococcus aureus*, were also present.

Transmission electron microscopy revealed that some bacterial species were associated with significant damage to the lining of the sinus suggesting that fungi may not be able to form biofilms where the immune defenses are intact. It appears that bacteria provide the necessary environment. Their biofilm might provide enhanced adhesion for the fungi and/or provide a firmer foothold for fungal attachment through the breakdown of the sinus's protective surface.

Ref. Sam Boase et al., *Int. Forum of Allergy & Rhinology*, 1 (5), 2011



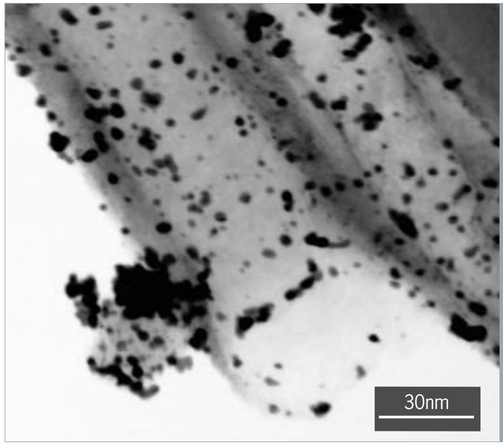
Confocal image of a fungal biofilm where the hyphae are long and green with interspersed bacteria appearing as tiny, green, round cells.

EFFICIENT ENERGY CATALYSTS

Direct-methanol fuel cells (DMFCs) are a proven alternative to batteries. They can be used to power a wide range of portable and mobile electronics such as laptop computers and mobile phones. Methanol is a liquid fuel and is therefore easier to store and transport than hydrogen, the major fuel currently used for fuel cells. The performance of a DMFC depends largely on the catalytic activities of the electrodes and the performance of the membrane through which the ions pass. Great efforts have been made to improve the durability and electrocatalytic activity of catalysts used to oxidise methanol in the anodes of DMFCs.

PhD student Ms Cuifeng Zhou and A/Prof. Zongwen Liu at the University of Sydney (UoS), have successfully improved the performance of DMFCs by preparing novel platinum-based nanocatalysts supported on nanostructured conductive polymers and their composites. Ms Zhou used the AMMRF at UoS to investigate these complex electrocatalysts, correlating their chemical and structural features to their observed super-electrocatalytic performance in the oxidation of methanol. High-resolution transmission electron microscopy and electron tomography revealed the catalyst distribution in the supporting networks. The nanostructured carbon materials that Ms Zhou developed have a core/shell structure and make excellent supports for the catalytic platinum nanoparticles. They give an approximately seven-fold improvement over the platinum alone and, if adopted, could greatly increase the efficiency of DMFCs.

Zhou et al. *Nanoscale Research Letters*, 7, 2012

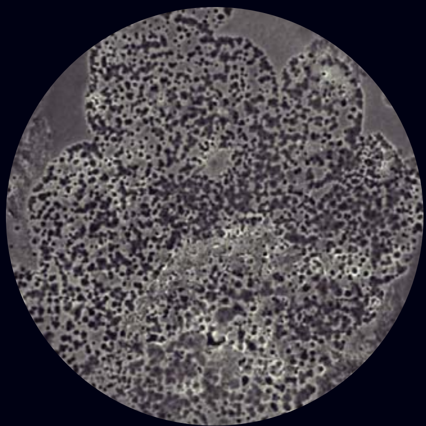


Scanning transmission electron micrograph shows platinum nanoparticles (black) supported on the surface of the nanostructured carbon materials.

impact implants

PROBLEM

Orthopaedic implants are used to repair or restructure damaged bones in medical and veterinary practice. Traditionally these implants have been fashioned from dense bio-inert materials such as stainless steel, titanium and cobalt-chromium based alloys. However, these alloys often contain a number of toxic elements that can be released into the body as a result of corrosion or wear, causing problems for the patient. They are also much stiffer than bone. This can cause a mismatch of properties during performance, which can lead to mechanical stresses developing in the bone to the point where cracks occur.



SOLUTION

A class of very strong alloys called bulk metallic glasses (BMGs) may solve these problems. Recent research at the University of New South Wales (UNSW) has focused on designing new BMGs entirely from elements that are naturally present in the human body: magnesium, zinc and calcium. These ions have also been associated with anti-bacterial activity and accelerated bone healing.

The research team, led by Prof. Michael Ferry and Dr Kevin Laws has used a variety of microscopy techniques in the AMMRF at UNSW and the University of Sydney to investigate the corrosion properties of these materials in conditions similar to those found in the human body. Scanning electron microscopy revealed that when exposed to synthetic body fluids, the BMGs corroded to give a porous network. The rate of dissolution can be tailored to specific applications by regulating the relative proportion of zinc in the alloys.

Unlike current metal implants, these new BMGs were found to have elasticity and density identical to bone. This should improve performance when implants are inserted into the body, reducing the risk of cracks caused by mechanical stress.

This combination of features could enable the new alloys to be used as bioresorbable metals for short-term orthopaedic applications, such as screws, plates and pins, that would normally have to be surgically removed.

IMPACT

If developed into slowly dissolving medical devices, these bio-compatible metals will

overcome complications due to mismatches in the properties of device and bone and stop toxic leaks from implants.

- reduce trauma and further risk to the patient from additional surgery
- save on heathcare costs and reduce the demands on operating theatres and staff
- hasten healing and therefore reduce the economic and personal impact of the injury.

J.D. Cao et al., *Acta Biomaterialia*, 8, 2012.

research

A CRACK IN THE ZIRCON TIME CAPSULE

The oldest pieces of the Earth's crust are zircon crystals, some dating back 4.4 billion years and revealing what the early Earth was like before the rock record begins. Prof. Birger Rasmussen of Curtin University and his colleagues have studied ancient zircons from Western Australia, focusing on tiny mineral grains enclosed within the crystals. These were thought to have crystallised from the same magma as the enclosing zircon, and consequently their compositions were used to infer that four billion years ago the Earth's crust was cool and composed of granite, as it is today.

The researchers used scanning electron microscopy and X-ray microanalysis in the AMMRF in the University of Western Australia to examine 7500 zircons. The sensitive high resolution ion micro probe in the AMMRF linked laboratory at Curtin University was used to date some of the inclusions showing them to be younger than the zircons themselves. Their compositions matched the younger surrounding metamorphic minerals. How this situation came about is not clear but as some inclusions lie along hairline fractures, it is possible that metamorphic fluids could have infiltrated by this route, and where inclusions appear to be entirely enclosed, mineralising fluids may have travelled along defects in the zircon's crystal structure that had been caused by radioactive decay. The finding that the inclusions inside the zircons are not pristine raises doubts about previous conclusions that have been drawn on the basis that the inclusion and the zircons are the same age.

Rasmussen, B. et al, *Geology*, 39, 2011.

GRINDING AND CRACKING – WEAR IN TOOTH ENAMEL

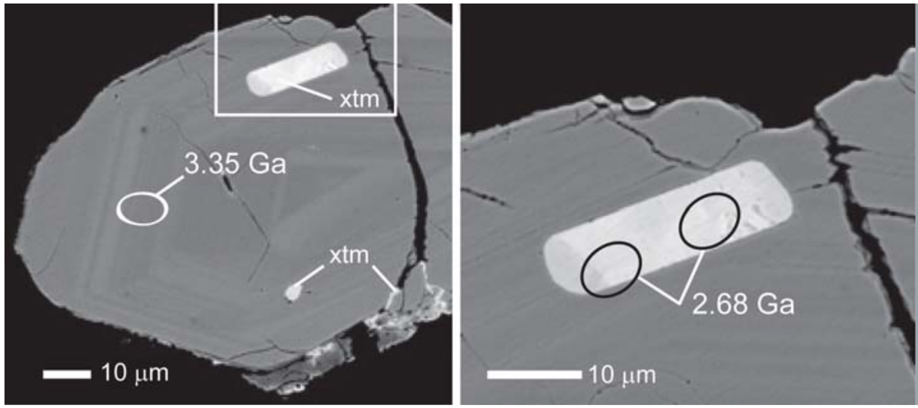
With the increasing longevity of teeth, wear on dental enamel is becoming an important issue. Excessive enamel wear greatly affects masticatory function, reducing quality of life and overall health.

Tooth enamel is made up of crystalline calcium phosphate, in the form of hydroxyapatite, formed around an underlying protein matrix. Dr Joseph Arsecularatne and Prof. Mark Hoffman at the University of New South Wales (UNSW), have been investigating the factors that influence wear by using focused ion beam (FIB) milling and subsequent transmission electron microscopy (TEM) in the AMMRF at UNSW.

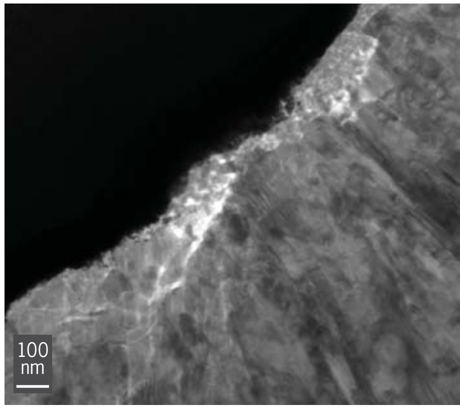
Brittle materials such as apatite can crack using traditional TEM preparation techniques. This is a particular problem when cracks are the subject of the study. FIB milling circumvents this problem. It also allowed the team to choose sites from specific regions that had been subjected to wear that simulated oral conditions. TEM observation revealed the formation of prominent cracks both parallel and perpendicular to the tooth surface. They found that the extent of the cracking is directly related to the pressure and friction at the tooth surface. Some cracks were observed to follow discontinuities in the crystalline structure of the enamel. Cracks close to the surface lead to small pieces of enamel breaking away causing significant loss of this important protective layer.

These results make it possible to develop a comprehensive wear model for enamel, and in doing so facilitate the development of restorative enamel-substitute materials and associated friction-reducing dental products.

Joseph Arsecularatne and Mark Hoffman, *J. Mech. Beh. Biomed. Mat.* 8, 2012



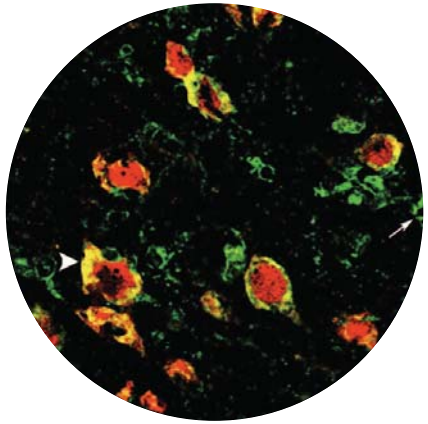
Zircon crystal and close-up with inclusions of xenotime (xtm). Circles show the location of, and dates derived from, SHRIMP analysis.



TEM image of the surface wear and subsurface cracks in tooth enamel.

impact stroke

Photo © VirginiaLockett



PROBLEM

Stroke is the sudden loss of blood flow to the brain. When this happens brain cells die, making stroke the leading cause of adult disability in Australia and the second most common cause of death. Currently there is no cure for stroke.

SOLUTION

In the Stroke Research Programme at the University of Adelaide (UoA) Dr Karlea Kremer and colleagues are investigating the use of dental pulp stem cells from the centre of adult teeth to repair the brain following a stroke. The cells are readily accessible in the aftermath of a stroke and research shows that they have a natural propensity to change into brain cells.

When dental pulp stem cells were injected into the brains of stroke-affected rodents, they migrated preferentially to the site of the damage and led to improvements in the animals' sensory and motor function. Confocal microscopy in the AMMRF at the UoA revealed that the implanted cells (shown above, labeled with green fluorescent protein) developed into neurons and supporting cells called astrocytes. Astrocytes predominated closest to the centre of the lesion suggesting that the functional improvements could be due to factors secreted from the astrocytes rather than the direct replacement of neural function. Transmission electron microscopy is being used to further investigate how dental pulp stem cells exert their beneficial effects on brain function.

IMPACT

This pre-clinical work could lead to

an effective treatment for stroke based on cells derived from the patient's own body:

- greatly improving patients' quality of life through stem cell therapy
- reducing the strain on families and carers
- saving billions of dollars in stroke-related care.

Wai Khay Leong, et al., *Stem Cells Translational Medicine*, 1, 2012

MAKING HEALTHIER PASTA

Healthy eating is of concern to most of us and eating foods with a lower glycaemic index (GI) has proven benefits. Ms Nisha Aravind, a postgraduate student at the University of New England, with a scholarship from the NSW Primary Industries Innovation Centre aims to develop healthier food through her research.

She has investigated ways to lower the GI of pasta through the incorporation of ingredients such as fibre, without adversely affecting the taste, feel in the mouth and behaviour on cooking. Ingredients tested include soluble fibres such as guar gum, carboxymethylcellulose and inulin as well as insoluble forms such as bran and wheat germ.

Ms Aravind used confocal microscopy in the AMMRF at the University of Sydney to investigate how the different ingredients affect the structural networks of protein and starch in the pasta. She found that carboxymethylcellulose is very good at reducing the glycaemic index and has no discernable affect on other properties. Inulin, however, was found to reduce the GI when used at low levels but increase the GI when incorporated at higher levels. Microscopy revealed that this occurs because changes in the microstructural networks alter access to the enzymes during digestion. The insoluble fibres, bran and wheat germ, did not reduce the GI but did adversely affect other properties.

Ms Aravind's work provides a great deal of evidence on which food manufacturers can base the development of healthier pasta that still tastes and feels like it should.

N. Aravind et al., *Food Chemistry* 131, 2012

N. Aravind et al., *Food Chemistry* 132, 2012

PLASTIC FROM SUGARCANE WASTE

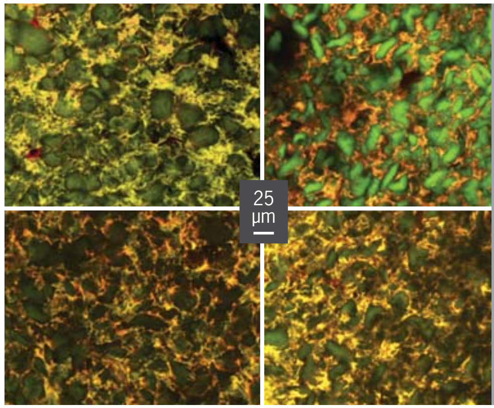
Renewable and biodegradable bioplastics are generating considerable interest as an alternative to petroleum-based plastics. Polyhydroxyalkanoates (PHAs) are bacterial carbon-storage polymers with plastic-like properties. However, they are expensive to produce in bacteria and need substantial fermentation infrastructure.

A/Prof. Stevens Brumbley and colleagues from the Cooperative Research Centre for Sugar Industry Innovation Through Biotechnology and the University Queensland (UQ) have found an alternative to bacterial fermentation for PHA production. They have engineered into sugarcane the three bacterial genes necessary to produce PHA. The resulting transgenic sugarcane plants activate these genes only in specialised compartments of cells called peroxisomes. These compartments have all the other components necessary to make PHA once the bacterial genes switch on production of the enzymes.

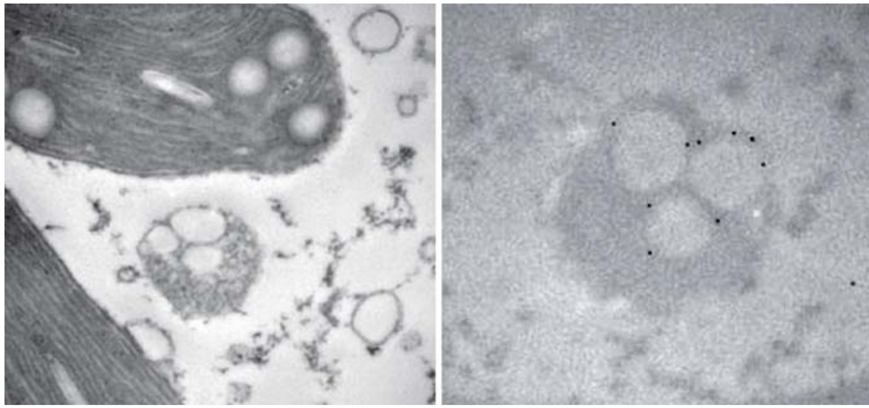
The team found that PHA was produced in the leaves of sugarcane and accumulates in the older leaves over time. Transmission electron microscopy (TEM) in the AMMRF at UQ was used to visualise immunogold-labelled PHA showing that it localised to the intended sites within the leaf cells, the peroxisomes and vacuoles. PHA biosynthesis did not appear to affect the growth and vigour of the transgenic plants leaving scope to increase the level of PHA production further.

These findings have the potential to transform the sugarcane industry by creating a sustainable, biodegradable and commercially valuable commodity from a part of the crop that usually goes to waste.

Kimberley Tilbrook et al., *Plant Biotechnology Journal,* 9, 2011



Confocal images of cooked spaghetti showing the protein network in orange and the starch granules in green. Increasing amounts of carboxymethylcellulose 0%–1.5% (clockwise from top left) do not alter the structural integrity of the pasta.



TEM image of granules within a peroxisome in a transgenic sugarcane leaf (left) and one showing gold particles that attach to one of the enzymes that remains bound to the PHA after synthesis (right). Peroxisomes are around 1 micrometre in diameter.

impact art

PROBLEM

Zinc oxide has been used as a white pigment for painting since the 1840s. Its popularity peaked in the first half of the twentieth century and it is found in many paintings from this period. Some are now showing a distinctive form of deterioration. Zinc oxide can react with fatty acids from the oils in paint to form zinc carboxylate soaps, such as zinc stearate, causing serious irreversible damage to the paintings. Many twentieth century oil paintings are at risk.

Art conservators want to know:

- how zinc soaps form?
- why, and under what conditions, do they accumulate?
- can the formation be prevented?

SOLUTION

Gillian Osmond, a conservator at the Queensland Art Gallery, is doing a PhD at the Australian Institute for Bioengineering and Nanotechnology at the University of Queensland. Funded through an ARC Industry Linkage Project, *The Twentieth Century in Paint*, Ms Osmond is investigating the mechanism of zinc stearate formation and its distribution in affected paint samples. She is using a combination of electron microscopy, X-ray analysis and Fourier transform infrared microspectroscopy in the AMMRF at the University of Queensland and at the Australian Synchrotron.

Specific pigment, oil and paint additive combinations from a reference collection were examined to understand the formation and behavior of zinc stearate 'soap' in naturally aged paint samples. Zinc stearate forms rapidly and other components, such as aluminium stearate, in the paint formulation significantly influence the amount of stearic acid available to react with the zinc, making the problem worse where aluminium stearate is present. Once it has accumulated in sufficient concentration, and as the chemistry of the paint film changes with age, the zinc soap is less able to remain dispersed and gradually migrates through the paint film aggregating into clumps. This can lead to unsightly damage or weaken adhesion between paint layers.

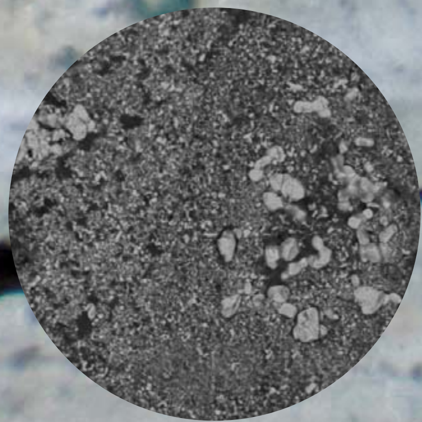
IMPACT

Ms Osmond's research helps art conservators to fine-tune best-practise and reduce time-consuming and costly stabilisation work.

- water-based conservation treatments should be minimised and optimised
- relative humidity and temperature control remains vitally important

This research helps conservators to

identify at-risk paintings and protect them from long-term damage



KNOW YOUR ENEMY

Phytophthora are pathogenic oomycetes that cause severe plant diseases and enormous losses in agriculture worldwide. For instance, they are responsible for potato blight, the cause of the Irish potato famine. Many *Phytophthora* species initiate infection of a plant by producing motile zoospores that swim to the plant's surface where they encyst, germinate and penetrate the plant cell wall. During this process, adhesive material is secreted from regions of the zoospore called cortical vesicles, facilitating the firm attachment of the spores to the plant surface. One type of vesicle, the so-called large peripheral vesicles, remains in the zoospore disappearing several hours later as their contents are degraded.

Recent research at the Australian National University (ANU) found that a protein component of the large peripheral vesicles, called PnCcp, was selectively secreted during encystment. Results from Ms Weiwei Zhang, Prof. Adrienne Hardham and Dr Leila Blackman indicate that PnCcp may be selectively released during transient fusion of the large peripheral vesicle with the cell membrane.

Immunofluoresent double-labelling and multiphoton confocal microscopy and electron microscopy in the AMMRF at the ANU were used to show that PnCcp is compartmentalised within the vesicle whereas another protein called PnLpv remains widely distributed.

Understanding the mechanisms behind the selective secretion of proteins from *Phytophthora* zoospores provides possible targets for the development of methods for controlling *Phytophthora* diseases.

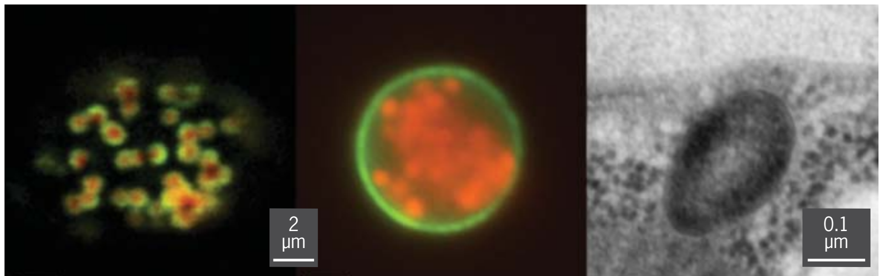
STRONGER CERAMIC COATINGS THROUGH MICRO-ENGINEERING

Ceramic coatings are widely applied to steels used for machine tools to increase their working life. One of the biggest problems with hard, wear-resistant ceramic coatings is their poor impact tolerance. The development of novel micro- or nano-structures has the potential to bring functional improvements to these coating materials. Prof. Paul Munroe from the University of New South Wales (UNSW), in collaboration with colleagues at Adelaide University and Edith Cowan University has led a project to study chromium aluminium nitride (CrAlN) coatings engineered onto steel substrates using magnetron sputtering. Varying the aluminium content up to 30 atomic % generated significant improvements in both hardness and toughness.

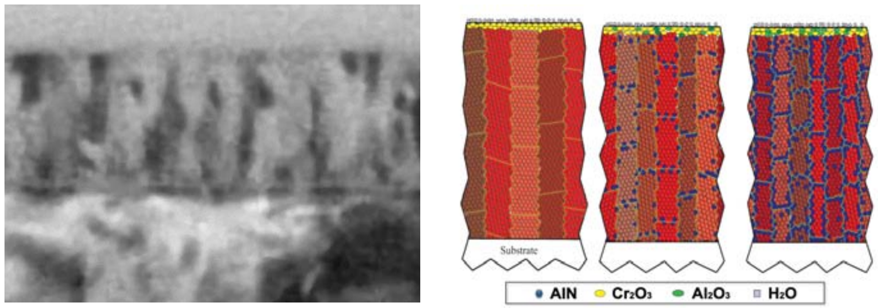
The team found that although the addition of Al does not significantly alter the microstructure of the coatings, it does change the preferred grain orientation and increases the coating's compressive residual stress. Evidence collected from the focused ion beam and transmission electron microscopy experiments in the AMMRF at UNSW helped to show that AlN exists in an amorphous state at the columnar CrN grain boundaries and has a crucial role in providing the unusual combination of high hardness and exceptional impact resistance.

The team's results provide a route to the commercial development of durable ceramic coatings with greatly improved properties under severe working conditions.

Zhao Li et al., *Acta Materialia* 60, 2012.



Immunofluoresence localisation of PnCcp (green) and PnLpv (red) in a *Phytophthora* zoospore (left) and a cyst (centre). In the zoospore, PnCcp occurs in an outer ring within the large peripheral vesicles. In the cyst, PnCcp coats the cyst surface while PnLpv remains within the vesicles. Electron microscopy (right) shows an electron-dense outer area in a large peripheral vesicle.



Cross-sectional FIB micrograph of a section through a CrAlN coating of 34 atom % Al with a thickness of 1.17 µm showing a fine, columnar structure. The diagram shows the interpretation of the EM studies.

impact water

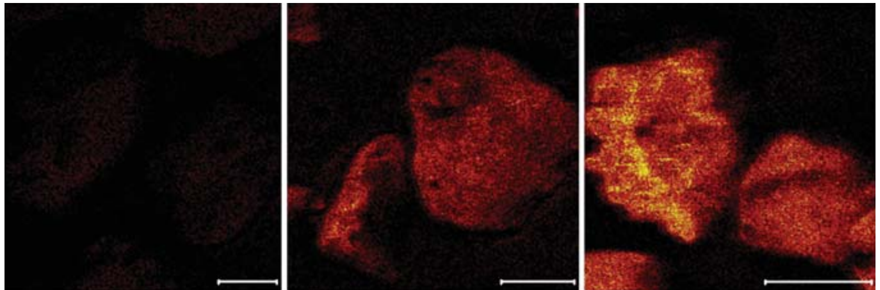
PROBLEM

Around one billion people worldwide still use unsafe drinking water sources. Pathogens cause disease, while major industries are a source of chemical pollution. Centralised water treatment is rarely feasible In rural areas, where untreated private groundwater is usually used. Water treatment is also a major issue in disaster zones, even in developed countries, where it can take up to ten days to deliver a water purification plant following a disaster.

SOLUTION

A product that can be deployed quickly in disaster areas to purify water without electricity would prevent disease and save lives. Dr Karyn Jarvis from the University of South Australia is researching ways to modify the surface of sand grains so that they can remove contaminants from whatever water is available.

She and her team are using plasma polymerisation to attach different molecule fragments to the sand (quartz). Their technique uses a rotating barrel plasma reactor to thoroughly coat the grains. The effectiveness of the coating was confirmed with time-of-flight secondary ion mass spectrometry (ToF-SIMS). The group has created positively charged allyamine-coated particles that have been shown to remove negatively charged humic acid, dyes and *E. coli*. Water-repelling surfaces have also been produced which can remove hydrophobic contaminants such as oil. Negatively charged coatings are in development, which are designed to remove positively charged contaminants such as dyes and heavy metals.



ToF-SIMS ion maps of uncoated and allylamine plasma polymerised quartz particles (scale bar=100 μm)

IMPACT

This proof-of-concept research shows that

treated sands could be made into simple, cost-effective water purification systems

- producing clean drinkable water in emergency situations with no need for power
- allowing poor and rural communities to maintain their own clean water supply without large-scale infrastructure
- removing specific chemicals from water after industrial spills and leaks.

research

MUTINOUS MACROPHAGES

Most cancer deaths are caused by spread of a primary tumour to other parts of the body. In order to develop more effective cancer treatments it is important to understand how tumours break into nearby blood vessels or lymphatics and spread to distant organs.

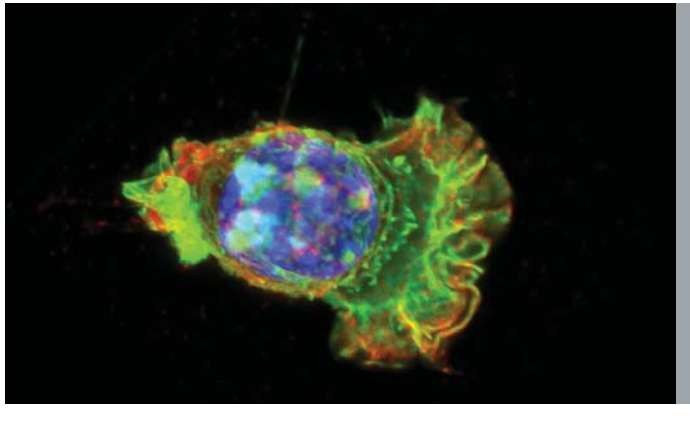
Macrophages, a type of immune cell, are known to infiltrate tumours and become tumour-associated macrophages (TAMs). Many cancers contain large numbers of TAMs and their presence is associated with poor outcomes.

TAMs set up a 'conversation' with tumour cells where each cell type switches on the other's migratory activity. TAMs secrete a protein called EGF that encourages tumour cell motility and tumour cells secrete a protein, CSF-1, which regulates the growth and motility of macrophages. This highly motile combination then moves readily to nearby blood vessels.

A/Prof. Fiona Pixley has shown that this mutual enhancement of motility is a critical element for tumour invasion. She and her colleagues at the University Western Australia (UWA) are using a broad range of microscopy techniques, including time lapse, confocal and total internal reflection fluorescence microscopy together with scanning and transmission electron microscopy in the AMMRF at UWA to examine the general morphology of tumour-stimulated macrophages and their signaling molecules. They have discovered that a specific signaling molecule, PI3K, is an important regulator of stimulated macrophage motility. The team is now working to identify its associated signaling molecules.

This work will help to identify specific molecules that can be targeted with drugs to prevent tumour invasion.

Samapaio et al., *Journal of Cell Science* 124, 2011



Confocal image of a tumour-associated macrophage

ATOM CLUSTERS IN ALLOY HARDENING

Age-hardenable aluminium alloys are a very important category of engineering material, widely used in the aircraft industry. Very subtle compositional variations witihin an alloy can significantly affect its mechanical properties. Research has investigated aluminium–copper–magnesium (Al–Cu–Mg) alloys by using diffusion couples, where the composition changes gradually across the sample.

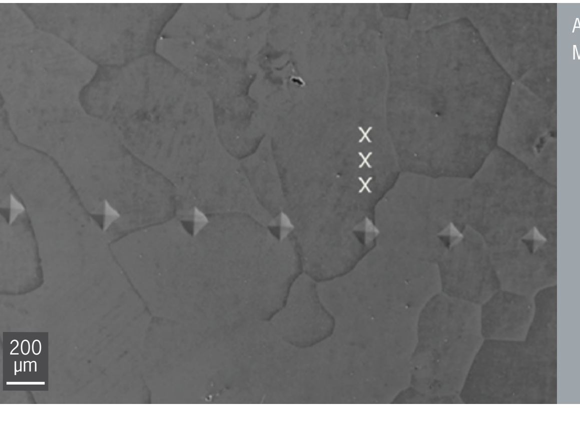
Led by Dr Ross Marceau, researchers from Monash University and the University of Sydney (UoS) collaborated to investigate compositional dependence of rapid-hardening phenomena in these alloys. Data was collected from two AMMRF flagship instruments, the atom probe at the UoS and the electron microprobe at the University of New South Wales.

A series of Al–Cu/Al–Cu–Mg and Al–Mg/Al–Cu–Mg diffusion couples were fabricated to contain a gradient of Mg or Cu concentration, where the effects of both total solute content and Cu:Mg ratio on the rapid hardening phenomena were examined. The hardness profile was measured across the diffusion gradients before and after artificial ageing. The composition profiles were quantitatively verified by electron probe microanalysis and the microstructure characterised using atom probe tomography (APT).

The results showed that the composition affected age-hardening. Above a critical level of copper, rapid hardening declines. Atom probe data showed that the extent of hardening corresponds with the number of Cu–Mg clusters and when they are richer in Mg, they have greater strengthening potential. Improvements in the understanding of alloys leads to the development of stronger light metals.

Ross Marceau et al., *Materials Science and Engineering A* 546, 2012

Al – Cu – Mg



Al – Mg

Scanning electron micrograph of hardness testing indents across a diffusion gradient. Xs indicate the location of triplicate electron microprobe measurements.

impact steel

PROBLEM

Steel is the most widely used metal. The stronger it can be made, the less is needed to achieve the same effect. However, increasing strength usually makes the metal more brittle and more likely to fail. In practice there is a trade-off between strength and maleability for a given application.

BlueScope Steel Pty Ltd have worked with other steel companies world-wide to develop the Castrip® process to produce thin, strip-cast steel. This process produces 70% less greenhouse gas emissions and needs less than 10% of the floor space of conventional steel mills. Initial applications of Castrip® steel include construction and tubing, but with improved strength through microalloying, this product could also be used in the lucrative automotive industry.

IMPACT

stronger, more malleable Castrip® steel would have wide range of applications and benefits

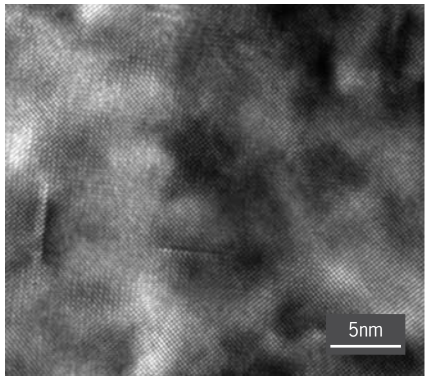
- use in the automotive industry would reduce that industry's carbon footprint
- stronger steel can be used in smaller quantities, generating less greenhouse gas both during manufacture and in the use of the final product
- economic benefits to Australia as BlueScope holds the licence for producing Castrip® steel in Australia.

SOLUTION

As part of an ARC Linkage Project led by Prof. Simon Ringer and A/Prof. Julie Cairney in the AMMRF at the University of Sydney, PhD student Mr Kelvin Xie worked with BlueScope on the development of new stronger, niobium-microalloyed grades of steel.

Through careful control of the casting conditions, composition and heat treatment, steels have been developed that display both high strength and good elongation, two properties that are usually mutually exclusive. The improved properties are attributed to cluster hardening, a phenomenon detected through the use of transmission electron microscopy (TEM) and atom probe tomography (APT). Cluster hardening has only recently been considered to play a role in the mechanical properties of steels.

Mr Xie also discovered that heating the steel with nitrogen salts so that nitrogen diffuses into the surface of the steel (nitriding) improves the strength further still. Again, by using TEM and APT, Mr Xie was able to see the structure of hard precipitates that had formed in the surface regions of the steel. BlueScope have submitted a provisional patent to protect this process (see p.35) and are currently trying to implement heat treatments on the production line that replicate the lab-based improvements.



DIAMONDS DEFORMED WITHIN THE EARTH'S MANTLE

Geoscientists from the ARC Centre of Excellence for Core to Crust Fluid Systems at Macquarie University reveal processes that take place deep in the Earth's mantle through their study of polycrystalline rocks called diamondites. The research team comprises PhD student Ekaterina Rubanova, A/Prof. Sandra Piazolo, Prof. William Griffin and Prof. Suzanne O'Reilly. The diamonds in these rocks are like tiny time capsules that preserve structures and encapsulated inclusions that give clues to their past.

Results collected from electron backscatter diffraction (EBSD) analyses in the AMMRF at the University of Sydney, showed for the first time that diamondite crystals can undergo significant plastic deformation and recrystallisation within the Earth's mantle. Despite being the hardest naturally occurring material known to man, diamonds can deform in a similar way to metals and other minerals.

Chemical analyses were carried out on the same rocks, by using electron microprobe analysis of inclusions within the diamonds. They indicated that different chemical environments at different pressures and temperatures had an impact on how the diamonds formed, and were subsequently deformed during separate episodes of their turbulent creation.

Diamonds come to the surface through volcanic action and are consequently found in the remnants of volcanic structures. This research shows that diamonds with vastly different chemical and structural histories are present at a single location indicating that various chemically distinct bodies in the mantle are mixing more vigorously than expected.

Ekaterina Rubanova et al., *Geochemistry Geophysics Geosystems*,13 (10), 2012.

LET THERE BE MILK

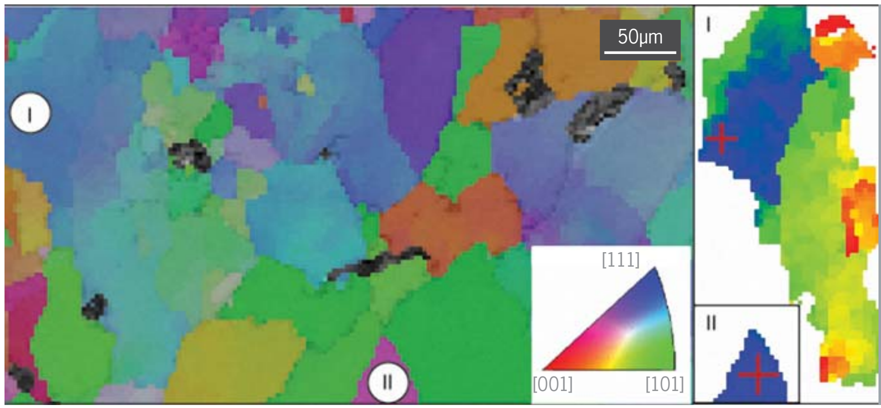
The repeated anatomical changes that take place in the mammary gland are unique in the human body. During pregnancy, the simple network of ducts starts to branch and elongate, forming milk-secreting alveoli at their ends. Through the proliferation of epithelial stem cells within the gland all the different functional types of cells are formed. When stimulated by suckling, they can produce all the components required to nourish a growing baby. After breastfeeding is stopped, the body clears the lactating cells and the gland returns to its original structure.

Ms Libby Thomas and her PhD supervisor Prof. Peter Hartmann at the University of Western Australia (UWA) have been able to use stem cells isolated from human milk to grow milk-secreting structures in a petri dish. These cells look almost identical to the milk-producing alveoli in a breast-feeding woman. The researchers found that only one stem cell is needed to form an alveolus.

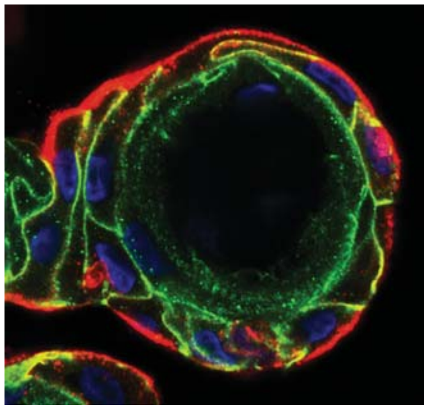
By using confocal microscopy in the AMMRF at UWA the researchers use the in-vitro structures to investigate the regulatory factors that drive development and subsequently control milk production and cessation. They have found that reactive oxygen species, produced as accumulated milk breaks down after weaning, appear to cause the selective removal of the milk-producing cells.

Their work is building an evidence base for the clinical management of human lactation problems. Mammary stem cells are also thought to be a source of breast cancer so this work could also have significance in this clinically important area.

Elizabeth Thomas et al., *Cell Death and Disease* 2, e189; doi:10.1038/cddis.2011.69, 2011



EBSD orientation map (far left) of typical diamondite with colour-coding showing relative orientations. Internal orientation change (near left) in grain I and grain II showing high and no internal lattice distortion, respectively.



A confocal micrograph of a single cultured alveolus showing a perimeter of stem cells (red) surrounding the forming layer of milk-secreting cells (green).

Scale: the larger alveolus is approx. 46micrometres in diameter

IMPROVED TUBERCULOSIS TREATMENT

Tuberculosis (TB) is a bacterial disease that largely affects the lungs. It is difficult to treat and requires long-term administration of three antibiotics. These are currently given orally but patients often stop taking the medication due to side effects and the length of the treatment. This increases the risk of antibiotic-resistant strains of the bacteria developing.

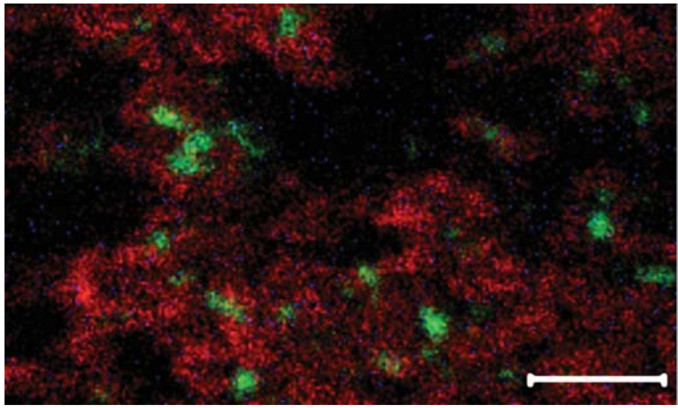
Because the oral route does not efficiently deliver antibiotics to the lungs, high doses are required. A more effective delivery route is likely to be through direct inhalation. Mr John Chan from the University of Sydney is looking at ways to effectively combine the three recommended antibiotics into an inhalable dry powder. When spray dried together the three antibiotics were physically stable, unlike when they were spray dried individually.

To confirm the composition of the particles ToF-SIMS in the AMMRF at the University of South Australia was used to determine characteristic ion fragments for each of the components. By recording ToF-SIMS images of the final drug powder, chemical maps were created so that the surface chemistry and spatial distribution of each antibiotic within the final preparation could be observed. The successful creation of spherical particles was confirmed in a scanning electron microscope in the AMMRF at the University of Sydney.

Inhaled administration of this triple antibiotic formulation could minimise side effects and potentially reduce the duration of treatment, thereby maximising patient compliance.

John Gar Yan Chan et al., Eur. *J. Pharmaceutics and Biopharmaceutics*, http://dx.doi.org/10.1016/j.ejpb.2012.08.007, 2012

Provisional patent application #2012901686 : A Novel Dry Powder Inhalable Formulation Incorporating Three First-Line Anti-Tubercular Antibiotics



ToF-SIMS image showing the distribution of the three antibiotics. Rifampicin is in red, isoniazid in green and pyrazinamide in blue. Scale bar=10 micrometres

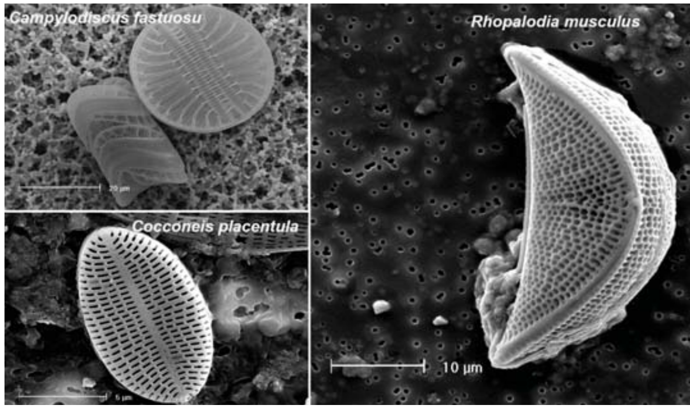
THE FISH'S FRIEND: ADAPTIVE DIATOMS

Diatoms are a major group of algae, and are one of the most common types of phytoplankton, with an estimated 100,000 species found in salt and fresh water around the world. These single-celled eukaryotic organisms are the primary source of food for fish in the ocean, so their survival is paramount to water-based ecological processes. A characteristic feature of diatoms are the nano-patterned cell walls built up of biomineralised silica. These structures make diatoms easy to measure with considerable accuracy.

By using scanning electron microscopy in the AMMRF at the University of Adelaide, Dr Sophie Leterme, Prof. Melissa Brown and A/Prof. Amanda Ellis from Flinders University are examining the effect of salinity changes on the molecular architecture of diatom nanopores.

They have looked at diatoms from naturally occurring environments with different salinities and found that, at least in some species, the nanopores are smaller in less saline conditions. Further analysis showed that the diffusion rate of ions around the cell surface at different levels of salinity remained constant as the pore size changed in response to the salinity changes. Nutrients too, can also affect structural features. This self-regulatory process by which the diatoms can alter their cell wall structures in direct response to changes in salinity and nutrients could account for the ability of some diatoms to adapt and survive changes in water quality that occur due to floods, droughts and seasonal changes in evaporation.

Sophie Leterme, et al., *Diatom Research*, DOI:10.1080/0269249X.2012.734530, 2012



Scanning electron micrographs of some of the diatoms from the study

SEXUAL DECEPTION FOR SURVIVAL

Many Australian orchids are under threat. It is therefore important to understand the mechanism of communication between orchids and their pollinators. The orchids employ a variety of specialised and intriguing pollination methods, including sexual deception, where the orchid flower attracts pollinators through chemical mimicry of insect sex pheromones. All known species of *Drakaea*, orchids endemic to Western Australia, are believed to deceive thynnine wasps for pollination.

An investigation of the compounds involved in this pollination mechanism is the subject of an ongoing collaboration between researchers at the University of Western Australia (UWA), Kings Park & Botanic Garden and the Australian National University (ANU). Prof. Rod Peakall and colleagues from ANU visited UWA to work with Dr Gavin Flematti on the project. The work has focused on three of the most naturally abundant orchid species, *D. glyptodon* (king in his carriage), *D. livida* (warty hammer orchid) and *D. thynniphila* (narrow lipped hammer orchid).

The volatile compounds produced by orchid flowers were analysed using a number of methods in the AMMRF at UWA. The bioactive components were identified by techniques including gas chromatography with mass spectroscopy. Supported by microderivatisation experiments, these results helped researchers to postulate the existence of several pyrazine-based compounds as the key molecules involved in this chemical communication.

The pyrazine compounds were then synthesised. Their structure was confirmed by nuclear magnetic resonance spectroscopy and X-ray crystallography. Current experiments are testing the synthetic compounds for their effects on wasps.

Bjorn Bohman, et al., *Journal of Natural Products*, DOI: 10.1021/np300388y, 2012.

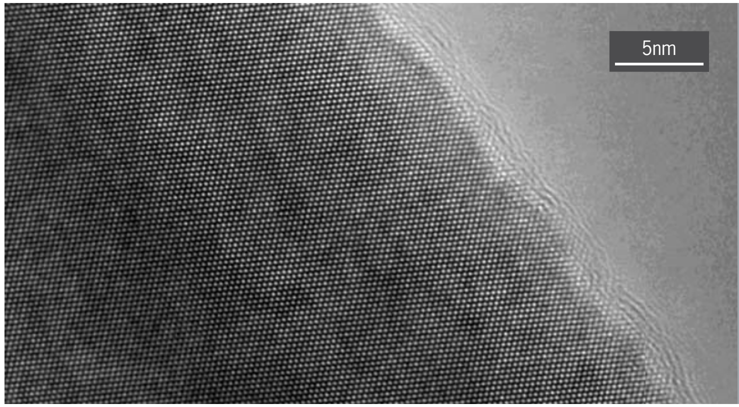
An unwitting wasp pollinates a *Drakaea glyptodon* orchid. Photograph: Rod Peakall

THE FUTURE OF POWER GENERATION

Solid oxide fuel cells (SOFC) will fill an important niche in power generation. They are efficient, can use a range of fuels and can be scaled up from kilowatt to megawatt systems in a modular way. At the heart of the SOFC is an oxygen ion conducting ceramic, known as the solid electrolyte. This can be made of a number of materials including gadolinium-doped cerium oxide. Successful design depends on the electrolyte having a good ionic conductivity that is stable for a long period of time. Current units must be operated at elevated temperature often in excess of 800°C, a fact that limits the lifetime of the electrolyte and the rest of the system.

Materials scientists Prof. John Drennan, director of the AMMRF at the University of Queensland (UQ) and Dr Toshiyuki Mori from the National Institute of Materials Science, in Japan are working on the problem. They are trying to develop systems that operate at lower temperatures and therefore prolong the life of the systems. Dr Mori and his group have developed electrolyte fabrication techniques where they can control many aspects of the microstructure. Atomic-scale transmission electron microscopy (TEM) in the AMMRF at UQ has given the researchers an understanding of these structural changes and how they correlate with the physical properties. This has led to a breakthrough in refining the ceramic processing. Through a combination of controlled chemical precipitation and advanced consolidation techniques they were able to produce gadolinium-doped cerium oxide with high enough conductivity to be incorporated into practical new fuel cells that will operate at the lower temperature of 500°C.

ZP Li, et al., *Physical Review B* 84, 2011



High resolution TEM of the improved SOFC electrolyte.

inspiring australia

MICROSCOPY EXHIBITION ON TOUR

Incredible Inner Space was created by the AMMRF to bring the excitement of world-class Australian research outcomes to the Australian people through the beauty of microscopic images. The exhibition's 28 striking images are currently touring around the country.

The exhibition was launched in November 2011 and displayed at Questacon, Canberra, until late January 2012. The next stop was the ACMM 22 conference in Perth, then a short hop across town to Scitech Discovery Centre, where it stayed until August 2012.

In September the show opened at RiAus, Adelaide with the addition of a new micrograph of brick from their heritage building and some movies. The exhibition remained in Adelaide until late November when it went north to Brisbane to grace the new Science and Engineering Centre.

The exhibition has been visited by over 270,000 people of all ages

Visitors from 63 countries have enjoyed our images online

QUESTACON, CANBERRA

SCITECH, PERTH

RIAUS, ADELAIDE

Incredible Inner Space is open to the public at Queensland University of Technology from early December 2012.

ammrf.org.au/innerspace

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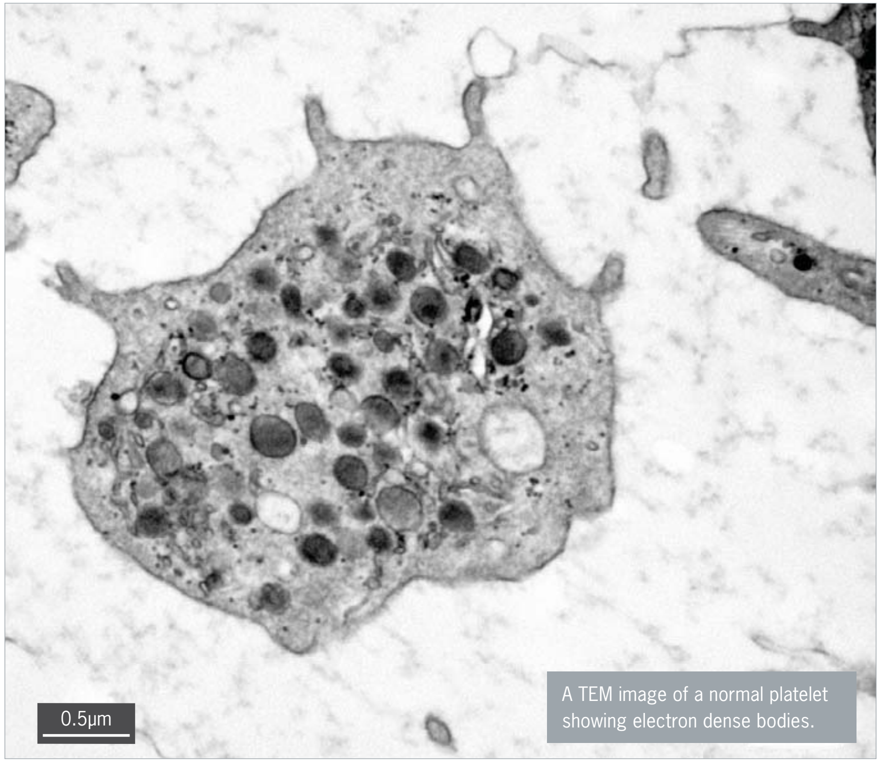
SOUTH EASTERN AREA LABORATORY SERVICES HAEMATOLOGY UNIT (SEALSHU) ACCESS THE AMMRF AT THE UNIVERSITY OF NEW SOUTH WALES



A TEM image of a normal platelet showing electron dense bodies.

PROBLEM

Dr Tim Brighton from the SEALSHU at Prince of Wales Hospital wants to be able to accurately diagnose blood platelet disorders. Platelet dysfunction can cause abnormal bleeding or bruising, but with standard histological techniques it is difficult to prove. Platelet Storage Pool Deficiency (SPD) is perhaps the most common inherited platelet disorder but it is frequently overlooked or misdiagnosed. Morphological and ultrastructural examination of platelets with transmission electron microscopy (TEM) would be very useful but very few centres utilise TEM techniques on a routine basis in the diagnosis of bleeding disorders.

SOLUTION

With the assistance of Ms Jenny Norman in the AMMRF, Dr Brighton is establishing diagnostic TEM techniques for platelet disorders. SPD is a particular focus and is characterised by a deficiency of dense bodies within the platelets. These bodies contain compounds essential for fulfilling the blood functions of platelets and are electron opaque, making them easily detected by TEM. So far, Dr Brighton has used his technique to identify several patients with bleeding disorders who were found to have varying deficiencies of these dense bodies.

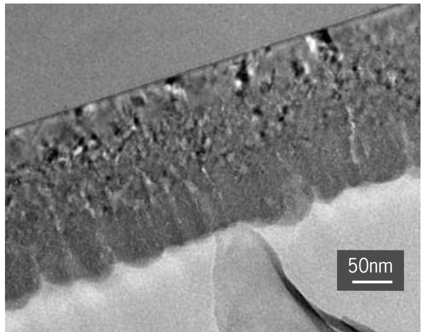
THE AMMRF AT THE UNIVERSITY OF SYDNEY PROVIDE TESTING SERVICES FOR USSS

PROBLEM

USSS holds patents on thin-coated solar technologies. They needed to determine whether their patents and licences are being respected by manufacturers of solar tubes around the world.

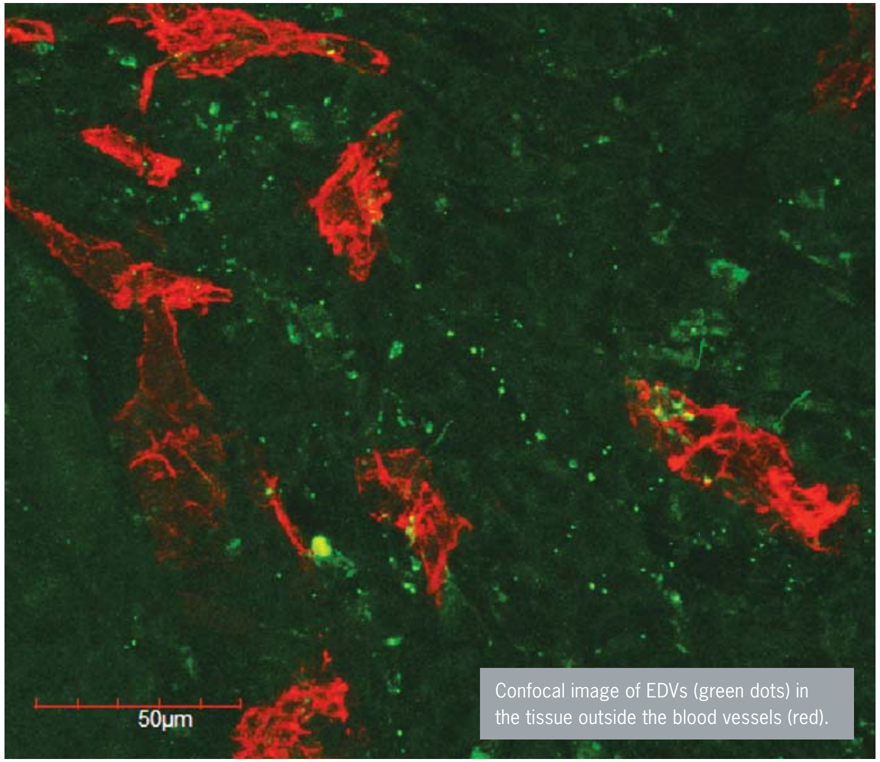
SOLUTION

The AMMRF provided advanced specimen preparation and analytical transmission electron microscopy to analyse currently available products collected by USSS. Results have clearly distinguished the structural details of different coatings and can therefore suggest the nature of the production process. A comprehensive survey of commercial products has provided evidence to support the company's position with respect to patents.



A TEM image showing the coating on one of the tubes tested.

ENGENEIC PTY LTD ACCESS THE AMMRF AT THE UNIVERSITY OF SYDNEY



Confocal image of EDVs (green dots) in the tissue outside the blood vessels (red).

PROBLEM

EnGeneIC Pty Ltd has developed a unique technology that can deliver different payloads of anticancer drugs and other therapeutic molecules to cancers by using antibodies. Their EnGeneIC Delivery Vehicles (EDVs) are 400 nanometre particles based on bacterial minicells. The researchers need to understand uptake and delivery of payload molecules to different tumour cells. Targeted drug delivery has the potential to minimise the harsh side-effects that cancer patients typically have had to endure during treatment.

SOLUTION

EnGeneIC used confocal microscopy at the AMMRF to visualise targeted EDVs within breast cancer cells grafted into mice to form tumours. The EDV particles, carrying a payload of fluorescent siRNA, effectively targeted only the breast cancer cells. Tumours from the EDV-treated mice were cryosectioned and examined to determine the distribution of EDVs in the tumour. Further experiments provided information on the fate of injected EDVs in relation to tumour blood vessels.

EnGeneIC's studies will help maximise the drug delivery potential of their system and provide an essential stepping-stone on the road from animal models to clinical trials. Ultimately multiple pharmaceutical companies will be able to license EnGeneIC EDVs for the targeted delivery of their own proprietary molecules.

Innovation from AMMRF-enabled research frequently leads to patents being filed. Three examples from 2011–12:

AUSTRALIAN PATENT APPLICATION 2012901686

A novel dry powder inhalable formulation incorporating three first-line antitubercular antibiotics

Daniela Traini, Paul Young, Hak-Kim Chan & John Chan.

For the full story see p. 29

US PROVISIONAL APPLICATION 61/306471

Nitriding of niobium steel and product made thereby

Y. Xie, C. Zhu, J.M. Cairney, S.P. Ringer, C.R. Kilmore, F. Barbaro & J. Williams.

For the full story see p. 27

INTERNATIONAL PATENT APPLICATION PCT/AU2012/000414

A method for the treatment of a solid tumour

Brian Hawkett, Trevor Hambley, Nicole Bryce, Thi Thuy Binh Phan & Nirmesh Jain.

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Cover
High-resolution transmission electron micrograph showing the crystal structure of an aluminium nitride coating. The atoms are approximately 0.2nm apart. Hongwei Liu

Access, p8-9
Scanning electron micrograph of a blood clot showing red blood cells in a mesh of fibrin. Red blood cells are approximately 7µm in diameter. Pat Trimby

Research, p14-15
Confocal image of mammary alveoli generated from stem cells in-vitro. The alveoli range in diameter between 50 and 200µm. Libby Thomas

Industry, p32-3
Colour-enhanced backscattered scanning electron micrograph of quenched coal slag; red is the former liquid phase and purple, the crystallised solids (feldspar). The horizonal field of view is 475µm. Alex Ilyushechkin

Back Cover
Confocal micrograph showing actin (green) depolymerising in cultured colon cancer cells after treatment with latrunculin A. Kristina Jahn

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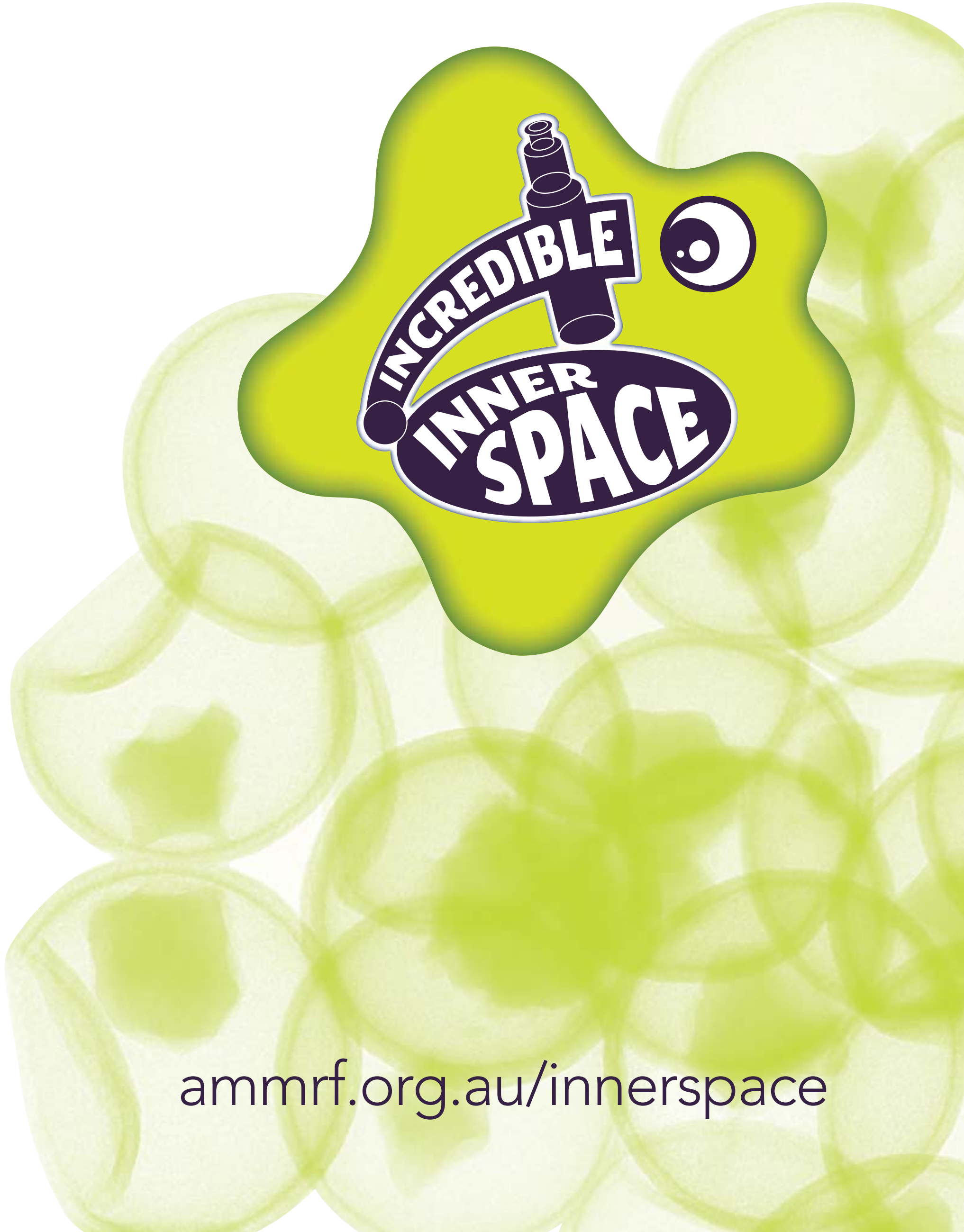

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