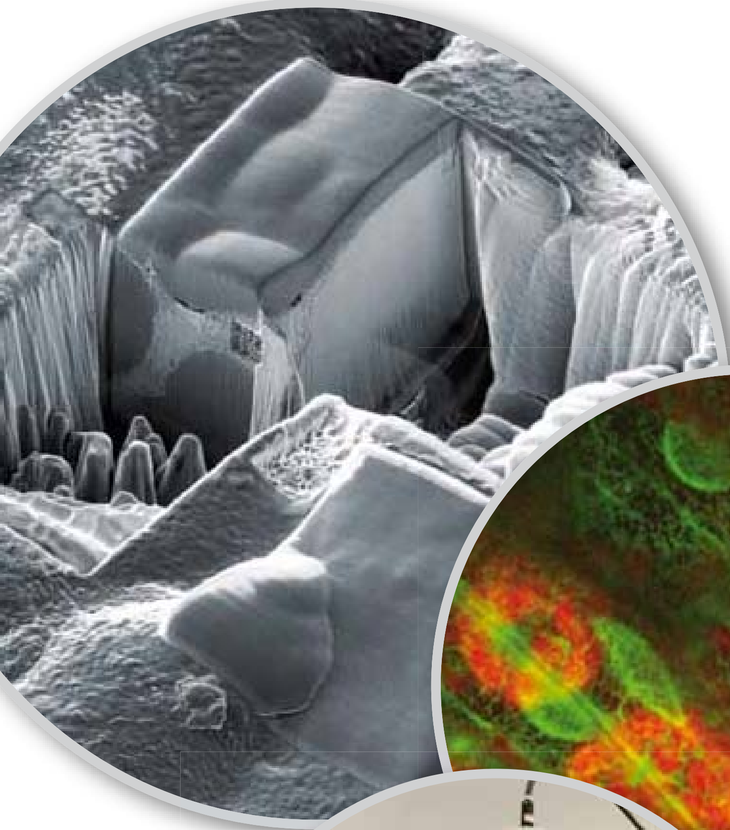
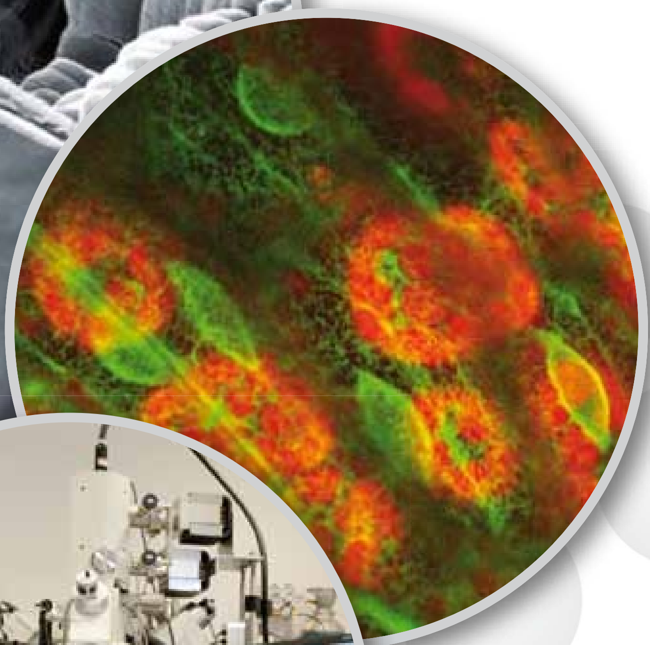
ammrf
Australian
Microscopy & Microanalysis
Research Facility





2010 PROFILE

MAKING AN IMPACT

The AMMRF is funded by

An Australian Government Initiative
National Collaborative Research Infrastructure Strategy

NSW Government Industry & Investment

Queensland Government

The Government of Western Australia

Government of South Australia

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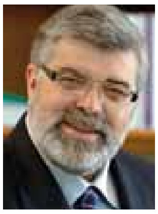
FROM THE MINISTER



Senator the Hon.
Kim Carr

The importance of research to our future prosperity cannot be underestimated. Research drives our economic productivity, addresses the challenges we face, attracts global investment and improves our quality of life. Through its world-class research infrastructure and leading expertise in high-end science, the Australian Microscopy & Microanalysis Research Facility is helping us to find solutions and pursue opportunities in areas as diverse as health, climate change and innovative manufacturing.

The Australian Government is proud to support this facility through the National Collaborative Research Infrastructure Strategy.

Senator the Hon. Kim Carr
Minister for Innovation, Industry, Science and Research

THE UNIVERSITY OF SYDNEY

THE UNIVERSITY OF QUEENSLAND

THE UNIVERSITY OF WESTERN AUSTRALIA
Achieve International Excellence

UNSW
THE UNIVERSITY OF NEW SOUTH WALES

ANU
THE AUSTRALIAN NATIONAL UNIVERSITY

SOUTH AUSTRALIAN REGIONAL FACILITY (SARF)

THE UNIVERSITY OF ADELAIDE AUSTRALIA

University of South Australia

Flinders UNIVERSITY

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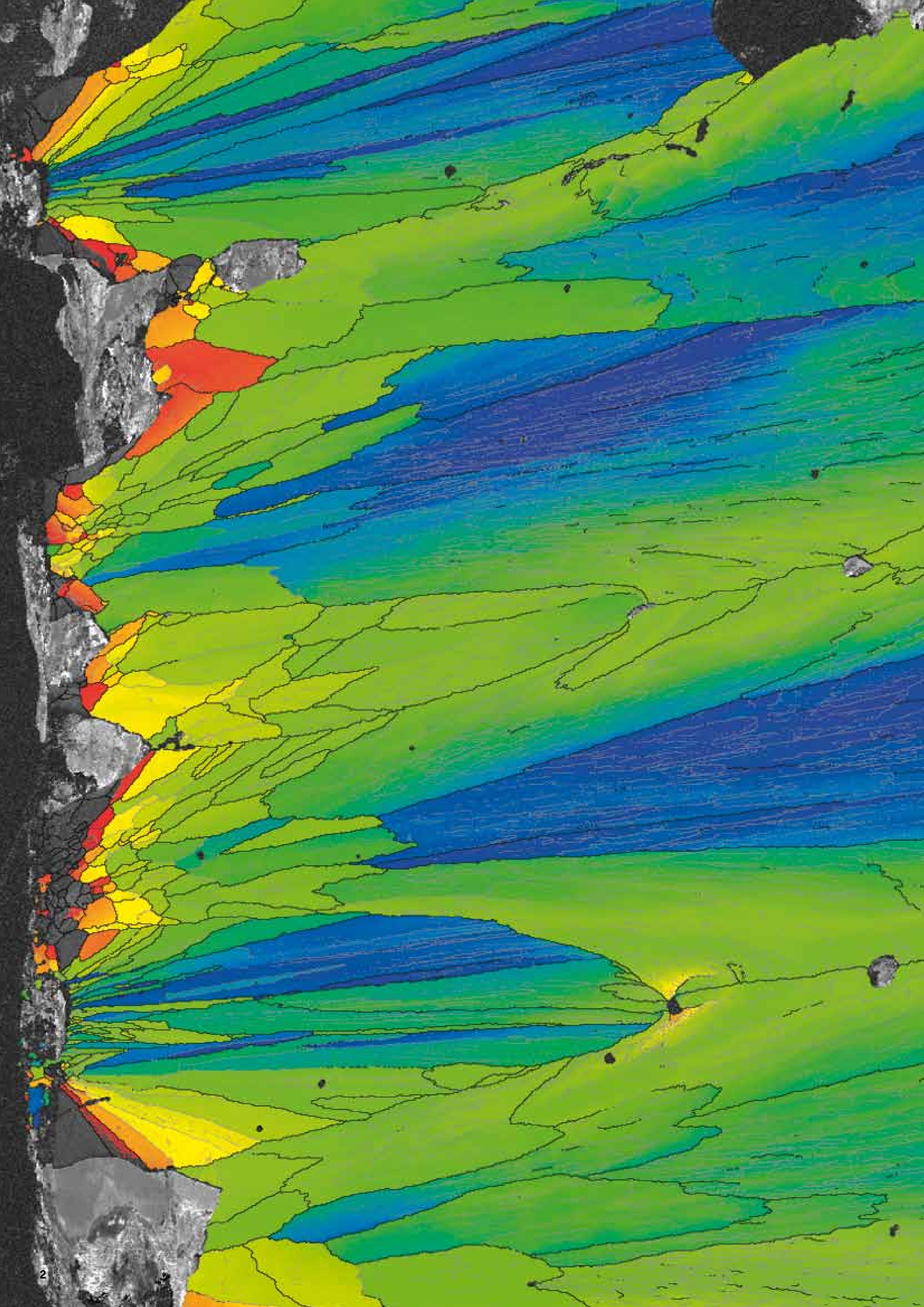


FROM THE CHAIR

The AMMRF has completed another year of outstanding outcomes. It is a continuing pleasure to chair the board of this national facility.

I recently travelled to Brazil with an AMMRF team and with members of the Australian national microscopy society. Our aim was to help support Australia's bid to host the International Microscopy Congress in Sydney in 2014. It proved disappointing (but understandable), that the microscopy voting community determined that the four-yearly congress should return to Europe in 2014, after 20 years in other regions. However, I also was able to attend a meeting of the AMMRF's International Technical and User Advisory Group. This meeting proved highly productive, but also was easy-going and enjoyable. Seven microscopy leaders from across the globe discussed the AMMRF's role in Australia's research infrastructure and considered future opportunities for links with other microscopy organisations in the USA and Europe. The recognition and respect shown for the AMMRF by its sister facilities elsewhere bodes well for the future.

In 2011, the federal government's National Research Infrastructure Council intends to reconsider the national research-infrastructure roadmap with a view to developing infrastructure-funding schemes that might succeed NCRIS and the SuperScience program. I am certain that high-end microscopy and microanalysis, which underpin so many areas of national research, will remain high on the list of essential infrastructure. I am well aware, from my many interactions with Australian industry and government, that the AMMRF is considered an exemplar for a successful national research facility, as it helps to create real benefits for Australia, while raising the international profile of Australian research.

Dr Gregory R. Smith
Chair of Board

FROM THE CEO

The AMMRF is at a stage where investments in research infrastructure are now translating into research outcomes that have societal impacts. Consequently, our *2010 Profile* is themed around, and highlights, some of these impacts. It demonstrates our concept of the transition of raw data into information and subsequent progression into knowledge, which can, and does, have societal impact. This translation is something that my Operations Committee and I spend a lot of time and effort working at with our outstanding staff and user community. It is especially pleasing to note that the research outcomes and impacts map well onto Australia's national research priorities of sustainability, health, frontier technologies and the safeguarding of Australia. The translation of research into significant outcomes is an important indicator of the success of investment in research infrastructure.

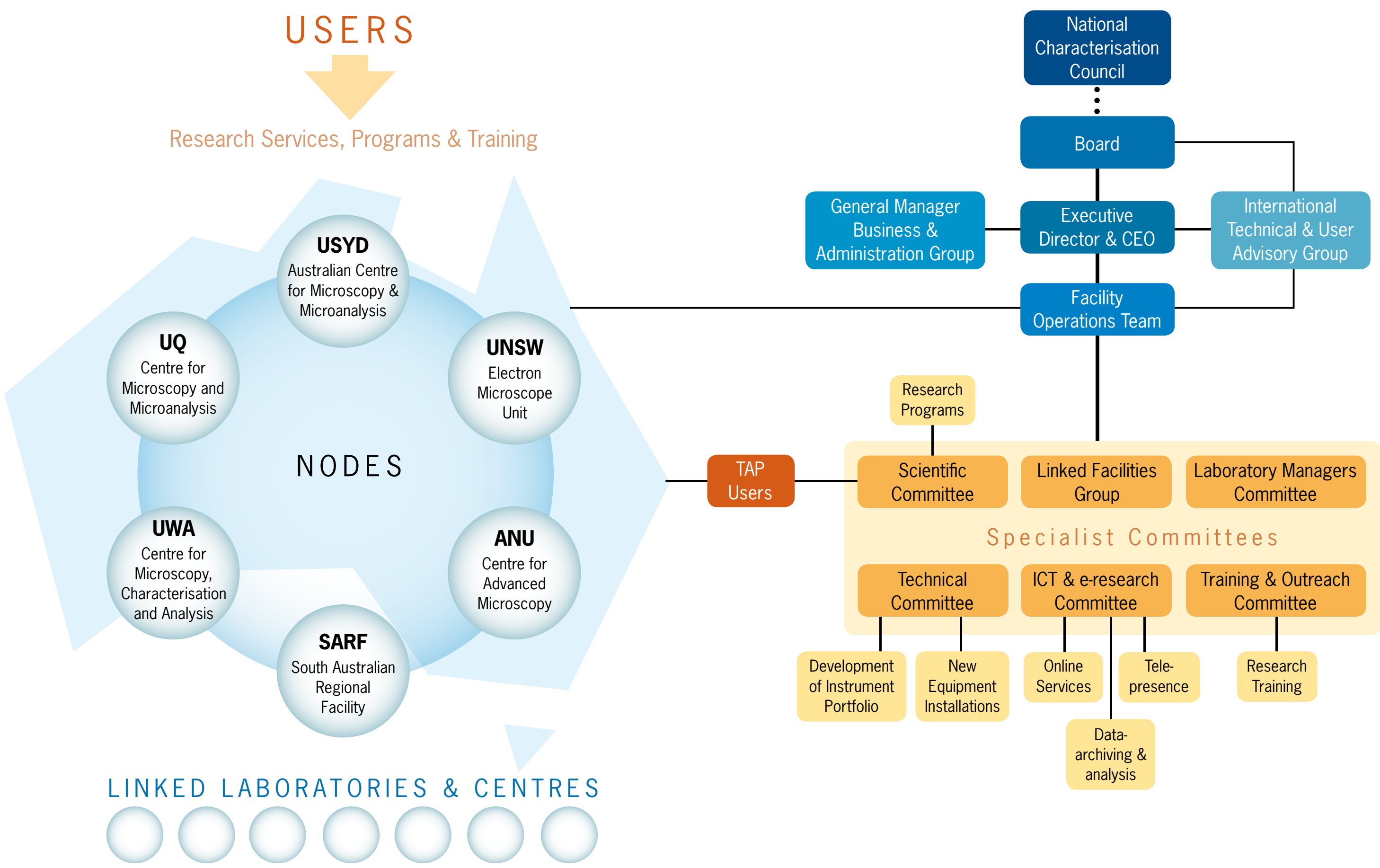
I feel that there is an added imperative for synergy between the AMMRF foundation nodes, Linked Laboratories and Linked Centres that make up our national hub-and-spoke organisation. These relationships are a feature of this *Profile*. Examples of successful partnerships between the AMMRF and kindred organisations are also highlighted. Our e-Research initiatives with the National e-Research Architecture Taskforce (NeAT), including the work on the Technique Finder with Intersect Australia Ltd, are something that we are very proud of. Our close working relationships with the Australian National Fabrication Facility, AuScope and the National Imaging Facility have generated value for users of all these facilities and we look forward to developing these relationships further in 2011 and beyond.

I commend to you the individual research stories and congratulate the researchers and AMMRF staff involved. I also ask you to consider that what we present in this *Profile* is just the very tip of a significant iceberg. Our facility is now serving in excess of 3000 researchers nationally and the microscopy beamtime required by Australian publically funded researchers and our industry colleagues continues to grow. A recent independent study was commissioned by the National Characterisation Council surveyed the Australian scientific community via the Federation of Australian Scientific and Technological Societies (FASTS) and other channels. Though, perhaps we shouldn't be surprised: they concluded unequivocally that demand for high-end microscopy and microanalysis significantly outstrips supply in the eyes of the majority of Australian researchers in science and technology – something that is well understood at all of the AMMRF laboratories.

Prof. Simon P. Ringer
Executive Director & CEO

A relative orientation map of a cross-section through a fossilised dinosaur eggshell, collected by using electron backscatter diffraction (EBSD) in the SEM. Sample courtesy of Dr Gerald Grellet-Tinner (Field Museum of Chicago). Image by Dr Pat Trimby @ The University of Sydney.

ORGANISATIONAL STRUCTURE

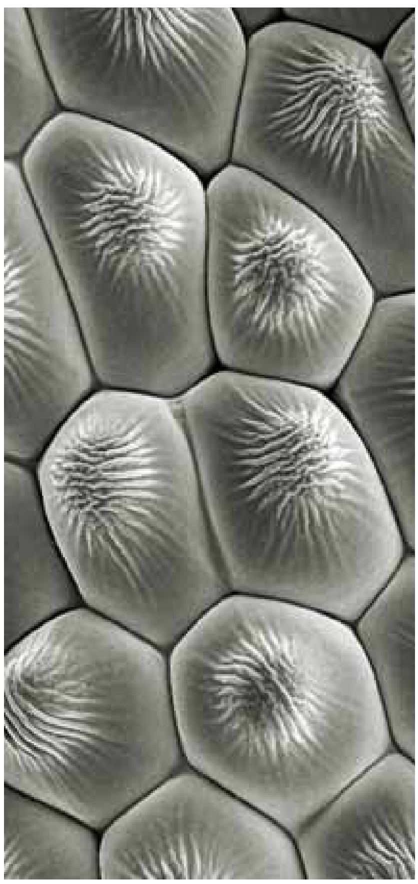


Established in 2007 under the Commonwealth's National Collaborative Research Infrastructure Strategy (NCRIS) the AMMRF is a joint venture between Australian university-based microscopy and microanalysis centres. It is a national grid of equipment, instrumentation and expertise in microscopy and microanalysis that provides nanostructural characterisation capabilities and services and is available to the entire Australian research community.

Its board oversees the activities of the AMMRF and is 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 management is overseen by the operations team, which consists of the node directors and General Manager. Meetings are held regularly.

The nodes have a wide range of overlapping and complimentary instrument types and expertise, together providing a network that brings both highly in-demand and cutting-edge techniques to the Australian research community. The Linked Laboratories extend that range of instrumentation and expertise in specialist areas.

All the nodes have their own research programs, provide research services to support external users and most provide services to industry.



NODES

Nodes are major university-based microscopy and microanalysis centres that have become an unincorporated joint venture forming the core of the AMMRF.

Australian Centre for Microscopy & Microanalysis (AMMRF Headquarters) The University of Sydney
Director: Prof. Simon P. Ringer

Centre for Microscopy and Microanalysis The University of Queensland
Director: Prof. John Drennan

Centre for Microscopy, Characterisation and Analysis The University of Western Australia
Director: Prof. David Sampson

Electron Microscope Unit The University of New South Wales
Director: Prof. Paul Munroe

Centre for Advanced Microscopy The Australian National University
Director: Prof. Tim White

South Australian Regional Facility (SARF)
Ian Wark Research Institute (University of South Australia)
Adelaide Microscopy (The University of Adelaide)
Flinders Microscopy (Flinders University)
Director: Prof. Hans Griesser

LINKED LABORATORIES

A Linked Laboratory provides access to specialist instruments at an institution or organisation within the university sector or some relevant part of a publicly funded research agency.

Microscopy and Microanalysis Facility RMIT University
Provides advanced electron microscopy facilities, including high-resolution and environmental scanning electron microscopes (SEM), transmission electron microscopes (TEM), scanning auger nanoprobe, X-ray photoelectron spectroscopy, and dynamic light-scattering spectroscopy.

Australian Biosecurity Microscopy Centre, CSIRO Australian Animal Health Laboratory
Offers a live-cell and cryo-TEM imaging facility within a PC3/PC4 bio-containment environment. This is a unique capability, enabling fundamental research with biological agents that need the highest level of containment.

Optical Microcharacterisation Facility Macquarie University
Combines technologies in Raman microscopy, fluorescence excitation and lifetime spectroscopy, surface-enhanced Raman microscopy and near-field scanning microscopy.

Analytical Electron Microscopy Facility Queensland University of Technology
Offers advanced SEM platforms, including a dual-beam focused ion beam with mineral-liberation analysis software, and an analytical environmental SEM complete with a cooling and heating stage.

Advanced Analytical Centre James Cook University
Provides specialist microanalysis capabilities, including electron-probe microanalysis, low-vacuum chamber SEM, confocal laser scanning microscopy and an atomic force microscope fitted with a nano-indentor.

John de Laeter Centre of Mass Spectrometry Curtin University of Technology
Houses single and multicollector sensitive high-resolution ion microprobes (SHRIMPs) for quantitative isotopic and elemental analysis.

LINKED CENTRES

A Linked Centre is established in conjunction with a concentration of specialist users based at a major research centre at a publicly funded institution, for example an ARC Centre of Excellence node or a Cooperative Research Centre node.

Australian Institute of Bioengineering and Nanotechnology (AIBN) The University of Queensland
The AIBN has a dedicated microscopist who advises researchers on appropriate techniques to support their nanotechnology projects with an emphasis on nanotoxicology research.

Australian National Fabrication Facility (ANFF) Australian National University
The ANFF node in the Australian Capital Territory comprises facilities at the Australian National University and the University of Western Australia and specialises in the area of photonic and electronic materials growth, and the processing and fabrication of devices.

ANSTO Institute of Materials Engineering Australian Nuclear Science and Technology Organisation
The ANSTO Linked Centre microscopist is embedded into the University of Sydney node and will use atom probe tomography and high-resolution TEM capabilities to support projects related to materials used in nuclear engineering.

CAPABILITIES

ENABLING EXCELLENT RESEARCH

Effective research demands advanced infrastructure and the AMMRF gives researchers access to a spectacular array of instruments and techniques to enable their research to really make an impact. AMMRF capability comprises instruments and substantial expertise that support and enable research excellence in fundamental and applied sciences within Australia and as part of international collaborations.

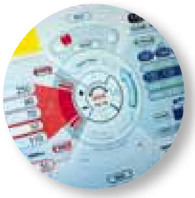
Over 250 individual instruments, all run by expert staff, support well over 60 different techniques that can provide finely tailored experimental approaches to diverse research questions. Our users are guided through all aspects of their project, from the original idea to planning, training, data collection and analysis, and of course assistance with writing papers and advice on grant applications.

To help researchers find the most appropriate techniques and instruments, we now have two complementary approaches. Descriptions of instruments are available on the nodes' websites and now our new Technique Finder tool encourages users to search directly for useful techniques. This application, showcased on the page opposite, was developed during the year and aims to provide a user-centric approach to identifying how the AMMRF can enable effective research. The researcher can select the type of experiment they want to carry out, and the application displays a list of microscopy and microanalysis techniques that could be applied to their samples in order to generate relevant results.

The tool gives an overview of what a given technique can do, examples of out-puts, references and contact details for the experts in AMMRF nodes around the country who can provide advice to the researchers so they can achieve great outcomes. There is also a search facility and a list of all the techniques.

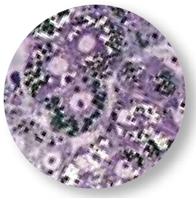
It is available through the AMMRF website at ammrf.org.au/techniquefinder.

WORLD-CLASS INSTRUMENTATION AT YOUR FINGERTIPS



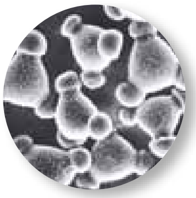
Specimen Preparation

Biological
Materials
Cell Culturing and Molecular Preparation
Thermomechanical Processing



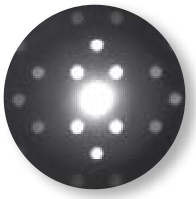
Light and Laser Optics

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



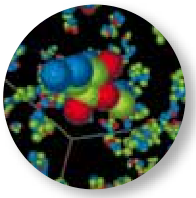
Scanning Electron Microscopy

Imaging and Analytical Spectroscopy
In-situ Imaging and Testing
Cathodoluminescence



Transmission Electron Microscopy

Imaging and Analytical Spectroscopy
Cryo Techniques and Tomography
Phase and Z-contrast Imaging
Diffraction



Advanced Ion Platforms

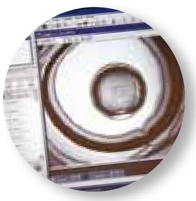
Nanoscale Mass Spectroscopy
Atom Probe Tomography
Ion Milling and Machining
Ion Implantation

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- and Nanotomography



Visualisation and Simulation

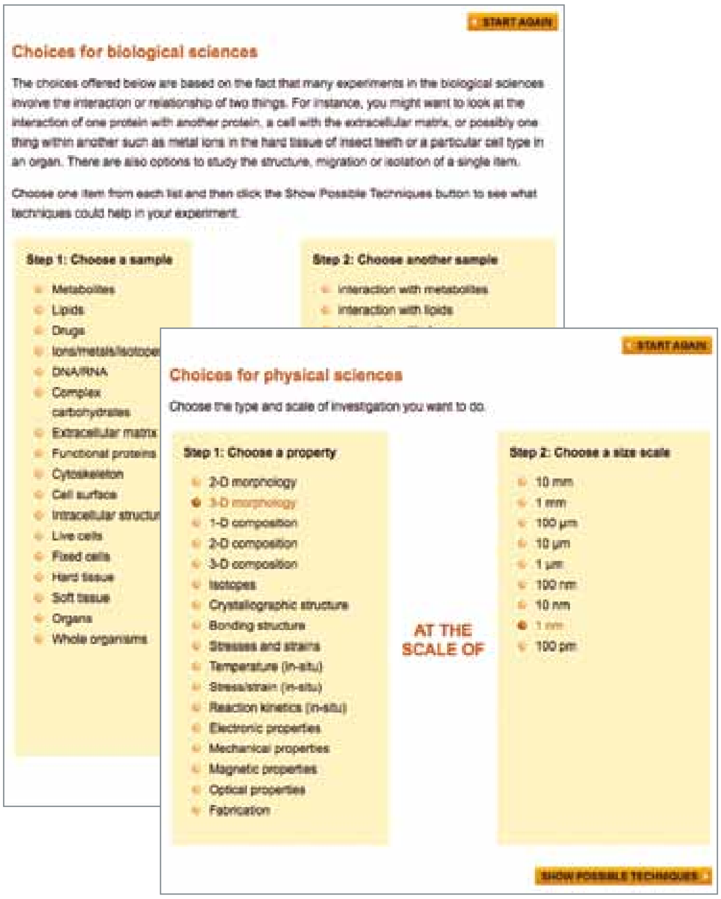
Computed Spectroscopy
Computed Diffraction
Image Simulation, Analysis and Data Mining

TECHNIQUE FINDER

This tool has been designed to help researchers to identify and understand microscopy and microanalysis techniques available to researchers through the AMMRF. Contact details are listed for our expert staff for each technique. They can provide all the information needed to guide a researcher through the planning, training, data collection and interpretation stages of their experiment.

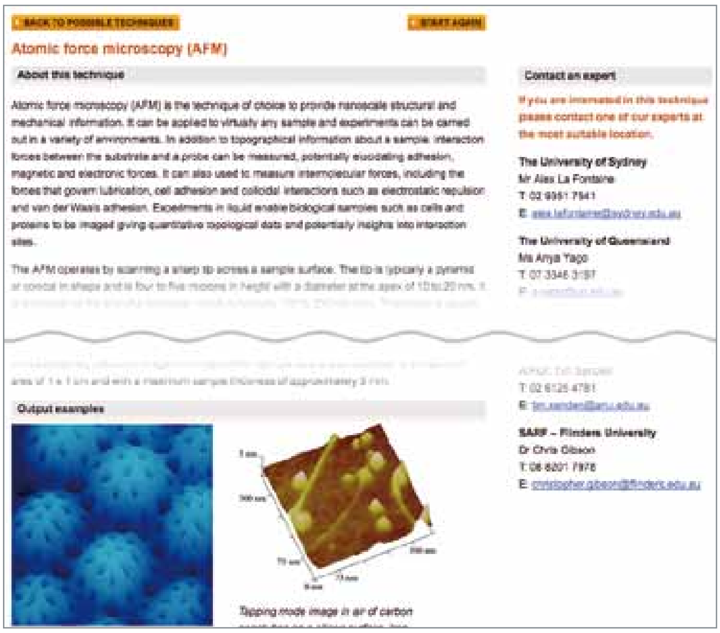
STEP 1 Choose your search approach

STEP 2 Choose your type of investigation



STEP 3 Review list of possible techniques

STEP 4 View details of a specific technique and expert staff in the field

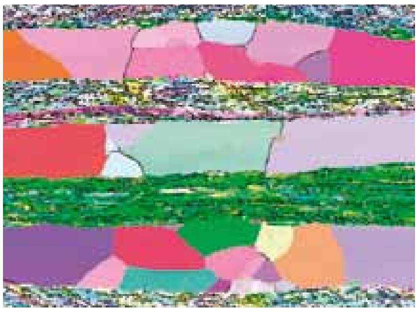


www.ammrf.org.au/techniquefinder

LEARN ABOUT THE TECHNIQUE(S) THAT CAN ANSWER YOUR RESEARCH QUESTIONS

MAKING AN IMPACT – FLAGSHIP INSTRUMENTS

The AMMRF flagship instruments are the top-flight platforms funded through direct investment by the National Collaborative Research Infrastructure Strategy (NCRIS). These capabilities often are unique in Australia, and their details and impact are outlined below.



HIGH-RESOLUTION SEM MICROANALYSIS FACILITY

Unique suite of field-emission scanning electron instruments for materials analysis

This suite of field-emission scanning electron microscopes provides a high-throughput, high-precision facility able to structurally characterise materials and to detect and quantify elements at very high spatial resolution. High-resolution SEM imaging completes this comprehensive imaging and analysis platform.

Electron Microscope Unit; The University of New South Wales

IMPACT

- Sub-micron, quantitative, spatially specific chemical analysis now available with a speed and resolution not previously available.
- The presence of the flagship supported research and increased collaborations with Australian and international academics and industry partners.
- The facility has been crucial in understanding the structural properties of Mg–Cu–Y–Zn bulk metallic glass
- It has supported researchers from materials science and the ARC Photovoltaics Centre of Excellence in doing innovative research not otherwise possible.

HIGH-THROUGHPUT CRYO-TEM FACILITY

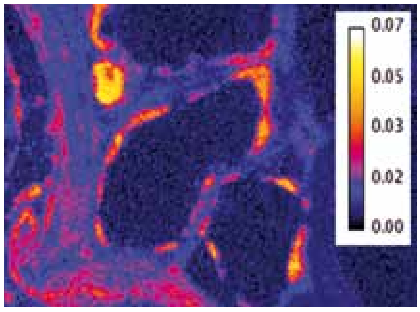
Unique high-throughput cryo-transmission electron microscopy (TEM) facility for structural analysis

This cryo-TEM facility has the latest technologies, including ultra-high-resolution CCD cameras and specialist cryo-holders, creating a world-class platform for high-throughput structure determination.

Centre for Microscopy and Microanalysis; The University of Queensland

IMPACT

- Elucidation of key structural features in cell surfaces that allow transport across cell membranes has resulted in key papers in high impact journals and the submission of a patent relating to drug delivery.
- Development of a blue-green microalgae energy conversion program has attracted national, international and industry funding. The flagship instrument has provided key structural information about the photosynthetic mechanisms.
- Key questions on how initial nucleation produces the final structures of mesoporous materials have been answered through 3-D microscopy techniques, resulting in high impact publications.



CAMECA IMS 1280 AND NANOSIMS 50 ION PROBES

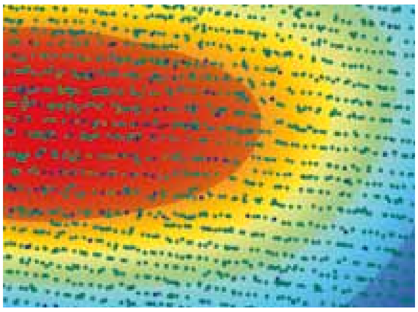
Ion probes for chemical and high-precision isotopic analysis and imaging to the nanoscale

This secondary-ion mass spectrometry facility offers high-sensitivity and high-precision isotope-ratio analysis for a diverse array of materials.

Centre for Microscopy, Characterisation and Analysis; The University of Western Australia

IMPACT

- Co-location of the NanoSIMS 50 and IMS 1280 is central to the success of the ARC Centre of Excellence for Core to Crust Fluid Systems.
- Work to reassign the timing of first appearance of eukaryotes and cyanobacteria on Earth was published in *Nature*.
- Excellent performance by the flagship capability has enabled the initiation of the process to become an International Atomic Energy Agency (IAEA) analytical laboratory to analyse environmental nuclear samples.



IMAGO LOCAL-ELECTRODE ATOM PROBES

Local-electrode atom probes for atomic-level analysis of materials

This world-leading facility provides comprehensive capabilities in atom probe tomography. Voltage-pulsed atom probe and pulsed-laser atom probe open up this powerful technique to a large variety of applications, from conductive to less-conductive materials.

Australian Centre for Microscopy & Microanalysis; The University of Sydney

IMPACT

- Atom probe has enabled world-leading research into key concepts in the relationships of structural and functional properties in polycrystalline materials at the nanoscale.
- Many significant papers have resulted including a high-profile and well-received *Nature Communications* paper on an entirely new topological assessment of materials nanostructure via atom probe tomography. Atom probe is the only approach available to assessing nanoscale grain texture – or nanotexture.
- A major Linkage Project with BlueScope Steel depends on atom probe capability to understand new generation steels.

FEI NOVA NANOLAB 200 DUALBEAM FIB AND THE FEI HELIOS NANOLAB DUALBEAM FIB

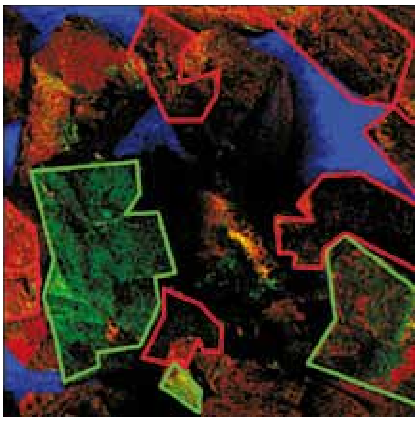
High-resolution scanning electron microscopes with focused ion beams (FIBs), energy dispersive X-ray spectroscopy and electron backscattered diffraction systems

With dual high-resolution electron and ion columns, these advanced microscopes offer a key capability in sub-nanometre-resolution imaging, in high-precision cross-sectioning by ion milling, and in elemental and orientational analysis. They also make possible 3-D image reconstruction by slice-and-view; script-driven large-scale prototype patterning; and preparation of thin-foil TEM samples of difficult materials.

Electron Microscope Unit; The University of New South Wales and Adelaide Microscopy; The University of Adelaide; South Australian Regional Facility (SARF)

IMPACT

- Achieved 4000 hours beam time a year (UNSW). Trained about 150 experienced FIB users and provided technical support for 25 TAP users.
- Supported teaching and research in a huge range of disciplines, including regular users from ANU, USyd, UQ, UOW, UWA, Monash.
- FIB is a critical technique to support major projects by Australian researchers. It fostered international collaborations with USA, Germany, New Zealand and China, and commercial companies, such as Bluescope, Cochlear and Sapphicon.
- Provided a new approach for characterisation of deformation mechanisms in multiphase interfaces and multilayer structure of nanomaterials.



PHI TRIFT V NANOTOF TOF-SIMS

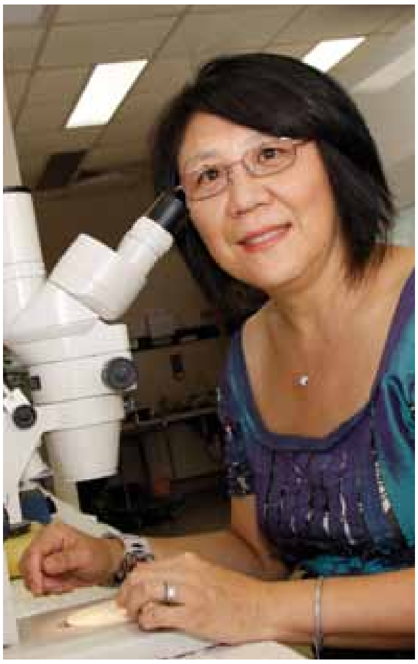
Time-of-flight secondary ion mass spectrometer (ToF-SIMS) for surface analysis and depth profiling

The PHI TRIFT V nanoToF ToF-SIMS is able to conduct surface analysis at the nanometre level for the identification and mapping of elements and molecules. This instrument is unique in its ability to combine sensitivity, spatial resolution and chemical specificity with parallel detection of atomic and molecular species.

Ian Wark Research Institute; University of South Australia; South Australian Regional Facility (SARF)

IMPACT

- Implementation of the C_{60} ion gun has opened up high-sensitivity detection of high-mass ions and molecular fragments, with a mass of up to 4000, from polymeric and biomaterials samples.
- The ToF-SIMS laboratory has been closely involved in an international study aiming to probe the limits of resolution in the depth profiling of polymer samples.
- The instrument has delivered key data for commercially oriented large projects, particularly with mining companies, and for smaller analytical consultancies.



ACCESSIBLE TO ALL AUSTRALIAN RESEARCHERS

Facilitating access to AMMRF instruments and expertise is fundamental to our day-to-day activities. All Australian researchers can use our instruments, with priority given to the best and most feasible projects. When a researcher has identified where they need to go to carry out their project, the experts at that location will discuss it with them, providing technical and scientific advice and support all the way from planning to data collection and analysis to publication. Only nominal charges are made for use of the instruments to contribute towards maintenance.

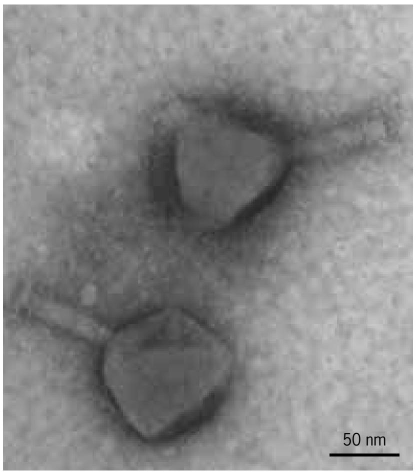
TRAVEL AND ACCESS PROGRAM

The Travel and Access Program (TAP) provides support to those researchers who need to access instruments other than those at their home institution. The program contributes to travel, accommodation and beamtime fees to help researchers gather some initial information to form the basis of a future grant application where more microscopy or microanalysis time can be included. Applications for this very popular scheme are made through the AMMRF website and they are evaluated within a few weeks.

ammrf.org.au

EXAMPLES OF FUNDED TAP PROJECTS (JULY 2009–JUNE 2010)

- *Modification of AFM cantilevers for dynamic force microscopy*
- *Atom probe tomography of grain boundaries in Castrip® steels*
- *The observation of 'invisible' gold in the Liba-Jinshan gold deposit*
- *Genesis of gold–copper mineralisation in the central Eastern Mindanao Ridge*
- *Using FIB to prepare samples for synchrotron X-ray nanotomography*
- *Discovery of intestinal genes that may play a role in colon cancer*
- *Use of NanoSIMS to measure fluxes of trace metals in plant roots*
- *Long-term imaging of calcium signalling in breast-cancer cells*
- *Studying the in-situ nucleation of nanocrystals*
- *Crystallisation of Ti-based amorphous powders during continuous annealing*
- *The role of symbiotic bacteria in early life stages of coral*
- *Mapping of ^{34}S, ^{197}Au and ^{108}Ag in pyrite from high-grade gold veins*
- *Searching for evidence of life in laminated sedimentary structures with NanoSIMS*
- *The corrosion mechanism of weldable martensitic stainless steel*
- *The crystallography of phase transformations in titania nanocomposites*
- *Surface analysis of new ion-conducting membranes for hydrogen fuel cells*
- *Nano-channelled polymeric sensors*
- *Microstructure and deformation of nanocomposite ceramic coatings on steel*
- *Identifying a mineral standard to calibrate Sr/Ca and Sr ratios in SIMS*
- *Precise composition of low-temperature-nitridised porous silicon*
- *Fundamentals of microbe–mineral surface interaction during bioleaching of chalcopyrite*
- *Oxygen isotope study of early-solar-system basaltic meteorites*
- *Stress-induced recombination in high-efficiency silicon solar cells*
- *Interaction of exoelectrogenic microorganisms with non-soluble surfaces*
- *Biomimetic design of aerospace composite joints*
- *Gold scavenging during pyrite crystallisation*
- *Resolving fluid flow regimes in subducted crust through oxygen isotope analysis of garnet*
- *QEMSCAN for routine analysis of clays in mineral processing*
- *Use of polarisation SHG microscopy to image cardiomyocytes from growth restricted and normal sheep foetuses*
- *NanoSIMS investigation of fossil preservation across the Precambrian–Cambrian boundary*
- *3D-imaging and elemental mapping of 3.5-billion-year-old cells*
- *Characterising plasma-polymerised surface gradients on 3-D scaffolds for tissue engineering*
- *FIB sample preparation for an EFTEM and HAADF-STEM study of implanted silicon carbide*
- *Al-based metallic glass with novel properties*
- *Diffusional rims and moats around ilmenite inclusions in garnet for geospeedometry*
- *Powder metallurgy to fabricate bulk metallic glasses for industrial applications*
- *Characterisation of crustacean larval eyeshine*
- *Processes responsible for gold and sulphide diagenesis in quartz-pebble-conglomerate deposits*
- *Study of phosphorus, boron and carbon in Alloy 718*
- *Interaction of benzo[a]pyrene with* Chlorella
- *Deformation mechanism of Cu_6Sn_5 intermetallics formed at the interface between Sn-based lead-free solder and Cu substrates*
- *Enzyme attachment to polystyrene films*
- *Bacteriophage of* Leptospira interrogans *for the treatment of contaminated environments*
- *Structure of interfaces in advanced functional materials*
- *Pore morphology and connectivity in shales*
- *Tracing the magmatic and metallogenic evolution of alkalic porphyry mineral systems in Eastern Tibetan Plateau, China*
- *Combining micro-CT and SEM to characterise fossilised dinosaur eggs and eggshells*
- *High-chromium white cast irons*
- *Micro-CT analysis of coral luminescence*
- *Development of multifunctional Ni–Mn–In(Sn, Sb) ferromagnetic shape-memory alloys*
- *Measuring charge density in a dielectric under an external electric field*
- *Novel surface modification of light metals*
- *Biocontrol of melioidosis*



EVAN ROBB FROM JAMES COOK UNIVERSITY ACCESSED THE UNIVERSITY OF QUEENSLAND

Bacteria, like people, can be infected by viruses. These are called bacteriophage and can potentially be used as a means of killing pathogenic bacteria. Mr McRobb is interested in finding a method for biological control of the soil-based bacterium (*B. pseudomallei*) that causes melioidosis, a human disease endemic to north Queensland. Environmental soil and water samples were processed to isolate a range of bacteriophage that could kill the bacteria. The process identified many samples that did appear to contain bacteriophage. Following amplification, transmission electron microscopy was used to confirm the presence of bacteriophage in each sample. This analysis identified a number of bacteriophage that can burst open the bacteria and therefore have the potential for the biocontrol of melioidosis where environmental persistence of the bacteria poses a public health threat.

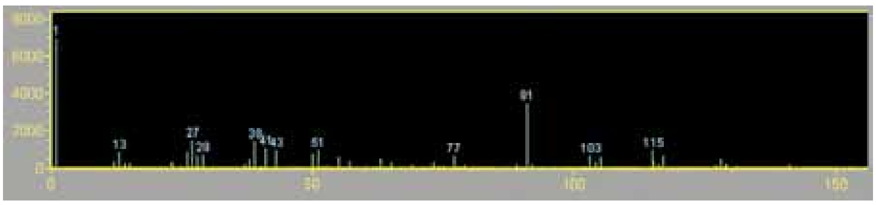
DR GERALD GRELLET-TINNER FROM THE FIELD MUSEUM IN CHICAGO VISITED THE UNIVERSITY OF SYDNEY

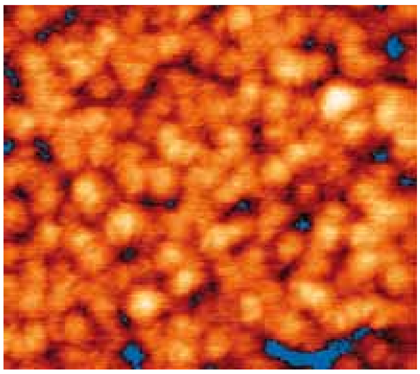
Dr Grellet-Tinner (far right) has largely pioneered the application of scanning electron microscopy (SEM) to the characterisation of fossilised dinosaur eggshells. His TAP project sought to discover new eggshell features that could act as keys to understanding the adaptive processes and nesting behaviours of the sauropod dinosaurs. These dinosaurs appear to have regularly returned to geothermal fields to shape nests and deposit eggs where they could be incubated by the ambient heat. This raises questions about the ecological triggers that underpinned these reproductive behaviors. Answers could be revealed in 3-D by using X-ray microtomography and electron backscatter diffraction to look at the carbonate microstructures and minute inclusions in eggshell.

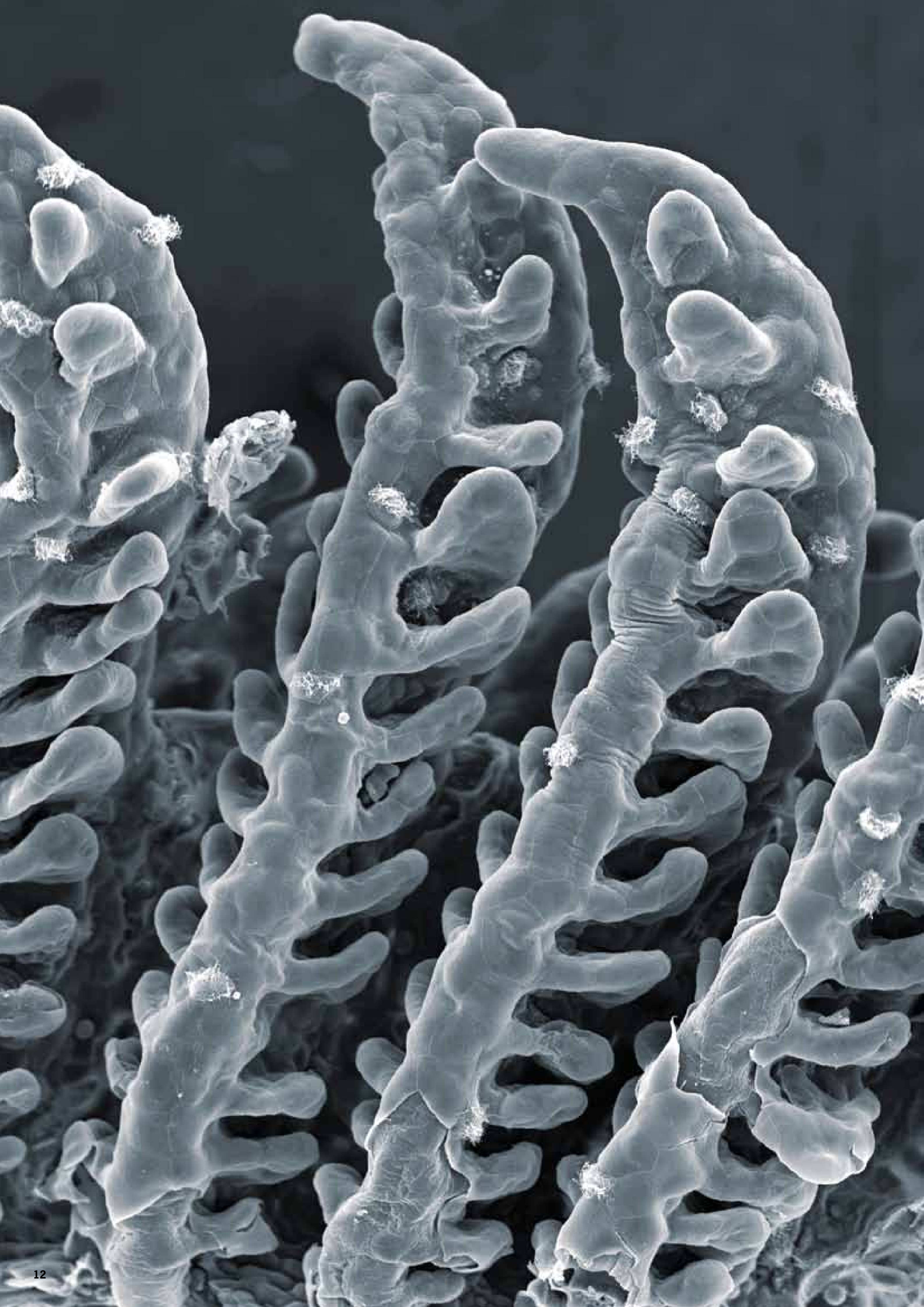
The analysis of the data that was collected will take many months, but already it is clear that the X-ray microtomography data can reveal, as never before, the internal pore structure of the eggshell fossils, and that SEM-based EBSD mapping can reveal a wealth of information on the structure and formation of the eggs.

STACEY HIRSH FROM THE UNIVERSITY OF SYDNEY VISITED THE UNIVERSITY OF SOUTH AUSTRALIA

The economic viability of ethanol fuel production from cellulosic biomass materials could be improved by using cellulase enzyme immobilisation, which enables enzyme reuse and continuous-flow reactor configurations. Plasma immersion ion implantation (PIII) was used to covalently immobilise a synergistic cellulase enzyme mixture onto a polymer surface. Analysis has indicated that cellulase adsorbed to PIII-treated polystyrene maintains its structural conformation and has high activity and stability. Earlier atomic force microscopy studies showed (below right) that the untreated surface, however, induces enzyme aggregation and shows considerable instability. The ToF-SIMS facilities at the University of South Australia have provided extensive data (an example shown below left) and enabled Ms Hirsh to not only further analyse the observed conformational differences, but also the composition of the cellulase enzyme mixture on both surfaces. These results are important for optimisation and control of the immobilised cellulase enzyme ratios.







ENABLING WORLD-CLASS RESEARCH

With 3300 researchers using AMMRF facilities this year alone, the support provided by the AMMRF reaches far beyond these individuals into research teams across Australia and around the world.

The world-class results emerging from these users' projects appear in high-impact journals and are conveyed at international conferences. They also contribute to substantial grant success, allowing further advances to be made in newly funded projects. Through significant contributions to new knowledge, crucial and innovative advances are made across the board, from fundamental academic endeavour to applied industrial R&D. As a consequence of AMMRF instrumentation, new research fields have been nurtured in Australia that would otherwise not have been possible, many of which now lead the world.

New technologies, sustainability and health have been identified as key priority areas needed to drive Australia's future success and the reports on the following pages provide a snapshot of progress in all these areas.

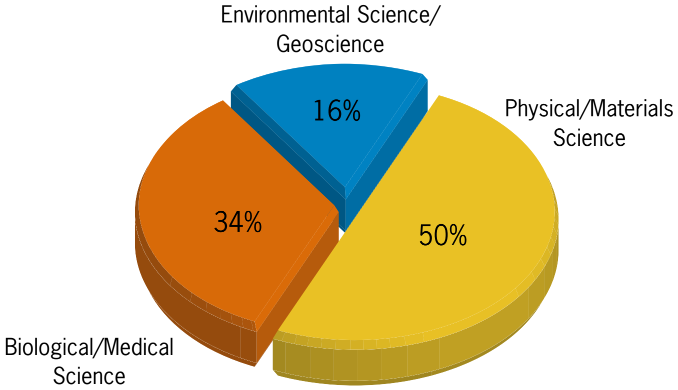
e-RESEARCH INITIATIVES

e-Research initiatives offer an important way to support research revolving around microscopy and microanalysis. They fit neatly into the AMMRF user experience, a multi-stage process comprising identification of the scientific problem, selection of a technique and registering at a node, a new user meeting to discuss the project details, instrument training, data acquisition, data analysis and finally an outcome such as publication. Through this entire experience, a range of e-Research tools and systems can add value.

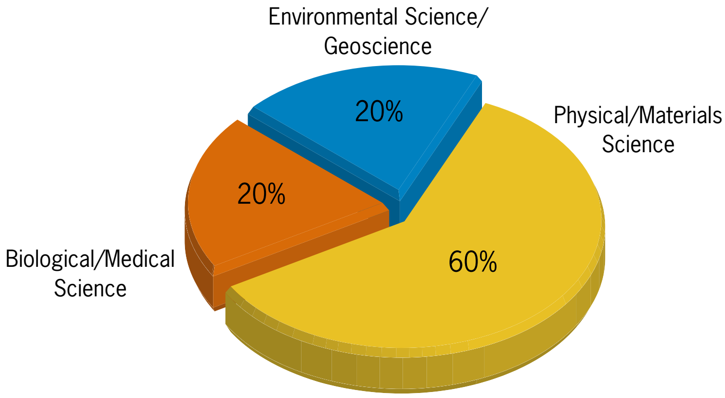
In conjunction with Intersect Australia Ltd, the AMMRF has been hard at work developing two e-Research tools that will support this comprehensive process. The first is the Technique Finder, a web application that enables researchers to identify the techniques most suited to their projects, based on a researcher-centric approach and terminology, as opposed to instrument-focused jargon. This will assist users, early on in their journey with the AMMRF, to identify more easily what we can offer them.

The second is a Data Management System (DMS) that will address the needs of increasing numbers of AMMRF users who are using high-end instruments to produce large datasets. These datasets need to be shared among collaborators or transferred to data repositories while remaining searchable by the broader research community. The DMS will make it easier for users to manage the large datasets, resulting in efficiencies in getting data analysed and ultimately published.

USERS BY DISCIPLINE (2009–2010) TOTAL: 3300



INSTRUMENT HOURS BY DISCIPLINE (2009–2010) TOTAL: 189,435



Scanning electron micrograph of the developing gills from a young lungfish. The branching structure increases the surface area available for gas exchange. Image by Dr Anne Kemp, taken at the AMMRF @ The University of Queensland.

MAKING AN IMPACT – RESEARCH

IMPACTING ON AUSTRALIA'S RESEARCH PRIORITIES

AN ENVIRONMENTALLY SUSTAINABLE AUSTRALIA

Transform the way we use land, water, mineral and energy resources through a better understanding of human and environmental systems and the use of new technologies.

- Gold in them there volcanoes (p. 17)
- Coral settles down (p. 22)
- Towards high-efficiency biofuels from algae (p. 25)
- Zooming in on mineral mapping (p. 26)
- Looking at invisible gold (p. 28)
- Why stainless steel corrodes (p. 29)

PROMOTING AND MAINTAINING GOOD HEALTH

Promote good health and wellbeing for all Australians.

- Bee stings and peanut butter (p. 16)
- Findings from fragile bones (p. 20)
- Nicotine and newborn brains (p. 27)

FRONTIER TECHNOLOGIES TO BUILD AND TRANSFORM AUSTRALIAN INDUSTRIES

Stimulate the growth of world-class Australian industries by that use innovative technologies developed from cutting-edge research.

- AMMRF e-research initiatives (p. 13)
- Improving burns treatment (p. 15)
- Clever garnets (p. 16)
- Baking our way to stronger steels (p. 19)
- Lighter, stronger metals (p. 21)
- Directing traffic (p. 22)
- Phase perfection in semiconductor nanowires (p. 28)
- Water-repelling termite wings (p. 30)

SAFEGUARDING AUSTRALIA

Safeguard Australia from terrorism, crime, invasive diseases and pests, strengthening our understanding of Australia's place in the region and the world, and secure our infrastructure, particularly with respect to our digital systems.

- Pathogens take control (p. 20)
- New virus discovered (p. 24)
- Towards analysis for the International Atomic Energy Agency (p. 31)

AMMRF CONNECTIONS

We are working with a range of organisations to ensure that research infrastructure of the highest quality is made available to Australian researchers.

ANFF

The Australian National Fabrication Facility (ANFF), and the AMMRF are jointly funding a support engineer at the Australian National University node to assist ANFF researchers access the AMMRF and make a significant impact in research into nanoelectronic devices.

National Imaging Facility

The AMMRF at the University of Western Australia (UWA) is now also a node of the National Imaging Facility. Combining X-ray microtomography and micro-MRI with advanced microscopy, the node is able to image the continuum from molecules to small animals.

AuScope

The Cameca IMS 1280 ion probe at the AMMRF at UWA was purchased with substantial co-investment from AuScope. It enables in-situ, high-precision measurement of isotope ratios, important to geoscience research. It now supports its mission to characterise the structure and evolution of the Australian continent.

INTERSECT

Intersect Australia Ltd provides e-Research solutions to drive new research and innovation. With the AMMRF they have developed a technique finder and a data management system: enabling users to identify suitable techniques for their research and efficiently manage the data generated.

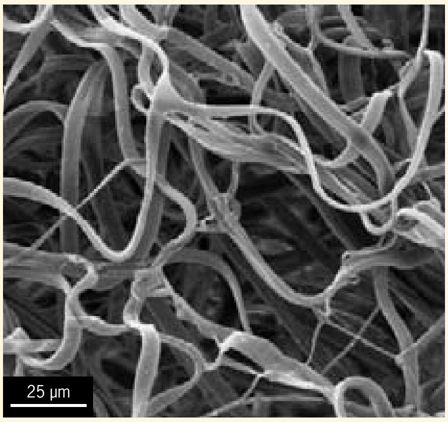
IMPROVING BURNS TREATMENT

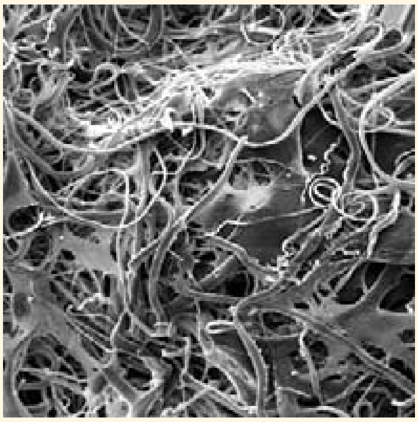
PROBLEM

- Burns are extremely dangerous, distressing and disfiguring.
- Over 6 million people worldwide suffer from severe burns each year. In Australia it costs around $700,000 to treat a single patient with major burns.
- Current treatments are not adequate to give reliably good coverage to protect wounds and encourage healing and to provide a solution to the problem of skin contraction.
- Skin grafts from elsewhere on a patient work well only if a small area is burned. For large burns there isn't enough healthy skin. Grafts from other people are often rejected.
- Existing skin substitutes tend not to be ideal in their biocompatibility or they don't overcome wound contraction.

SOLUTION

Jelena Rnjak, a postgraduate student with Prof. Tony Weiss at the University of Sydney is working on a system that encourages skin healing and provides lasting elasticity to the healed burn. The researchers are testing synthetic human elastin that can be either formed into a hydrogel matrix or spun into fibrous scaffolds that mimic the structure and elasticity of the elastin seen in normal human skin.





A network of spun elastin fibres (left) and fibroblasts growing in an elastin network (right).

To be effective, fibroblasts, the main type of skin cells needed to rebuild skin, must attach and grow on the elastin scaffold. Scanning electron microscopy done at the AMMRF at the University of Sydney is essential to studying this process and the images show the structure of the spun elastin network scaffold and fibroblasts growing on it. The different types of elastin scaffolds were evaluated for their properties and for how well the cells attached and proliferated. It was found that a spun network with large spaces allowed the cells to attach well and grow right into the scaffold, providing the best outcome.

This work lays the foundation for the development of synthetic elastin scaffolds as improved treatments for burn patients.

J. Rnjak et. al. *Biomaterials* 30, 2009.

IMPACT

Burn coverings that promote skin cell growth and retain elasticity will lead to:

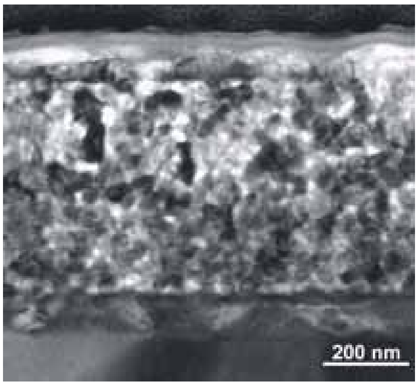
- faster healing,
- less infection,
- no rejection

resulting in shorter hospital stays and reduced costs.

Less skin contraction will lead to better mobility, less scarring and therefore less follow-up treatment, reduced costs and diminished patient distress.

CLEVER GARNETS

Bismuth-substituted iron garnets exhibit remarkable magneto-optical properties. These garnets are used as magnetic photonic crystals in optical integrated circuits for communication networks and optical-sensing devices. For most applications, garnet is deposited onto a substrate as a thin film. The thickness, composition and surface roughness of the garnet film have significant influence on device properties. Equally, the magneto-optical properties of a garnet film are highly dependent on its microstructure, especially grain size and crystallographic orientation. Post-deposition annealing is commonly used to induce crystallisation from the as-deposited amorphous structure or to modify the crystallographic texture of crystalline films. However, little is known about the interrelationship between the processing, microstructures and magneto-optical properties, as there have been few direct observations of film microstructures before and after post-deposition processes. Although film thickness is traditionally measured by optical interference and ellipsometry methods, direct thickness measurement from the cross-section is rarely performed.



TEM image of a tri-layered garnet film of $Bi_2Dy_1Fe_4Ga_1O_{12}$ sandwiched between two $Gd_3Sc_2Gd_3O_{12}$ layers.

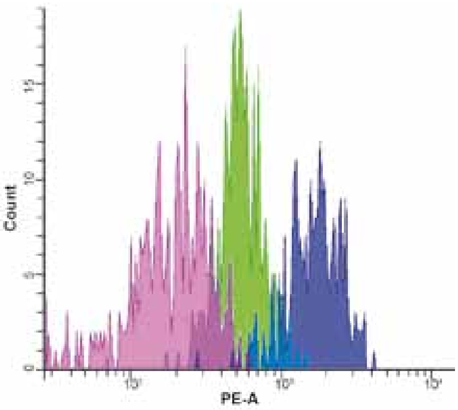
Dr Mikhail Vasiliev and colleagues from the Western Australia Centre of Excellence for Microphotonic Systems at Edith Cowan University prepared bismuth-substituted iron-garnet films under various conditions. At the AMMRF at the University of New South Wales, the microstructures and chemical compositions of the films were characterised by using transmission electron microscopy (TEM). Thin cross-section foils were made from the films by focused ion beam milling. TEM analysis provided unprecedented information about the crystal structures, grain size, crystallographic orientations, elemental compositions, surface roughness and thickness of the films. It was found that the best magneto-optical properties are achieved when the film has small grains, a high content of the garnet phase and low surface roughness, which can be achieved by adding layers of non-magnetic garnet that protect the underlying film during annealing. This kind of information is essential in developing economical, reliable manufacturing processes for high-performance garnet films and for nanostructured devices that contain magneto-optic garnet layers.

Vasiliev et. al. *Journal of Physics D* 42, 2009.

BEE STINGS AND PEANUT BUTTER

Anaphylaxis is a severe allergic reaction triggered in some people by foods, insect stings and drugs. The incidence of anaphylaxis has increased dramatically over the last ten years. The most severe cases are characterised by hypotension, hypoxia and possible unconsciousness. As anaphylaxis is an unexpected, life-threatening event that requires emergency management, defining the biological mediators that influence the clinical presentation and severity of the reaction has been difficult. A range of immune mediators has been implicated by studies in animal models and cultured cells, but work on acute human anaphylaxis is lacking.

Assist/Prof. Shelley Stone and Prof. Simon Brown from the Western Australian Institute for Medical Research have identified a number of potential immune mediators involved in anaphylaxis. The Emergency Department Anaphylaxis (EDA) Study is a unique collaboration of eight emergency departments in Western Australia and New South Wales that are collecting sequential blood samples from patients with acute anaphylaxis. A total of 432 patients were enrolled in the EDA, including 98 with severe anaphylaxis, making this the largest study of anaphylaxis in the world.



Analysis of serum from a patient with severe anaphylaxis demonstrating high levels of IL-6 (blue), soluble TNF receptor (green) and IL-10 (pink).

By using multiplexed cytometric bead arrays (CBAs), analysed with flow cytometry at the AMMRF at the University of Western Australia, the team was able to measure serum levels of 15 immune mediators in only 50 µl of serum. Preliminary data showed a significant correlation between peak levels of pro-inflammatory (IL-6), anti-inflammatory (IL-10) and mast-cell-derived (MCT and histamine) mediators with both the severity of the reaction and the occurrence of hypotension. Interestingly, a number of mediators identified in animal models of anaphylaxis were not detected in human samples.

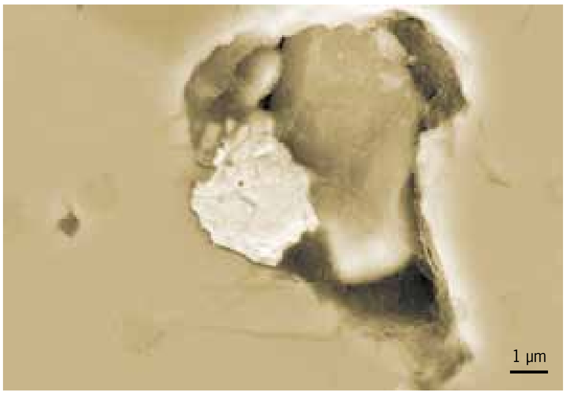
Investigation of additional mediators of anaphylaxis, including platelet activating factor and anaphylatoxins, are underway. Characterisation of the molecules present during anaphylaxis is a starting point for developing new treatments, including improved immunotherapy designs for long-term desensitisation of patients.

S. Stone et. al. *Journal of Allergy and Clinical Immunology* 124 (4), 2009.

GOLD IN THEM THERE VOLCANOES

In his fiery home beneath Vulcano (Italy), the ancient greek god Hephaistos made the armor for the warrior Achilles, and hammered out lightning bolts for Zeus. But where did he get the metals from? Even though today we know that most of the world's biggest gold deposits were formed under active volcanoes there are still similar mysteries; where did the gold come from and how did it get there?

Now Drs Dick Henley and John Mavrogenes from the Australian National University (ANU) have found, for the first time, clusters of gold crystals inside tiny gas bubbles preserved in samples only a few million years old from gold deposits located high in the Chilean Andes and Colorado Rockies. By using field-emmission scanning electron microscopy (FESEM) at the AMMRF at ANU, they have shown how these bubbles were trapped when arsenic, antimony, copper and sulphur condensed as sulphosalt melts from expanding volcanic gas. These melts too, have never previously been recognised.



Left: high-temperature volcanic gas discharging from a fumarole. Sulphosalt melts and gold deposition occur a few hundred meters below the surface in these settings. Right: cluster of gold crystals in a cavity inside iron-tennantite from El Indio, Chile.

They have a complex chemistry with tin, bismuth, iron and even silver substituting arsenic and antimony in the mineral tennantite, $Cu_{12}(As,Sb)_4S_{13}$, as it crystallises from the suplohosalt melt at temperatures near 600°C. Other bubbles contained phosphate, copper sulphide and silicate crystals grown from the vapour. Perfectly formed zoned aluminium-doped quartz crystals also grew from these melts, again, previously undescribed.

These discoveries help develop new ideas for gold exploration worldwide but they also tell us a lot more about sources of toxic arsenic in groundwater and the higher risk of risk of bladder and kidney cancer associated in drinking water in volcanic areas. They even help us understand the chemistry of volcanoes on Venus!

J. Mavrogenes et. al. *Economic Geology* 105 (2), 2010.

A MID-OCEAN RIDGE REVEALED

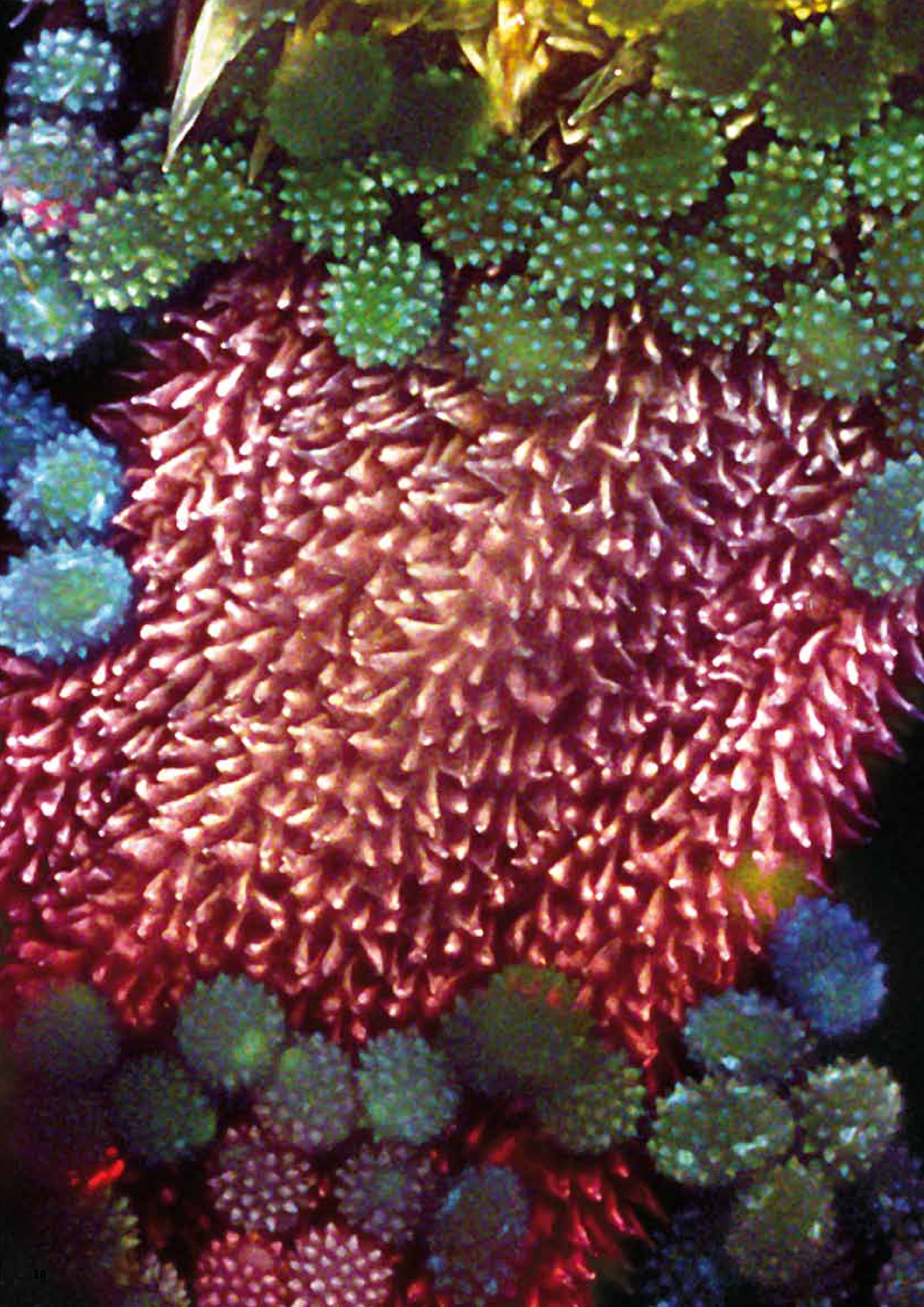
On Macquarie Island, halfway between Tasmania and Antarctica, is a fossilised mid-ocean ridge. Between six and twelve million years ago, this area was in the middle of an ocean and the volcanic rocks that were formed at that time are now exposed on the island, in a relatively intact state. Naturally it is very hard to study the formation of volcanic rocks in mid-ocean ridges in-situ, so geologists are reliant on these fossilised slices of oceanic ridge found on land. The one on Macquarie Island is particularly good because it is so young and provides the opportunity to study all aspects of its geology.

Dr Nathan Daczko and his team at Macquarie University have studied these volcanic rocks in detail. They looked at the relationship between the processes of eruption, fragmentation, transport and subsequent rock formation by linking large-scale field observations to microscopic imaging and analyses with light and electron microscopy. There has been much debate about how some of these processes work, such as the question of how the volcanic rock fragments into glassy shards. The shards could result from eruptive explosions or the rapid contraction of the lava as it is extruded into the cold ocean. The research showed that the second of these possibilities was occurring. Scanning electron microscopy at the AMMRF at the University of Sydney revealed that a chemical reaction, known as a palagonite alteration occurred on the surface of the fragmented grains, causing them to aggregate into new rock.

The team's research provides a window on the processes taking place at mid-ocean ridges without the need to take up residence at the bottom of the ocean.

J. Dickenson et. al. *Sedimentary Geology*, 216, 2009.

Scanning electron micrograph using backscattered electrons (BSE) showing glassy grains (light areas) sutured together by their palagonitised rims (darker areas). Scale shown is 200 µm.



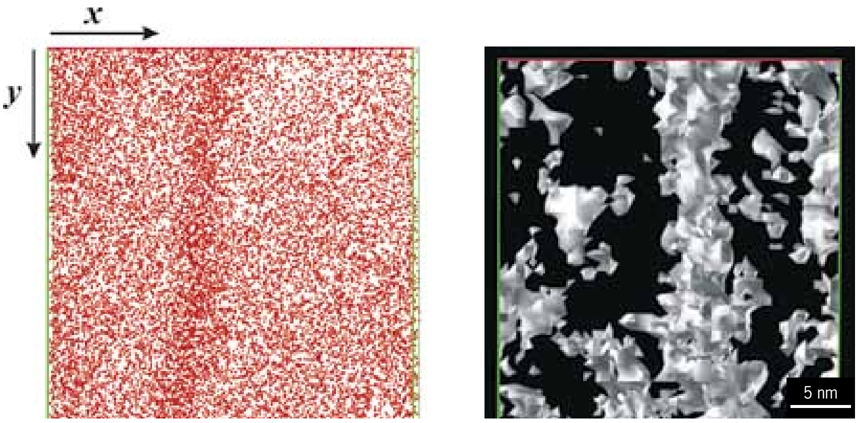
BAKING OUR WAY TO STRONGER STEELS

FLAGSHIP

Increasing the strength of steels is an important step towards more fuel-efficient vehicles, allowing less metal to be used in the panels and chassis. Yet increases in strength of steels typically come at the expense of their formability, reducing the ease and cost-effectiveness of shaping the components. A way to circumvent this is to use steel that can be bake-hardened, by heating to 150–200°C for approximately 30 min, after the panels are formed. This retains the necessary formability for the forming step, but still gives increases in strength after shaping. What is particularly clever about this approach is that bake-hardening can be done during the existing heating step that is used to bake the automotive-paint finishes, plus it allows use of cheaper low-alloy steels.

Dr Ilana Timokhina and Prof. Peter Hodgson from Deakin University and researchers from the universities of Wollongong and Sydney have determined the structural origins of bake-hardening behavior in three different multi-phase steels. The team compared the microstructures and properties of the steels before and after bake-hardening treatments. Structural analysis was done by transmission electron microscopy (TEM), and the participants from the AMMRF node at the University of Sydney applied atom probe tomography to help determine the effects of solute redistribution on hardness. The combination of TEM and atom probe revealed that the increase in strength during bake hardening depends on a complex interplay of structural factors that include the amounts and distributions of specific phases and carbides, of dislocations and of solute atoms such as carbon and niobium. In the dual-phase steel that was examined, for example, the team found clear segregation of carbon atoms to the dislocations and formation of rod-like precipitates. Up to a doubling of yield strength resulted from bake-hardening, demonstrating the value of this treatment in automotive applications.

I. Timokhina et. al. *Materials Technology* 80 (7), 2009.



Distribution of carbon atoms in TRIP (transformation-induced plasticity) steel after pre-straining and bake-hardening, showing enrichment of the carbon atoms at specific planes in the retained austenite.

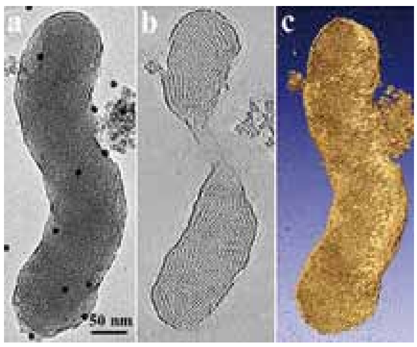
EXPLORING MESOPOROUS STRUCTURES

FLAGSHIP

Fabrication and characterisation of ordered mesoporous materials with unconventional symmetries, siliceous vesicles with various morphologies and ordered macroporous materials with pore sizes of approximately 100 nm has become a global focus because of the unique properties and broad potential applications of these materials.

Their large pores and high surface area give functional nanoporous materials great advantages in bio-applications such as protein immobilisation and peptidomics, proteolysis, bio-sensing, and drug- and gene-carrier applications. Although many types of nanoporous materials have been successfully synthesised, the designable fabrication of nanoporous materials with finely adjustable parameters, such as pore size, pore structure and morphology, is still a challenge. Successful synthesis and careful analysis are vital to controlling the designs for specific applications.

In a joint project, Prof. Jin Zou at the University of Queensland (UQ) and Prof. Chengzhong at Fudan University in China have developed a direct and effective method to determine the complicated hierarchical helical mesostructure of these materials by using the powerful technique of electron tomography at the AMMRF at UQ. The structural parameters were directly determined and the origin of helical fringes in hierarchical helical mesostructures and the distribution of fringes as a function of the helical parameters have been clearly elucidated. Based on the structural characterisation, the researchers demonstrated a topological helix–coil transition between the internal and external helices to reveal the origin of the hierarchical helical mesostructure and the relationship between the straight helical and hierarchical helical rods. An intriguing evolution was determined from a simple internal helix to a hierarchical helical mesostructure or a complicated screw-like and concentric circular mesostructure. Their success has generated new opportunities in the characterisation of complex porous architectures, thus opening up an avenue to remarkable advances in the field of synthesis, understanding and application of novel porous materials.

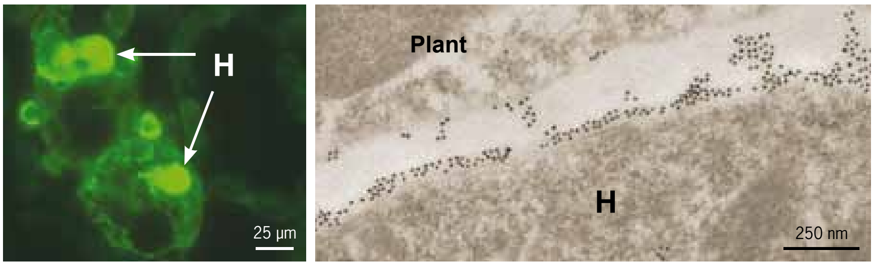


TEM image of a typical hierarchical helical mesostructure, its corresponding tomographic thin-slice and 3-D model.

P. Yuan et. al. 2010 *Chem. Comm.* 46.

Multispectral autofluorescence image of capeweed flower stamen and pollen grains collected on a multiphoton microscope. Image by A/Prof. Paul Rigby @ The University of Western Australia.

PATHOGENS TAKE CONTROL



Immunofluorescence showing bright areas of AvrM in haustoria (left) and immunogold localisation of AvrM in infected flax-leaf cells (right) showing AvrM (dark spots) moving from the haustoria (H) at the bottom into the plant cell at the top.

Rust and powdery mildew fungi are two groups of highly destructive plant pathogens that cause extensive losses to agricultural crops worldwide. Both are biotrophic pathogens that must establish a stable relationship with living host cells in order to infect, colonise and reproduce within the host organism. These fungi form specialised infection structures, called haustoria, within the plant cell, which take up nutrients from the plant.

Recent research has identified groups of pathogen effector proteins that facilitate infection by helping colonisation and suppressing host defence mechanisms. Indirect evidence suggests that some effector proteins secreted by the pathogens, move into the host cell cytoplasm from where they orchestrate changes in host cell structure and metabolism. Localisation studies by Prof. Adrienne Hardham, Dr Maryam Rafiqi and Pamela Gan at the Australian National University provide direct evidence that these flax-rust effector proteins are transported into the plant cytoplasm and give insights into the molecular basis of their uptake.

The protein, AvrM, has been found within infected flax leaves by using immunofluorescence and immunogold assays. It was shown to be secreted by fungal hyphae and haustoria, accumulating in and around the haustorial wall and being transferred into the cytoplasm of the plant cell. In collaboration with the AMMRF at the University of Queensland, examination of infected leaves provided the first ultrastructural evidence of AvrM within the plant cytoplasm. It was found to occur in small vesicles and other organelles. The team has identified a specific uptake domain at one end of AvrM responsible for its transport across the plant plasma membrane. This internalisation occurs in the absence of the pathogen, indicating that a plant uptake mechanism, probably the plant's endocytic pathway, is hijacked by the pathogen to bring about the plant's downfall.

M. Rafiqi et. al. *The Plant Cell*, 22, 2010.

FINDINGS FROM FRAGILE BONES

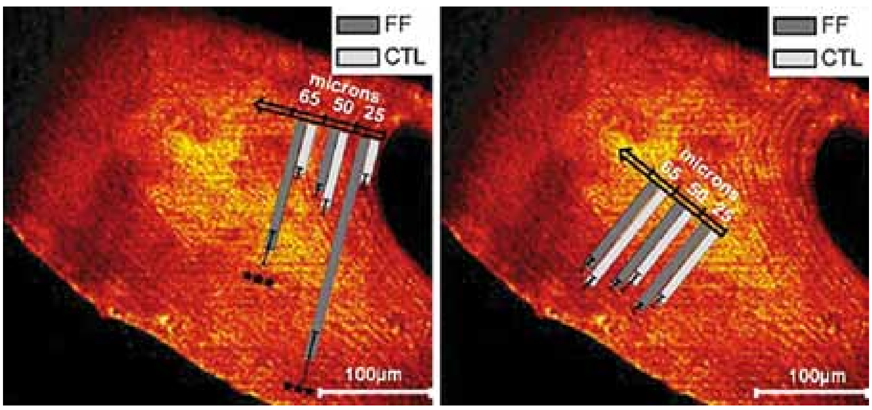
FLAGSHIP

Bone is a nanocomposite material containing organic and inorganic components. The main organic scaffold is the protein collagen, and the inorganic component, the calcium-containing mineral hydroxyapatite (HA), is laid down on the collagen. Broadly speaking, the HA provides the strength and the collagen gives the flexibility. Bones can become fragile from a number of pathological conditions, a major one being osteoporosis.

To shed light on just how the strength of bone can become compromised is a research goal of Dr Ruth Zoehrer from Flinders University. Her work involves analyses of the micro- and nanostructures of human bone matrices from patients with fragile bones and from healthy controls. She has used time-of-flight secondary ion mass spectrometry (ToF-SIMS) at the AMMRF at the University of South Australia combined with nanoindentation experiments on the atomic force microscope (AFM) at the AMMRF at Flinders University to map and correlate the chemical composition, protein constituents and nanomechanical properties of the bones.

ToF-SIMS produced a wealth of data, and the image shows a typical ion map of Ca levels from part of the femur of a patient who had sustained fragility fractures. Calcium levels were relatively higher in newly formed bone areas (darker orange), within 25 µm of the surface, in the patients when compared to the controls. In agreement with these findings, AFM-based nanoindentation results showed compromised nanomechanical properties in the fragile bone group. In older, more highly mineralised bone (yellow) further away from the surface, neither the calcium levels nor the AFM-based nanoindentation were significantly different in the two groups.

The results suggest that when new bone is formed in patients with fragile bones, deposition of calcium is faster resulting in more highly mineralised areas within the newly formed organic scaffold. This may result in brittle bones due to the higher levels of calcium displacing the flexible organic matrix.



A representative ToF-SIMS image of bone from a patient with fragility fractures forms the background to both panels. The graphs show the calcium levels (heights of bars) in regions of newly formed bone (left) from both patients (FF) and controls (CTL), and in older bone (right) from both patients and controls. The open black arrows indicate typical regions within the bone samples in which calcium levels were measured in the patients and control subjects.

LIGHTER, STRONGER METALS

PROBLEM

- Increasing energy use is having a major impact on our planet. Reducing energy use is vital.
- There is great competition in the transport industries for lighter, stronger materials for cars, trucks and trains. Steel provides the strength required for these applications at a reasonable price. Titanium is lighter and strong, but very expensive. Aluminium alloys are light, but even the strongest so far are only about half the strength of steel. Aluminium is already used in aerospace however further weight savings would be very beneficial.
- The development of new structural alloys with higher specific strength is a key technological imperative of the metals industry – great demand exists across numerous sectors.

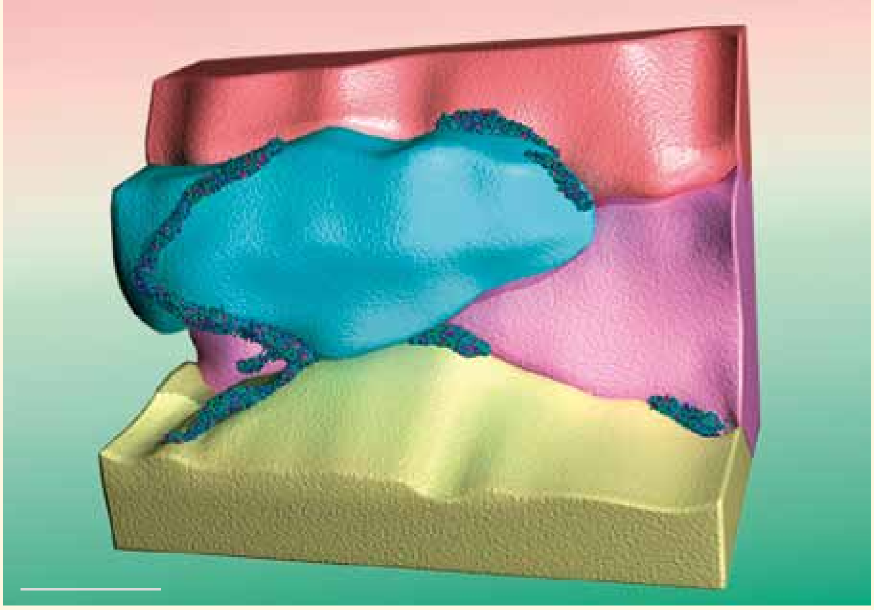
SOLUTION

FLAGSHIP

Making aluminium alloys with the same strength as steel would lead to lighter vehicles that would use less energy, thereby helping to reduce global energy consumption.

Dr Peter Liddicoat, Prof. Simon Ringer and Dr Xiaozhou Liao from the University of Sydney, as part of an international collaboration, have succeeded in making a super-strong aluminium alloy with the same strength as steel. By squeezing and twisting the metal under extremely high pressures they have made a very fine-grained product.

Atom probe analysis done at the AMMRF at the University of Sydney showed that a hierarchy of nanostructures within this new alloy is responsible for its exceptional strength. The tiny grains and arrangement of alloying elements can be seen in the images. The AMMRF at the University of Sydney is the only place in Australia where this amount of detail can be revealed and the nature of the alloy understood.



Tomographic view of solute nanostructures on grain boundaries of the 7075 alloy. Scale bar is 10 nm.

P. Liddicoat et. al. *Nature Communications* (1), 2010.

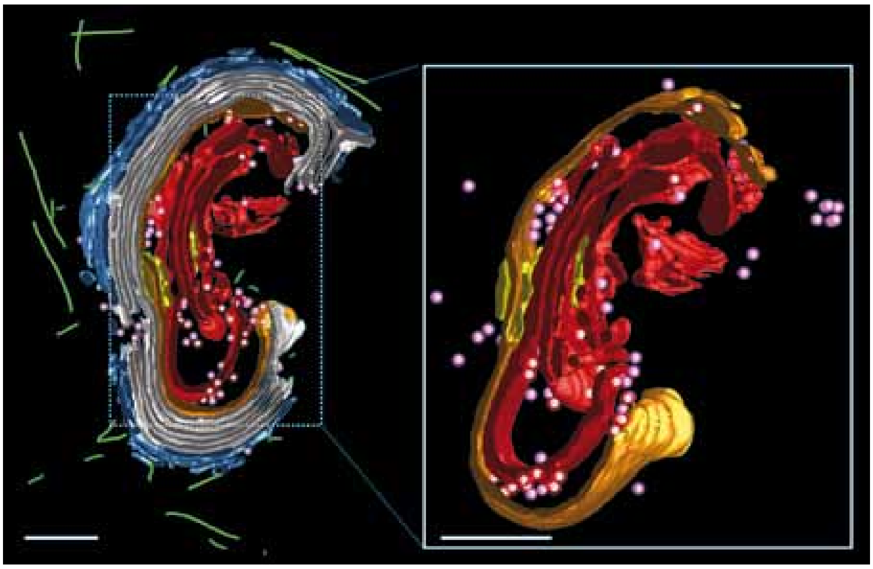
IMPACT

- Australia operates a competitive export-oriented aluminium industry and global production of aluminium has been forecast to reach 50 million tonnes by 2012 at a projected market value in excess of $60 billion. Retaining and ultimately growing these markets requires technical innovation.
- This research demonstrates that super-strong light-metal alloys can be fabricated. As we consider what processes must now be developed to achieve these microstructures and properties on larger scales, there are tantalising considerations for the environmental and economic impacts of successfully manufacturing cars, planes and even space vehicles at *half* their current weight.

DIRECTING TRAFFIC

FLAGSHIP

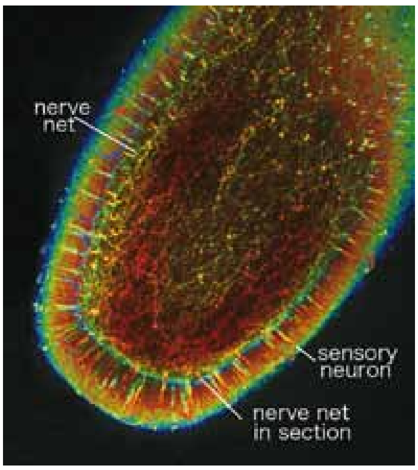
Over recent years, studies have shown that even minor changes in normal protein transport mechanisms can culminate in disruption of cellular function and even death of cells. In some cases, such changes directly contribute to the onset of chronic human disease. The efficient movement of proteins from one cell compartment to another is tightly regulated by specific proteins, although the mechanisms that underpin their role remain unclear. Importantly, aberrant protein transport often results from environmental, as well as physiological, factors. The protein Rab6 has been shown to play a crucial role in regulating the specificity and efficiency of protein transport between one particular compartment, called the Golgi apparatus, and other key stations on the pathway along which proteins are secreted from the cell.



3-D model of the Golgi in Rab6-depleted HeLa cells showing the increase in the length and number of Golgi cisternae (left). The arrest of protein transport vesicles associated with trans-Golgi cisternae is seen on the right. Color key: trans-most cisterna/TGN, red; penultimate trans-cisterna, gold; microtubules, green; endoplasmic reticulum, yellow; medial-cisternae, gray; cis-cisternae/CGN, blue; clathrin-coated vesicles, red; COPI-coated vesicles, fuchsia. Scale bars: 500 nm.

In an ongoing collaboration between a team headed by Dr Brad Marsh at the University of Queensland (UQ) and Prof. Brian Storrie at the University of Arkansas for Medical Sciences, correlative light and electron microscopy, in conjunction with RNAi (to disrupt protein production), is being employed to better understand how Rab6 and another protein, myosin IIA, regulate protein trafficking to and from the Golgi. When either Rab6 or myosin IIA were disrupted, large-scale changes were seen in the organisation of the Golgi. These changes were observed by using high-resolution electron tomography at the AMMRF at UQ. Rab6 depletion caused an increase in the length and number of Golgi cisternae in each 'Golgi stack' and induced an increase of autophagic mechanisms, where the cell destroys some of its own contents. Depletion of myosin IIA also caused ultrastructural changes to the Golgi and its vesicles, but they differed significantly from the effects of reduced Rab6. Rab6 severely inhibits the efficiency and kinetics of Golgi vesicle release and also regulates membrane carrier fission, a role not previously assigned for the Rab family of proteins.

This project was supported by a project grant from the NHMRC (569535).



In this depth profile the nerve net is visible as a fine network near the surface, and as a line separating the two tissue layers deeper in the larva. Sensory cells extend from the nerve net at their bases to the surface of the planula.

CORAL SETTLES DOWN

Due to rising temperatures and ocean acidification, coral populations throughout the world are in decline, yet we understand relatively little about many critical aspects of coral biology. One such aspect is settlement – the process by which freely swimming coral larvae metamorphose into the sedentary polyps that subsequently grow into the calcified colonies that we recognise as 'coral'. The nervous system plays a critical role in this process, both in the selection of a place to settle and in metamorphosis itself.

The coral larva is roughly cylindrical and less than 1 mm long with one of the simplest nervous systems in any living animal. A nerve net is connected to an array of sensory neurons that make contact with the outside environment. When it receives specific chemical cues, the larva changes behavior and morphology dramatically, first searching for a place to settle and then flattening into a base from which the first polyp grows.

By using confocal and light microscopy at the AMMRF at the Australian National University (ANU), Ros Attenborough and Ursula Wiedemann, working with Eldon Ball and David Hayward at ANU, are investigating two coral neurotransmitters, LWamide and RFamide, during the development of the nervous system of the coral *Acropora millepora*. Their previous work, and that of others, has established that external application of LWamide causes settlement and metamorphosis of larvae. Their work has shown that neurons containing these transmitters disappear at metamorphosis and are recreated after settlement, consistent with the behavioural data in suggesting a role for the nervous system in mediating the response to environmental settlement cues. Additional studies have suggested that endogenous serotonin may also play a role in settlement. This combination of behavioural and anatomical work is revealing the role of the nervous system in coral settlement. An understanding of this aspect of coral biology will better enable us to maintain and repair coral reefs, possibly protecting developing coral from stimuli that interfere with settlement, or enabling settlement to be induced in devastated areas.

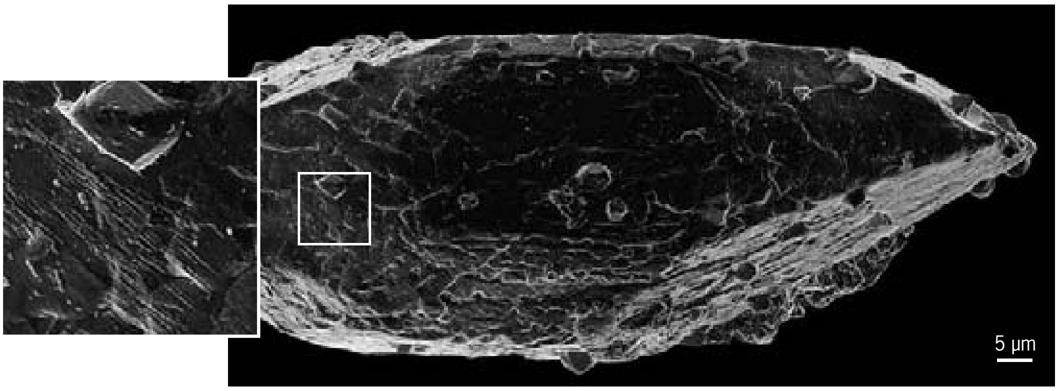
A colony of Acropora millepora. *Photo by Dr Madeleine van Oppen.*

CRATERS AND CRITTERS

The end-Permian mass extinction occurred 252 million years ago, and is the largest of the five biotic crises that punctuate the fossil record of the last 540 million years. The cause of this catastrophe is still unknown, even though its biological effects were more than twice as severe as those unleashed by the 65 million-year old impact that created the crater at Chicxulub in Mexico. The Chicxulub impact is thought to have caused the extinction of the dinosaurs. An ongoing study of several major impact craters around the world is being spearheaded by Assist. Prof. Eric Tohver from the University of Western Australia and Dr Fred Jourdan from Curtin University of Technology. One aim is to provide more accurate age constraints on large impact events to assess their effects on the life on Earth.

Their geochronological investigation of the 40 km wide Araguainha crater in central Brazil is yielding interesting information. The effects of shock metamorphism and recrystallisation are clear in the pictured grain of zircon (below). Diagonal and horizontal, light-colored striations cutting across the grain (inset) are two sets of deformation features of a type caused only by the compression wave generated by impact events. The smaller discrete crystals growing on the surface of the larger crystal indicate that new zircon growth nucleated on older zircons in the impact melt. The age of this newly crystallised material was investigated with the sensitive high-resolution ion microprobe (SHRIMP) at the John de Laeter Centre of Geochronology, a Linked Laboratory of the AMMRF. The results indicate an impact event occurring at approximately 252 million years ago.

Earlier, less comprehensive dating results gave an impact date of 244 million years, whereas these new results clearly place the impact in the same time window as the end-Permian mass extinction. This co-incidence of timing means that the impact is a factor that must be considered when searching for causes of this biotic crisis. Taken together with other impacts, this data contributes to the idea that mass extinctions may share a common extraterrestrial cause.



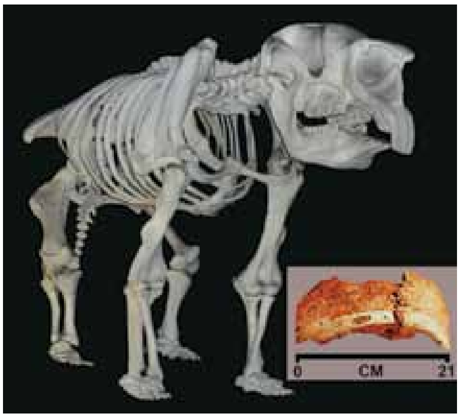
Zircon grain from the Araguainha crater.

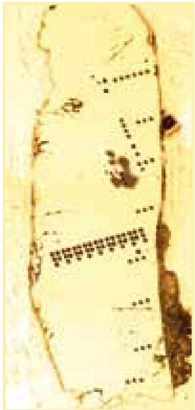
TRACKING WANDERING DIPROTODONS

FLAGSHIP

Little is known about the migratory behaviour of extinct Australian mammals, in particular that of the extinct rhinoceros-sized diprotodon, *Diprotodon optatum*. The diprotodon was one of the most widespread Pleistocene marsupials living in Australia before the last ice age. Teeth of these animals retain information about their environmental and physiological conditions and growth over the time period that is recorded in the tooth.

The analysis of teeth and bones has established that relationships exist between oxygen isotopes and climate, carbon isotopes and diet, and oxygen and strontium isotopes and geographical regions. Therefore, by measuring strontium isotopes and elemental ratios from the tooth enamel it is possible to reconstruct the migration patterns of the megafauna. To start this investigation, an 80,000-year-old fossilised diprotodon incisor, held at the Western Australian Museum, was analysed by Lynette Howearth of Curtin University.





Left: diprotodon optatum *cast skeleton at the WA Museum with insert of a fossilised top incisor from which enamel cores were taken for analysis. Right: diprotodon enamel analysed with the ion probe.*

Combining data from the ion probe at the AMMRF at UWA, where they analysed small spots around 40 µm in diameter from uncontaminated enamel regions, with thermal ionisation mass spectrometry (TIMS) at Curtin University of Technology (an AMMRF Linked Laboratory), the signatures of strontium isotopes in the tooth were determined precisely.

Early results point to the animal having-spent portions of its life in at least two different geological settings. Analysis of oxygen, carbon and lead isotopes will be undertaken of rocks and soil from the Pilbara region where the fossil was found, so that seasonal information can be matched to geologically distinct areas, allowing the home range and migration paths to be reconstructed. Migration patterns of extinct fauna are important for studies of palaeobiology, rates of evolution, extinction and speciation, and palaeoclimatic reconstructions.

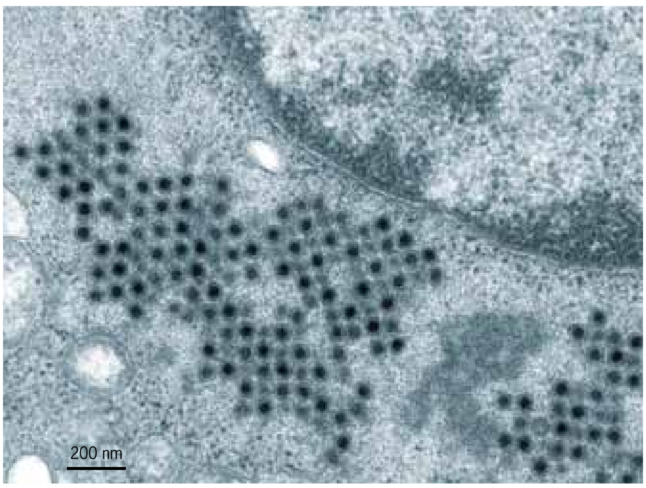
NEW VIRUS DISCOVERED

A sick, little red flying fox was found in a schoolyard in Broome and, while the flying fox's symptoms appeared to be caused by a virus known as Australian bat lyssavirus (ABLV), when it was sent down to the CSIRO Australian Animal Health Laboratories (AAHL) in Geelong, it was found to be carrying another previously unidentified virus.

Microscopy at the Australian Biosecurity Microscopy Facility at AAHL, a Linked Laboratory of the AMMRF, revealed that cultured cells, grown in the presence of the virus, fused together to form larger, multi-nucleated cells, a behaviour typical of infection with some orthoreoviruses. However, none of the known orthreoviruses or other bat-bourne viruses were detected. Transmission electron microscopy was carried out on the fused cells, demonstrating accumulations of virus particles surrounded by material thought to be viral components awaiting assembly. The particles were 70 nm in diameter, were not contained within a membrane coat, but did have a double-layered capsid. These observations enabled the researchers to definitively classify this new virus as a member of the genus, *Orthoreovirus*.

Together with results on the double-stranded RNA genome, the data showed unequivocally that this is a new virus, which the researchers named Broome virus.

Fruit bats are known reservoirs for many important viruses that can be a public-health risk including Hendra, Nipah and the rabies-like ABLV. Two other recently discovered orthoreoviruses were associated with fruit bats and caused acute respiratory illness in humans in Malaysia. The infectious potential of this new virus is not yet known, but it does share some unusual features with the neuroinvasive baboon orthoreovirus. The spectrum of animals susceptible to orthoreovirus infection is broad and the types of diseases caused are varied. It is therefore important to both human and animal health to understand the extent of potential sources of new disease.



Transmission electron micrograph of a cell infected with Broome virus. The virus particles have a dark centre surrounded by a lighter halo. They are 70 nm in diameter.

Thalmann et. al. *Virology* 402, 2010.

TOWARDS HIGH-EFFICIENCY BIOFUELS FROM ALGAE

PROBLEM

- Developing clean fuels for the future is one of our most urgent challenges, to minimise the effects of climate change, enhance fuel security and provide a secure basis for economic growth.
- Fuels currently make up about 83% of the global energy market with around 2.5 billion tonnes used each year.
- Most renewable energy systems are focused on the production of electricity (e.g. photovoltaic, wind, wave etc). The renewable fuels market is largely untapped, with biofuels the main contenders for supply.
- Biofuels from crop plants (eg. corn ethanol) raise concerns about the effects on food security and appropriate land use.

SOLUTION

FLAGSHIP

Microalgae are a promising source of biofuels and bio-products with around $1 billion invested into microalgal biofuel technologies since 2007.

Microalgal systems can be located on non-arable land and often use saline or waste-water streams. They have short life cycles, which facilitate rapid breeding, and can also theoretically deliver higher yields than crop plants through the optimisation of light distribution as well as CO_2 and nutrient supply.

A/Prof. Ben Hankamer from the University of Queensland (UQ) founded the international Solar Biofuels Consortium with Prof. Olaf Kruse in 2006 to develop high-efficiency microalgal biofuel production systems. It now includes eight international teams with around 100 researchers and has projects with approximately ten industry partners.

Laboratory-based algal reactor (left), light micrograph of Chlamydomonas reinhardtii *(centre) and a tomogram of an algal cell showing sub-cellular structures highlighted in different colours (right).*

The first step of all biofuel production is light capture. Maximising the efficiency of this step is central to developing profitable biofuel processes. A key strategy to increase light-capture efficiency is to finetune the light-harvesting proteins. This requires a detailed structural understanding of the machinery, so a comprehensive 3-D molecular atlas of the photosynthetic machinery would be of great benefit. This is currently being produced by using advanced electron tomography at the AMMRF at UQ. A/Prof. Hankamer and Dr Brad Marsh are constructing a 3-D visible cell atlas for the alga *Chlamydomonas reinhardtii*. Their work is yielding fundamental new insights that can be used for the optimisation of biofuel production.

E. Stephens et. al. *Nature Biotechnology* 28, 2010.

IMPACT

- The 3-D models will assist in targeted engineering of light-harvesting systems. Higher energy conversion has already been achieved from the first engineered algae.
- Higher light-capture efficiency is fundamental for improved production of biodiesel, bio-methane, bio-ethanol and bio-hydrogen.
- Algal biofuel production systems have the capability to reduce dependence on arable land and fresh water, thereby greatly reducing food-versus-fuel concerns of crop-based biofuel systems.

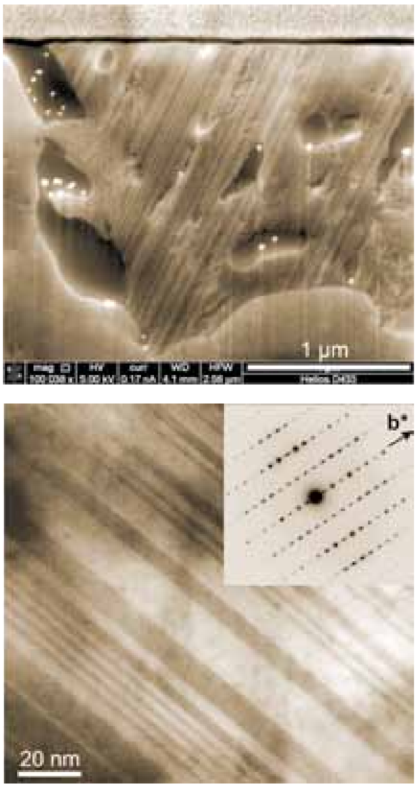
ZOOMING IN ON MINERAL MAPPING

FLAGSHIP

Minerals record their histories via compositional and structural variations, and, in particular, textures and patterns observable at scales ranging from metres down to nanometres. The traditional difficulty in going from the micrometre-scale resolution of the electron microprobe down to the sub-nanometre (atomic) scale of the transmission electron microscope (TEM) on the same analysis spot has long hampered attempts to understand the link between textures and compositions across these scales of observation.

Research by Dr Cristiana Ciobanu, Prof. Nigel Cook, Prof. Allan Pring and co-workers at the Centre for Tectonics, Resources and Exploration (TRaX), at the University of Adelaide and South Australian Museum, is focused on the nanoscale characterisation of common sulphides such as pyrite and sphalerite. This work relies on the opportunities offered by the flagship Helios focused ion beam (FIB) scanning electron microscope at the AMMRF at the University of Adelaide. Cross-sectional imaging and preparation of TEM foils will be integrated with nanoscale X-ray fluorescence element mapping at the Australian Synchrotron by using the same FIB-prepared slices, addressing processes behind minor-element incorporation in sulphides.

The research has shown the applicability of FIB methods to mineral-deposit geology, as well as identifying both optimal working conditions and problems associated with the behaviour of certain metal-bearing minerals under the ion beam. One current project addresses the relationship between trace-element geochemistry in copper–iron sulphides, as determined by in-situ laser-ablation, inductively coupled plasma mass spectroscopy, and the crystal structure as determined by TEM investigation of FIB-prepared foils. This work requires imaging and subsequent thinning of carefully selected parts of mineral grains that have been characterised chemically. Outcomes are currently being applied to one of South Australia's sizeable iron oxide–copper-gold deposits, with results having potential implications for near-mine exploration.



FIB cross-section image showing indium-bearing sphalerite with lamellar banding replaced by tin-silver-rich sphalerite (top); TEM image showing disordered oscillatory twinning in silver-rich chalcocite and corresponding electron diffraction pattern inset (bottom).

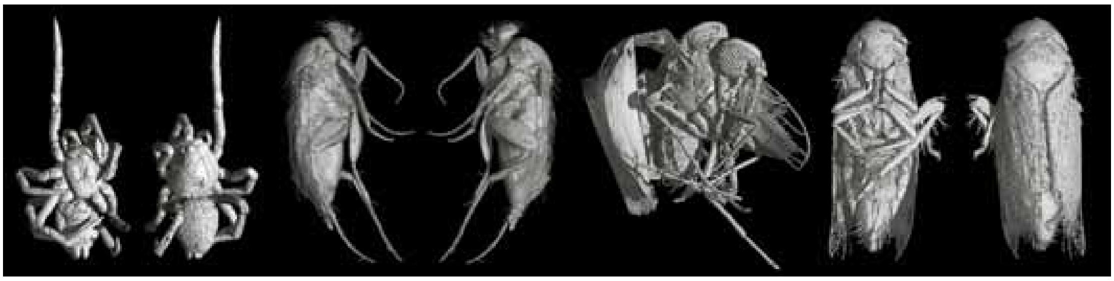
AUSTRALIA'S FIRST AMBER

The first Australian amber was found in the remote reaches of the Cape York Peninsula two years ago, and has sparked an extraordinary research story that stretches from these crocodile-infested wilds to the European Synchrotron (ESRF) in France and then back to Australia. The amber, rescued from beaches in Cape York by palaeobiologists from the University of New South Wales (UNSW), presents a unique opportunity for us to look back in time and examine insects and other biological material that formed the ecosystem of this part of Australia about 17 million years ago. Trapped in these amber samples is an incredibly well-preserved collection of arthropods.

While a good percentage of these amber finds are transparent and allow the inclusions to be studied by traditional light microscopy techniques, many are opaque and peppered with bubbles and rough surfaces, making it impossible to see what is inside.

To tackle this problem the team of researchers, including A/Prof. Allan Jones from the University of Sydney and the UNSW researchers, turned to X-ray microtomography, which utilises X-rays to look inside these samples and virtually reconstruct these lost insects in 3-D. The resolution acquired is at the microscopic level, with pixels two orders of magnitude smaller than can be achieved by a hospital scanner. The samples were scanned at the European Synchrotron Radiation Facility (ESRF), in collaboration with Dr Carmen Soriano, to generate huge 3-D data sets of more than 40 insects. The data visualisation and final 3-D reconstructions were done with the advanced technology at the AMMRF at the University of Sydney. The trapped specimens can now be viewed in all their fascinating detail, from any angle while leaving the amber samples completely intact.

C. Soriano et. al. *Comptes Rendes Palevol* doi:10.1016/j.crpv.2010.07.014.



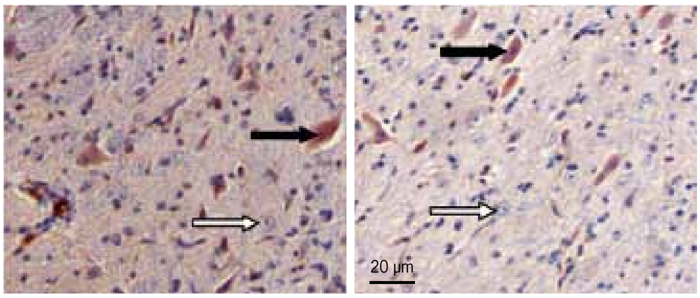
3-D reconstructions of some of the arthropods found in the amber. They are all approximately 5 mm in length.

NICOTINE AND NEWBORN BRAINS

Exposure to cigarette smoke is a major risk factor for sudden infant death syndrome (SIDS). Nicotine is neurotoxic and, although work has been done on its effects in adolescent and adult brains, early postnatal brains had not previously been investigated. The current model for the causes of SIDS centres on disrupted control of the heart and breathing – both functions controlled by the brain.

In order to understand how nicotine can increase the risk of SIDS, Dr Rita Machaalani and her team at the University of Sydney studied its effects on the brains of newborn piglets. The researchers were particularly interested in what happens to two of the most important protein subunits (α7 and β2) of nicotine-sensitive acetylcholine receptors following continuous nicotine exposure. The experimental regime was designed to mimic the exposure endured by a newborn living in a household of smokers or being breastfed by a mother who smokes.

Positively stained neurons (black arrows) and negatively stained neurons (white arrows) for an α7 subunit in the brains of control and nicotine-treated piglets.



By staining for the two specific receptor subunits in parts of the brain important for breathing and heartbeat, the team could detect the location of the two proteins. They used conventional light microscopy to see the stained cells and, with the use of image analysis software and expertise at the AMMRF at the University of Sydney, the team were able to quantify the changes that had occurred as a result of nicotine exposure. Statistical analysis of the images revealed that the level of α7 was generally decreased in crucial areas of the brain, while levels of β2 were increased, although this tends to be the result of desensitisation, which causes reduction in function.

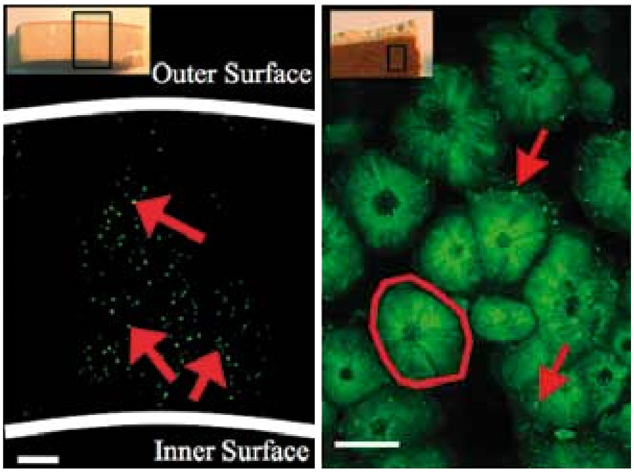
These combined results suggest that there is serious compromise in the function of these receptor subunits, which therefore is likely to affect the proper regulation of breathing and heartbeat in the newborn infant suggesting a likely mechanism for the increased risk of SIDS.

▤ C. Browne et. al. *International Journal of Developmental Neuroscience* 28, 2010.

FOSSILISED EGGSHELL HARBOURS ANCIENT DNA

Eggshell fragments excavated from deposits across the globe are widely used in archaeological and paleontological research to infer dates, diets and environmental change, largely on the basis of their excellent biomolecule preservation. DNA is generally found in all biological materials but has not previously been isolated from eggshell. Dr Michael Bunce and PhD student Charlotte Oskam, from Murdoch University's ancient DNA (aDNA) lab, led a large international collaboration to investigate why this is so.

When attempting to isolate aDNA it is important to understand its location within the sample. The AMMRF at the University of Western Australia was able to visualise the preserved genetic material within the eggshell matrix by using confocal imaging, together with fluorescent double-stranded DNA-binding dyes. It is most likely that the DNA in eggshell has come from abraded cells incorporated during the formation of the eggshell within the bird. Localising the aDNA in the eggshell was a key step that enabled the researchers to optimise their sampling protocols and develop an extraction technique specifically tailored to eggshell. The researchers were able to recover the aDNA from extinct megafaunal birds such as the giant New Zealand moa and the elephant bird from Madagascar. The DNA preservation seemed to extend back to nineteen thousand years in an emu eggshell from an archaeological site near Margaret River. To date, this is the oldest authenticated aDNA ever retrieved from Australia.



Ancient DNA in fluorescent 'hot spots' (red arrows) located within fossil avian eggshells. Cross-section of an elephant-bird eggshell, scale 400 µm (left), inner aspect of the moa eggshell with a mammillary cone encircled; scale bar 50 µm (right).

This work is the first description of successful isolation and visualisation of aDNA from fossil avian eggshell and showcases its utility for investigating the genetics of eggshell in fossil and archaeological deposits. The techniques described also have applications in the fields of conservation and forensic genetics. Lastly, genetic profiles when analysed together with ^{14}C dating and stable-isotope profiles will significantly enhance the accuracy of understanding both past biodiversity and extinction processes.

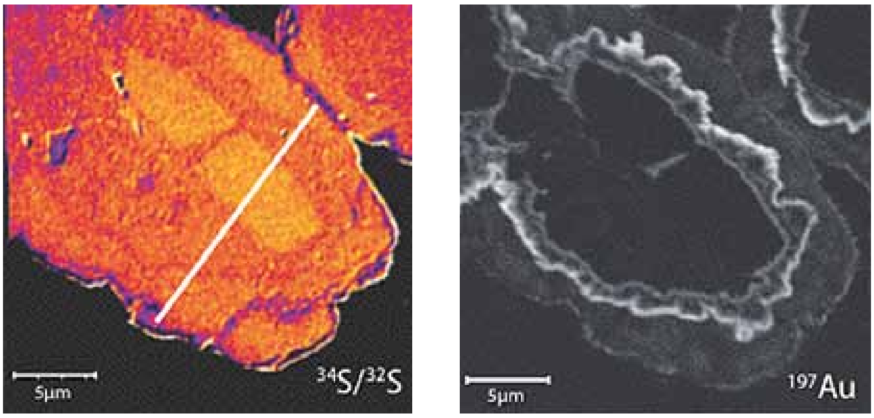
▤ Oskam et. al. *Proceedings of the Royal Society*, July 7, 2010.

LOOKING AT INVISIBLE GOLD

FLAGSHIP

Gold is one of the world's most precious metals. In many large gold deposits, the gold itself is invisible – dissolved within the crystal lattice of other minerals. In a similar way to which tree rings can be used to infer information about past climate change, minerals containing invisible gold, such as pyrite, can be used to derive information about how gold deposits form.

Dr Shaun Barker and colleagues from the University of British Columbia and the University of Nevada – Las Vegas visited the AMMRF at the University of Western Australia (UWA) to examine pyrite grains in samples that contained invisible gold from two gold deposits in northern Nevada, USA. These deposits are examples of the very important Carlin-type class of gold deposit, responsible for about 10% of current global gold production. By using the NanoSIMS instrument to map gold, other trace elements and sulphur isotopes within selected, small pyrite grains (5–50 μm) from each deposit, they were able to resolve, for the first time, that gold was deposited in at least two discrete episodes in each deposit. Each episode of gold deposition was accompanied by increased concentrations of trace metals that are often associated with magmas. These results emphasise that gold may be deposited in episodic bursts during the formation of gold deposits, and has important implications for the genesis and controls on Carlin-type gold deposit formation.



Pyrite grain from the 'Banshee Deposit', northern Carlin Trend, Nevada, USA with NanoSIMS maps of the distribution of gold and sulphur isotopes.

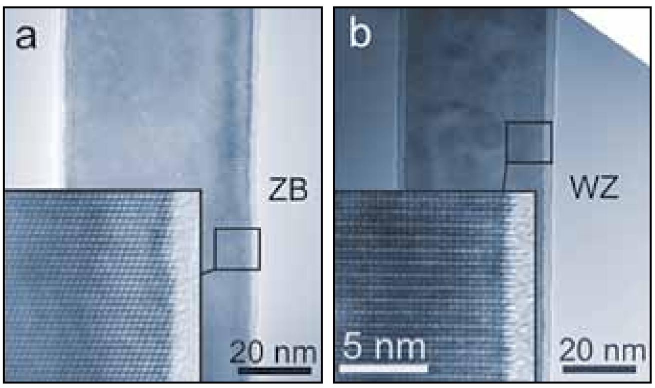
S. Barker et. al. *Economic Geology* 104 (7), 2009.

PHASE PERFECTION IN SEMICONDUCTOR NANOWIRES

III–V semiconductor nanowires are an important area of semiconductor research, having possible applications in solar cells and optoelectronic devices such as lasers, photodetectors and light-emitting diodes (LEDs). Nanowires typically have outstanding optoelectronic properties thanks to their one-dimensional quantum structure; being III–V semiconductors, they also can be easily integrated with conventional fabrication processes for microelectronics. Practically, the structure and chemistry of the nanowires determine their band structure and bandgap, and hence their suitability for specific opto-electronic devices.

Prof. Chennupati Jagadish and his team in the department of Electronic Materials Engineering at the Australian National University (ANU) have successfully grown nanowires of controlled crystal structures (phases) by using metal-organic chemical vapour deposition (MOCVD). By varying the growth temperature and the V:III ratio – i.e., the partial pressures of the two precursor gases that provided the arsenic (V) and indium (III) or gallium (III) – the team created defect-free nanowires that had either a zinc blende (cubic) crystal structure or a wurtzite (hexagonal) structure. The nanowire growth was catalysed by gold nanoparticles at the tip of each nanowire through a vapour–liquid–solid process.

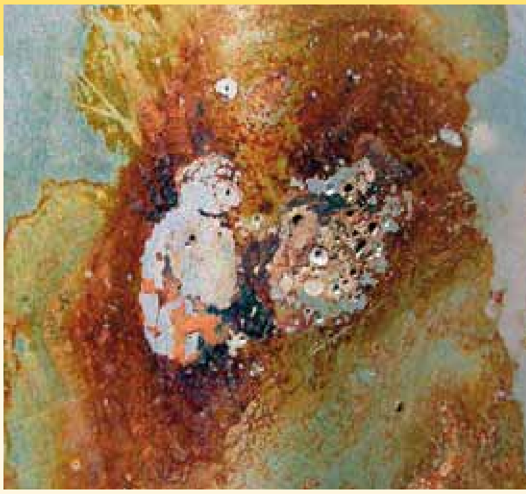
After the nanowires were grown, the researchers characterised them by scanning electron microscopy (SEM) and transmission electron microscopy (TEM) at the AMMRF at ANU. This allowed measurement of the phases of the nanowires and identification of the key growth parameters. In contrast to normal III–V nanowires, which typically are uncontrolled blends of the cubic and hexagonal phases, the microscopy showed they had produced defect-free, single-phase zinc blende or wurtzite nanowires, depending on the growth temperature and the V:III ratio used. Consequently, the team established a comprehensive nucleation model that incorporated the chemical potential of the different elements and compounds relevant to the nanowire grown, the surface energies of the facets and other relevant growth parameters. The results provide key understanding to control the crystallography and, therefore, optoelectronic properties of III–V nanowires in future applications.



Transmission electron micrographs of (a) defect-free zinc blende GaAs nanowire grown at 375°C with V:III ratio of 46 and (b) defect free wurtzite GaAs nanowire grown at 550°C with V:III ratio of 1.4.

H. Joyce et. al. *Nano Letters* 10, 2010.

WHY STAINLESS STEEL CORRODES



PROBLEM

- Corrosion is an extremely costly failure mechanism, consuming 3–5% of GDP depending on the extent of a nation's development.
- Stainless steel, despite its name, is not immune to corrosion. It is subject to a variety of localised corrosion phenomena, pitting corrosion being the most important. This devastating failure mechanism – which can manifest as anything from rust spots on a kitchen appliance to a large hole in a tank or pipe – appears, apparently, at random.
- Pitting corrosion is the starting point for crevice corrosion; another nasty scourge where the stainless steel rusts rapidly in narrow gaps.
- Currently, to overcome pitting corrosion, more expensive grades of steel, containing more chromium and also containing molybdenum, need to be used.

SOLUTION

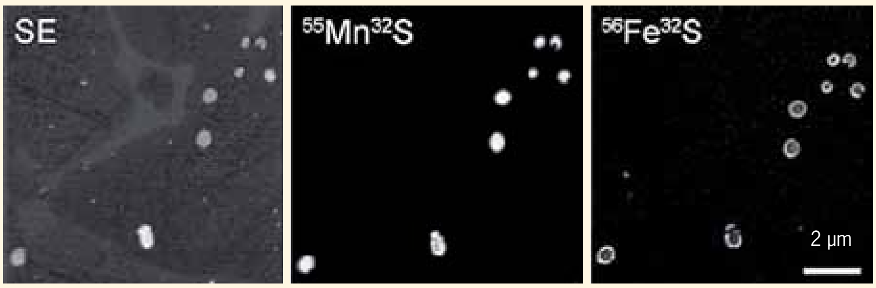
FLAGSHIP

Stainless steel is an alloy of iron and chromium and owes its general corrosion resistance to the presence of a very thin layer of chromium oxide that forms on the surface, protecting the underlying steel.

When pitting corrosion does occur, it nucleates around unavoidable sulphur impurities in the steel. Manganese is added during production to sequester the sulphur as microscopic inclusions of inert manganese sulphide (MnS). As a consequence, most inclusions in the steel remain unreactive. However, some appear to become especially active and react around their edges.

Prof. David Williams from the University of Auckland is working to understand this phenomenon by using the NanoSIMS to examine the composition around MnS inclusions. He found that the inclusions were surrounded by a thin skin (less than 100 nm) of reactive iron sulphide (FeS). This reactive halo is likely to be the reason for the corrosion initiation that occurs around inclusions. FeS is unstable relative to MnS at steel-manufacturing temperatures – indeed the reason for adding manganese is to prevent the formation of FeS.

These results point to a possible means of processing the steel to remove the FeS halo around the inclusions and hence mitigate this important form of corrosion. If the steel were cooled more slowly, there would be more time for the manganese to thoroughly sequester the sulphur and maximise the formation of the more energetically favourable MnS, reducing the likelihood that pitting corrosion could initiate in the future life of the final product.



NanoSIMS images of inclusions in a commercial 316-grade stainless steel. Secondary electron image (left), MnS^- (centre), FeS^- (right).

David E. Williams et. al. *Corrosion Science,* 52 (11), 2010.

IMPACT

Improved processes will lead to reduced potential for corrosion, in turn leading to:

- Longer life of stainless steel and therefore reduced replacement costs.
- The ability to use less expensive types of stainless steel in certain applications.
- Greater confidence in the longevity of stainless steel products.

WATER-REPELLING TERMITE WINGS

The strange phenomenon of termites that choose to fly in the rain has led to the discovery of a micro- and nano-architechture that efficiently acts to repel water. Many species of termites tend to fly in the rain or during storms, usually when they are establishing a new colony. This is thought to help them to avoid predators and to be sure that there will be mud available for establishing a new nest when they arrive at their destination.

A collaborative project between Dr Gregory Watson and Dr Jolanta Watson from James Cook University and Dr Bronwen Cribb from the AMMRF at the University of Queensland has discovered that termites' wings are ideally structured to repel water, providing high repulsion for minimal weight gain. By using a variety of microscopic techniques at the AMMRF, the team has found that these termite wings are covered with many thousands of long, grooved hairs that can support water droplets up to about 10 µl in size. Interspersed between the hairs, approximately 10 µm apart, are smaller parabolic, star-shaped domes that repel the smaller water droplets. The top surfaces of these domes also have even-smaller-scale structures to further minimise water adhesion. Combining these structures has allowed the termite to maximise the water-repelling properties of its wings while keeping additional weight to a minimum, an important outcome for an insect that is not a strong flyer.

Water-repelling hair and star-shaped domes on the surface of a termite wing.

The ability to produce efficient water-repelling surfaces is essential to many industrial applications, from medical diagnostics to large-scale anti-fouling surfaces. Therefore, understanding how nature has created its own efficiencies will be extremely valuable to innovation in the design of new types of water-resistant surfaces. Biodiversity provides ready-made reservoirs of useful molecules and structures that, when harnessed, can inform modern innovation.

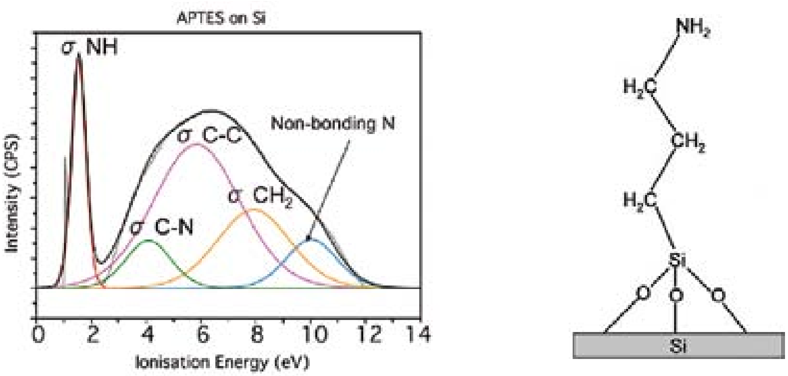
G. Watson et. al. *ACS Nano* 4 (1), 2010.

REACTIONS STEP BY STEP

Surfaces can be functionalised with many useful molecules for a multitude of applications. Short stretches of DNA called oligonucleotides, when attached to a silicon surface, can bind to and classify forensically relevant DNA fragments.

Attaching oligonucleotides to a silicon surface has to be done in several stages. Each layer is attached to the previous one by specific chemical reactions. It is important to design the compounds present in each layer to provide the best functional groups for the attachment of the next layer. Achieving optimal coverage of the surface with oligonucleotides depends on the density of attachment sites; too many or too few might reduce the final coverage.

Dr Gunther Andersson at Flinders University is building a system to do just this. He is focusing on the first two steps in modifying a silicon substrate for the ultimate attachment of the oligonucleotides. Termination of the silicon surface is achieved with hydroxyl groups for the subsequent reaction with aminopropyltriethoxysilane (APTES). Succinimidyl 4-formyl benzamide (SFB) can then be attached to the APTES.



MIE spectrum (left) of APTES attached to a hydroxyl terminated silicon surface (right).

As each step is dependent on the success of the previous one, it is essential to monitor progress. Dr Andersson does this by using metastable induced electron spectroscopy (MIES) at the AMMRF at Flinders University. Its exquisite surface sensitivity allows MIES to probe only the composition of the outer-most surface. When used in combination with other spectroscopy techniques that penetrate further into the surface, it confirmed the adsorption of APTES to the hydroxyl-terminated silicon surface. However, results showed that many of the APTES molecules were in fact lying on their sides rather than standing upright on the surface. In this configuration not all APTES molecules will be available for the chemical reaction with SFB. Thus, MIES monitoring has enabled processes to be modified and optimised as development proceeds.

TOWARDS ANALYSIS FOR THE INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

FLAGSHIP

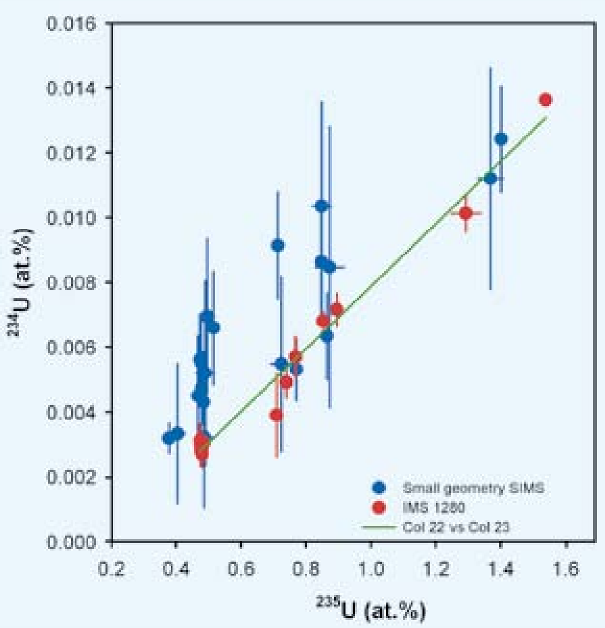
The AMMRF at the University of Western Australia (UWA) is in the process of applying to become a member of the Network of Analytical Laboratories (NWAL) of the IAEA.

With increasing energy needs and concern about carbon emissions, it is likely that we will rely more heavily on nuclear energy in the future. As the world's dependency on nuclear energy grows, so does the risk that nuclear materials may be diverted to clandestine activities. The IAEA is the most visible organisation that monitors nuclear facilities around the world, maintaining a network of analytical labs to achieve the nonproliferation objective of preventing the spread of nuclear materials. One of the main tools for detecting undeclared activities is the particle analysis of dust-containing inspection samples.

The flagship IMS 1280 ion probe is an ideal instrument for this kind of analysis and is at the heart of the Western Australian application to become an IAEA NWAL. Typical forensic samples contain sub-micrometre-sized, uranium-bearing particles. Isotopic analyses of these particles can reveal not only if the material has been enriched above the declared level, but also can shed light on the feedstock that was used and the type of enrichment process that was used to produce the material.

Secondary ion mass spectrometry has long been used for this task, but the interpretation of data obtained from older, smaller instruments is hampered by unresolved interferences. Recent tests on the UWA instrument with real nuclear forensic samples gave an excellent outcome. Working with Magnus Hedberg from the European Commission's Institute for Trans-uranium Elements, Assist/Prof. John Cliff at the AMMRF at UWA has comprehensively tested the IMS 1280. Newly developed particle-search software was tested, and the

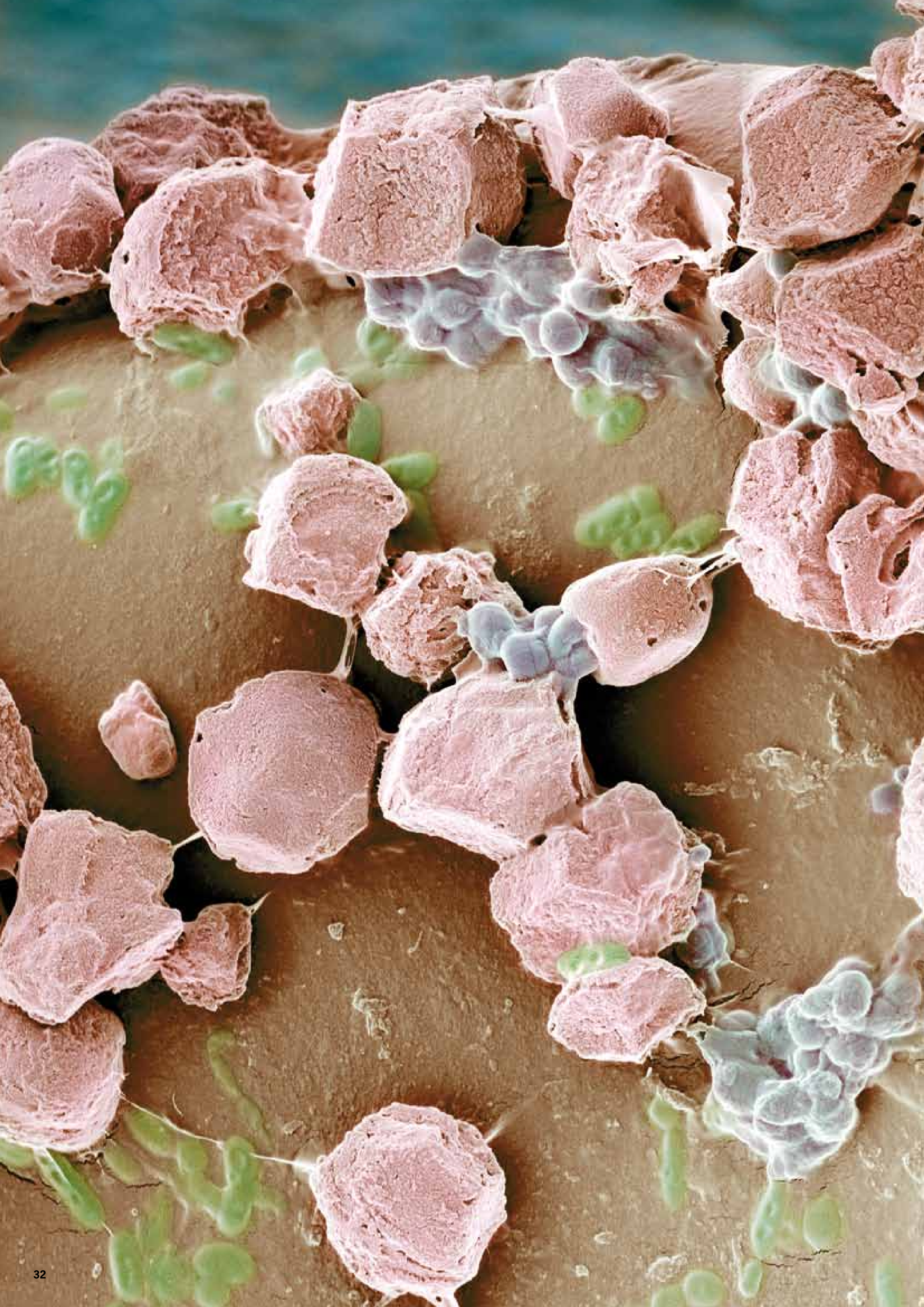
performance of the IMS 1280 evaluated on real nuclear forensic samples. Of particular interest was the IMS 1280's performance in multi-collector mode in which all uranium isotopes can be measured simultaneously. The measurements were rapid and clearly of sufficient quality for nuclear safeguards purposes. This success has formed an important milestone along the application pathway towards becoming an approved laboratory.



The ^{234}U–^{235}U enrichment line is revealed on a difficult nuclear forensics sample because of the superior performance of the IMS 1280. Each point represents an individual sub-µm-sized uranium-bearing particle from a single forensic sample. Natural uranium is always around 0.7% ^{235}U. This sample has been enriched to at least 1.5%.

It is common to see 3–6% enrichment for use in reactors, while weapons-grade uranium generally contains >85% ^{235}U.

The Cameca IMS 1280 ion probe at the University of Western Australia.



SUPPORTING OUR INDUSTRY PARTNERS

The purpose of the AMMRF is to enable Australian research and innovation. Although this happens largely through its support for academic research, the AMMRF also plays an important role in industrial research and development. Industry access to the AMMRF can follow a number of paths, according to the needs of the individual business concerned. The major forms of industry interaction or access are:

CONTRACT R&D PROJECTS

These relationships occur where an industry partner will fund the costs of research, including beamtime fees, consumables and salaries for research staff or student scholarships.

LEVERAGED R&D PROJECTS

This type of partnership includes ARC Linkage Projects and may involve multiple collaborative partners. ARC Linkage Projects provide an ideal way for industry partners to access the full range of academic and technical expertise that exists within the AMMRF. They provide long-term alliances to solve major research questions relevant to the industry partner and extend the research profile of the academics.

ACCESS BY INDUSTRY USERS TO INSTRUMENTS AND CAPABILITY

Industry employees enter the AMMRF user experience in the same manner as other researchers. They are trained and provided with access privileges in-line with their level of competency. Instrument or beamtime fees are charged at commercial rates that are determined by individual nodes of the AMMRF.

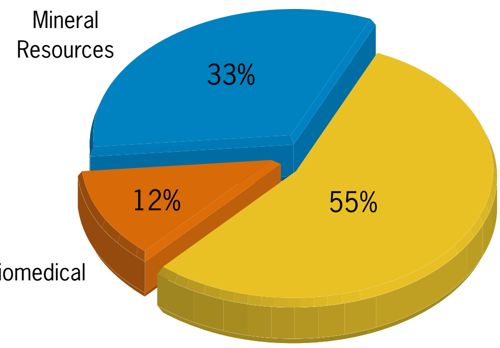
TESTING AND CONSULTANCY SERVICES

Testing and consultancy services are offered at commercial rates by the AMMRF. The variety of capability that the AMMRF has to offer is large and consequently the facility is used for testing services by a broad range of industry sectors.

TRAINING

AMMRF training courses and programs are open to industry users and researchers. Participation in these courses builds in-house competency for the companies or it can enable industry users to access instruments within the nodes themselves.

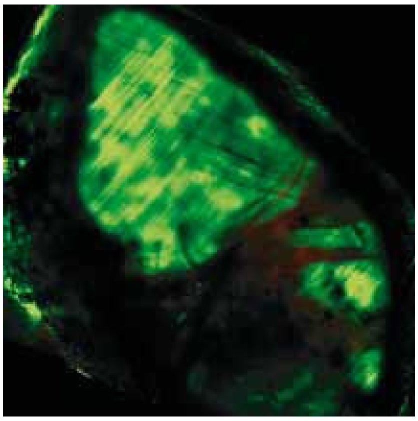
USERS FROM INDUSTRY BY SECTOR (2009–2010)



Colour-enhanced scanning electron micrograph of a used kitchen sponge. There are crystals (pink), probably sugar or salt, bacteria (blue) and other nucleated micro-organisms (green). Image by Dr Ian Kaplin @ The University of Sydney.

INDUSTRY SNAPSHOTS

The snapshots below provide a few examples of the many successful interactions between the AMMRF and industry clients. Many are highly commercially sensitive and confidentiality precludes their inclusion here.



Confocal micrograph of an Argyle pink diamond.

COLLABORATIVE RESEARCH BETWEEN THE UNIVERSITY OF WESTERN AUSTRALIA AND RIO TINTO DIAMONDS

Problem: The colour of natural pink Argyle diamonds is due to an unidentified crystalline defect that causes the colour of the diamonds to be affected by certain wavelengths of light. Rio Tinto diamonds wanted to characterise this change, find the optimal wavelength at which to perform a reversal and to discover the underlying cause of the defect and its behaviour.

Solution: Confocal microscopy allowed direct imaging of optically active defects within single-crystal diamonds and was used to show the structure and orientation of graining to which the pink colour is restricted. It was found that the graining lies along the planes of easy slip within a crystal. The colour-causing defects are being mapped in 3-D to make out the boundaries where pink regions and clear regions meet. This provides guidance to help identify areas for more detailed investigations. Identifying the characteristics of this defect will provide Rio Tinto with methods for verifying authenticity of Argyle pink diamonds. The properties of this crystalline defect could also be of use in research into optical systems and technologies.

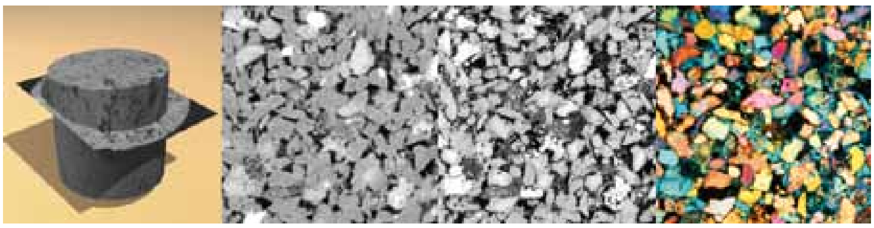
www.riotintodiamonds.com

CONTRACT RESEARCH BY THE AUSTRALIAN NATIONAL UNIVERSITY FOR DIGITALCORE PTY LTD

Problem: This company provides computer modelling of petrophysical properties of reservoir rocks and coal, based on X-ray microtomographic data. However, conventional tomography provides poor mineralographic identification.

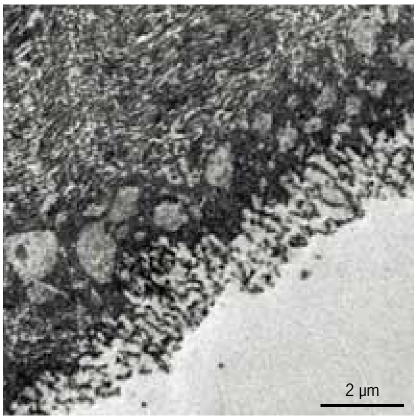
Solution: Alignment of 2-D mineralographic or elemental information affords an additional layer of information on top of the 3-D microstructure defined by the microtomography. Over the past year the researchers have successfully developed methods to automatically register images of polished sections captured by a variety of techniques after the core has been tomographically scanned. These combined maps are used to aid modelling of fluid flow or mechanical properties and are contributing significantly to the company's success.

www.digitalcore.com.au



From left: An illustration of an arbitrary cut through a core already tomographically scanned; the slice in the tomogram; the corresponding registered SE SEM image and the registered polarised micrograph of the polished section.

ADCO | Advanced Geomechanics | AECOM | Afmeco Mining & Exploration | Agilent Technologies (Varian) | AGR Science and Technology | Alcoa | ALS Laboratory Group | AMPACK Medical | Antaria | AQIS | Aramco | Argyle Diamond Mine | ARL | Atlas Iron | AusQuest | Australian Carbon Technologies | Australian Water Quality | Bauxite Alumina Technology Centre | BEMET Services | BHP Billiton | Biotica | Blue Circle Southern Cement | BlueScope Steel | Boambee | BP | Breville | Bureau of Sugar Experiment Stations | Bureau Veritas | Caltex | Canterbury Health Laboratories | Carl Zeiss Vision | Carnegie | Cement Australia | Chevron | Cochlear | Coles Meyer | Conoco | Coopers Brewery | CSIRO | Cuno Pacific | Dermcare-Vet | Digitalcore | DMG Microlabs | Downer EDI Mining | Dyesol | FEI | Fertility Specialists | Finisar | Fonterra | Fortress Systems | G. James Australia | Geochempet Services | HRL Technology | Groundwork Plus | Heggies | Hollywood Fertility | Incospec & Associates | ISIS Group Australia | Ivanhoe | JOGMEC | KEMM Environmental | Maersk | Mason



Transmission electron micrograph of the newly described structure on the surface of cartilage

TESTING SERVICES AT THE UNIVERSITY OF SYDNEY FOR SYLVAN SCIENTIFIC

Problem: Sylvan Scientific makes pharmaceuticals to treat arthritis. They need to understand the fine structures on the surface of cartilage to gain insight into how their drug functions to treat the disease.

Solution: With extremely careful specimen preparation, transmission electron microscopy revealed structures never seen before on the surface of cartilage. The self-assembling structure appears to be made of lipid and proteoglycan and provides a very important barrier function in the joint. It is thought that their drug acts to intercalate and stabilise this structure and the microscopy forms a solid basis for further developmental work.

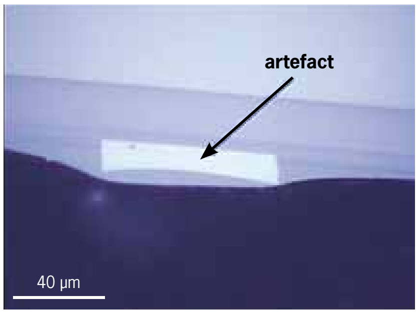
www.sylvanscientific.com.au

CONTRACT RESEARCH AT FLINDERS UNIVERSITY FOR CARL ZEISS VISION (GERMANY)

Problem: Ophthalmic lenses are generally coated with a number of different functional layers. For the development and manufacturing of such optical layer stacks, it is crucial to get detailed information about the chemical composition of the layers and possible artefacts that may occur during processing.

Solution: State-of-the-art confocal Raman microscopy has allowed chemical information about surfaces to be determined with sub-micrometre resolution. This technique has established the chemical composition of a number of optical layer stacks on ophthalmic lenses provided by Carl Zeiss Vision. This helps Carl Zeiss Vision to further optimise their coating processes and to guarantee consistently high product quality and performance.

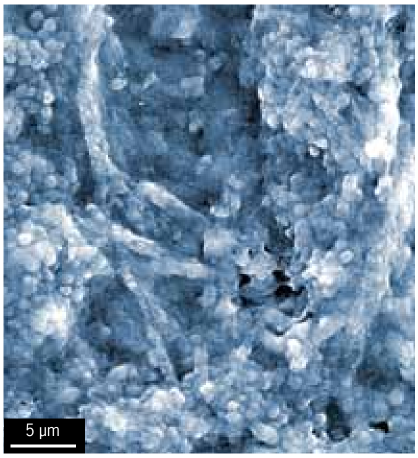
www.zeiss.com



TESTING SERVICES AT THE UNIVERSITY OF SYDNEY FOR A PRODUCT-DESIGN COMPANY

Problem: This company was about to launch a new drink product when they noticed floating contamination in some bottles. The contaminant looked like a biofilm, but standard microbiological analysis failed to detect any microorganisms. This problem was causing a dispute with the bottling company, which was costing considerable sums of money.

Solution: Examination by scanning electron microscopy clearly revealed the presence of micro-organisms. These results justified more extensive microbiological work, which identified a low-temperature, slow-growing bacteria that was then also found in the bottling equipment. These results are currently supporting the company in the resolution of their dispute.



Coloured scanning electron micrograph of a bacterial biofilm found in the drink bottles.

Geoscience | Mater Pathology | MATSA Resources | Maxim | MBA Petroleum | Mesaplexx | Mining & Civil Geotest | MPL Envirolab | Murrin Murrin Operations | NFK Glazing & Industrial Supplies | National Measurement Institute | ONDEK | Origin Energy Resources | PathWest | Petrobras | Petronas | Phillips-Gerrard Petrology | PicaMS | Pivet | Pontifex & Associates | Primary Industries/DEEDI | Protech | Provisor | Pterodia | Queensland Fertility Group | Queensland Police | Research Laboratories of Australia | Reserve Bank of Australia | Reservoir Solutions | RHS | Rio Tinto Alcan | RJ Roberts | Robson Environmental | SANTOS | Shell | Simon Cox & Associates | Sir Charles Gairdner Hospital | Sirtex Medical | Site Environmental & Remediation Services | Spitfire Resources | SRK Consulting | Steri Flow | Sydney Environmental & Soil Laboratory | Sylvan Scientific | Tasmanian Alkaloids | Teale & Associates Holden | TSW Analytical | Uranium Exploration Australia | Very Small Particle Company | Visiocorp Australia | vivoPharm | VRMT | Water Corporation | XeroCoat | XTAL Enterprises

AMMRF AT SHANGHAI WORLD EXPO

On 28 June 2010, Prof. Simon Ringer, the AMMRF Executive Director and CEO (right) and Dr Rongkun Zheng from the AMMRF at the University of Sydney, convened a one-day symposium on the emerging technology of spintronics at the Australian pavilion of the Shanghai World Expo. The symposium was a resounding success. It allowed the AMMRF researchers to showcase their leadership in this field, and to build new links, and strengthen existing collaborations, with premier spintronics researchers in China.

Prof. Jin Zou from the AMMRF at the University of Queensland was also at the Shanghai Expo where his successful collaborations with Chinese research groups led him to receive an award for Best Practice in Collaborative Research.

SCIENCE MEETS PARLIAMENT

Science Meets Parliament was held on 10 March 2010. Prof. David Sampson, Director the University of Western Australia (UWA) node, and Angus Netting, Deputy Director of Adelaide Microscopy, attended the event and highlighted the importance of microscopy for Australian research and innovation. They held discussions about some interesting research outcomes with Senator Louise Pratt and Sophie Mirabella, MP. Sophie Mirabella, MP, was so intrigued that she visited the AMMRF at UWA as a direct result of Science Meets Parliament.

FIDEL CASTRO DÍAZ-BALART VISITS THE AMMRF

On 20 October 2009, Dr Fidel Castro Díaz-Balart, Scientific Advisor of the State Council of Cuba, visited the AMMRF at the University of Sydney as part of a visit by a Cuban delegation, coordinated by the Commonwealth Government's Department of Innovation, Industry, Science and Research. Dr Castro is the eldest son of Fidel Castro and a highly qualified scientist. The delegation was examining Australia's research in the fields of biotechnology and nanotechnology and looking for opportunities for collaboration and exchange of ideas. Dr Castro was particularly interested to learn about the innovative collaborative structure of the AMMRF and to see the facilities and the research done within one of its nodes.

NATIONAL CHARACTERISATION ROADSHOWS

The AMMRF, along with its sister National Collaborative Research Infrastructure Strategy (NCRIS) characterisation facilities, the Australian Synchrotron, the National Imaging Facility and the National Deuteration Facility, has taken part in a number of roadshows where we presented our capabilities to a wide audience of researchers in cities around Australia. There were opportunities for researchers to hear successful case studies and to discuss their individual experimental needs with microscopy and microanalysis experts. Hundreds of researchers attended the roadshows that were held in Perth, Adelaide, Melbourne and Hobart and very positive feedback has been received.

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