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Cover Image: X-ray micro-computed tomography (micro-CT) of teeth from the marine mollusc Acanthopleura hirtosa. Data captured on a Zeiss Versa 520 XRM. Image visualised using Drishti software. Image acquired by Dr Jeremy Shaw at CMCA.

Inside Cover Image: Antarctic ‘Hair Grass’ root cross-section, showing the arrangement of cells. Image by Assoc. Professor Peta Clode.
From the Director

There is an ever-increasing appreciation of the new scientific opportunities enabled by convergence – the coming together of scientific insights and approaches from originally separate fields. This convergence provides the power to think beyond usual paradigms and to approach issues informed by many perspectives instead of few. Convergent research is driving the solution of the most difficult problems facing us as a society today.

CMCA is a convergence research organisation, engaged in synthesizing and integrating all areas of science – pouring the traditional disciplines in Biological Sciences, Biomedical Sciences, Earth Sciences, and Physical Sciences into a large melting pot. In 2014, CMCA’s Associate Professor Matt Kilburn, a geologist who leads the AMMRF Flagship Ion Probe Facility, took his sabbatical at Harvard Medical School, to advance his understanding of how a geoscience tool, the NanoSIMS 50, might be applied to biomedical research – convergence in action.

Convergence implies breadth and such breadth is in evidence in similar core facilities around the country, especially in Go8 universities. Several universities, such as Monash and UNSW, have already established broad, integrated core facilities. Others, such as Melbourne, Sydney, and UQ, have placed their science infrastructure under the spotlight seeking to better integrate, coordinate and link. And the drive to do this was present in the national framework as far back as the 2011 Strategic Roadmap for Australian Research Infrastructure, which highlighted the future need for interaction between research priorities and capabilities. As a broad and integrated organisation, CMCA has remained ahead of this national curve.

In Western Australia, CMCA is promoting convergence amongst the local research community. Through its membership of the National Resource Sciences Precinct, it is participating in a seamless integration of the resource science Characterisation infrastructures of CSIRO, Curtin University and CMCA. It is also poised to level the science infrastructure playing field in WA, with a landmark agreement with Murdoch University to provide its researchers with the same access to CMCA facilities as UWA researchers.

No area of science epitomises the opportunity and need for convergence more than the biosciences. CMCA has traditionally not gone beyond examining cells, an artificial and increasingly restrictive barrier in 2015. Molecular analysis of single cells represents an important area of future investment. And to capitalise on its bio-mass spectrometry capability, CMCA is currently in the advanced stages of integrating with the UWA node of Metabolomics Australia, which will see a great enhancement in its molecular science capability, supporting leading UWA research in plant biology and medicine.

So why do we do all this? Well, CMCA is all about its users – about helping to make your research better – about making sure you can access the facilities and expertise you need, when you need it, across the board. Working together, we can make your great research even greater.

Image: CMCA Director - Professor David Sampson

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The CMCA is a focus for microscopy, characterisation and microanalysis activities across Western Australia and, through strong links and collaborations, has an excellent reputation both nationally and internationally.

Established in 1963 as a science infrastructure facility within The University of Western Australia to support research activity, the Centre has a long and distinguished record of collaboration with researchers, industry and government agencies in the provision of research expertise and technology.

Its world-class facilities, with a replacement cost of $50M, comprise an extensive range of microscopy, microanalysis and imaging instruments across six sites.

**Western Australian Centre for Microscopy (WACM)**

Together The University of Western Australia, Murdoch University, Curtin University, and Edith Cowan University form the Western Australian Centre for Microscopy (WACM). These four publicly funded universities have a very strong and long collaborative history in regard to electron microscopy and related facilities, which is presently defined by the 2010–2015 Memorandum of Understanding (MoU).

This agreement between the partner institutions sees CMCA acting as the hub for microscopy activities in the State, and strong cross institutional support for infrastructure acquisition and management. The basis of the WACM MoU is that major capital infrastructure must be shared to achieve the most cost-efficient utilisation.

Under the terms of the MoU, researchers from all of the partner universities can access the grouped facilities of WACM without discrimination. This agreement has led to another landmark agreement with Murdoch University to cross subsidise its researchers access to CMCA.

**Australian Microscopy and Microanalysis Research Facility (AMMRF)**

Established under the Commonwealth Government’s National Collaborative Research Infrastructure Strategy (NCRIS), AMMRF is Australia’s peak research facility for the characterisation of materials through advanced microscopy and microanalysis. The AMMRF facilitates access for all Australian researchers to world-class equipment, instrumentation and expertise through a national grid of nodes with varying microscopy capabilities and an array of flagship instrument platforms at the international cutting edge.

The CMCA is the West Australian node of the AMMRF and features the flagship ion probe capabilities, which consist of the NanoSIMS50 and IMS 1280 and a second NanoSIMS50L funded by the National Resource Science Precinct, is due to arrive in mid-2015. Each of these instruments is unique to the Southern Hemisphere.

The CMCA also collaborates with the John de Laeter Centre, which enjoys linked laboratory status in the AMMRF, in the management and operation of Western Australia’s ion probe facilities.
Australian National Fabrication Facility (ANFF)

Established under NCRIS, the Australian National Fabrication Facility (ANFF) provides researchers and industry with access to state-of-the-art fabrication facilities. The capability provided by ANFF enables users to process hard materials (metals, composites and ceramics) and soft materials (polymers and polymer-biological moieties) and transform these into structures that have application in sensors, medical devices, nanophotonics and nanoelectronics.

The CMCA houses the Panalytical Empyrean powder diffractometer.

National Resource Sciences Precinct

The National Resource Sciences Precinct (NRSP) is a collaboration between CSIRO, Curtin University and The University of Western Australia (UWA) to connect the world’s best researchers with industry and government to tackle some of the most complex challenges facing the resource industry. The Federal Minister for Industry, the Hon Ian Macfarlane MP, officially launched the National Resource Sciences Precinct on Tuesday 8 April 2014.

CMCA’s role within the NRSP will be to help establish the Advanced Resources Characterisation Facility (ARCF). Funded by CSIRO’s Science and Industry Endowment Fund (SIEF), the ARCF will install and operate state-of-the-art analytical instrumentation for high-end research in the resources industry. CMCA will augment its world-class Ion Probe Facility with a new NanoSIMS 50L. Curtin University will install a LEAP 4000 for atom probe tomography, which CSIRO will develop its Maia mapper XRF detector to operate with the need for synchrotron radiation. CMCA’s new NanoSIMS will arrive in mid-2015.

National Imaging Facility (NIF)

Established under NCRIS and expanded under the Commonwealth Government’s Education Investment Fund (EIF), the National Imaging Facility provides state-of-the-art imaging capability of animals, plants and materials for the Australian research community.

In 2009, CMCA became the Western Australian node of the facility, the first organisation to host two NCRIS capabilities. The facility features leading edge imaging capabilities for Western Australia including in vivo micro-CT, multispectral imaging, and X-ray microscopy, as well as the flagship 30cmbore 9.4 T MRI located at CMCA@Perkins in the Harry Perkins Institute of Medical Research, at the QEII medical Centre.

AuScope

AuScope is a characterisation capability funded through the National Collaborative Research Infrastructure Strategy (NCRIS) with a focus on establishing world-class research infrastructure to characterise the structure and evolution of the Australian continent in a global context from surface to core in space and time.

In partnership with the AMMRF, the Government of Western Australia and UWA, AuScope enabled the establishment of the world-class ion microprobe facility at CMCA, for the benefit of all Australian researchers.

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The CMCA houses the Panalytical Empyrean powder diffractometer.
Techniques

The CMCA provides the capabilities to characterise the continuum from atoms to small animals.

- Transmission Electron Microscopy
  - Analytical spectroscopy
  - Diffraction
  - Element mapping
  - Imaging
  - Tomography

- X-ray Diffraction
  - Charge density measurement
  - Powder X-ray diffraction
  - Small molecule structure determination
  - Thin film analysis, XRD phase analysis, rocking curve analysis

- Nuclear Magnetic Resonance Spectroscopy
  - Multi dimensional spectra
  - Multinuclear spectra
  - Solid state spectra

- Biological Mass Spectrometry
  - Electron and chemical ionisation
  - Fast atom bombardment

- Scanning Probe Microscopy
  - Confocal Raman microscopy
  - Atomic Force microscopy
  - Nanoindentation

- Scanning Electron Microscopy
  - Secondary and backscattered electron imaging
  - X-ray microanalysis
Image: 100um-thick sections of a new perennial herbaceous pasture legume. Stems were prepared on a vibratome and images taken on the zeiss axioskop optical microscope. Images: Peta Clode.
Feature Story
CMCA moves into the Harry Perkins Institute of Medical Research

The 2015 New Year brought the long-awaited relocation of CMCA@QEII from M-Block into purpose-designed, integrated facilities on level 3 of the Harry Perkins Building. The move brings together CMCA’s cytometry, optical, and live animal imaging infrastructure, staff offices and data analysis facilities onto a single floor. CMCA@Perkins is now home to four academics and five research staff supporting 19 instruments, plus data management, analysis, and visualisation.

The open lab environment is facilitating interaction between researchers (and staff!) who previously were in isolated labs dispersed over two floors. This improves efficiency and productivity for researchers, and also allows staff to train and support instruments across multiple platforms, creating a more effective and user-friendly research setting.

The relocation also sees the CMCA Biomedical Applications Group centralised with the local biomedical community, providing better support to CMCA’s growing number of users in biomedical research programs. Introduction of the new Research Group Subscription for 2015 is also proving popular with biomedical research groups, by facilitating more affordable access for multiple users with low hourly requirements.

CMCA continues to demonstrate commitment to facilitating biomedical research excellence through acquisition and support of world-class infrastructure (and many firsts for WA!) including the live-animal Bioimaging Facility, Influx single-cell sorter, Aperio digital slide scanners, Australian National Imaging Facility flagship 9.4 T MRI scanner, and most recently a Fluidigm mass cytometer.

In addition, researchers have access to instruments in CMCA@Physics, including recently commissioned SEM and TEM facilities, and our Australian Microscopy and Microanalysis Facility (AMMRF) flagship SIMS facility, and in CMCA@Bayliss featuring newly upgraded 500 MHz and 600 MHz NMR spectrometers.
Research Highlights

Image: X-ray microscopy of gecko head (~1 cm long) – Acquired by Dr. Jeremy Shaw, sample supplied by Assoc. Professor Matt Kilburn (CMCA).
Microscopic creatures that live on tiny ocean plastics greatly affect the fate and ecological impacts of marine plastic pollution, according to researchers from The University of Western Australia.

PHD candidate Julia Reisser and colleagues have published an article in the international journal PLOS One that contributed many new records of microbes and invertebrates living on sand-sized marine plastics.

Professor Chari Pattiaratchi, Ms Reisser’s PhD supervisor, said there were huge numbers of floating plastics at sea and the study was the first to document biological communities on pieces from Australian waters.

The tiny ocean plastics come from the breakdown of discarded plastic items, such as single-use packaging and fishing gear.

More than 1000 images were taken while examining ocean plastics from Australia-wide sample collections using a scanning electron microscope at UWA’s Centre for Microscopy, Characterisation and Analysis.

The good news is that some of the plastic inhabitants may decrease plastic pollution level at the sea surface, where major environmental impacts occur.

Study co-author Dr Jeremy Shaw said large numbers of silica-forming algae weighed down their plastic host, potentially causing tiny pieces to sink to the bottom of the ocean.

The researchers were also able to see colonies of microbes that seem to be “eating plastics”.

“Plastic biodegradation seems to happen at sea. I am excited about this because the ‘plastic-eating’ microbes could provide solutions for better waste disposal practices on land,” Ms Reisser said.

But she also said “epiplastic” organisms could also make ocean plastics more attractive as food for animals, inducing plastic ingestion and negative impacts. Furthermore, species living on ocean plastic could disperse across oceans, potentially invading new habitats and impacting local ecosystems.

Ms Reisser’s PhD surveys were conducted aboard vessels of the Marine National Facility, Australian Institute of Marine Science, and Austral Fisheries. She is receiving an International Postgraduate Research Scholarship and a CSIRO Wealth from Oceans Top-Up Scholarship.


Image: Diatoms (green) and bacteria (pink) living on ocean plastic. This is a false coloured SEM image of part of the surface of a 5 mm long piece of plastic (yellow) from waters off eastern Tasmania, Australia. CREDIT: Julia Reisser and Jeremy Shaw
Biomedical Sciences

Alpha-1 adrenoceptors on peripheral nerve fibres may contribute to pain

Complex regional pain syndrome is a difficult problem for patients to endure and for clinicians to treat because mechanisms are not fully understood. Patients are often highly anxious because the pain may spread away from the initial site of injury and gradually get worse. As well, pain often intensifies during psychological stress and even after a sudden fright (e.g., a car horn or the phone ringing unexpectedly).

Historically, the typical approach to treatment involved repeated injections of local anaesthetic drugs into the sympathetic ganglia supplying the injured area to block activity in sympathetic nerves. This approach was supported by many well-controlled experiments in animal models of pain but, in the absence of rigorous clinical data, recently fell from favour. However, some new findings suggest that the approach might work, at least in certain cases.

Professor Peter Drummond and colleagues at Murdoch University used immunohistochemistry and confocal microscopy to examine the distribution of alpha-1 adrenoceptors (a target for the sympathetic neurotransmitter noradrenaline) in peripheral nerve fibres in an animal model of pain involving sciatic nerve injury, and in patients whose chronic pain began after a similar type of injury (Drummond et al., 2014). Both in the experimental model and in patients with complex regional pain syndrome, there was evidence of an increased number of receptors on sensory nerve fibres in painful skin (see Figures 1 and 2). As stimulating alpha-1 adrenoceptors increases the excitability of these nerves, these findings may explain why pain often increases during psychological stress, and why pain occasionally decreases after sympathetic blockade.

Professor Drummond said that in his view “sympathetic blocks should be considered when there is convincing evidence that alpha-1 adrenoceptors contribute to pain.” This might require diagnostic injections of adrenergic drugs into painful skin to assess whether pain changes in the expected way (i.e., increasing after stimulation of alpha-1 adrenoceptors and decreasing after their blockade). He said that “alpha-1 adrenoceptors appear to play a role in about one quarter of patients with complex regional pain syndrome.” These patients might benefit most from sympathetic blockade.

This study was supported by grants from the National Health and Medical Research Council and from the Australian and New Zealand College of Anaesthetists, and was assisted by UWA staff at the Centre for Microscopy, Characterisation and Analysis.

Reference:

Image 1. Alpha-1 adrenoceptor (α1-AR) expression (red) was up-regulated in dermal nerve bundles in skin ipsilateral to partial sciatic nerve lesion (PSL). Nerve fibres were identified using the pan-neuronal marker TUJ1 (blue). Adapted with permission from Drummond et al. (2014).

Image 2. Alpha-1 adrenoceptor (α1-AR) expression was also up-regulated on axons in the sciatic nerve labelled with the pain-marker IB4 at 4 days after partial sciatic nerve lesion (PSL) (A-D) in comparison to sciatic nerve after sham surgery (E-H). Arrows show axons that are co-labelled with IB4 and the pan-neuronal marker TUJ1, and which also have up-regulated expression of α1-AR. Scale bar = 50 μm. Adapted with permission from Drummond et al. (2014).
How and when microbial life arose on Earth, and what metabolic pathways it used, are not known. What is known is that life was present on the Earth before the oldest preserved rocks were formed. At this time, and prior to about 2.4 billion years ago, the Earth’s atmosphere and oceans contained effectively no oxygen and had very different chemistries than they have today. The physical remains of microbial organisms are seldom preserved in rocks formed prior to 2.4 billion years, however the presence of life can be deduced either from mineralized structures preserved within ancient sedimentary rocks, or from more subtle signs in the chemical signatures of such rocks. In particular, the fractionation of sulfur isotopes can provide clues to the sources of sulfur in ancient rocks, and whether life was involved in their formation.

Sulfur has four stable isotopes: $^{32}$S (95.02%), $^{34}$S (4.21%), $^{33}$S (0.75%) and $^{36}$S (0.02%). Life has a strong preference for the lighter $^{32}$S over $^{34}$S and therefore biological processes result in a fractionation of the two most common isotopes. Sulfide minerals, such as pyrite (FeS$_2$), that result from biological activity therefore have less than the natural abundance of $^{34}$S, and pyrites with depleted $^{34}$S are good indicators of the presence of sulfate-reducing microbes. Micro-organisms using a sulfate-reducing metabolism are believed to have evolved very early in Earth history, and therefore they should have been well established by the Neoarchean period, 2.8-2.5 billion years ago. Against this, sulfur isotope studies of well-preserved Neoarchean rocks from Western Australia’s Hamersley Province, and similar rocks from the Transvaal in South Africa, do not have strong signals of sulfate-reducing life, however a new study of rocks of similar age from Brazil has found strong fractionations interpreted to be associated with microbial sulfate reduction. These results were published in the leading journal, Science.

The AMMRF Flagship Cameca IMS 1280 ion microprobe, housed in CMCA and managed by John Cliff, was pivotal to this study in providing high-resolution sulfur isotope analyses of the Brazilian rocks. The study was undertaken by Iadviga Zhelezinskaia, a doctoral student of Prof. James Farquhar of the University of Maryland who spent some months at CMCA in 2012 as a Gleddon Fellow hosted by Dr Cliff. Leading questions arising from the study are what was the sulfate content of the Neoarchean ocean, and why do the results from the Brazilian rocks differ from those from Western Australia and South Africa? The sulfate content of the early oceans is hotly debated, but is generally agreed to be much lower than today because of the lack of oxidative weathering of continental rocks. The lack of evidence for well-established sulfate-reducing microbes in the Neoarchean has been attributed by some researchers to the low levels of sulfate in seawater at that time, and modelling of the results from the Brazilian rocks suggests levels <1% of modern values. Why then do the Brazilian rocks record such strong evidence for sulfate reducers? The answer may lie in a difference in sedimentary environment compared with the rocks from Western Australia and South Africa. They are interpreted to have been deposited in deep water in the open ocean, and comprise mixed carbonate rocks and shales. The Brazilian rocks are carbonates and may have been deposited in shallower water in a restricted setting, barred from the open ocean. The sulfate levels in the water may become enriched by evaporation in such an environment, leading to the enhanced signal of the presence of sulfate-reducing microbes. A test of this hypothesis will come from sulfur-isotope studies of shallow-water carbonate rocks from the Western Australian and South African sequences.

Viruses in fossils

Viruses are the most abundant biological entities throughout marine and terrestrial ecosystems, but little is known about virus–mineral interactions or the fossil record of viruses.

Dr David Wacey and Assoc. Prof. Matt Kilburn from the AMMRF at the University of Western Australia (UWA), along with collaborators from Switzerland, France and Italy, have shown for the first time that viruses can act as sites of mineral precipitation in microbial mats, and in so doing they enhance their own preservation potential in the fossil record. Microbial mats, one of Earth’s most primitive and enduring ecosystems.

The team used a combination of high resolution microscopy including scanning and transmission electron microscopy (S&TEM), and the flagship NanoSIMS. They combined this with data on virus genetics to show that viruses occur in high numbers and with high diversity in modern microbial mats from lakes in Brazil. Then, by performing ageing experiments on the microbial mats, which lasted for up to three years, they were able to demonstrate that mineral precipitation took place directly on free viruses and, as a result of viral infections, on cellular debris. The initial minerals that precipitated in the vicinity of viruses were amorphous magnesium silicates. With further ageing they then altered to magnesium carbonate nanospheres of around 80–200 nanometres in diameter. These modern nano-spheres are remarkably similar to enigmatic carbonate nanospheres that are relatively common throughout the geological record. Previous interpretations of ancient nanospheres suggested that they might be mineralised nano-bacteria, bacterial fragments or extra-cellular polymers; now it seems likely that these nanospheres may in fact be ancient viruses.

The ability to identify viruses in the geological record has wide ranging implications because viruses are important agents of genetic exchange and mortality for all life forms, playing fundamental roles in global biogeochemical cycles. Viruses also serve as gene reservoirs that allow their hosts to adapt to changing ecological niches, hence they may have been instrumental in promoting the evolution of early microbial ecosystems on Earth and elsewhere.

One of UWA’s ARC Future Fellows, Assoc. Prof. Martin Hill leads the work on new plasmonic nano-lasers at School of Electrical, Electronic and Computer Engineering. Martin is employing the microelectronic fabrication facilities at the UWA, in particular Reactive Ion Etching, Plasma Enhanced Chemical Vapor Deposition, and metal deposition equipment, to produce new plasmonic laser structures.

In recent years there have been significant advances in the size and characteristics of nano-lasers, i.e. lasers with dimensions or modes sizes close to, or smaller than, the wavelength of emitted light. This work has primarily been led by innovative use of new materials and cavity designs. In a recently published review article in the journal Nature Photonics Martin Hill and Malte Gather (from the University of St. Andrews) analyzed the progress that has been made over the last few decades in the development of nano-lasers. Both the development time scales and size scales for the various laser types are shown, put in context and compared, in order to clarify how the magnitude and speed of miniaturization in lasers is occurring.

The most dramatic progress has been in the emergence of lasers made from small metallic structures, as well as refinements in dielectric cavity lasers and the beginning of their penetration into new areas such as biology. Via the use of a simple laser model, it can be seen that small lasers based on dielectric and metallic cavities use different strategies to reduce the size of lasers. In general, small dielectric lasers employ cavities with long photon lifetimes to reduce demands on the laser gain medium. In contrast, metallic cavities typically have much shorter photon lifetimes, often due to absorption in the metal. Increased confinement of the optical mode to the gain medium does however provide a design window in which lasing can occur in the metallic structures, though the gain medium is still often pushed to its limit. By analyzing results from many publications on small lasers, Martin Hill and Malte Gather showed that, typically, dielectric small lasers have cavities with dimensions and volumes greater than the wavelength of light, and quality factors >1,000 whereas the cavities of metal based small lasers can be smaller than the wavelength of light, and have quality factors < 1,000.

Interest in making lasers smaller does not seem to have been discouraged when established laser concepts approached the conventional diffraction limit; on the contrary, recent years have clearly seen a very significant interest in making ever smaller and lower power lasers. High-impact applications where small size and low power are of key importance are starting to emerge, particularly in short distance communications. To lay the groundwork for additional applications, continued research will be necessary in nano-lasers, in their fundamental properties and constituent materials, and in related research areas that depend on small lasers and optical amplifiers such as plasmonics and nano-photonics. Having access to facilities provided by the CMCA will play a vital role in the development of this work.

Research Usage and Training

CMCA 2013 & 2014 - hours per technique

The number of hours used across the facilities remained strong over the 2013-2014 period, with ~53000 and ~59000 hours utilised each year, respectively. In particular, the Bioimaging and Ion Probe platforms usage increased significantly as uptake of these systems continues to grow within the research community. SEM remained the most heavily utilised area, with >14000h conducted in 2014 across four instrument platforms. Similarly, the number of users remained consistently high across all platforms over the 2013-2014 period, with new instruments in the SPM space particularly resulting in increased user interest. CMCA continued to contribute strongly to research training with almost 1000 users trained over the 2013-2014 period. Within this, more than half of those trained were research students.

### Usage 2013 2014

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Impacting on Industry

CMCA has a long history of partnering with industry from small scale analysis, instrument hire and training of individuals, to large scale consulting and complex research contracts worth hundreds of thousands of dollars.

Access is tailored to the needs of your organisation or project and we welcome queries on how we can apply our expertise and world class instrumentation to your problem solving initiatives.

During 2013–2014, CMCA served the needs of the following industry through contracted engagement:

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<th>Energy and minerals</th>
<th>Biomedical and miscellaneous</th>
<th>Environmental and engineering</th>
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<td>Analytical Reference Laboratories</td>
<td>Procter &amp; Gamble</td>
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<td>Bambury Product Development</td>
<td>Botanic Gardens and Parks Authority</td>
<td>PV Consulting</td>
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<td>Department of Fisheries WA</td>
<td>Glossop Consultancy</td>
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<td>Epichem</td>
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<td>Fertility Specialists of WA</td>
<td>Safety Rescue Technologies Australia</td>
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<td>Pivot</td>
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Who would have thought the shampoo you used this morning had been through a NanoSIMS, AMMRF flagship instrument at UWA? Well, strictly speaking it hasn’t – but as part of Procter and Gamble’s (P&G) ongoing research to develop better cosmetic products, a small fraction of its molecules may well have done so!

CMCA’s Ion Mass Spectrometer facility is the only one in the world running two Cameca nanoSIMS and one IMS 1280 instruments together. Led by Associate Professor Matt Kilburn, the facility operates three of less than seventy of these active instruments worldwide, illustrating a key factor in why Dr. Haibo Jiang came from Oxford University to Australia and UWA, bringing with him an important industry collaboration.

Getting back to the shampoo… CMCA is providing analysis on the penetration of specific molecules into hair for P&G. The NanoSIMS technique allows high resolution visualisation of stable isotope labeled molecules. These molecules act the same as the unaltered molecules because this specific labelling does not alter their behavioural characteristics. Even though P&G have very specialised instruments in their own labs, including ToF-SIMS and electron microscopes, CMCA’s instruments provide a unique high resolution analysis which is very important to this research. This is just another example of how cutting edge research expertise and instrumentation is benefitting industry outcomes and accessibility in a global context.

Image: Inner aspect of the MOA Eggshell of the extinct elephant bird from Madagascar acquired at CMCA by Dr. Paul Rigby.
Image: Reverse osmosis membrane image courtesy of Dr. Einar Fridjonsson and Prof. Michael Johns, School of Mechanical and Chemical Engineering, UWA - important for understanding/preventing fouling of membranes used in desalination plants. Acquired on the Bruker BioSpec 94/30 MR.
Professor Johns said “There is no doubt that access to state-of-the-art, multi-million dollar facilities hosted by CMCA is a great asset to researchers in WA. A key feature that enables researchers to make the most of the facilities is the expert advice provided by CMCA academic staff and on-the-ground support by CMCA research and technical staff.”

can rely on the Australian National Imaging Facility (NIF) flagship high-field 9.4 T (400 MHz) MRI scanner located in CMCA@Perkins. The 9.4 T magnet has a large 30 cm bore, three different sizes of imaging gradients, and a range of imaging coils to accommodate a wide array of experimental setups. For example, Dr Einar Fridjonsson has utilized CMCA to complete high-resolution MRI experiments on reverse osmosis membrane systems (ROMS), which are used in industrial desalination plants. Identifying and optimizing when ROMS require cleaning or replacement can significantly improve plant efficiency and reduce operational costs. Prof. Johns’ team is working toward a low-cost NMR-based mobile technology solution for early detection. Dr Sarah Vogt and PhD candidate Kumarini Seneviratne have also benefited from access to UWA’s flagship 9.4 T MRI facility, enabling the freeze-out process of liquefied natural gas (LNG) analogues to be studied non-invasively in 3D. Understanding (and mitigating) LNG freeze-out is critical to prevent unwanted and costly shut-downs of West Australian LNG trains due to frozen hydrocarbon accumulation.

In addition, the recent upgrade of the CMCA nuclear magnetic resonance (NMR) facility located in the Bayliss building, included a powerful single-axis diffusion probe for use on the 14.1 T (600 MHz) magnet. Professor Johns’ group has plans to use this new capability to characterise rock cores and a range of colloidal systems relevant to both the mining and oil and gas industries.

Professor Johns said “There is no doubt that access to state-of-the-art, multi-million dollar facilities hosted by CMCA is a great asset to researchers in WA. A key feature that enables researchers to make the most of the facilities is the expert advice provided by CMCA academic staff and on-the-ground support by CMCA research and technical staff.”
Grants Success

CMCA successful grants — 2013

CRIS/NCRIS: David Sampson. AMMRF and NIF. $776,500.


NHMRC Equipment: Matthew Linden, David Sampson, Paul Rigby, Wendy Erber. Expanding multiparameter flow cytometry to meet medical researcher demands at QEII Medical Centre. $50,000.


Perpetual Philanthropy Services: Matthew Linden. Fluorescent cell sorting of rare populations for scientific and medical research. $65,000.


Ian Potter Foundation: Matthew Linden. Expanding capability in flow cytometry for medical research: state-of-the-art high throughput analysis. $25,000.


UWA Research Collaboration Award: Michael Stat. Comparative analysis of nutrient uptake by coral endosymbionts under ambient conditions and thermal stress. $12,000.

Externally Led

A digital mineralogy & materials characterisation hub for petrology, mineralogy, exploration, metallurgy and reservoir characterisation research. $700,000.


Perpetual Philanthropy Services: David Sampson. Fluorescent cell sorting of rare populations for scientific and medical research. $65,000.


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CMCA successful grants — 2014

ARC Linkage, Infrastructure, Equipment & Facilities: David Sampson; Shaun Collin; Martin Hill; Yinong Liu; Martin Saunders; Steve Reddy; Gretchen Benedix; Craig Buckley; Katy Evans; Birger Rasmussen; Lai Chang Zhang; Zongwen Liu; Ravinder Anand; Stephen Barnes; Andrew Thompson; Gamini Senanayake. Ultra-high resolution focussed ion beam facility for Western Australia. $1,060,000.

ARC Linkage, Infrastructure, Equipment & Facilities: David Sampson; Shaun Collin; Andrew Whiteley; David Mackey; Matthew Linden; Michael Berndt; Philip Newsholme; Giuseppe Verdile; Janina Tirnitz-Parker; Delia Nelson; Simon Mallal; Una Ryan; Phil Stumbles; Garth Maker; Ralph Martins; Mel Ziman; Elin Gray; Deborah Strickland; Jason Waithman; Meegan Howlett; Bree Foley. Mass Cytometry: A breakthrough in multidimensional systems biology. $440,000.

ARC Linkage, Infrastructure, Equipment & Facilities: Harvey Millar; Peta Clode; Gavin Flematti; Peter Leedman; Dongke Zhang; Klii Grice; Michael Bunce; Richard Oliver; Kar-Chun Tan; Robert Tregove; Garth Maker; Andrew Thompson; Steve Wilton; Ralph Martins; Chriiss Abbiss; Dr Mary Boyce. High resolution mass spectrometry for metabolomics and proteomics research. $670,000.

ARC Linkage, Infrastructure, Equipment & Facilities: Paul Low; Thomas Becker; Peta Clode; George Koutsantonis; Killugudi Swaminatha-Iyer; Julian Gale; Amir Karton; Damien Arrigan; Mark Ogden. An STM/AFM Facility for Electroactive Materials Characterisation. $150,916.

ARC Future Fellowship: David Wacey. New insights into the origin and evolution of life on Earth. $767,444.

ARC Discovery Program: Killugudi Swaminatha-Iyer, Pilar Blancafort, Timothy St Pierre, Martin Saunders, Keith Stubbs, Jon Dobson. Magnetofection In An Oscillating Magnetic Field. $484,600.

Neurotrauma Research Program: Sarah Dunlop, Killugudi Swaminatha Iyer, Michael House. Kirk Feindel. Using nanotechnology to prevent localised, as well as remote, inflammation and breakdown of the blood brain barrier following neurotrauma. $90,000.


Ada Bartholomew Medical Research: Matthew Linden. Developmental haemostasis: Age-specific differences in the blood clotting of children. $28,471.
Image: False coloured X-ray microscopy of juvenile abalone shell (~5 mm long) – acquired by Dr. Jeremy Shaw, sample supplied by Dr. Carmel McDougall (UQ)
Scientist of the year 2014 finalist

The University News reported on CMCA Director Professor David Sampson’s nomination for Scientist of the Year 2014. With over 20 years’ research experience in optics, photonics and microscopy, Professor Sampson understands the value of world-class equipment to scientific research and local industry.

As Director of the CMCA, he oversees the WA nodes of the Australian Microscopy and Microanalysis Research Facility and the National Imaging Facility, supporting industry access to these WA facilities. Under his direction, the Nanoscale Characterisation State Government Centre of Excellence attracted $20 million in research funding. Professor Sampson established the award-winning Optical+Biomedical Engineering Laboratory, which now has an international reputation for excellence in biomedical optics and biophotonics.

Launch of new EM instruments

An event was held on Thursday 23rd October 2014 to launch the new FEI Titan TEM and Verios SEM instruments. The two microscopes, both the first of their kind in Australia, were funded through large ARC LIEF grants with additional support from UWA, the other WA universities, University of Sydney and CSIRO. The facility was officially launched by Professor Robyn Owens (UWA DVCR), who acknowledged the importance of the new facilities to WA researchers. Professor Owens’ comments were echoed by Dr Miles Apperley, representing the AMMRF, who noted the national significance of the two new instruments. Associate Professor Martin Saunders, Head of the CMCA Electron Microscopy Group, provided a brief overview of the capabilities of the new facilities before guests enjoyed refreshments and tours of the electron microscopy laboratories.

Many thanks to Akos Bruz, Senior Video Production Officer at iVEC@UWA who produced a video for the event.

Top press picks

Four publications in high profile journals:

1) CMCA’s John Cliff was co-author of a paper that was published in the journal Science.

One of Earth’s most ancient and widespread life forms, sulfur using bacteria, has the distinctive odour of hydrogen sulfide gas – or rotten egg smell! There is debate among scientists who study our 4.5 billion-year-old planet about the evolution of sulfate-dependent bacteria. In the research published in the journal Science, Ladivga Zhelezinskaia from University of Maryland and three co-authors—John Cliff of the University of Western Australia and geologists Alan Kaufman and James Farquhar of UMD—show that bacteria dependent on sulfate were plentiful in some parts
of the ocean 2.5 billion years’ ago, even though sea water typically contained about 1,000 times less sulfate than it does today.


2) David Wacey, Martin Saunders and Malcolm Roberts from CMCA were co-authors of a paper published in Nature Scientific Reports.

The study shows that 1 billion-year-old microfossils from lake sediments in Scotland were remarkably preserved by a combination of clay minerals and phosphate, with clay minerals providing the highest quality of preservation. This, in turn, provides the earliest evidence for cells preserved in clay minerals anywhere in the geological record, extending the known range by nearly 500 million-years, and challenges the conventional view that the highest quality fossil preservation occurs in phosphate and quartz minerals. The advanced elemental mapping capabilities of the newly installed FEI Titan TEM were essential to the study, enabling nano-scale zones of clay minerals attached to cell walls to be visualised.


3) David Wacey, and Matthew Kilburn from CMCA were co-authors of a paper published in Nature Communications.

This study used a combination of high-resolution microscopy (SEM, TEM, epifluorescence and NanoSIMS) plus metagenomic data to show for the first time that viruses can act as sites of mineral precipitation in microbial mats, and in so doing they enhance their own preservation potential in the fossil record. The ability to identify viruses in the geological record has wide ranging implications because viruses are important agents of genetic exchange and mortality for all life forms, and serve as gene reservoirs that allow their hosts to adapt to changing ecological niches, hence they may have been instrumental in promoting the evolution of early microbial ecosystems on Earth and elsewhere.


4) Two users of CMCA facilities, Martin Hill and Malte Gather, were successful in having an article published in Nature Photonics, with their CMCA image making the front cover.

Small lasers have dimensions or modes sizes close to or smaller than the wavelength of emitted light. In recent years there has been significant progress towards reducing the size and improving the characteristics of these devices. This work has been led primarily by the innovative use of new materials and cavity designs. This Review summarizes some of the latest developments, particularly in metallic and plasmonic lasers, improvements in small dielectric lasers, and the emerging area of small bio-compatible or bio-derived lasers.

We examine the different approaches employed to reduce size and how they result in significant differences in the final device, particularly between metal- and dielectric-cavity lasers. We also present potential applications for the various forms of small lasers, and indicate where further developments are required.


UWA news articles

August 2013:
For the second year in a row, Professor David Sampson, Research Associate Professor Robert McLaughlin and Professor Christobel Saunders have been selected as finalists for the ANSTO Eureka Prize for Innovative Use of Technology. Microscope in a Needle: featured on ABC News.

August 2013:
The University of Western Australia has doubled its capacity to help find new mineral ore deposits through funding from SIEF for a new NanoSIMS imaging and analysis facility announced by Federal Innovation, Industry Science and Research Minister Kim Carr.

November 2013:
Evidence of complex microbial ecosystems dating back almost 3.5 billion years has been found in Western Australia’s Pilbara region by an international team including UWA’s Dr David Wacey. An ABC TV crew came to CMCA to film Dr Wacey for a feature aired on ABC Radio news on 13 November 2013.
The microscope in a needle, which may be used during surgery to help in the removal of breast cancer tumours, was developed by a team from UWA’s Optical + Biomedical Engineering Laboratory, in collaboration with clinicians from Royal Perth Hospital and Sir Charles Gairdner Hospital, and with support from Cancer Council WA, the National Breast Cancer Foundation, the Raine Medical Research Foundation, the National Health and Medical Research Council and the Australian Research Council.

CMCA Student news

CMCA graduated students

CMCA current students

Students who are supervised and co-supervised by CMCA staff:

- Crystal Cooper: Identification of an unknown acel flatworm (Acoela) from Rottnest Island, Western Australia. Supervised by P. Clode, C. Peacock and A. Thompson.
- Gerard Ricardo: The impacts of dredging on the early life histories of corals off Western Australia’s coastline. Supervised by A. Negri, R. Jones and P. Clode.
- Liza Roger: Response of calcareous pteropods (Euthecosomata) to environmental change. Supervised by A. George and J. Shaw.
- Patrick Hayes: Does calcium toxicity explain the absence of most Proteaceae from calcareous habitats? Supervised by H. Lambers and P. Clode.
- Taryn Foster: Potential impacts of higher ocean acidity and warmer water temperatures on Abrolhos Island corals. Supervised by M. McCulloch, P. Clode, J. Falter, J. Gilmour and M. van Keulen.
- Wenli Ding: Is the distribution of calcium and phosphorus between leaf cell types the key reason why Lupinus species respond differently to soil pH? Supervised by H. Lambers, J. Clements and P. Clode.

Brian Strehlow, who is supervised by CMCA’s Peta Clode, won best poster for his X-ray microscopy work at the AIMS@JCU Poster Day.
New Staff

Andrew Mehnert

Andrew Mehnert joined the CMCA in December 2014 as Senior Lecturer in Data Management, Analysis and Visualisation. He was previously Associate Professor in Medical Image Analysis at Chalmers University of Technology in Sweden. Andrew’s research focuses on the development of image analysis methods for biological imaging applications. To date this has been in the areas of optical microscopy (automated cytology), MRI (breast, brain, musculoskeletal injuries) and x-ray CT (forensic identification).

Andrew’s role is to introduce, develop and apply data management, analysis and visualisation expertise in collaboration with researchers using microscopy and imaging techniques across various disciplines at UWA.

Heejin Jeon

In February 2015 Heejin Jeon joined CMCA as a SIMS Research Assistant for 12 months. Heejin received her Bachelor and Master degrees at the School of Earth and Environmental Sciences, Seoul National University. Heejin was awarded a PhD in 2012 at the Research School of Earth Sciences, Australian National University. She then had two years of postdoc experience in the NORDSIM ionprobe lab (ims-1280), Swedish Museum of Natural History where she worked on the Neoproterozoic Arabian Shield, with the topic of how much this previously-known-as-juvenile-crust is contaminated by older crustal materials.

Haibo Jiang

Haibo joined CMCA in April 2015 as a Lecturer to support the SIMS team. He studied Materials Science and Engineering at Shanghai Jiao Tong University, and completed his PhD at University of Oxford in 2014. Following his PhD study, Haibo worked as a postdoctoral research fellow in applications of NanoSIMS analysis on biological materials with Prof. Chris Grovenor.

Haibo’s research interest is in the development of multimodal characterization methods and their applications on visualization of biological processes and materials behaviors. He is now involved in multiple interdisciplinary collaborative projects with academic and industrial partners.

Staff List

- Prof. David Sampson (Director)
- Assoc/Prof. Peta Clode (Deputy Director)
- Sean Webb (Centre Manager)
- Dr Peter King (Technical Operations Manager)
- Steve Parry (Laboratory Manager)
- Dr Tamara Abel
- Liz Albert
- Dr Thomas Becker
- Alysia Buckley
- Dr Lindsay Byrne
- Dr John Cliff
- Dana Crisan
- Dr Aaron Dodd
- Peter Duncan
- Diana Engineer
- Dr Kirk Feindel
- Dr Paul Guagliardo
- Prof. Brendan Griffin (Honorary)
- Jeanette Hatch
- Dr Heejin Jeon
- Dr Haibo Jiang
- Assoc/Prof. Andrew Johnson (Honorary)
- Assoc/Prof. Matt Kilburn
- Lyn Kirilak
- Prof. John Kuo (Honorary)
- Irma Larma
- Assoc/Prof. Matthew Linden
- Dr Laure Martin
- Dr Andrew Mehnert
- Dr Janet Muhling
- John Murphy
- Dr Anthony Reeder
- Assoc/Prof. Paul Rigby
- Dr Malcolm Roberts
- Assoc/Prof. Martin Saunders
- Dr Jeremy Shaw
- Assoc/Prof. Brian Skelton
- Dr Michael Stat
- Dr Alexandra Suvorova
- Dr David Wacey (Joint appointment with UWA School of Earth and Environment)
- Hava Zhang
Conferences and Visits

Image: A false-coloured back-scattered electron image of a shergottitic meteorite. Image acquired on an FEI Varios-SEM by Malcolm Roberts. Sample from Gretchen Benedix (Curtin University).
Visitor Highlights

February 2014
A group of 31 people from the Australasian Industry Research Group (AIRG), including an ex-VP Woodside, representatives of Alcoa, AMMRF Board Chair and COO, and the Chief Scientist of Victoria in attendance, toured the Centre in February 2014. The tour was part of the AIRG National Summer Meeting.

March 2014
Mr David Stewart, the Australian Ambassador to Austria, came to CMCA in March. Mr Stewart had met CMCA’s Professor Matt Kilburn in Vienna where Matt extended the invitation to visit CMCA and inspect the facilities at UWA that are used to provide analytical support to the IAEA. Mr Stewart was very engaged in the visit and expressed strong support for the work done at CMCA.

May 2014
A number of biology students from UWA’s affiliate high school Taylor College visited CMCA on 9th May and looked at sample preparation undertaken on the SEM and TEM.

June 2014
CMCA hosted a delegation from Harbin Engineering University, China. This was a senior delegation including the institution’s vice president and other senior officials accompanied by UWA staff.

July 2014
Her Excellency Mrs Nineta Barbulescu, the Ambassador of Romania, visited the University on Tuesday 15 July and was given a guided tour of CMCA. She was very impressed with the Centre and the enthusiasm of Centre staff.

October 2014
Professor Jerzy Dobrucki from the Faculty of Biochemistry, Biophysics and Biotechnology at Jagiellonian University in Poland visited CMCA to talk around the use of the characteristics of DNA probes (like DAPI and Hoechst) for super-resolution microscopy. While here, Professor Dobrucki gave a seminar titled “Super-resolution optical imaging of chromatin, DNA damage and repair”.

November 2014
Dr Sally Nimon, Director, Information and Analysis, Go8 Secretariat. Go8 is a group of Australia’s eight leading universities, of which The University of Western Australia is a member.

December 2014
CMCA was included in the itinerary when Dr Kris Ahlers and Mr Ken Caster, Program Officer from the Asian Office of Aerospace Research and Development (AOARD) from the Tokyo field office of the US Air Force Office of Scientific Research (AFOSR) visited the university in December 2014.

AOARD and AFOSR are part of the Air Force Research Laboratory (AFRL), which has extensive R&D programs in nine different technical directorates, including Physics and Mathematics, Nanoscience, and Materials and Chemistry, at multiple locations within the USA. Program Officers (POs) at AOARD work closely with POs at AFOSR to fund basic research in the Asia-Pacific region in support of the AFRL mission. AOARD and AFOSR work closely with AFRL scientists and engineers across all technical areas.
Conferences

Out and about

June 2013
Assoc.Professor Matt Kilburn was an invited lecturer at the SIMS school at the NORDSIMS facility in Stockholm.

Dr Dave Wacey and Assoc.Professor Matt Kilburn convened a session at the 2013 Goldschmidt Conference in Florence, Italy.

November 2014
Assoc.Professor Matt Kilburn was an invited lecturer at the NanoSIMS school at the Technical University Munich in November 2014.

Assist.Professor John Cliff was invited to give a presentation at the IAEA ‘Symposium for International Safeguards’ in Vienna 2014. His paper “Novel Mass Spectrometric Techniques for the Rapid Characterisation and Fingerprinting of Nuclear Fuel Materials” was authored by J.Cliff, M.Kilburn, L.Martin and J.Denman. This invitation required nomination by the Australian Government.

Ultra High Field MRI Symposium – June 2014
Dr Kirk Feindel was invited to speak at the Ultra High Field MRI Symposium at the Centre for Advanced Imaging, University of Queensland, held over three days in June 2014. Dr Feindel’s talk was titled ‘Toward endogenous, pathology specific MRI contrast’.

IUMAS Conference in July 2014
Assoc.Professor Peta Clode was one of eight invited plenary speakers at the International Union of Microbeam Analysis Societies (IUMAS) Conference in July 2014 and also a symposium convenor at the Microscopy & Microanalysis Annual Meeting. Both events were held in Connecticut, USA.
2013

Book chapters


Journal publications


2013 Journal papers

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36. X. Duan, J.P. Wu and T.B. Kirk, Rotated hough filtering for automatically distinguishing the collagen bundles in the most superficial layer of articular cartilage, Journal of Biomedical and Health Informatics, 17(5): 922-927, 2013


55. B. He, J.P. Wu, J. Xu, R.E. Day and T.B. Kirk, Microstructural and compositional features of the fibrous and hyaline cartilage on the medial tibial plateau imply a unique role for the hopping locomotion of kangaroo, PLoS One, 8(9): e74303 1-8, 2013


63. H. Husin, Y.K. Leong and J.S. Liu, Surface force arising from adsorbed diethyltetraminepentacetate acid (DTPA) and related compounds and their metal ions complexes in alumina suspensions, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 422: 172-180, 2013


111. P.J. Mark, J.L. Lewis, M.L. Jones, J.A. Keelan and B.J. Waddell, The inflammatory state of the rat placenta increases in late gestation and is further enhanced by glucocorticoids in the labyrinth zone, Placenta, 34: 559-566, 2013


120. P.R.T. Munro, C.K. Hagen, M.B. Szafraniec and A. Olivo, A simplified approach to quantitative coded aperture X-ray phase imaging, Optics Express, 21(9): 11187-11201, 2013


The University of Western Australia


127. N. Noffke, D. Christian, D. Wacey and R.M. Hazen, Microbially induced sedimentary structures recording an ancient ecosystem in the ca. 3.48 Billion-Year-Old Dresser Formation, Pilbara, Western Australia, Astrobiology, 13(12): 1-22, 2013


2014

Book chapters

1. Y. Chew, A.J. Holmes and J.B. Cliff, Visualization of metabolic properties of bacterial cells using nanoscale secondary ion mass spectrometry (NanoSIMS), In: Environmental Microscopy, Methods in Molecular Biology, Volume 1096: 133-146, 2014


Journal publications


12. R.A. Boulous, F. Zhang, E.S. Tjandra, A.D. Martin, D. Spagnoli and C.L. Raston, Spinning up the polymorphs of calcium carbonate, Scientific Reports, 4: 3616 (1-6), 2014


2014 Journal papers

Key: ♣ ISI highly cited papers


34. L. Chin, A., Curatolo, B.F. Kennedy, B.J Doyle, P.R.T. Munro, R.A. McLaughlin and D.D. Sampson, Analysis of image formation in optical coherence elastography using a multiphysics approach, Biomedical Optics Express, 5(9): 2913-2930, 2014


61. M.M. Giangregorio, B. Dastmalchi, A. Suvorova, G.V. Bianco, K. Hingerl, G. Brunoa and M. Losurdo, Effect of Interface energy and electron transfer on shape, plasmon resonance and SERS activity of supported surfactant-free gold nanoparticles, RSC Advances, 4: 29660, 2014


67. C.K. Hagen, P.R.T. Munro, M. Endrizzi, P.C. Diemoz and A. Olivo, Low-dose phase contrast tomography with conventional x-ray sources, Medical Physics, 41: 070701 (1-6), 2014

68. M.T. Hill and M.C. Gather, Advances in small lasers, Nature Photonics, 8: 908-918, 2014


73. E.S. Ingham, N. Cook, J.B. Cliff, C.L. Ciobanu and A. Huddleston, A combined chemical, isotopic and microstructural study of pyrite from roll-front uranium deposits, lake eye basin, South Australia, Geochimica et Cosmochimica Acta, 125: 440-465, 2014


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96. W. Lei, R.J. Gu, J. Antoszeweki, J. Bohlmann, Foliar application of methyl jasmonate does not increase terpenoid accumulation, but weakly elicits terpenoid pathway genes in sandalwood (Santalum album L.) seedlings, Plant Biotechnology , 31: 585-594, 2014


117. J. Muhling, A. Suvorova and B. Rasmussen, The occurrence and composition of chevkinite-(Ce) and perrierite-(Ce) in theolithic intrusive rocks and lunar mare basalts, American Mineralogist, 99: 1911-1921, 2014

118. P.R.T. Munro, D. Engelke and D.D. Sampson, A compact source condition for modelling focused fields using the pseudospectral time-domain method, Optics Express, 22(5): 5599-5613, 2014


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<td>Low temperature fracture toughness of PMMA and crack-tip conditions under flat-tipped cylindrical indenter</td>
<td>Polymer Testing</td>
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Image: False coloured shells - Jeremy Shaw.