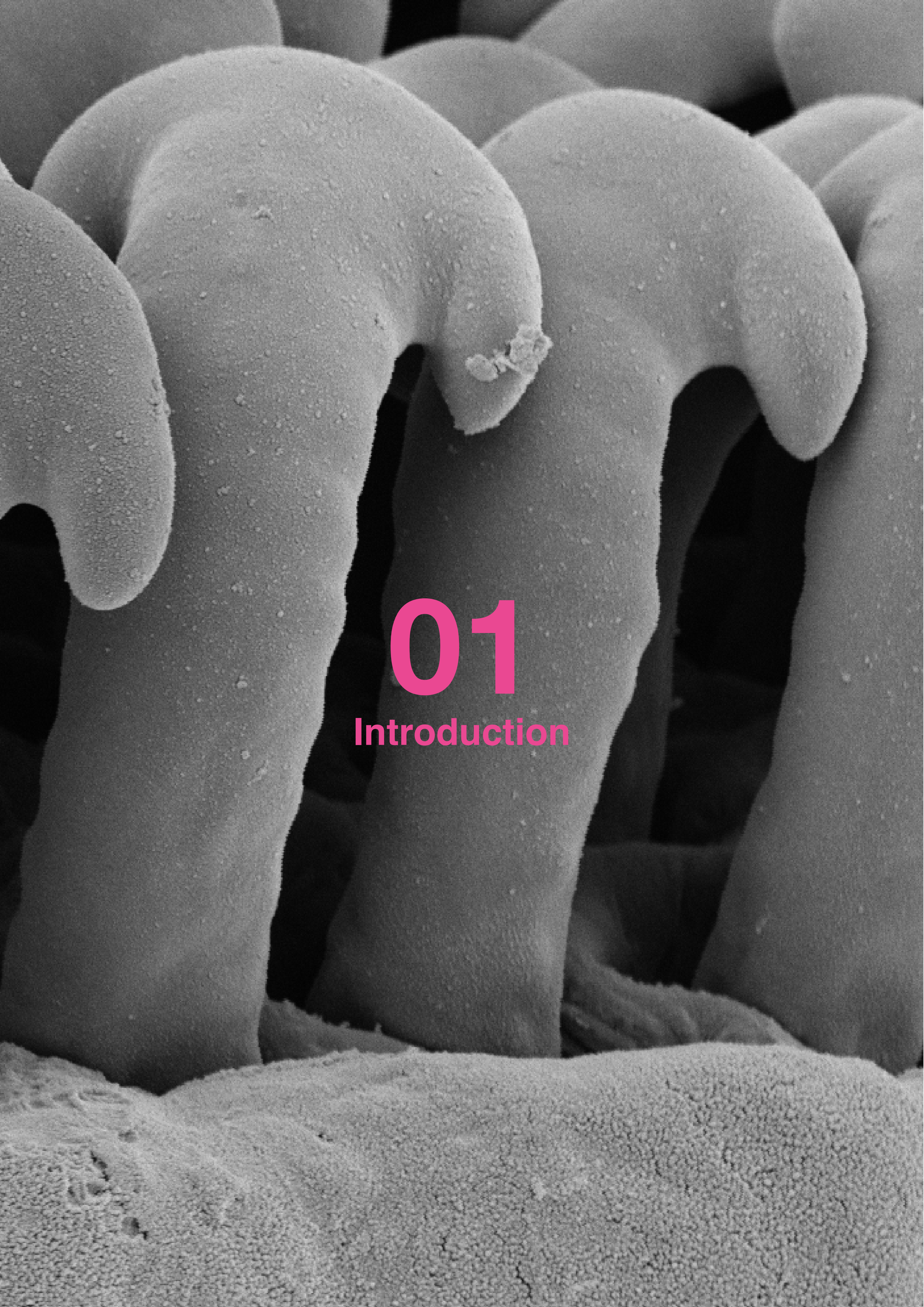
2017 Annual Report

CENTRE FOR MICROSCOPY & MICROANALYSIS

Making the invisible visible

Contents



01
Introduction

The Centre for Microscopy and Microanalysis (CMM) is an interdisciplinary research, teaching and service centre. We play an integral role within the research programs of The University of Queensland and participate in both undergraduate and postgraduate education. We provide a comprehensive suite of analytical instrumentation and a high standard of training programs for university researchers. Our highly experienced, specialist staff are committed to providing a supportive and resourceful working environment where clients receive expert advice and training that equips them to achieve their research goals.

CMM is a foundation member and the Queensland Node of the Australian Microscopy and Microanalysis Research Facility (AMMRF) which was established in July 2007 under the Commonwealth Government's National Collaborative Infrastructure Strategy (NCRIS).

CMM actively supports and initiates microscopy and microanalysis related research and development projects with the aim to maintain future technological competitiveness for UQ. CMM is also in charge of the renewal of instruments to ensure the optimal balance in instruments dedicated to general education, service and research and to further push research projects beyond the current frontiers.

CMM reports directly to the Faculty of Science and is governed by a Director (Roger Wepf), a Deputy Director for scientific services (Kevin Jack) and Deputy Directors for scientific strategy in life-science (Robert Parton) and material science (Jin Zou). They also act as CMM ambassadors in their disciplines. CMM has an independent interdisciplinary Scientific Advisory Board (Head: Parton), representing the different research interests at UQ. An internal Steering Committee acts in an advisory capacity and has a final approval authority for all major proposed research and services.

Vision

The Centre for Microscopy and Microanalysis is a research facility dedicated to an understanding of the structure and composition of all natural and man-made materials across different scales. Our challenge is to meet present needs of researchers for microstructural characterisation and to equip The University of Queensland to meet new horizons in analysis research.

Mission

Our service to the university community is provided in three key areas, namely a comprehensive suite of analytical instrumentation, strongly motivated and experienced personnel and high standard of training programs for university researchers. Our highly experienced, specialist staff are committed to providing a supportive and resourceful working environment where clients receive expert advice and training that equips them to achieve their research goals.

Message

from the Director

It gives me great pleasure to welcome you to the Centre for Microscopy and Microanalysis' 2017 annual report.

In line with the University of Queensland's vision to create change and its current motto "***Not if, when***.." I am pleased that CMM continues to embrace change through the purchase of state-of-the-art and leading-edge scientific equipment that allows our stakeholders, from within both research and commercial organisations, to perform their scientific experiments and analysis in the pico, nano and micro space. This would not be possible without the generous and continued financial support of the University.

In short CMM creates and enables an environment for discovery.

To create change has been our underlying mission for over 50 years. CMM's history started in the 1960s with the formation of the Electron Microscope Unit at UQ. In 1985 the Brisbane Surface Analysis Facility/BSAF was founded, and in 2007 this was integrated into CMM. Around the same time in the late 1980s, UQ commenced a phase of centralising its electron microscopy, with the central unit being named CMM in 1990. By 2007 all UQ electron microscopy and X-ray surface science units, as well as many X-ray diffraction and scattering techniques, were merged into CMM.

To ensure that we can meet the demand of both our internal and external stakeholders, 2017 saw a change to CMM's executive organisational structure, introducing three deputy-directors: Associate Professor Kevin Jack (Deputy Director Operation), and Ambassadors in their scientific field Professor Robert Parton (Deputy Director Life-Sciences) and Professor Jin Zou (Deputy Director Material Science).

CMM's executive team has been well supported by our first Scientific Advisory Board, which includes new members representing QUT, Griffith University and the University of the Sunshine Coast.

The strategy introduced in 2016 to assess and build on our microscopy infrastructure saw CMM expand its microscopy capacity to seven TEMs, 11 SEMs, six X-ray tools, five MS instruments, one EPMA, one XPS, one FIB/SEM and two EBLs (nano fabrication tools). This is an impressive collection of resources, and each of CMM's four laboratories, based at AIBN, Hawken, QBP and our X-ray facility have gained capabilities.

2017 also saw the arrival of six mass spectrometry instruments, including two Maldi-TOF instruments, that were donated to CMM and the Centre for Advanced Imaging (CAI) from the Mater Hospital. This MS capacity will initially focus on imaging MS applications in life-sciences and expand from there into other application fields and, if demand keeps growing, then towards Tof-SIMS or similar high-resolution and high-sensitivity imaging MS applications.

In 2017 we installed two 120kV Hitachi HT7700 workhorse TEMs: one equipped with EDX and the other with a high-resolution exalens set-up at AIBN and, in addition UQ's first dedicated EBL system, the Raith e-Line Plus was temporarily installed in the AIBN laboratory.

In 2017 our procurements for frontier and renewal continued with the final equipment delivery in 2018 to be just as impressive; including:

- » Australia's first Cs-corrected pixelated STEM/TEM from Hitachi, the HF5000, allowing better than 70pm resolution in STEM and SE-mode and fast data acquisition for in-situ TEM/STEM experiments – arriving in May 2018.
- » Australia's first EBPG 5150 from Raith for large-scale and high-throughput nanofabrication – arriving in May 2018

- A FEI Apreo Volumescope delivered in 2017 to be commissioned in February 2018
- Orders for a Xenocs Xeuss 2.0 SAXS system and a scanning-XRF system Atlas X from iXRF were finalised. Both systems are unique to Australia and will be commissioned in the X-ray laboratory around June 2018

In 2017 the refurbishment of the Hawken Laboratory commenced to create a new home for the Cs-STEM and a small clean room for the two EBL systems, with adjacent sample preparation area and new laboratories and services. Construction of the new Hawken laboratory should be finalised by the end of May 2018 and be back to full operation in June 2018.

The expert team at CMM has capably met this infrastructure growth. Our team grew in 2017 to 22 full time equivalent positions. At the close of 2017 we saw the retirement of our Centre Manager, Jill Prescott and our OHS Officer Wendy Armstrong. Jill excelled in managing CMM's and AMMRF administrative requirements for more than a decade, and we are most grateful to her. Wendy provided excellent OHS training and support to CMM clients and staff and worked for more than 40 years for UQ; we sincerely thank her for her support over the years. We wish Jill and Wendy all the best for their new adventures in their next new phase of life.

In terms of delivery and output, CMM has again excelled. It is a prerequisite to undertake training and education prior to a new client being registered to use CMM equipment. Our 2017 training courses were well subscribed with over 170 users trained in 15 CMM training courses.

Our focus on stakeholders and expanding our expertise beyond UQ clients is also having much success. In 2017 CMM collaborated with 12 Australian universities. Added to this we had 23 national collaborations and 34 international collaborations. Our reach spreads through the US and Canada, Europe and Asia. But it is not just research institutes that we collaborated with; CMM's relations with industry continues to grow as we provide solutions to industrial problems, and work with industry to seek new innovative approaches and better designs.

2017 has been a year of strong growth for CMM. With the delivery of new equipment, not only our capacity to deliver better analysis and therefore research findings have been improved, but also our training and education programs, our outreach and collaborations. Most importantly our people have benefited from this continued growth. To support all the activities, in 2017 we introduced a new booking and accounting system, which allows us to move to project based management of client requests and swiftly affiliate expert staff and OH&S requirements giving the client an improved overall client experience.

Our 2017 success comes with the strong support of UQ's Faculty of Science. Our special thanks go to the Faculty's Executive Dean, Professor Melissa Brown, and the Deputy Executive Dean, Professor Ian Gentle.

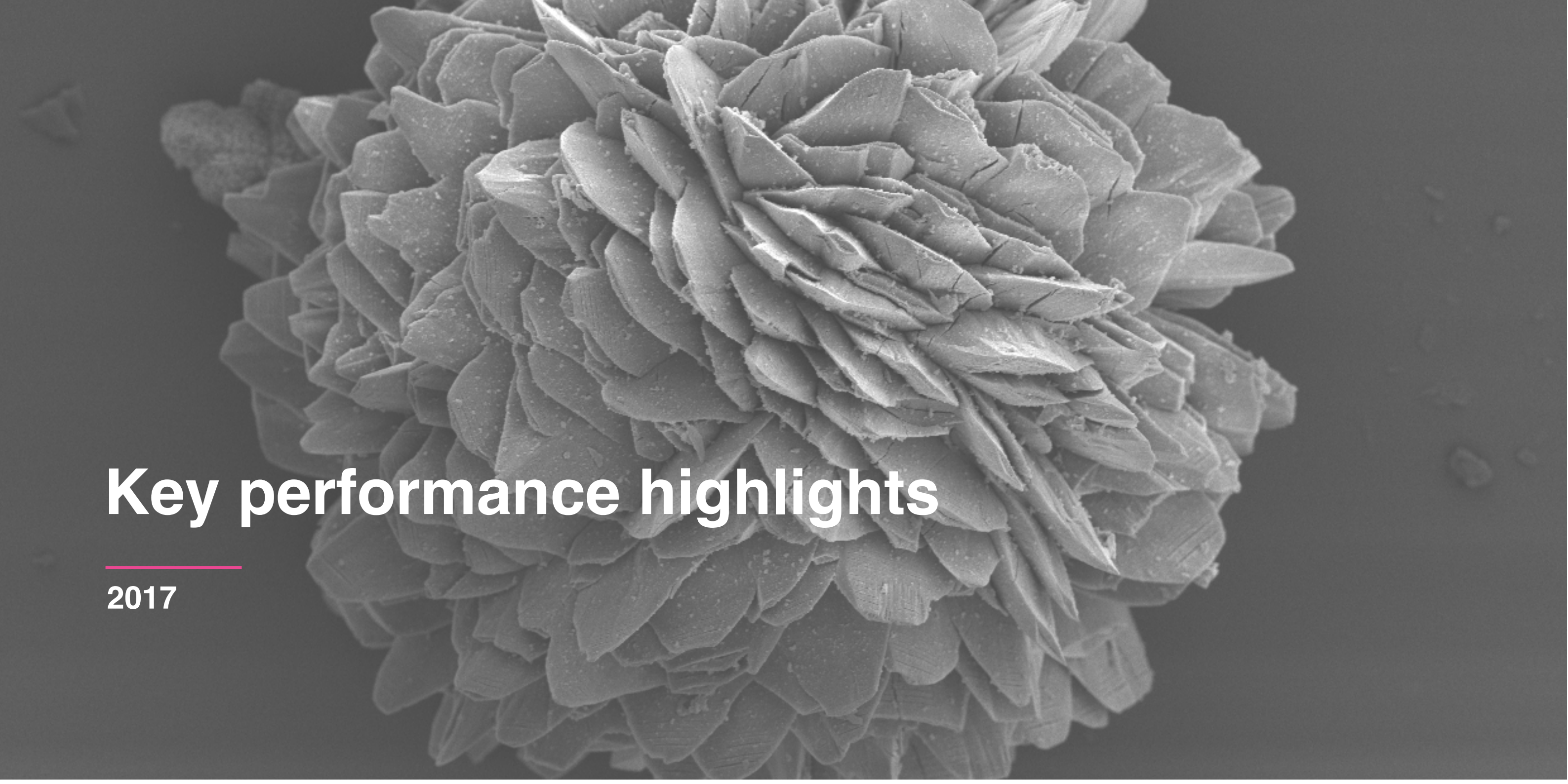
UQ's strategic investment of $15 M in 2016/2017 in frontier analytics was rewarded by securing the largest single item LIEF grant in Australia for a new cryoTEM (with a $3.2 M contribution by the ARC). This is a clear statement of both UQ and our Federal Government's desire to help and promote structure research for all scientific disciplines and it is a special honour for me to help UQ to bring these investments to a real spin. I invite all CIs and clients to embrace these opportunities for their discoveries and take their share and responsibility to help operate these new analytical tools at the forefront of science and discovery for a better future.

Finally, I would like to thank all centre staff for their excellent support and contribution throughout 2017 and for the on-going changes and challenges we are working on in 2018/19 and beyond.

I hope you enjoy the 2017 Annual Report and the highlighted research projects.

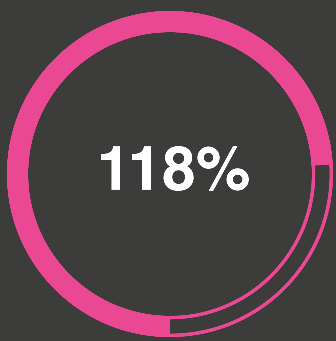
Professor Roger Wepf
Director CMM

Scientia ac Labore
(by means of knowledge and hard work)

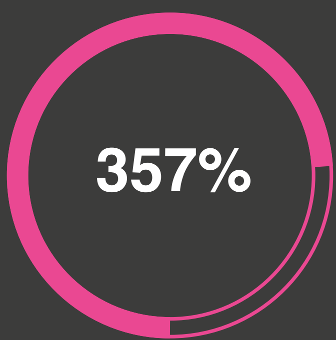


Key performance highlights

2017



GROWTH IN CMM USERS



GROWTH IN CMM WORKSHOPS

173 ATTENDEES at **15** TRAINING COURSES

375 ATTENDEES at **25** WORKSHOPS

890 FLAGSHIP INSTRUMENT HOURS

2,288 EXTERNAL USER HOURS

347 USERS

32,259 INSTRUMENT HOURS

59 TOTAL RESEARCH COLLABORATORS

35 INTERNATIONAL COLLABORATORS

10 CENTRE MEMBERS CONTRIBUTED TO TEN UNDERGRADUATE COURSES IN 2017

341 PUBLICATIONS RESULTING FROM CMM FACILITIES

279 ACTIVE PROJECTS IN 2017

72 FINALISED PROJECTS

RESEARCH IMPACT

10 PAPERS ARE IN THE TOP **1%** OF PAPERS*

17 PAPERS ARE IN THE TOP **2%** OF PAPERS*

37 PAPERS PUBLISHED ARE IN THE TOP **10%** OF PAPERS*

38 PAPERS WERE PUBLISHED IN JOURNALS WITH AN IMPACT FACTOR LARGER THAN **10** (INCITES, APRIL 2018)

**WORLDWIDE FOR THEIR SUBJECT AREA AND AGE (INCITES, APRIL 2018)*

History timeline of CMM

1960s

In the 1960s UQ's first Electron Microscopy Unit opened in the Anatomy building, including its first electron microscope, the Elmiskop Electron Microscope made by Siemens in Germany (still on display at the Physics Museum at the Parnell Building). The microscope column consists of several sections which link together to form the complete column, including an electron source, condensers 1 and 2, specimen air-lock, objective lens and Intermediate lens, projector lens, viewing portion and photograph chamber.

1980s

Commencement of the Brisbane Surface Science/Brisbane Surface Analysis Facility (BSAF), with Ian Gentle appointed Director and Barry Wood as Manager. In 1988 Dr Ian Mackinnon commenced the centralisation of electron microscopes at UQ, which eventually resulted in the formation of CMM in 1990 under his directorship.

2000s

Professor John Drennan was appointed Director of CMM in 2000. In 2001 NANO was announced under the Major National Research Facilities program (MNRF) program, receiving $11.5M of commonwealth funds over five years. This was the largest MNRF program. In 2002 NANO MNRF commenced, with John Drennan appointed to the Board as Scientific Director. In 2003 – NANO MNRF Flagship Equipment was installed at UQ including the FEI Tecnai F30, a 300kV cryogenic FEG-TEM, The Tecnai F30 became the only such instrument in Australia at that time. In 2007 NANO morphed into AMMRF.

2016

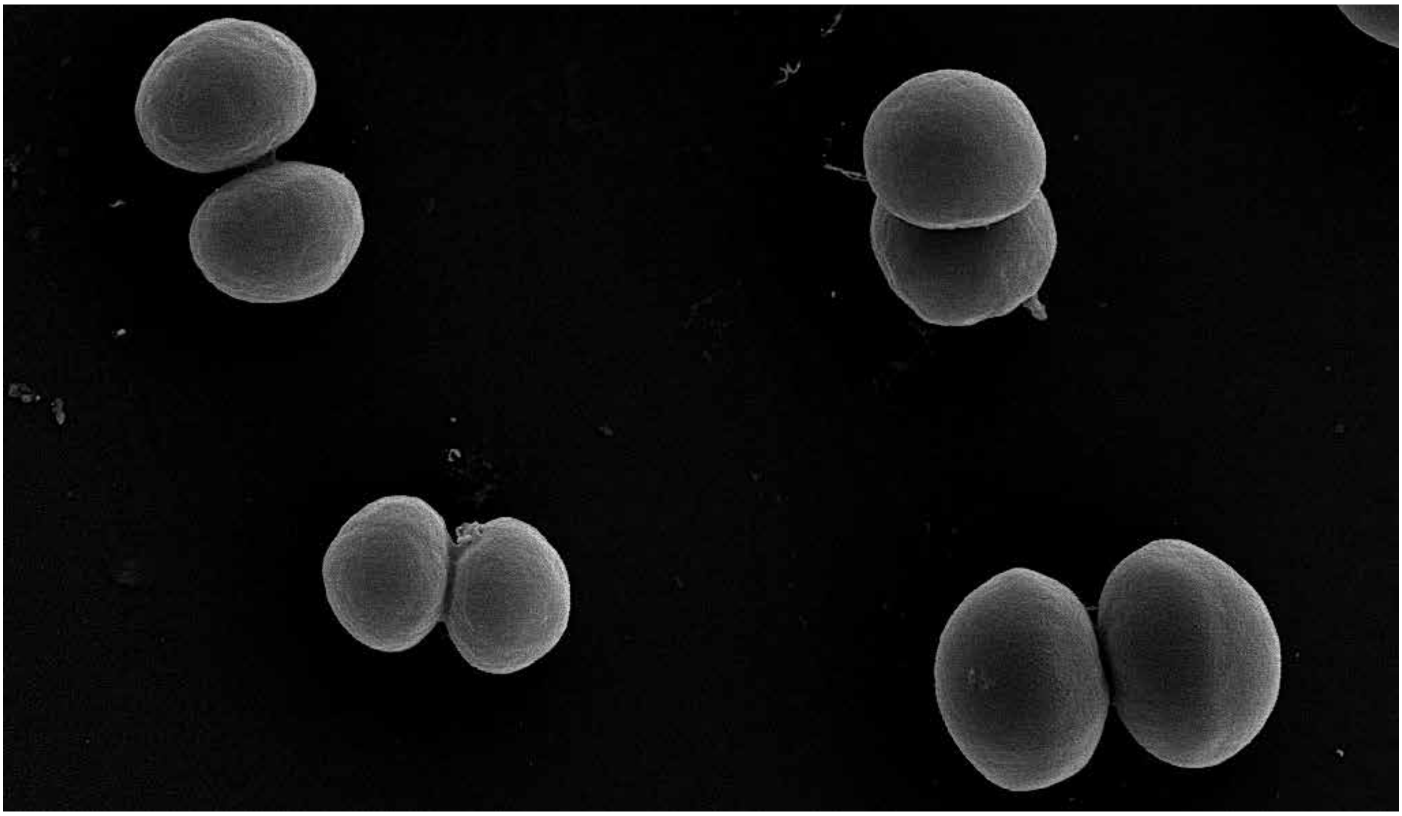
Professor Roger Wepf appointed as new Director of CMM with the aim to develop more linking tools for imaging and spectroscopy so the same samples can be studied holistically across different equipment to explore new frontiers in medical, biological, life, plant and materials science. In several CMM team retreats, ideas to renew CMM have been generated, which led to a working document CMM 2.0.

2017

In 2017 the first part of CMM 2.0 was implemented, including introducing new governing structures and deputy directors as we established the first CMM Scientific Advisory Board (SAB) to engage more with the future needs of our researchers at UQ and in QLD. 2017 was also the year of taking first action to renew CMM by planning the refurbishment and extension of the Hawken laboratory, evaluating and testing the new frontiers instruments such as the cs-STEM and the two EBL systems all to finally be installed in the refurbished Hawken laboratories. We also held our first user assembly meeting with talks across all application fields from client projects. With a joint team effort of 20 CIs we finally were awarded a $3.2 M LIEF grant for the next generation cryo-TEM facility for QLD and Australia at the end of 2017. Finally we established a new booking and accounting system for a better client experience as well as a better OHS recording and reporting.

2018

In the beginning of 2018, we welcome Karl Byriel and Gordon King and their protein crystallography facility - UQRocX's - as new integral part of the CMM structural biology laboratory at QBP. Hawken laboratory refurbishment and extension with a EBL clean-room facility will be finalised and back to operation. The CMM X-ray laboratory will also undergo a refurbishment and a small expansion to host not only CMM's X-ray tools but also the X-ray tools from SCMB from the Faculty of Science. The new instruments, the pixelated Cs-STEM, two EBL systems, a Volumescope, a scanning-XRF and a SAXS system will be installed and expand our research activities and opportunities.



Scientific Advisory Board

In 2017 CMM formed a Scientific Advisory Board to guide the future development of the Centre. The Board develops and discusses the future strategic plan and resources for CMM, based on the users future needs.

Members of the Board provided scientific and technical guidance in the fields of emerging technology, applications of microscopy and microanalysis and procedures for the individual CMM facilities. The Board communicated a UQ-wide view of CMM needs (and across other UQ platforms) and worked with user groups, facility staff and strategically with the Director of CMM to ensure standards of services requested by UQ users are met and are heading towards their future needs.

The Scientific Deputy Directors of CMM (Robert Parton and Jin Zou) chair the Scientific Advisory Board.

The Board met twice in 2017 (May and September). Also on the Board (as well as those below), are Roger Wepf, Kevin Jack, Robert Parton, Richard Webb, and Jin Zou.

Professor Ian Brereton

Professor Ian Brereton is the Director (Research and Technology) of UQ's Centre for Advanced Imaging (CAI) and is responsible for the high resolution NMR service. He has over 20 years' experience in the application of NMR spectroscopy to the chemical and biomedical sciences. He is the inaugural Director of the Queensland NMR Network, which received Smart State Research Facilities Funding (SSRFF) to establish a network of state-of-the-art, high field nuclear magnetic resonance (NMR) equipment, including the most powerful machine of its kind in the southern hemisphere – a 900 MHz high-resolution spectrometer.

Professor Ian Gentle

Professor Ian Gentle joined The University of Queensland in 1993 and was seconded to the Australian Synchrotron 2008-2010 as Head of Science and returned full time to UQ in 2011. In 2013 he was appointed Associate Dean (Research) in the Faculty of Science, while continuing to lead his group in the School of Chemistry and Molecular Biosciences. In 2015 he was appointed Deputy Executive Dean, Faculty of Science.

Professor Peter Hayes

Professor Hayes is Professor of Metallurgical Engineering within the School of Chemical Engineering. He is currently the Metallurgical Engineering Program leader and is senior researcher in the Pyrometallurgy Research Group (PYROSEARCH). He received his PhD from the University of Strathclyde in Glasgow, Scotland, in 1974.

Dr Ruth Knibbe

Dr Knibbe's research interests are in materials for energy generation and storage with specific interest in electrochemistry and electron microscopy. She received her PhD in Chemical Engineering from UQ in 2007. She then spent four years at DTU-Energy (Danish Technical University) and subsequently five years at the Robinson Research Institute at Victoria University of Wellington. Dr Knibbe's interests are concerned with: *in-situ* methods for characterising fuel cell and battery materials, the application of machine learning in new material design, development of new materials for Li-S battery systems and understanding degradation mechanisms in fuel cell and battery systems.

Dr Stephen Love

Dr Stephen Love has been Director of Research Infrastructure at UQ for the past 2 years. He has 14 years of research infrastructure and facilities managerial experience, eight of these at UQ. He was a Researcher in the Institute for Molecular Bioscience (IMB), from where he transitioned into management of Research Infrastructure at the Australian Institute for Bioengineering and Nanotechnology (AIBN), and most recently, the Translational Research Institute (TRI). He has been leading laboratory implementation, providing strategic management and advice, in the development of infrastructure systems and services. His knowledge of research facilities and infrastructure in the higher education sector spans three decades and three countries.

Professor Roland De Marco

Professor Roland De Marco has been Deputy Vice-Chancellor (Research and Innovation) at University of the Sunshine Coast (USC) since 2016 after taking up the position of inaugural Pro Vice-Chancellor (Research) at USC in 2011. Prior to his roles at USC, he served as Professor of Chemistry and Associate Deputy Vice-Chancellor (Research Strategy), Dean of Research in Science and Engineering and Head of Chemistry at Curtin University from 2001-2011. Throughout all of his leadership roles, both past and present, he has maintained an active research profile leading a small group focussed on the characterization of electromaterials, especially chemical sensor, fuel cell and electrocatalyst materials. Since 2015, he has held Honorary Professorships in the School of Chemistry and Molecular Biosciences at UQ and the Fuels and Energy Technology Institute at Curtin University.

Professor Darren Martin

Professor Darren Martin is a senior group leader at UQ’s Australian Institute for Bioengineering and Nanotechnology. He is a global leader in research and commercialisation of polyurethanes, polymer nanocomposites and renewable nanomaterials. He has been an active researcher in both the ARC Centre of Excellence for Functional Nanomaterials and in UQ’s Centre for Translational Polymer Research. Martin is the Founder and Chief Scientific Officer (CSO) of the successful UQ startup company TenasiTech Pty Ltd.

Professor Fred Meunier

Professor Frederic Meunier was the recipient of a European Biotechnology Fellowship and went on to postgraduate work at the Department of Biochemistry at Imperial College (1997-1999) and at Cancer Research UK (2000-2002) in London, UK. After a short sabbatical at the LMB-MRC in Cambridge (UK), he became a group leader at the School of Biomedical Sciences at The University of Queensland in 2003. He joined UQs Queensland Brain Institute in 2007 and is currently part of the Centre for Ageing Dementia Research.

Associate Professor Peter Noakes

Associate Professor Peter Noakes is investigating the cell and molecular mechanisms that underlie the development and breakdown of the neuro-motor system. His laboratory works on the following: 1) cell and molecular mechanisms surrounding the establishment of neuromuscular and motor neuron (CNS) synapses. 2) The generation and development of motoneurons in health and in disease (e.g. motor neuron disease {ALS}). 3) The role of innate immune system in motor neuron health and disease. His laboratory employs biochemistry, immuno-histology, electrophysiology, live cell imaging, behaviour, cell and molecular biology to study these issues.

Professor Gordon Southam

Professor Gordon Southam received his BSc (Honours) and PhD in Microbiology from the University of Guelph. He joined the Departments of Earth Science and Biology at the University of Western Ontario when he was appointed Canada Research Chair in Geomicrobiology (2001-2011), and Director of the Centre for Environment and Sustainability (2010-2012). In 2012, Professor Southam joined the School of Earth Sciences at The University of Queensland as the Vale-UQ Geomicrobiology Chair.

Professor Jenny Stow

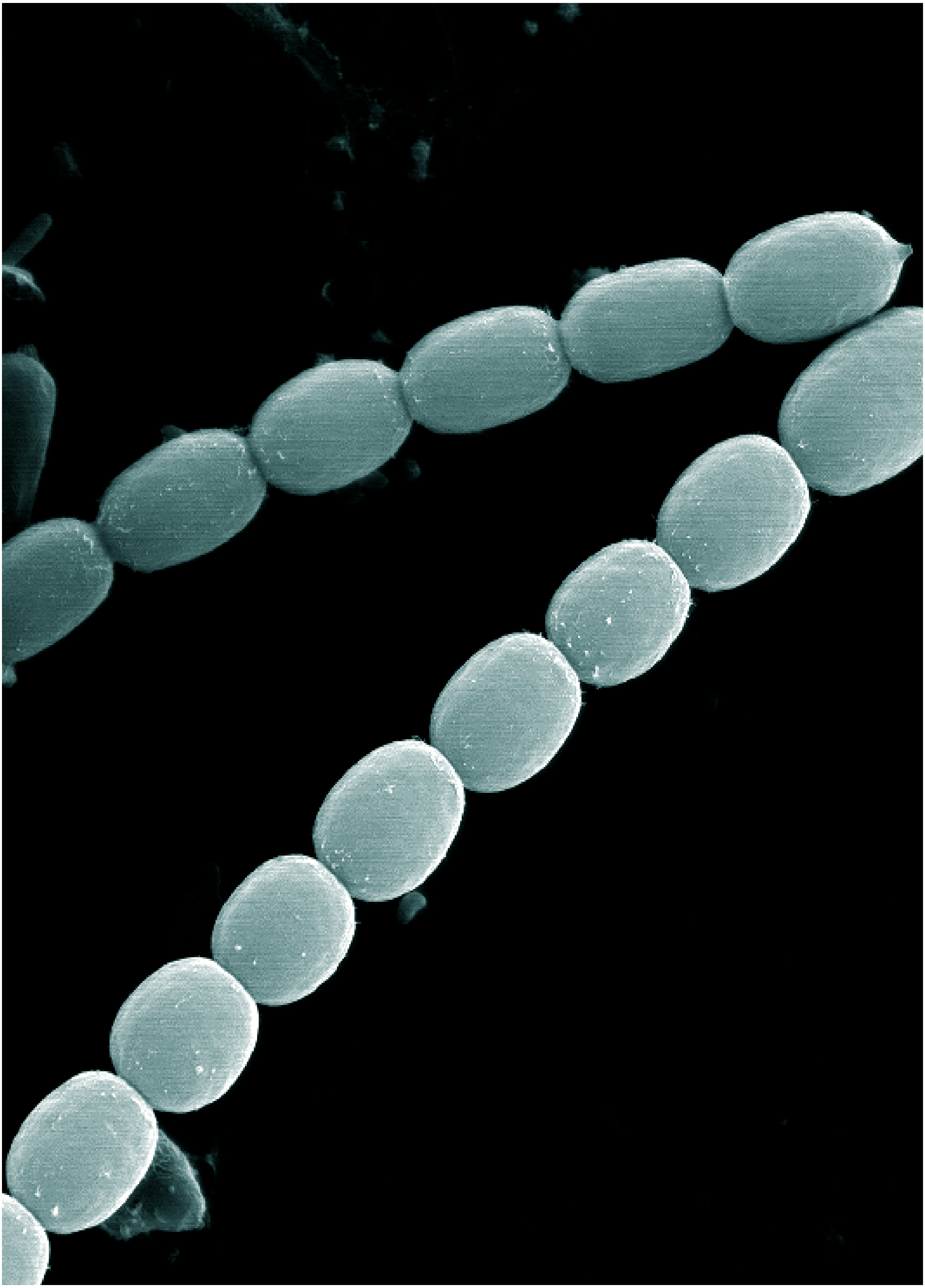
Professor Jenny Stow undertook postdoctoral training at Yale University's School of Medicine as a Fogarty International Fellow. She was soon appointed Assistant Professor in the renal unit at Massachusetts General Hospital, where she established an independent research group in cell biology. She returned to Australia in 1994 as a Wellcome Trust Senior International Fellow to join UQ's Centre for Molecular and Cellular Biology (now IMB). Professor Stow leads her own IMB laboratory.

Professor Lianzhou Wang

Professor Lianzhou Wang has joint positions with the School of Chemical Engineering, and the Australian Institute for Bioengineering and Nanotechnology. He received his PhD degree from Shanghai Institute of Ceramics, Chinese Academy of Sciences in 1999. Before joining UQ in 2004, he has worked at two leading national research institutions (NIMS and AIST) of Japan as a research fellow for five years. He is an Australian Research Council (ARC) Future Fellow; and past recipient of an STA Fellowship of Japan; and an ARC Queen Elizabeth II Fellowship.

Professor Paul Young

Professor Young completed his PhD at the London School of Hygiene and Tropical Medicine and was appointed to a lectureship in the University of London in 1986. He returned to Australia as Senior Research Fellow at the Sir Albert Sakzewski Virus Research Centre in 1989 and joined the University of Queensland as a Senior Lecturer in 1991. He is the current President of the Australian Society for Microbiology and the President of the Asia Pacific Society for Medical Virology.



CMM Team

Executive

Professor Roger Wepf
Director

Professor Roger Wepf's research direction leads to developing tools for integrative imaging and spectroscopy to explore new frontiers in structure research. E.g. developing connectivity between cryo-microscopes and other characterisation tools via cryo- or inert-gas transfer for best sample protection and for correlative imaging and analytics. Roger is currently also serving as past President of the European Microscopy Society (EMS).

Associate Professor Kevin Jack
Deputy Director, Operations

Associate Professor Kevin Jack's broad research interests are in the understanding of structure-property-performance relationships in a range of materials; that is, the use of molecular level findings and understanding to direct the development of better performing materials, devices or chemical processes

Professor Robert Parton
Deputy Director, Life Sciences

Professor Parton's research focuses on the cell surface and, in particular, on the structure and function of caveolae. Caveolae are small pits in the plasma membrane which have been linked to tumour formation and muscular dystrophy. He is investigating the role of caveolae in cell physiology and their exploitation by pathogens.

Professor Jin Zou
Deputy Director, Material Science

As a Chair in Nanoscience, Professor Zou's research interest has been focused on the understanding of the evolution of advanced, smart and nano-scaled materials and the understanding of fundamental properties of these materials

CMM Team

Overview

DIRECTOR

» Professor Roger Wepf

AIBN LABORATORY

» Mr Richard Webb
» Dr Graeme Auchterlonie
» Ms Robyn Chapman
» Dr Elliot Cheng
» Dr Hui Diao
» Han Gao
» Mun Soo (Abby)
» Qiang Sun
» Ms Rachel Templin

HAWKEN LABORATORY

» Mr Ron Rasch
» Ms Heike Bostelmann
» Ms Eunice Grinan
» Dr Kim Sewel
» Ms Ying Yu

ADMINISTRATION

» Ms Jill Prescott
» Ms Jennifer Brown
» Mr Robert Gould
» Travis Hagstrom
» Professor Jin Zou
» Professor Robert Parton
» Mr Andrew Stark

QBP LABORATORY

» Dr Matthias Floetenmeyer
» Dr Kathryn Green
» Dr Erica Lovas

X-RAY LABORATORY

» A/Prof Kevin Jack
» Dr Lachlan Casey
» Dr Barry Wood

MASS SPEC IMAGING FACILITY

» Dr Brett Hamilton

AFFILIATE APPOINTMENTS

» Dr Bronwen Cribb
» Emeritus Professor John Drennan
» Dr Justin Kimpton
» Dr Toshiyuki Mori

CMM Collaborators

NORTH AMERICA

CANADA
University of Victoria, British Columbia
University of Toronto

USA
Northwestern University, Evanston, Illinois
Georgia Institute of Technology, Atlanta, Georgia
The University of Texas at Dallas, Richardson, Texas

EUROPE

European Molecular Biology Laboratory (EMBL)

CZECH REPUBLIC
Institute of Scientific Instruments, Czech Academy of Sciences, Brno

FRANCE
Curie Institute, Paris
European Synchrotron Radiation Facility (ESRF), Grenoble

GERMANY
MPI Atomically Resulved Dynamics Department and CFEL, Hamburg
Centre for free-electron laser Science, CFEL, Hamburg
Max Planck Institute, Dresden

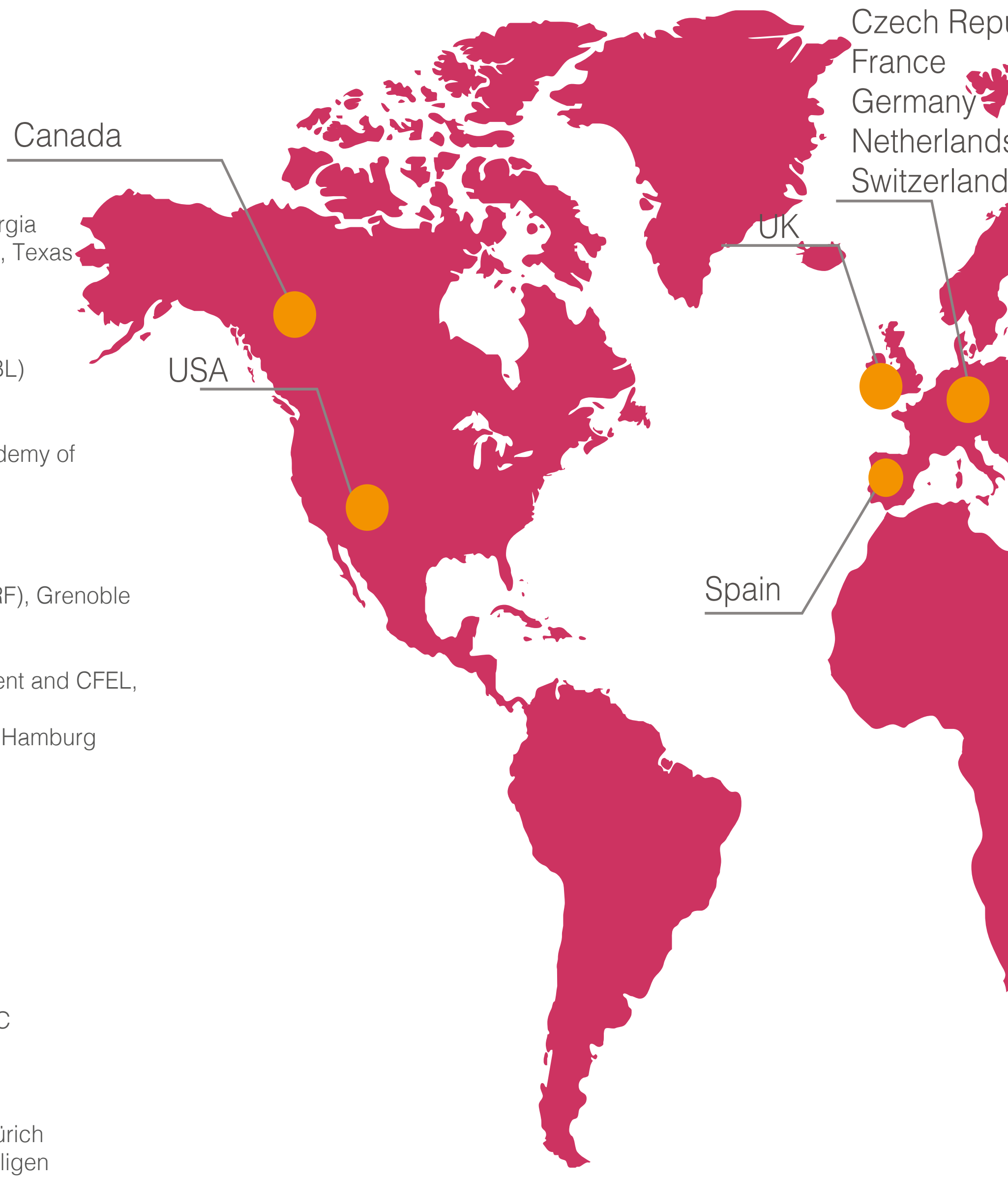
THE NETHERLANDS
Faculty of Applied Science, TU-Delft

NORWAY
University of Oslo

SPAIN
Centro Nacional de Biotecnologia (CNB)/CSIC
University of Barcelona

SWITZERLAND
ETH/Swiss Federal Institute of Technology, Zürich
Paul Scherrer Institute Swiss Light Source, Villigen
University of Geneva

UK
School of Pharmacy, Kings College, London
MRC - Laboratory of Molecular Biology, Cambridge
King's College, London
University College, London



24
National collaborators

35
International collaborators

AFRICA & THE MIDDLE EAST

North-West University, Potchefstroom, South Africa
University of Cape Town, Cape Town, South Africa
Tel Aviv University, Israel
Kaust, Saudi Arabia

ASIA

CHINA
Fudan University, Shanghai
Shanghai Institute of Technical Physics, Chinese Academy of Sciences, Shanghai
Beijing University of Technology, Beijing
Zhejiang University, Hangzhou
Central South University, Changsha
Shanghai University, Shanghai

INDIA
National Centre for Biological Sciences, Bangalore

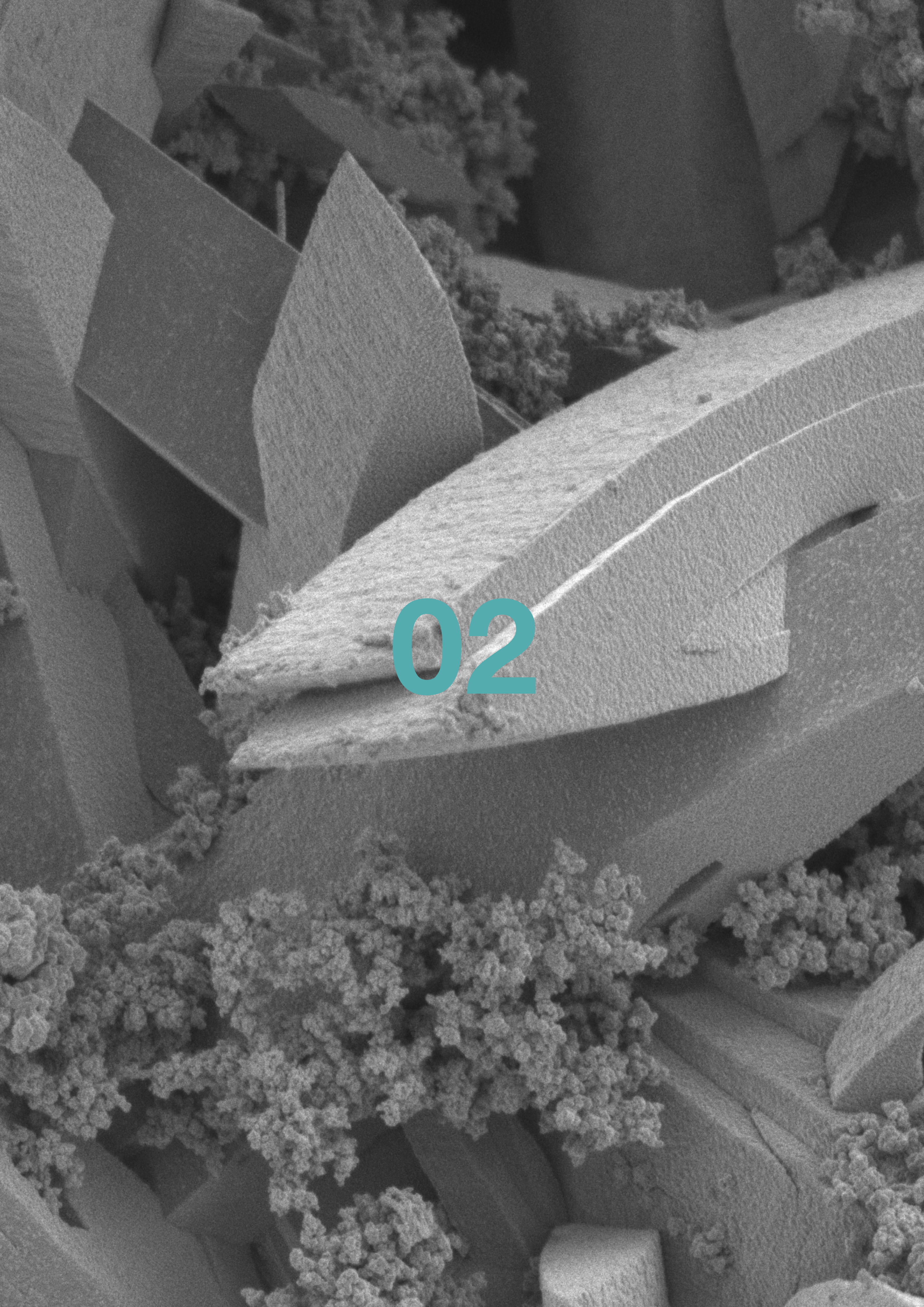
JAPAN
National Institute for Material Science, Tsukuba Ibaraki
Kyushu University, Fukuoka

SINGAPORE
National University of Singapore

NATIONAL COLLABORATORS

RMIT University, Melbourne, Vic
Flinders University, Adelaide, SA
Australian National University, Canberra, ACT
Griffith University, Nathan Campus, Brisbane, QLD
Monash University, Melbourne, Vic
Queensland University of Technology, Brisbane, QLD
University of New South Wales, NSW

Australian Institute of Bioengineering & Nanotechnology, UQ
School of Chemistry & Molecular Bioscience, UQ
School of Mechanical & Mining Engineering, UQ
Institute for Molecular Biosciences, UQ
School of Pharmacy, UQ
School of Veterinary Science, UQ
Faculty of Science, UQ
Faculty of Medicine, UQ
School of Agriculture and Food Sciences, UQ
School of Chemical Engineering, UQ
Diamantina Institute, Brisbane
Faculty of Health and Behavioural Science, UQ
Queensland Alliance for Agriculture and Food Innovation, UQ
Queensland Brain Institute, UQ
Queensland Micro- and Nanotechnology Centre, Griffith University
ACMM, University of Sydney, Sydney, NSW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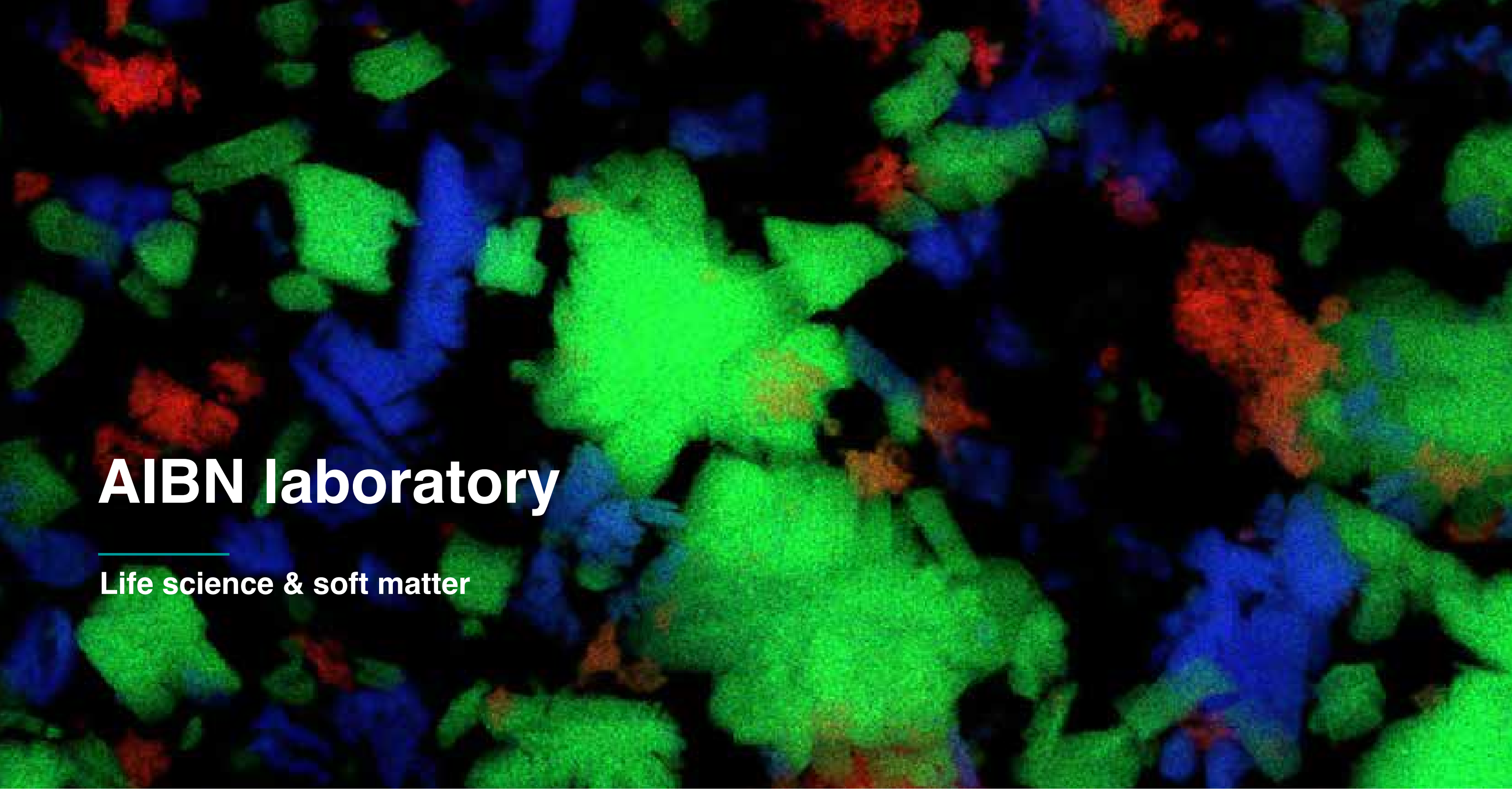
CMM LABORATORIES

CMM has four laboratories across UQ. 2017 saw many highlights including infrastructure upgrades, laboratory refurbishment and new collaborations/amalgamations with other UQ facilities.



AIBN laboratory

Life science & soft matter

The AIBN laboratories are located on the ground floor of the Australian Institute for Bioengineering and Nanotechnology building. These purpose built laboratories house four state-of-the-art transmission electron microscopes and four scanning electron microscopes plus a range of sample preparation facilities. In addition the laboratory is equipped with a sophisticated optical microscopy suite with three optical microscopes in various configurations.

Team

- Mr Richard Webb, Laboratory Manager
- Dr Graeme Auchterlonie, Research Officer
- Ms Robyn Chapman, Scientific Officer
- Dr Elliot Cheng, EBL Specialist
- Dr Hui Diao, Dual Beam FIB/SEM Engineer
- Han Gao, Casual Research Officer
- Mun Soo (Abby), Casual Research Officer
- Qiang Sun, Casual Research Officer
- Ms Rachel Templin, Research Assistant

Equipment

Microscopes

- Hitachi HT7700 with Bruker EDS
- Hitachi HT7700 Exalens
- Tecnai F20 200 kV TEM/STEM with Oxford EDS, STEM BF/DF/HAADF, Gatan OneView Camera, Gatan High Temperature D/T Holder (1000°), Nanofactory 30997 D/T STM Holder, GIF EELS/EFTEM/STEM-EELS 2002CCD camera
- JEOL 2100 200 kV TEM/STEM with Oxford EDS, STEM BF/HAADF
- JEOL JSM-5000 Neoscope
- Zeiss Sigma SEM with Gatan 3View
- Raith eLine EBL system
- FEI Scios FIB with Oxford EDS, Oxford EBSD, Easy Lift micromanipulator, Gas Injection system with platinum, tungsten, silicon and selective carbon etching

Installed 2018

- Thermo Fisher Apreo SEM with VolumeScope (installed 2018)

AIBN laboratory highlights

2017 presented as another exciting year for the AIBN laboratory with many developments. Early in the year two new Hitachi HT7700 TEMs were installed in the laboratory to replace the 20 year old JEOL 1010 TEMs. These have proved to be incredibly versatile, being used by both biological and physical scientists. Within the first couple of months of their operation 50 CMM clients had been trained in their use and these people and many more have continued to use the instruments strongly during 2017. One of the microscopes is equipped with STEM and EDS for elemental analysis of samples while the other instrument is capable of extremely high resolution, in the order of <0.2nm, equaling or bettering the resolution on even the 200kV TEM instruments in the lab.

One of the specialist areas within the AIBN laboratory has been 3D electron microscopy and we saw new developments in this during 2017. Several papers published in high impact journals have been generated using this technology including Zenker et al in Science and Stone et al in Current Biology (see publications list in this report).

In a collaboration between CMM Deputy Director Professor Rob Parton and other members of the ARC Centre of Excellence in Convergent Bio-Nano Science and Technology 3D data obtained from the Zeiss Sigma/Gatan 3View system has been used to create a Virtual Reality system based on a human breast cancer cell. This has generated incredible interest in the media and is always a highlight of visiting tours of the AIBN laboratory (see report on page 34).

In April Nicole Scheiber from EMBL, Heidelberg, and a previous member of staff in CMM visited to help teach us the use of the FIB in acquiring 3D datasets of biological samples. This is now a routine technique in the laboratory and has been used on a range of samples.

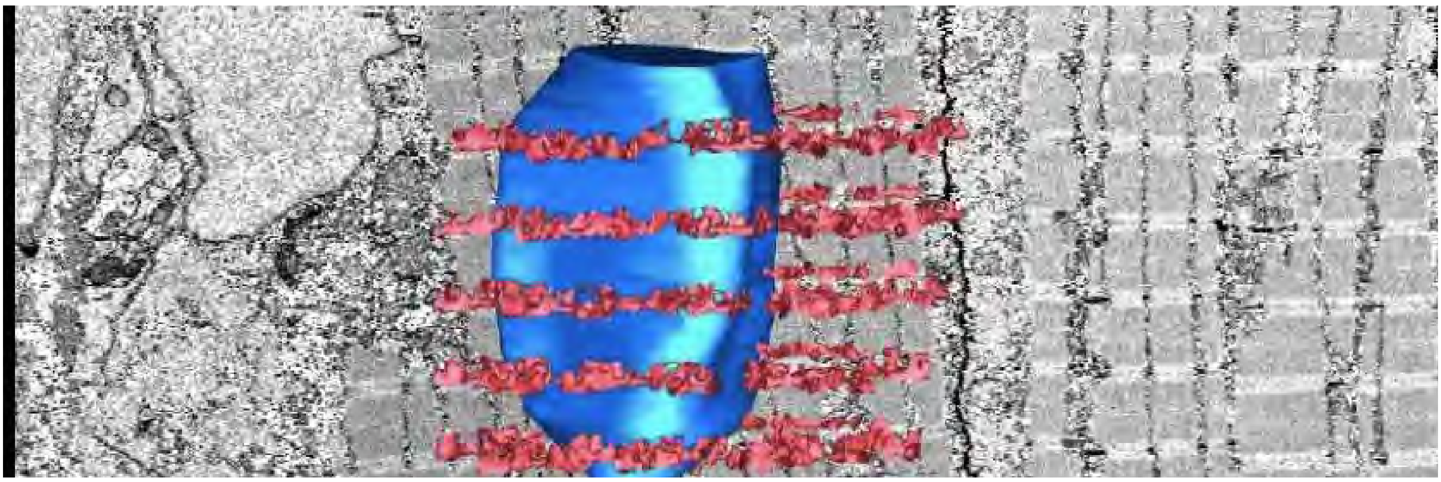
A grant from the Australian Cancer Research Fund led by Professor Jenny Stow from IMB was successful in obtaining money to purchase a new 3D instrument, the Thermo Fisher Apreo/VolumeScope which will be installed in the AIBN laboratory in early 2018. This will complement the already existing systems, expanding the CMM capabilities in this area. A room which housed the light microscopes has been refurbished to take this instrument.

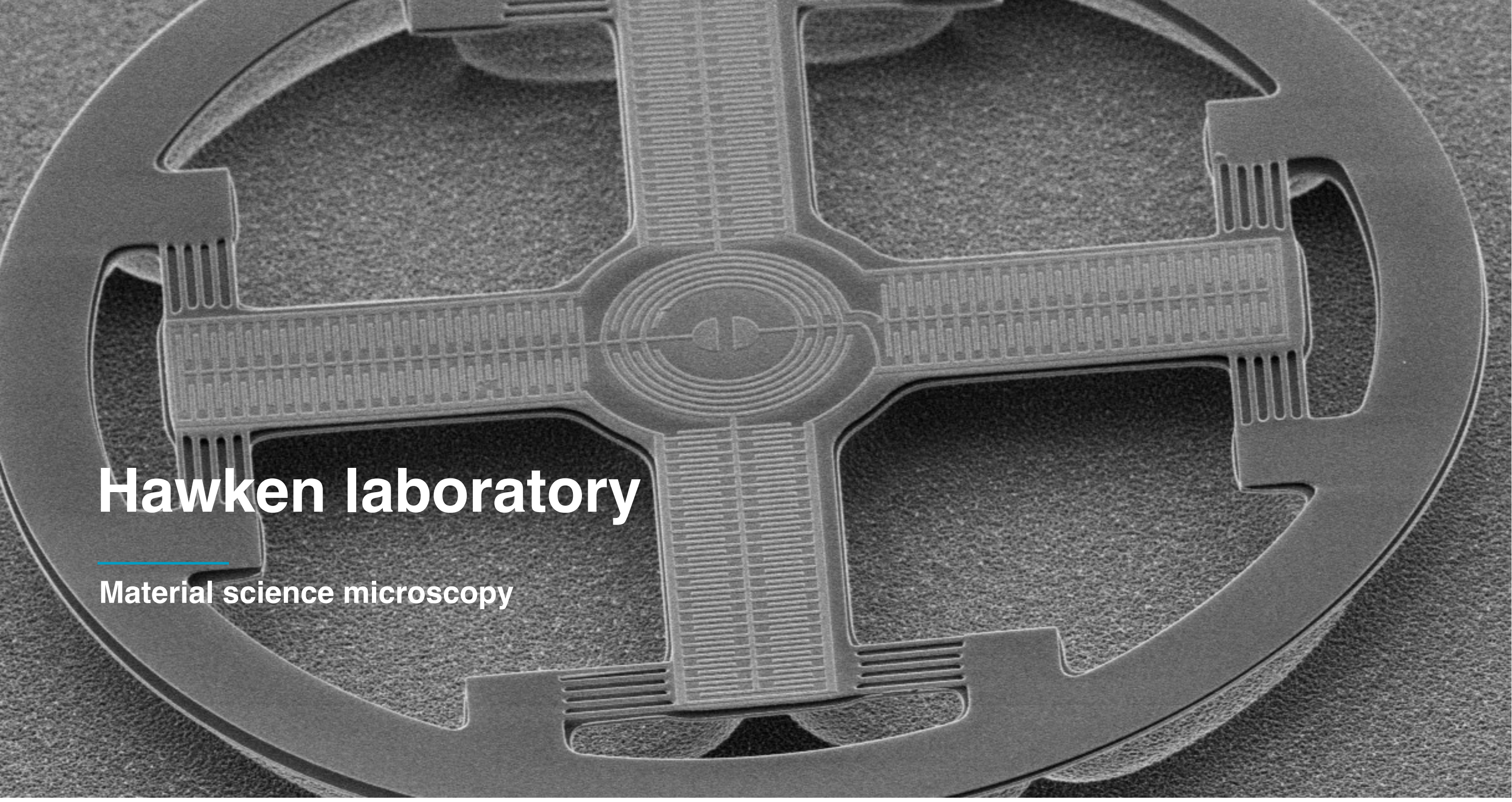
In June we saw the installation of the Raith eLine Plus a new nanofabrication tool. It caters to a variety of different applications: SEM imaging and analysis; Nano lithography; Nano manipulation and Focused Electron Beam Induced additive fabrication by material deposition and subtractive fabrication by etching. CMM was lucky to obtain the services of Dr Elliott Cheng to run this instrument. Many people will remember Elliot as he worked for CMM in the past running our previous EBL system some years ago. While this instrument will be relocated to cleanroom facilities in the newly refurbished Hawken laboratory it has been used very successfully in the AIBN laboratory and has generated a lot of interest from the UQ community.

2017 also saw some other staffing changes. Mun Soo (Abby) who was employed as a casual research officer to assist with TEM, was awarded her PhD and moved back to Malaysia. In her place we have taken on two new research officers, Han Gao and Qiang Sun.

The JEOL 2100 TEM became superfluous to the needs of CMM so in early 2018 will be decommissioned and sold. The money from the sale will pay for an upgrade to the Hitachi HT7700 Exalens instrument to give it STEM and EDS facilities. With this upgrade the two Hitachi TEMs will provide a wide range of TEM capabilities to the CMM clients.

This growth and development of new techniques and instrumentation seem set to continue into 2018 so we look forward to a promising future for the AIBN lab.





Hawken laboratory

Material science microscopy

The refurbishment of the Hawken laboratories will offer a significant improvement to the operation of the advanced materials electron microscope (EM) instrumentation placed within. This is a consequence of the purchase of state-of-the-art instruments, such as the pixelated Cs corrected STEM for atomic characterisation of future materials and EBL lithography for quantum computation research. The Hawken laboratory now incorporates Imaging Mass Spectroscopy (MS). All these changes are encapsulated in the new descriptor as CMM's Material Science and Scanning EM/MS Facility.

Team

» Mr Ron Rasch, Laboratory Manager, Senior Scientific Officer
» Ms Heike Bostelmann, Casual Laboratory Technician
» Ms Eunice Grinan, Senior Technical Officer
» Dr Brett Hamilton, Imaging MS Facility Manager
» Dr Kim Sewell, Scientific Officer
» Ms Ying Yu, Senior Technical Officer

Equipment

Scanning Electron Microscopes

» Hitachi SU3500 with Oxford Xmax SDD EDS elemental analysis
» JEOL JSM6610 with combined Oxford Xmax SDD EDS and Nordlys EBSD detectors
» Philips(FEI) XL30 with cryo shuttle transfer system
» JEOL JSM7001F with JEOL minicup EDS detector
» JEOL JSM7100F with Gatan Alto Cryo system and JEOL SDD EDS detector
» JEOL JSM7800F with two in-lens detectors
» JEOL JXA8200 EPMA with 5 WDS detectors and John Donovan PfEPMA software

Imaging Mass Spectrometry

» Bruker Amazon Speed iontrap with ETD - coupled to AP-MALDI
» Bruker Ultraflex III - MALDI-TOF/TOF (x2)
» Bruker MicroTOF Q II (QqTOF) – coupled to AP-MALDI

Hawken laboratory highlights

The Hawken Laboratories began 2017 with a number of significant machine upgrades completed and was followed in mid-2017 by their move to two temporary laboratory spaces to keep the instruments in service during the refurbishment of the labs. This refurbishment will bring the Hawken laboratory up to world-class standard in terms of controlling room temperature, humidity, vibrations and EMF fields; allowing the existing high-resolution machines to operate at the highest quality as well as making it feasible to install newly purchased state-of-the-art machines, such as the 200 kV Cs corrected STEM for atomic resolution, and EBL lithography for quantum computation research, two requirements needed to keep UQ at the forefront of research.

During 2017 the Nordlys camera (the EBSD diffraction detector on the JEOL 6610 SEM) was upgraded to a contemporary camera standard. The upgrades provide a significant improvement in client productivity, as it is possible to directly image the diffraction contrast produced by a specimen in real time, thus saving many hours in examining the specimen.

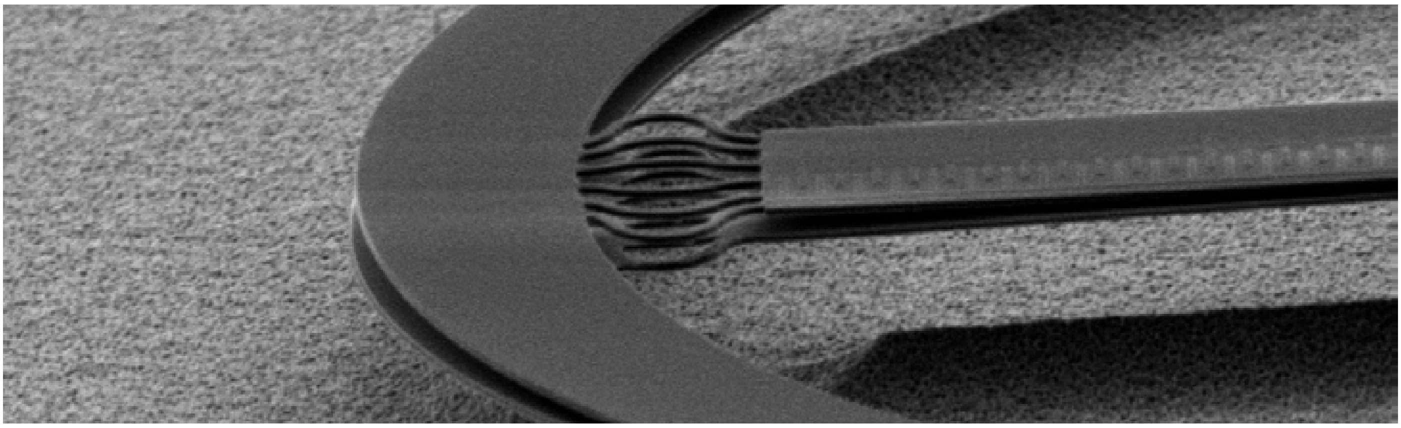
To complement the hardware upgrade to the EBSD detector, the Oxford software that controls both the EBSD (crystal orientation) detector and the EDS (elemental analysis) detector was also upgraded to the latest generation of control software and an extra feature of larger area mosaic mapping was added. This mosaic mapping software takes control of both the SEM beam and the SEM stage to effectively stitch together many orientation or elemental maps to produce a very large-scale image that may be interrogated at multiple magnifications.

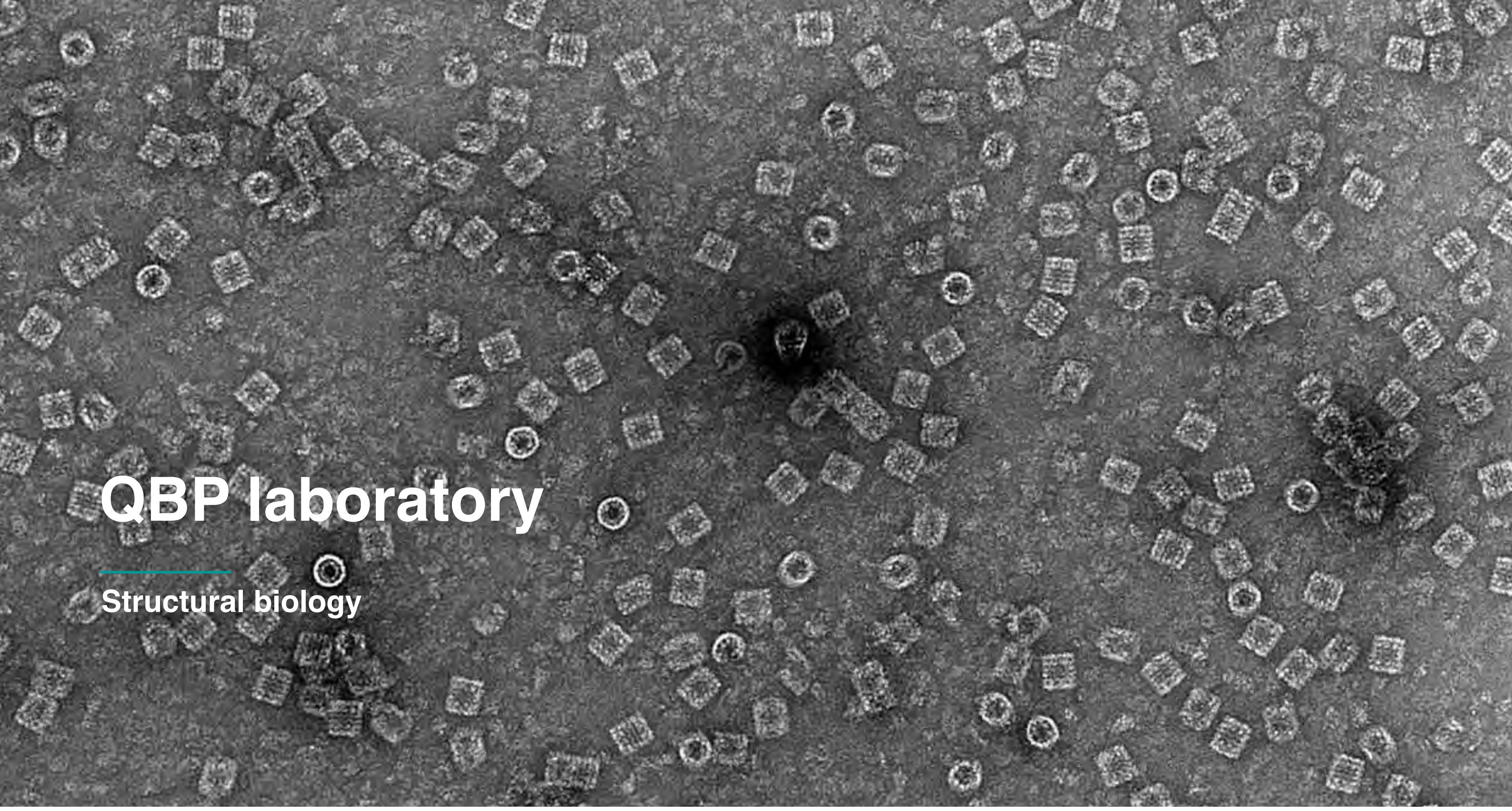
Additional upgrades included: a new generation SDD EDS elemental analysis x-ray detector fitted to the Hitachi SU3500 SEM, which provided analytical capabilities and was compatible with other systems and updating of the EPMA software to the John Donovan PfEPMA analytical package, thus improving the analytical accuracy, speed and flexibility of the WDS analysis on the probe.

A significant achievement was the relatively seamless transition of the Hawken services to two temporary distillation sites at UQ to allow for the total refurbishment of the Hawken Laboratories. One laboratory in the Don Nicklin building was setup to operate the high-resolution FE-SEMs and EPMA probe and a second laboratory in the Chemistry building was setup to operate the sample preparation equipment, conventional SEMs and new MS instruments. During this time the disruption to research was minimised and a subset of SEMs were always available for client measurements.

In addition, despite these transitions, CMM still managed to complete its standard six Introductory SEM & EDS Analysis courses per year; four done before the move and two after the move. Moreover, a number of research outcomes were facilitated by the Hawken laboratories through 2017 and highlights include research in collaboration with Pyroresearch and QUT to reduce the interaction volume during analytical analysis (Rasch et al, page 32) and the development of advanced materials (e.g. Liu et al, Zhaung and Lyu et al, pages 37 and 38).

In 2017 we also welcomed Dr Brett Hamilton to the Hawken team. Brett was previously from the Mater Hospital and is an expert in mass spectrometry and chemical imaging of biomolecules and biomaterials. Brett will manage the new suite of MS instruments in CMM and the Centre for Advanced Imaging at UQ.





QBP laboratory

Structural biology

Located in the Queensland Bioscience Precinct at The University of Queensland, the Cryo-Transmission Electron Microscopy (TEM) Facility is a laboratory that was purpose-built for standard and cryo-TEM sample preparation and analysis, as well as electron tomography of both resin embedded and cryo-samples (for three-dimensional analysis).

From 2018, the macromolecular crystallography unit – UQROCX - will be administered by the Centre of Microscopy and Microanalysis and together with the cryo-TEM facility will from the Macromolecular Structure Research Facility

Team

» Dr Matthias Floetenmeyer, Laboratory Manager
» Dr Kathryn Green, Scientific Officer
» Dr Erica Lovas, Casual Laboratory Assistant

UQROCX LAB

» Karl Byriel
» Dr Gordon King

Equipment

QBP Cryo TEM Instruments

» Tecnai F30 G2 TEM
» Tecnai T12 G2 TEM
» JEOL JEM-1011 TEM
» JEOL JSM-5000 Neoscope
» Leica EM AFS2, Automatic Freeze-Substitution Unit
» Vitrobot Mark 2, Automatic Plunge-Freezer
» Quorom 150TE Carbon Coat
» Baltec MED-020, Carbon Coater/Glow Discharge Unit
» Baltec HPM-010, High Pressure Freezer
» Leica EMPact2, High Pressure Freezer
» Leica UC6-FCS Cryo-Ultramicrotome (x2)
» Leica Ultracut UC6 Ultramicrotome (x2)

UQROCX Instruments

» Rigaku FR-E+ SuperBright X-ray Generator Tecan liquid handling robot
» Rigaku Saturn 944 CCD area detector
» Mosquito Crystal & Mosquito LCP
» ACTOR
» Rigaku R-Axis IV++ area detector
» Rock Imager
» Viscotek TDA 305

QBP laboratory highlights

The QBP laboratories have undergone a number of exciting evolutions throughout the year. In November 2017 CMM was able to secure the largest single item LIEF grant to date for an Automated High-Resolution CryoTEM and in 2018 UQROCX the 'UQ Remote Operation Crystallization and X-ray Diffraction Facility' will come under the umbrella of CMM.

This acquisition is great news for the structural biology community at UQ and across Australia. With the new Cryo-Microscope, CMM will be able to offer fully automated high-resolution image acquisition of isolated proteins and protein complexes that allow the 3D reconstruction of these structures down to almost atomic resolution. Moreover, this cryo-TEM will also provide greatly enhanced cryo-tomography capabilities to the research community and will be a vital part of a newly formed frontier cryo-TEM alliance within Australia.

Installation of the instrument will occur in 2018. As a part of this installation planning has commenced for the creation of dedicated and modernised laboratories, as well as dramatically enhanced data and informatics infrastructure, within the QBP laboratories.

Furthermore, with the expertise of our new colleagues Karl Byriel and Gordon King from UQROCX, we can soon also offer services for protein crystallization and X-ray diffraction data collection in house or at the Australian Synchrotron in Melbourne. With this integrated approach we will be able to offer a workflow where isolated proteins are systematically tested on whichever methodological approach works best and is the most appropriate for a successful structural analysis of proteins and protein complexes. An example workflow is shown below.

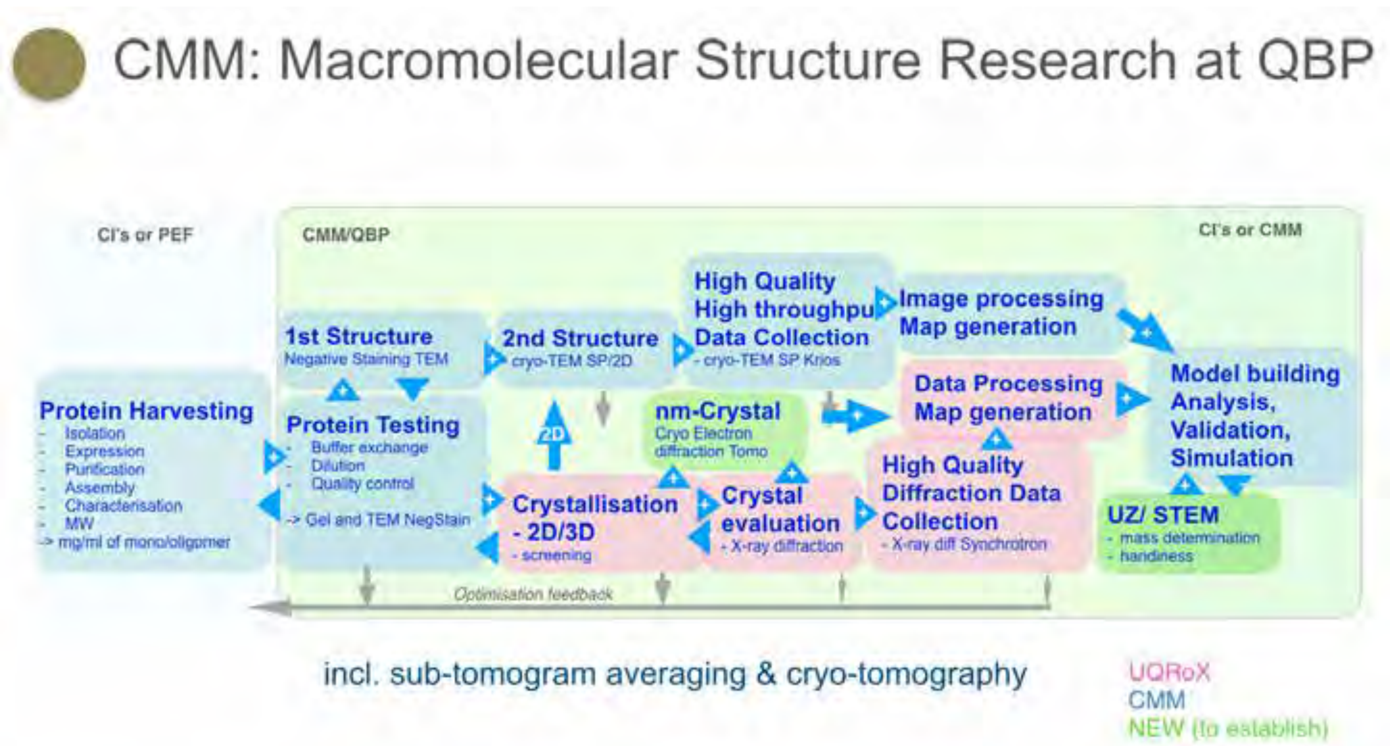
Finally 2017 has seen an increased interest in cryo transmission electron microscopy reflecting the recent technical breakthroughs in the field, last but not least highlighted with the award of the Nobel Prize for chemistry to the pioneers of the field at the end of 2017.

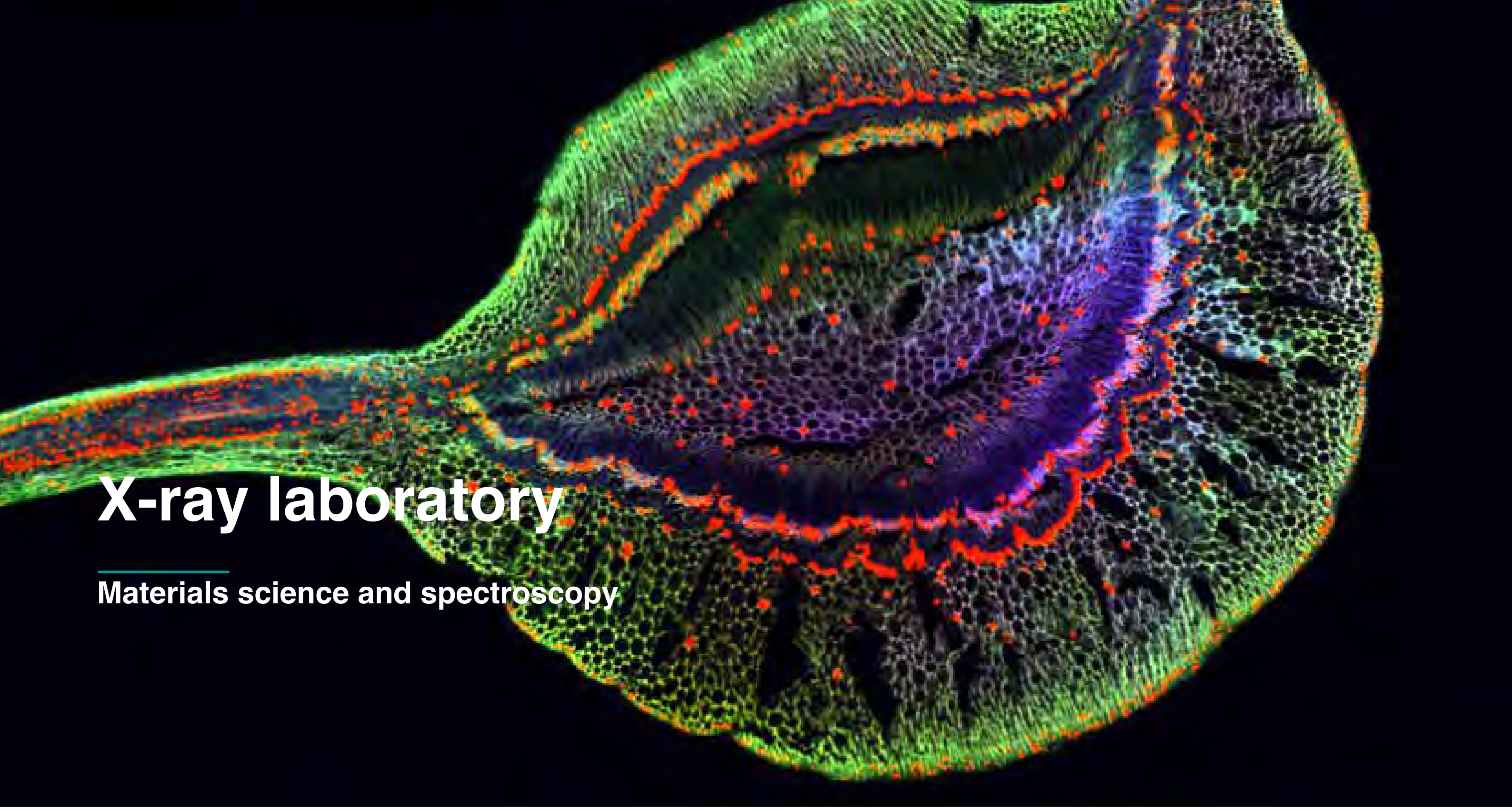
The training and support of our clients in cryo electron microscopy is starting to show results with Vikas Tillus cryo electron tomograms as one highlight (page 35) or Sarah Piper's from Michael Landsbergs laboratory high resolution reconstruction of a bacterial ABC toxin complex that is about to be published.

2017 also had a number of research and teaching highlights including CMM hosting cryo-EM workshops in workshops in conjunction with AMAS.

The UQ ROCX Facility

The UQ ROCX Facility provides access to protein crystallization condition screening, crystal diffraction screening, data collection, data processing, and structure determination. Nano-litre liquid handlers and automated imaging means that large numbers of crystallization conditions can be investigated with small quantities of protein. The diffraction facility has Queensland's brightest research X-ray source and the state's only robotic sample storage and retrieval system, which allows for multiple data sets to be collected without user intervention.





X-ray laboratory

Materials science and spectroscopy

The X-ray analysis facility at CMM is based on level two of the Chemistry building and provides a range of X-ray techniques, including diffraction, scattering, spectroscopy and imaging, for studying chemical composition, nano-scale size and crystalline phases in a range of materials. The facility provides complementary techniques to the electron-based methods afforded by the AIBN, QBP and Hawken Laboratories and to the macromolecular diffraction facilities in the QBP laboratories though small-angle scattering and small-molecule diffraction techniques.

Team

» A/Prof Kevin Jack, Laboratory Manager
» Dr Lachlan Casey, X-ray specialist
» Dr Barry Wood, Scientific Manager
» Ms Anya Yago, Research Officer

Equipment

Analytical X-ray Tools

» Bruker D8 Advance powder XRD
» Rigaku SmartLab thin-film and micro-diffraction XRD
» Anton Parr SAXSess SAXS
» Kratos Axis Ultra XPS

Purchased 2017 for 2018 delivery

» Xenocs Xeuss 2.0 small- and wide- angle X-ray Scattering Instrument
» iXRF Atlas X X-ray Fluorescence Spectrometer – customised for high resolution XRF mapping.

X-ray laboratory highlights

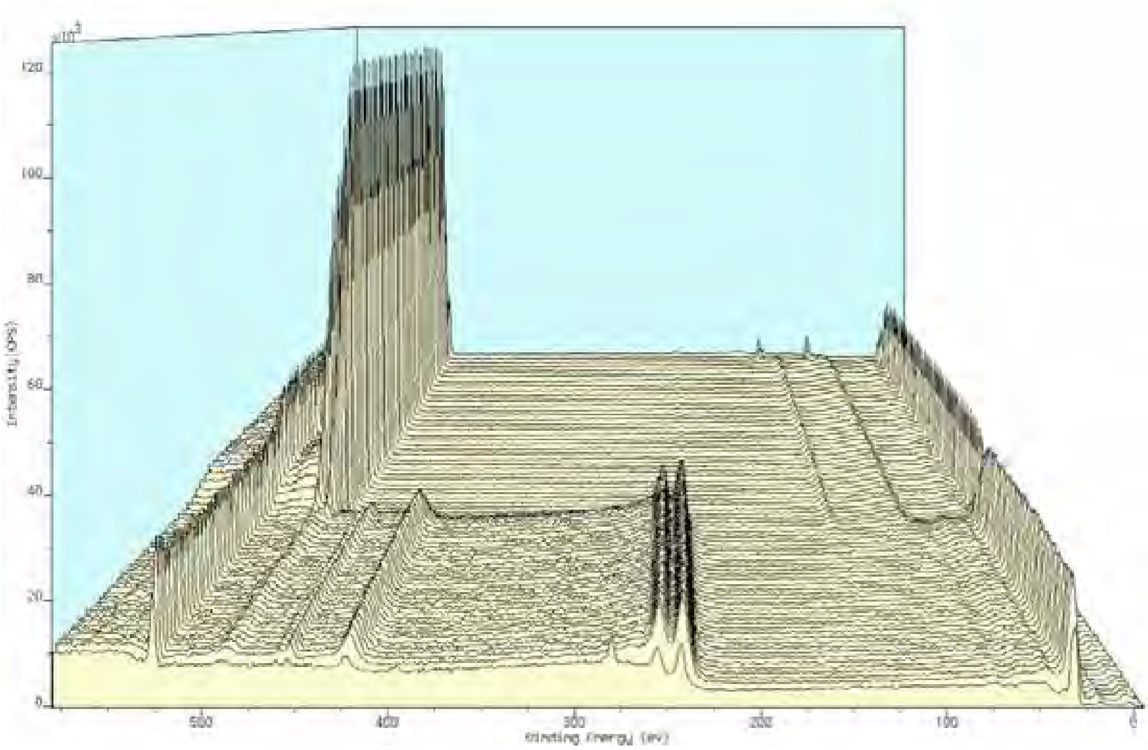
2017 marked the start of a period of substantial growth and renewal for the X-ray laboratories and was very much in line with what has taken place in other laboratories in the CMM. The year saw the planning, funding and/or initial phases of upgrades beginning across many parts of the lab; with the majority of these projects to be completed early in the following year.

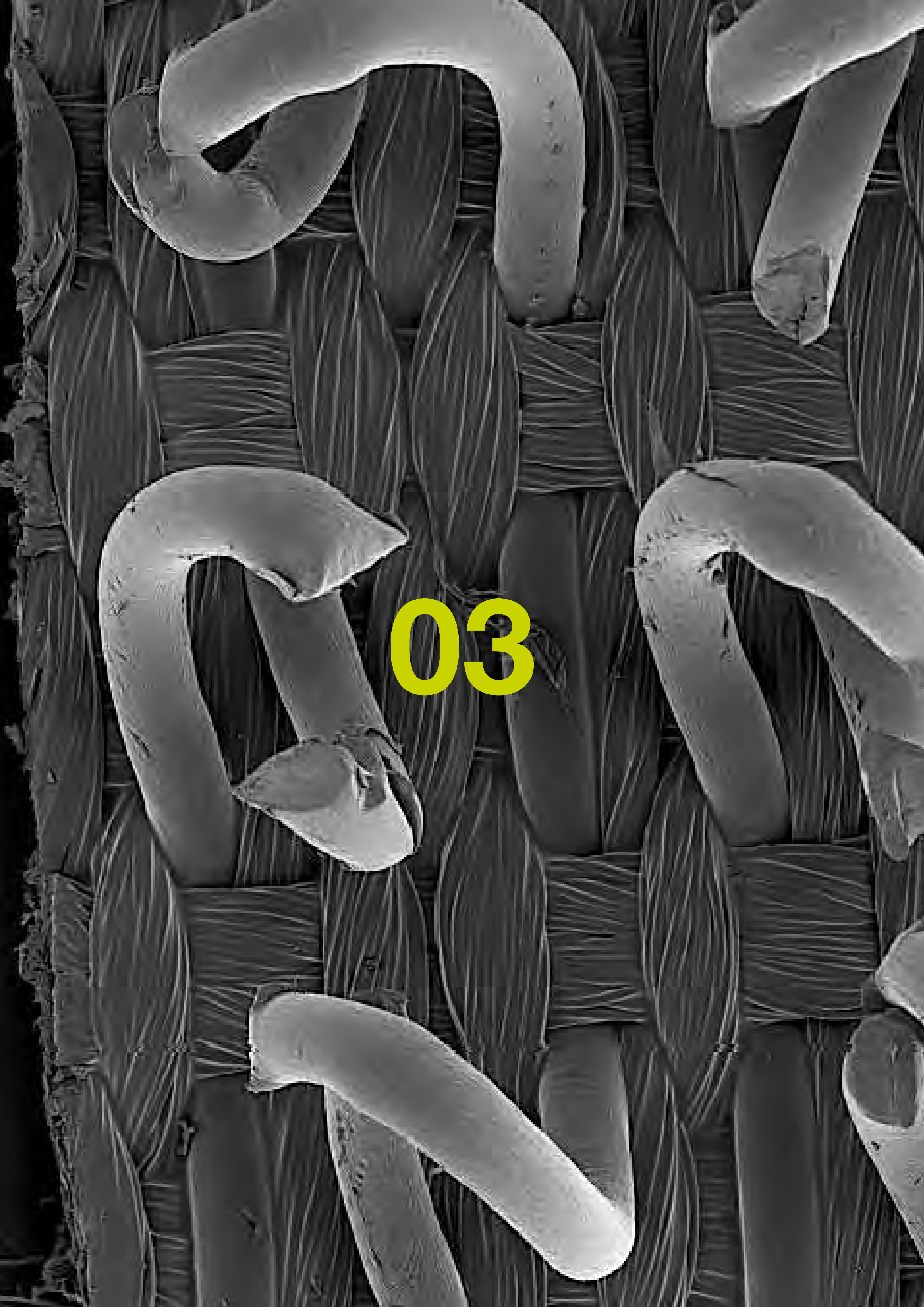
Extensive procurements for both the high-intensity and -resolution small-angle X-ray scattering (in collaboration with AIBN) and the scanning X-ray microscopy (in collaboration with SMI) instruments were finalised in 2017. The instruments selected are world leading in terms of capabilities and functionality they will bring to UQ and the Australian research landscape. Commissioning of both of these instruments will occur around the end of the second quarter of 2018 and once commissioned both instruments will provide unique capabilities for the analysis of a broad range of sample types including materials, biological and geological specimens.

CMM was also successful in obtaining funding from UQ to modernise and upgrade the X-ray laboratory. This funding will provide for purpose-built facilities for new tools such as the small-angle X-ray scattering and scanning X-ray microscopy systems on order and advanced spectroscopy and X-ray diffraction tools, a significant increase in the quality and range of X-ray analysis that can be provided to clients and a stronger collaboration between SCMB and CMM in the management of X-ray analytics.

The year was also highly productive in terms positive outcomes for the clients of CMM. Some highlights include the facilitation of work by the group of James Vaughan into the advanced recovery of minerals and processing of bauxite ores that have led to new alliances between UQ, Industry and the State Government as well as future funding opportunities (see Peng et al. in the Research Highlights on page 39). Other highlights include the continued collaboration between North-West University (South Africa) and CMM looking at more efficient burning of coals (see Wood et al., page 36) and the development of materials for future energy demands (e.g. reports by Zhuang and Lyu, pages 37 and 38).

The capacity and capabilities of the X-ray staff were boosted by Dr Lachlan Casey joining the X-ray facility in mid-2017. He will be in charge of the commissioning and management of the scanning X-ray microscopy tool as well as providing much needed succession for the provision of X-ray photoelectron spectroscopy at UQ. Lachlan has experience in X-ray analytics, including synchrotron-based methods, as well as in structural biology. The incorporation of UQROCX into the CMM umbrella will also see greater opportunities for the X-ray laboratory to add to the Macromolecular Structure Research through complementary methods such as SAXS.





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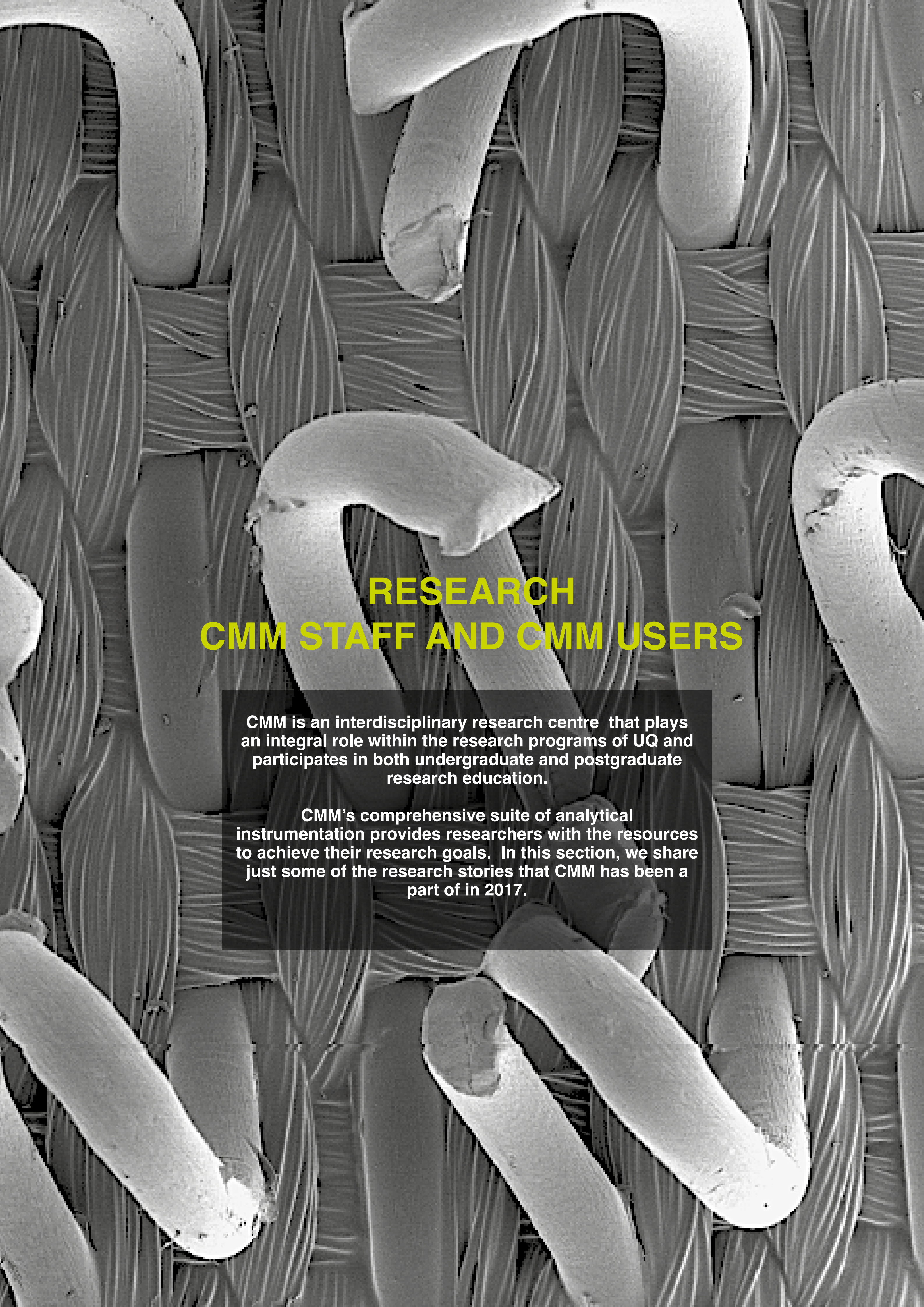


RESEARCH
CMM STAFF AND CMM USERS

CMM is an interdisciplinary research centre that plays an integral role within the research programs of UQ and participates in both undergraduate and postgraduate research education.

CMM's comprehensive suite of analytical instrumentation provides researchers with the resources to achieve their research goals. In this section, we share just some of the research stories that CMM has been a part of in 2017.

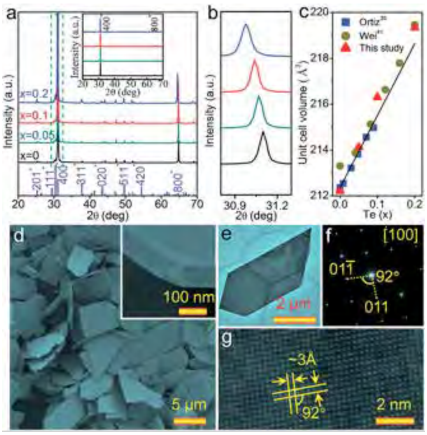
Projects

HIGHLIGHTS FROM CMM STAFF

Development of Thermoelectric Nanostructures

Jin Zou

Thermoelectric nanostructures, directly convert waste heat to electricity and provide opportunities to harvest useful electricity, which has been considered as a promising candidate to generate clean energy. In this program, we employed low cost and environmental friendly approaches to synthesize various chalcogenide-containing semiconductor nanostructures and their thermoelectric performances are evaluated using our newly installed facilities.



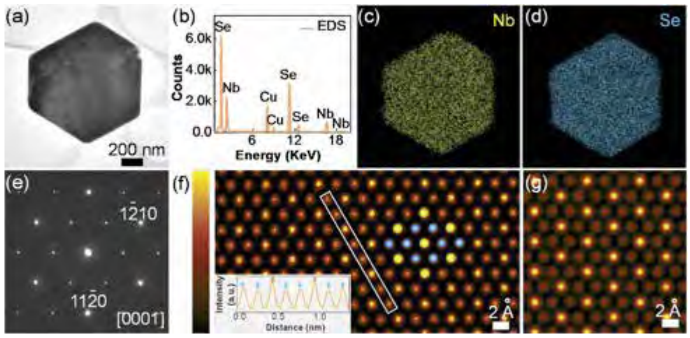
XRD, SEM and TEM investigations of as-synthesized $SnSe1_{-x}Te_x$ nanoplates.

Ref: M. Hong, Z. G. Chen, L. Yang, T. C. Chasapis, S. D. Kang, Y. C. Zou, G. J. Auchterlonie, M. Kanatzidis, G. J. Snyder, J. Zou
Enhancing the thermoelectric performance of SnSe1-xTex nanoplates through band engineering
Journal of Materials Chemistry A (2017) 5, 10713.

Understanding of 2D Nanostructures

Jin Zou, (Collaborating with Professor Faxian Xiu at Fudan University, Kyeongjae Cho at The University of Texas at Dallas, and Professor Syo Matsumura at Kuyshu University)

2D nanostructures, such as topological insulators, are a new type of material. Due to their inherent exotic physical properties, 2D nanostructures have been considered as a promising candidate for next-generation high-performance devices. In this project, we fabricate a range of 2D nanostructures and understand their structural characteristics and properties.



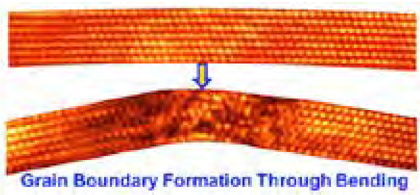
(a) BF TEM image obtained from a typical $NbSe_2$ nanoplate. (b) EDS point profile obtained from the nanoplate (Note: Cu peaks are due to the copper grid used for supporting the samples). (c, d) Corresponding EDS element maps for Nb (c) and Se (d). (e) SAED pattern obtained along the [0001] axis. (f) Atomic-resolution HAADF-STEM image obtained from the nanoplate imaged along the [0001] zone-axis. The structural model and the atomic coordinate are overlaid on the image, with the yellow and blue balls denoting Nb and Se atomic columns, respectively. The bottom panel shows the corresponding line intensity profile obtained from the line highlighted by white rectangle. (g) Simulated HAADF-STEM image.

Ref: Y. C. Zou, Z. G. Chen, E. Z. Zhang, F. X. Xiu, S. Matsumura, L. Yang, M. Hong, J. Zou
Superconductivity and magnetotransport of single-crystalline NbSe2 nanoplates grown by chemical vapour deposition
Nanoscale (2017) 9, 16591-16595.

In-situ transmission electron microscopy

Jin Zou (Collaborating with Professor Xiaodong Han at Beijing University of Technology)

The ultimate goal of materials research is to develop materials with desirable properties for practical applications. Understanding the structural behaviour of materials under external stimuli, including heat, applied stress and/or electrical voltage/field has become a research focus in the materials research community. In this regard, *in-situ* TEM is playing a key role in understanding the intrinsic properties of individual nanostructures. In this program, we are employing *in-situ* TEM techniques to measure strain-stress curves and/or current-voltage curves of individual nanostructures.



Ref: L. H. Wang, D. L. Kong, Y. Zhang, L. R. Xiao, Y. Lu, Z. G. Chen, Z. Zhang, J. Zou, T. Zhu, X. D. Han
Mechanically Driven Grain Boundary Formation in Nickel Nanowires
ACS Nano (2017) 11, 12500-12508.

Hadronyche infensa modulate secreted venom composition via compartmentalized toxin production and storage

*#*David Morgenstern[1], #Brett Hamilton[2,3], Darren Korbie[4], Karl R. Clauser[6], Brian J. Haas[6], Greg Bowlay[5], Alun Jones[1], Deon J. Venter[5], Eivind A. B. Undheim[2,*] and Glenn F. King[1,*]

[1]Institute for Molecular Bioscience, [2]Centre for Advanced Imaging, [3]Centre for Microscopy and Microanalysis, and [4]Australian Institute for Bioengineering and Nanotechnology, The University of Queensland, Brisbane, QLD 4072, Australia

[5]Pathology Department, Mater Health Services, South Brisbane, QLD, Australia

[6]Broad Institute of MIT and Harvard, Cambridge, Massachusetts, USA.

Animal venoms are complex chemical arsenals containing hundreds or even thousands of diverse small molecules, peptides, and proteins that affect a myriad of molecular targets. Because this biochemical arsenal is metabolically expensive, venom must be used sparingly and therefore one might predict that venom evolution would result in retention of only the most essential toxins for predation and/or defence. However, this presents a strong dichotomy in the functional requirements of venoms that are used for both predation and defence, which results in extensive functional redundancy. Here we show, for the first time, that spiders can overcome this potential metabolic burden by modulating the biochemical composition of their venom.

Analysis of the series of defensive secretions, collected dropwise from a *Hadronyche infensa*, by MALDI-TOF and LC-MS revealed that venom peptidome changes both qualitatively and quantitatively throughout (Figure 1). The most potent insecticidal toxins are preceded by secretion of non-insecticidal, presumably defensive, toxins. To investigate further the observation of apparent venom secretion modulation, we conduced mass spectrometry imaging of the venom glands of *Hadronyche infensa.* Mass spectrometry imaging revealed that toxins were significantly compartmentalized within the gland – as opposed to a homogenous distribution (Figure 2). This observation gave rise to the hypothesis that the modulation of toxin secretion is facilitated by differential storage of toxins in the venom gland. We propose that the establishment of distinct venom-gland zipcodes for toxin production is an adaptation that reduces the metabolic expense of venom production and perhaps also serves to minimize effects from development of toxin resistance during predator-prey co-evolution.

Analysis of the LC-MS data revealed a small number of components consistently correlated with insecticidal toxicity and these components were revealed by mass spectrometry imaging to be stored towards the rear of the gland (PC3 in Figure 2). This observation fits well with the defensive display for which *Hadronyche infensa* is known, where droplets of venom are displayed on the tips of the fangs of the agitated spider. This suggests that the spider has adapted to preferentially retain the metabolically expensive insecticidal toxins required for successful predation, which are not a part of the venom presented during the defensive display but are only deployed during predation or extreme defensive events.

Our results highlight the importance of considering behavioural aspects of natural venom secretions in understanding toxin function and evolution.

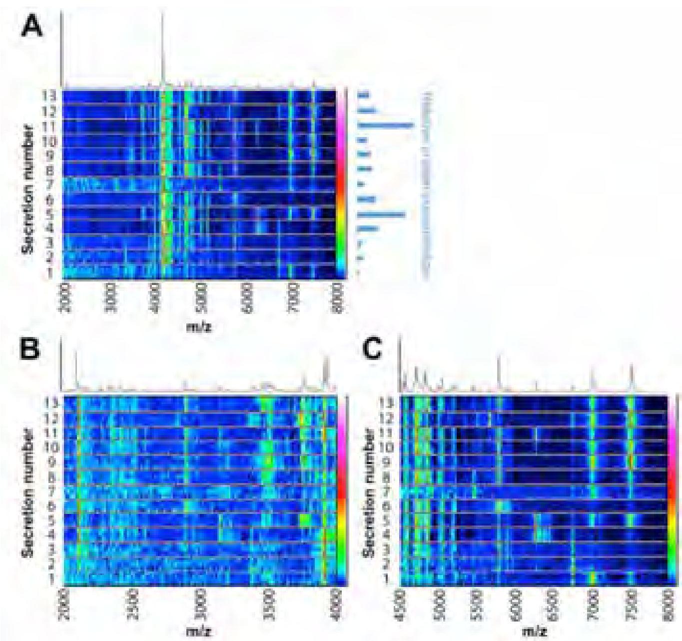


Figure 1. MALDI-TOF analysis of the venom secretion series from Hadronyche infensa

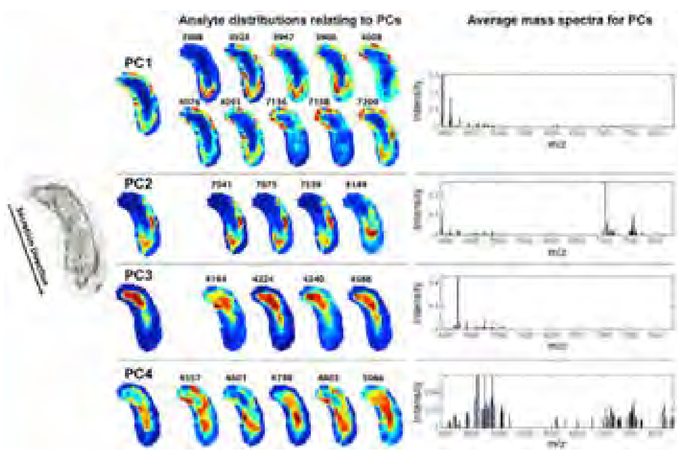


Figure 2. MALDI Imaging Analysis of Hadronyche infensa venom gland

Analysis of sub-micron phases using EDS and WDS on FE-SEM and FE-EPMA

Ron Rasch[1] in collaboration with Jeff Chen[2], Henrietta Cathey[3], Ying Yu[1] and Hui Diao[1]
[1.]Centre for Microscopy and Microanalysis, The University of Queensland
[2.]PYROSEARCH, School of Chemical Engineering, The University of Queensland
[3.]Central Analytical Research Facility, Queensland University of Technology

Elemental analysis of submicron phases in the SEM and EPMA microprobe is often problematic. Traditional methods that use high accelerating voltages for measurement of x-ray intensities with energies above 1 keV commonly produce interaction volumes larger than the phase of interest. We investigated two alternative methods of reducing the electron-specimen interaction volume in order to analyse small metal and sulphide phases in a synthetic Fe-Ni oxide slag.

The first method involves reducing the accelerating voltage (7kV) on a field emission EPMA equipped with WDS detectors to measure intensities of low energy Lα x-rays for the transition metals, instead of higher energy Kα x-rays more commonly measured at routine accelerating voltages (20kV). Previous investigations show that analytical accuracy depends strongly on the analytical standards used. At 20kV it is acceptable to use pure element metal standards for the Kα x-ray lines of elements such as Cr, Fe and Ni in analysis of metal alloys. However, the use of pure element standards at 7kV for the Lα lines commonly produces erroneous results on mixed metal alloys due to the large uncertainties in the mass absorption coefficients (MAC) of soft x-rays passing through dense material. The ZAF corrections therefore are less reliable under these conditions. One solution is to use analytical standards very close in composition to the material being analysed. This approach is impractical in most circumstances because foreknowledge of the approximate composition of the unknown material is required, and the analyst must be in possession of an extensive set of analytical standards including customized materials to meet various analytical requirements.

The second method involves creating a thin specimen (~100nm) with a dual beam FIB and then mounting this specimen over a faraday cup-like assembly in the FE-SEM equipped with a SDD-EDS x-ray detector, and quantifying the x-ray intensities with a simplified ratio technique at routine SEM accelerating voltages (20kV). The improved peak stability, energy resolution and low energy sensitivity of modern SDD-EDS detectors have made them particularly suitable to such thin film work. No *a priori* knowledge of specimen composition is required, and the technique is standardless whereby the x-ray intensity ratios are normalized to 100%.

As a final proof of concept, we found the thin foil standardless ratio technique in the FE-SEM using a SDD-EDS detector produces acceptable results when applied to a known NIST SRM reference material.

Figure 1. FIB thin section of slag inclusion in FE-SEM

Table 1. Analysis of Fe-Ni Slag Inclusion, Wt% (SDOM)

	7kV – WDS Pure Metal Std	7kV – WDS Pure Metal Std	7kV – WDS SRM1158 Std	7kV –WDS SRM1158 Std	20kV – EDS Thin Foil
Fe	49.33 (0.4)	41.23	48.43 (0.4)	45.84	44.25 (0.8)
Ni	70.30 (0.3)	58.75	57.20 (0.3)	54.14	55.75 (0.8)
Total	119.65 (0.6)	100.0	105.65 (0.5)	100.0	100.0

Table 2. Analysis of NIST SRM 1155 standard material, Wt% (SDOM

	Reference Value	20kV –EDS – Thin Foil
Si	0.51	0.95 (0.1)
Cr	18.37	18.45 (0.3)
Mn	1.62	1.76 (0.2)
Fe	64.19	63.03 (0.5)
Ni	12.35	11.99 (0.4)
Mo	2.39	3.83 (0.3)

Dispersion of hydroxyapatite nanoparticles in solution and in polycaprolactone composite scaffolds

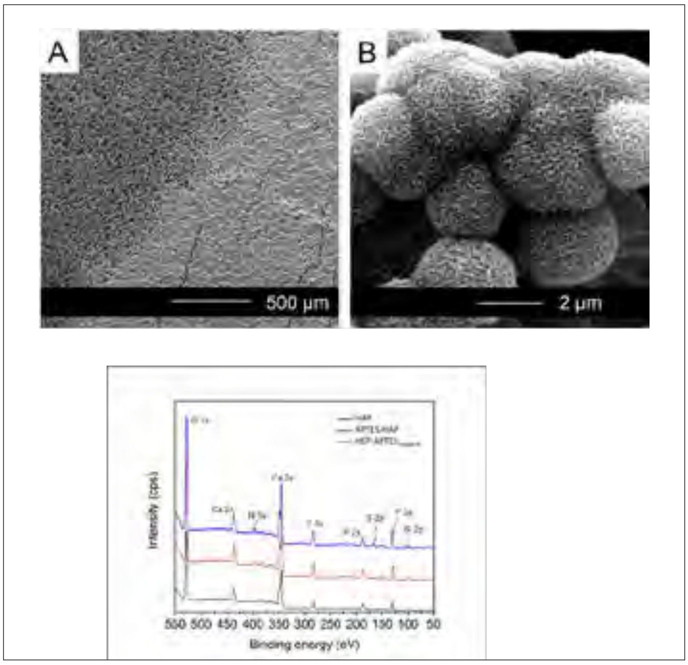
Associate Professor Kevin Jack (In Collaboration with Justin Cooper-White, Lisbeth Grøndahl)

A thorough investigation of the dispersion of stability of surface modified and pristine hydroxyapatite nanoparticles (HAP) was carried out both in solution and in polymer scaffolds. It was determined that the solvent used has a significant contribution to the success of a surface modifier in improving colloidal stability in solution and in polymer composite scaffolds.

Investigation of the surface modification (by XPS) and distribution of the particles within solutions and scaffold walls by TEM and SEM demonstrated that the behaviours of the particles did not necessarily mirror their behaviours in solution. Instead, it was concluded that the polymer-solvent system used and the phase-separation mechanism that occurs, influences the distribution of the particles significantly.

Importantly, the use of DO as a solvent in the fabrication of composite TIPS scaffolds afforded primary particles which were well dispersed in the walls of the PCL scaffolds and the inclusion of filler particles significantly improved the mineralisation capacity in SBF compared to pristine PCL scaffolds.

Despite the different particle distribution observed by TEM for the different scaffold types, there was no significant effect (at a loading of 3 wt%) on bulk properties (compressive modules or crystalline content). This lack of enhancement in bulk mechanical properties of the PCL scaffolds which posses relatively high crystallinity (70-74%) may be attributed to the particles being present in the amorphous phase of the polymer and therefore having little effect on the overall modulus of the scaffold at these relatively low loadings.



SEM and XPS images of composite polymer scaffolds after immersion in simulate body fluid showing morphology and chemistry of mineralisation

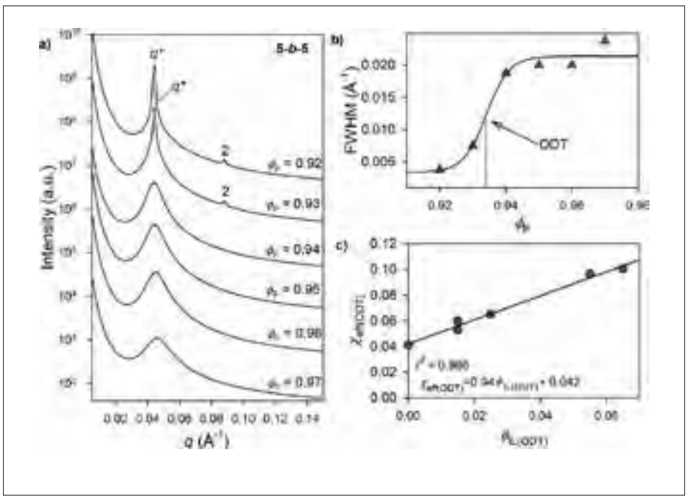
Perturbation of the experimental phase diagram of a diblock copolymer by blending with an ionic liquid

Associate Professor Kevin Jack (In Collaboration with Kris Thurecht, Idriss Blakey)

Understanding the phase behaviour of block copolymer/ionic liquid mixtures is an important step toward their implementation in commercial devices. Work was undertaken at The University of Queensland's Centre for Microscopy and Microanalysis and the Australian Synchrotron to provide a systematic study of the lyotropic phase behaviour of a series of polystyrene-b-poly(methyl methacrylate) (PS-b-PMMA) block copolymers in the ionic liquid, 1-ethyl-3-methylimidazolium bis(trifluoromethane sulfonyl)imide (EMIM Tf2N).

The ionic liquid induces disorder–order transitions for a number of low molecular weight systems, and the onset points of these transitions are used to calculate the scaling laws and the dependence of the effective Flory–Huggins interaction parameter (χ_{eff}) on the ionic liquid concentration. This enabled construction of an empirical phase diagram, which reveals that, at higher ionic liquid concentrations, the experimental phase boundaries shift significantly when compared to theoretical calculations for block copolymer melts.

It is also demonstrated that the scaling of the domain spacing with ionic liquid concentration is dependent on the molecular weight for low degrees of polymerization. Finally, the addition of the ionic liquid is able to access a wide range of meso-structures (including co-continuous phases) and to induce phase separation in normally disordered block copolymers to achieve individual lamellar domains as narrow as 7.2 nm; significantly narrower than those for neat PS-b-PMMA. These findings should be an important tool in future investigations that target specific self-assembled morphologies to suit a desired application.



SAXS of blends of the ionic liquid and block copolymer showing the onset of the order-disorder transition and the effective interaction parameter (χ_{eff})

Journey to the centre of the cell: Virtual reality immersion into scientific data

Angus P.R. Johnston[1,2], James Rae[3,4], Nicholas Ariotti[3], Benjamin Bailey[5,6], Andrew Lilja[5,6], Robyn Webb[7], Charles Ferguson[3,4], Sheryl Maher[1], Thomas P. Davis[1,2,8], Richard I. Webb[7], John McGhee[5,6], Robert G. Parton[3,4,7]

Visualization of scientific data is crucial not only for scientific discovery but also to communicate science and medicine to both experts and a general audience.

Until recently, we have been limited to visualizing the three-dimensional (3D) world of biology in 2 dimensions. Renderings of 3D cells are still traditionally displayed using two-dimensional (2D) media, such as on a computer screen or paper. However, the advent of consumer grade virtual reality (VR) headsets such as Oculus Rift and HTC Vive means it is now possible to visualize and interact with scientific data in a 3D virtual world. In addition, new microscopic methods provide an unprecedented opportunity to obtain new 3D data sets.

In this perspective article, we highlight how we have used cutting edge imaging techniques to build a 3D virtual model of a cell from serial block-face scanning electron microscope (SBEM) imaging data. This model allows scientists,students and members of the public to explore and interact with a “real” cell. Early testing of this immersive environment indicates a significant improvement in students’ understanding of cellular processes and points to a new future of learning and public engagement. In addition, we speculate that VR can become a new tool for researchers studying cellular architecture and processes by populating VR models with molecular data.

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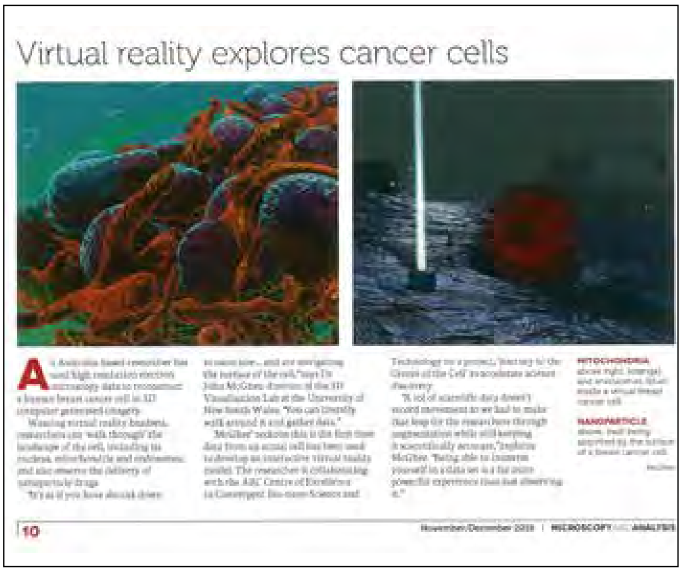


Microscopy and Analysis 2016 119: 10

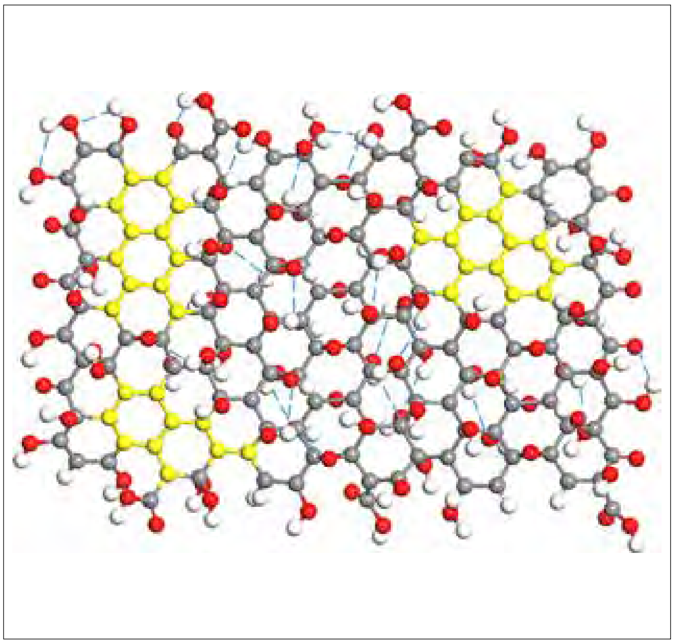
This work, published in the journal Traffic, has attracted a lot of attention both in the print and television media, with a story on the ABC science series Catalyst dedicated to it. http://www.abc.net.au/catalyst/stories/4519963.htm

Cover image from journal Traffic. Reference: Johnston, A., Rae, J., Ariotti, N., Bailey, B., Webb, R., Ferguson, C., Maher, S., Davis, T.P., Webb, R.I., McGhee, J. and Parton, R.G. (2018) Journey to the centre of the cell: Using virtual reality to visualize scientific data. Traffic 19: 105-110

Theoretical modelling of graphene oxide

Graeme Achterlonie, Haining Luo

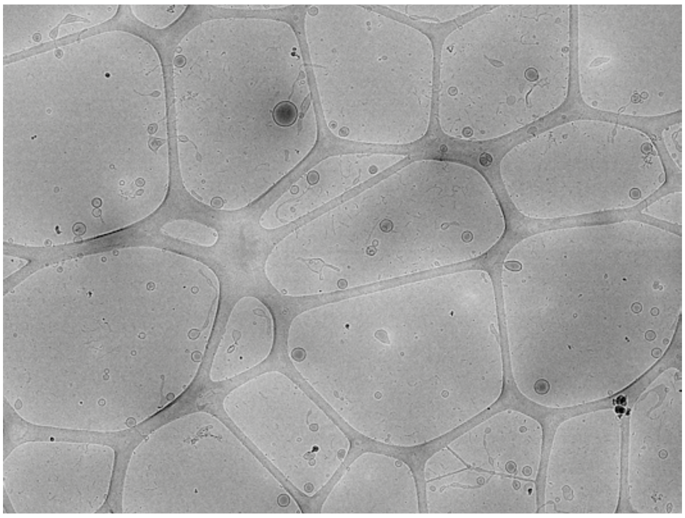
Graphene oxide is an easy-to-make material that has a similar structure to graphene. However, the real structure of graphene oxide is still controversial, and an accurate structural model is crucial for understanding its various properties. In this study, by using molecular mechanics and density functional theory, we introduce a thermodynamically favorable structural model of graphene oxide with chemical composition variable from C1:5O to C2:5O . We also calculate their theoretical Raman spectra and electronic properties. It has been found that, in the proposed graphene oxide structure, the para-substituted epoxide groups stay in close proximity to the hydroxyl, but on the opposite sides of the carbon sheet. In addition, on the edge of graphene oxide sheet, the carboxyl prefers attachment in the armchair orientation, while the carbonyl prefers the zigzag orientation. An image of Haining's model for Graphene Oxide is shown below.

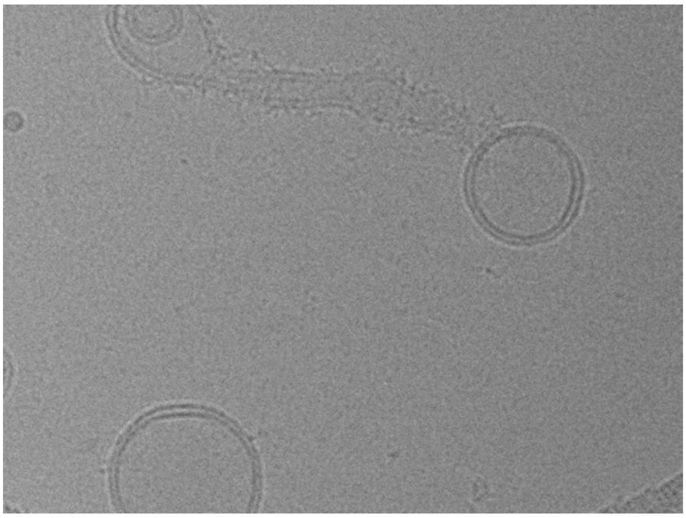


Cryo electron tomography on lipid - cavin interactions.

Vikas Tillu

Caveolae are small invaginations of the plasma membrane and are a characteristic feature of eukaryotic cells. Described morphologically in the early 1950s their many important functions are only just beginning to be revealed. Caveolae are multifunctional organelles, that play a vital role in normal cellular processes such as signalling and membrane homeostasis, and are perturbed in cancer, lipid storage and muscle diseases. A new family of coat proteins called 'cavins' have recently been discovered that are essential for the formation of caveolae. In this project CryoEM and Cryo-electron tomography is used to find out more about the mechanism how cavins are able to contribute to the formation of caveolae.





Next-gen steel under the microscope

Roger Wepf

Next-generation steel and metal alloys are a step closer to reality, thanks to an international research project involving a University of Queensland scientist.

The work could overcome the problem of hydrogen alloy embrittlement that has led to catastrophic failures in major engineering and building projects.

UQ Centre for Microscopy and Microanalysis Director Professor Roger Wepf said the problem had been recognised for almost 140 years.

"The current generation of these metals can suffer hydrogen embrittlement, where they become brittle and fracture due to the accidental introduction of hydrogen during manufacture and processing," he said.

"A major example of alloy embrittlement occurred in 2013, when bolts in the eastern span of the San Francisco-Oakland bridge failed tests during construction."

Professor Wepf said hydrogen was extremely volatile and diffused quickly.

"Our research collaboration has, for the first time, localised and visualised hydrogen in steels and alloys," he said.

"This is essential for the development of new alloys with greater endurance."

"We have shown that it's possible to localise hydrogen at atomic resolution – at the scale of a single atom – or at a nanometre (less than one-billionth of a metre) scale by combining different technologies in a closed and protected workflow.

"These include state-of-the-art cryo electron microscopy freezing techniques, low-temperature sample preparation in a cryo focused ion beam microscope, and inert cryo-transfer.

The research, published in Science, involved scientists from the Oxford and Sheffield universities in the UK and ETH Zurich in Switzerland.

The effect of acid demineralising bituminous coals, and de-ashing the respective chars, on nitrogen functional forms

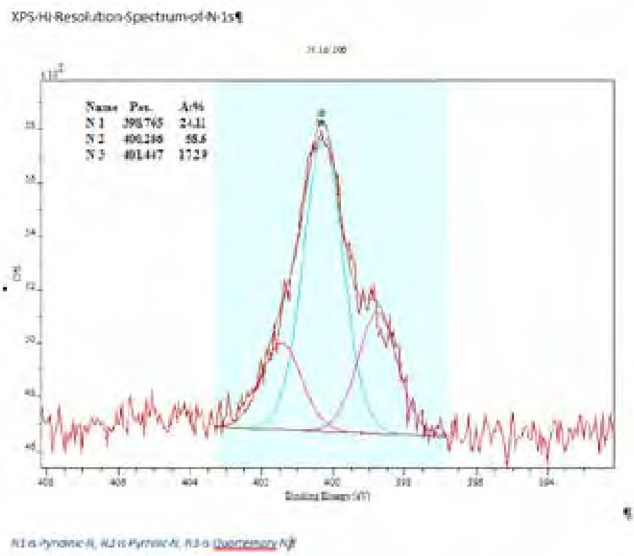
Barry Wood, in conjunction with Zebron Phiri, Raymond Everson, Hein Neomagus – North-West University Potchefstroom South Africa

In a research collaboration between CMM and the Coal Research Group within the School of Chemical and Minerals Engineering at North-West University in Potchefstroom South Africa, researchers set out to compare changes in the nitrogen chemistry as a result of acid and other treatments of South African bituminous coals and their respective chars.

The pre-treatment of coals and chars, e.g. leaching by an acid or alkali solution to reduce mineral or ash content significantly, are often employed as the presence of inorganic matter in coal influences its chemical attributes and potential utilisation. Increasing the efficiency of coal usage and the call to mitigate environmental implications of coal combustion are some of the major reasons needed for coal chemical pre-treatment.

In this research, X-ray photoelectron spectroscopy (XPS) was used to determine functional forms of nitrogen in raw coals, chars and after pre-treatments as this understanding will be critical to developing commercially viable technologies for clean coal production.

An outcome was that it was found that the forms of nitrogen were relatively invariant to many of the pre-treatments studied. However, acid treatment changed the organic nitrogen structural forms by inducing a portion of pyrrolic and oxidised-pyridinic/ protonated nitrogen. Severely pyrolysed char (1400 °C) from a relatively low ash and inertinite-rich, also underwent similar organic nitrogen structural changes after de-ashing. These findings are very important on the prospects of conducting exercises like modelling of the chemistry of coals during such treatments and thereby designing better regimes.



Projects

Highlights from CMM users

Ga-based Pb-free solder alloys for low temperature microelectronics

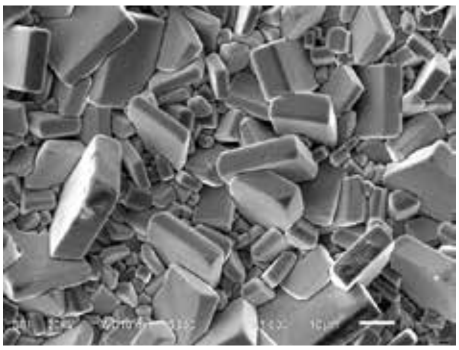
Ms Shiqian Liu, PhD candidate

Ga and Ga-based alloys are promising materials for low temperature soldering in microelectronics. Knowledge about the interfacial reactions between these low melting point metals and the commonly used substrates at low temperatures is needed to enable the next-generation microelectronic packaging industry.

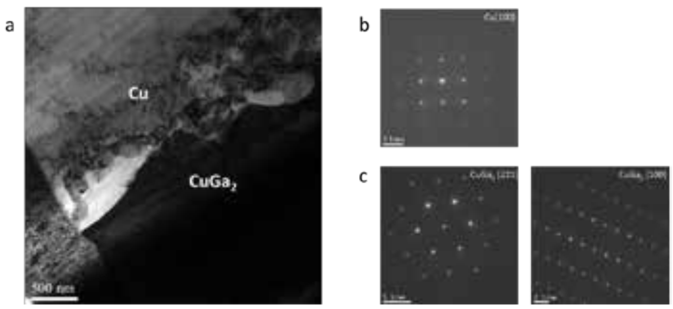
This research involved an analysis of the joint interfaces that resulted from reactions between Ga or Ga-based alloys and Cu substrates at both room and low temperatures. At CMM, the morphologies of the intermetallic compounds were observed using a Philips Tecnai F20 (TEM), FEI Scios FIB and JEOL JSM-6610 (SEM). Elemental distribution and phase identification were also carried out. Examples are shown in the figures below.

The outcome of this project is an advance in the current knowledge and the development of techniques for optimizing the alloy design for industry use. We gratefully acknowledge financial support from the University of Queensland-Nihon Superior collaborative Research Program.

S. Liu is financially supported by a University of Queensland International Scholarship and a China Scholarship Council Scholarship.



SEM image of Ga-Cu IMCs on a Cu substrates (top-view)



Interfacial microstructure of the pure Ga-Cu IMC on a Cu substrate (a) TEM image; (b) Cu selected area electron diffraction (SAED) pattern and (c) $CuGa_2$ SAED pattern at different zone axes

Fabrication of highly compact $CH_3NH_3Sn_{0.5}Pb_{0.5}I_3$ perovskite thin films for efficient solar energy generation

(This research is part of Miaoqiang Lyu`s PhD thesis under the supervision of Professor Lianzhou Wang)

Lead halide perovskites are emerging as a promising candidate for next generation photovoltaics in addressing the global challenge of renewable energy utilization. This project aims to develop a solution-processable, compact and low band-gap perovskite thin film for photovoltaic application. To reduce the energy band-gap, partial replacement (50% in this work) of the traditionally adopted $CH_3NH_3PbI_3$ perovskite is a viable approach. However, Sn (II) is not very stable in the ambient air and can be easily oxidized into Sn (IV). Therefore, proper characterizations are crucial to determine the film quality of the $CH_3NH_3Sn_{0.5}Pb_{0.5}I_3$ perovskite thin films, which in turn should be very important to improve the overall device performance.

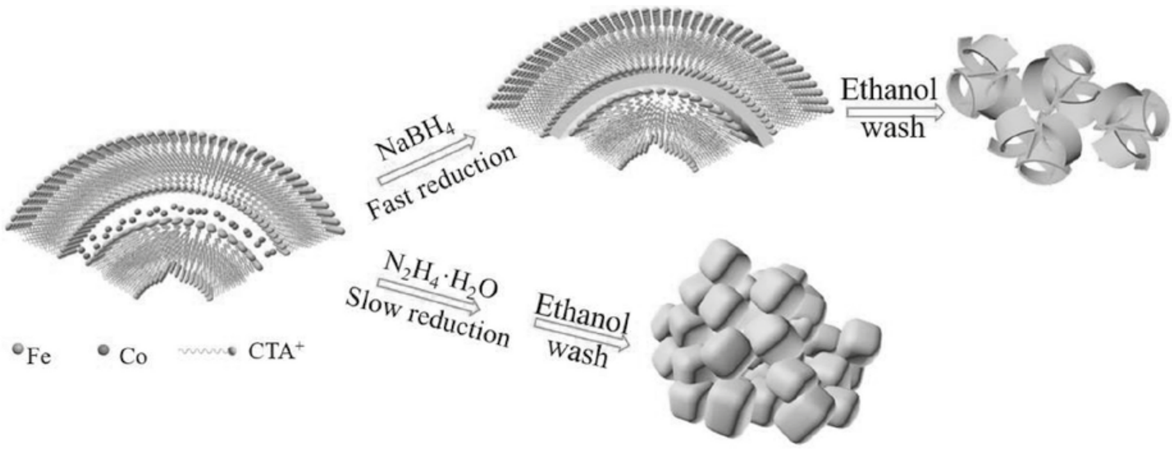
Powder X-ray diffraction (XRD, Bruker D8) spectra can be used to determine the phase purity of the as-prepared sample. XRD peaks around 14.04° and 27.96 ° (2θ) are corresponding to the (110) and (220) crystal planes, respectively, which confirms the perovskite structure of the as-prepared films. Field-emission scanning electron microscope (SEM, JEOL 7100) was employed to confirm the coverage of the perovskite thin-film on the substrate. As is shown in the SEM image, a full coverage was achieved, which can be of key importance in avoiding device failure due to unfavourable electric shortage. X-ray photoelectron spectrum was collected on an X-ray photoelectron spectroscopy (XPS, Kratos Axis Ultra), indicating the existence of Sn (IV) species in the thin film, which can be resulted from partially oxidation in the air. Understanding the amount of the Sn (IV) in the perovskite thin-film is important because these Sn (IV) species normally are detrimental to the device performance. In this project, the various characterizations of the $CH_3NH_3Sn_{0.5}Pb_{0.5}I_3$ perovskite thin films provide key information on the as-prepared sample as well as useful guidance to further optimize the experimental procedures. Finally, we achieved an efficient planar perovskite solar cell based on fully-covered, lead-reduced $CH_3NH_3Sn_{0.5}Pb_{0.5}I_3$ perovskite films by a fully low-temperature method.

Ultrathin iron-cobalt oxide nanosheets with abundant oxygen vacancies for the oxygen evolution reaction

Linzhou Zhuang, Lei Ge, Yisu Yang, Mengran Li, Zhonghua Zhu (The University of Queensland) Yi Jia, Xiangdong Yao (Griffith University)

Electrochemical water splitting has attracted substantial interest in recent years, as it offers possible means for large-scale storage of intermittent energy (e.g., solar and wind) in the form of hydrogen fuels (H_2). However, the development of promising water splitting technologies is limited by the sluggish anodic oxygen evolution reaction (OER), and a large over-potential (η) that requires big energy consumption to produce H_2 at a practical rate. Currently, RuO_2 and IrO_2 are the most widely used and efficient OER catalysts, but their mass application is limited by their scarcity, high cost and unstable catalytic performance. Therefore the development of highly efficient and stable OER catalysts, based on earth-abundant metals, will be key for improving hydrogen production capabilities.

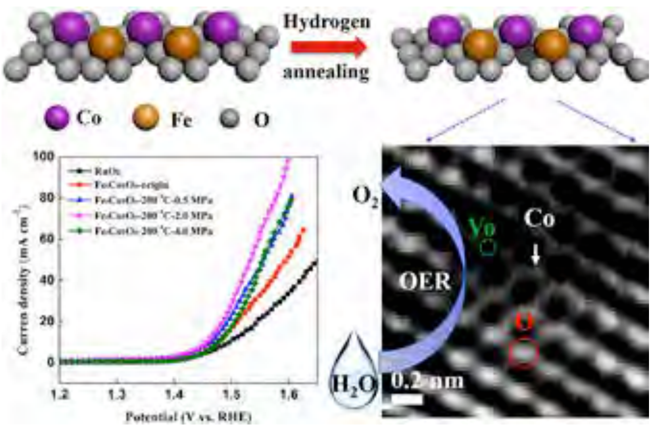
Techniques such as XPS and analytical EM are essential for determining the surface chemistry and chemical changes occurring in these samples and for designing better functional materials.



Schematic diagram of the preparation of Fe_1Co_1-ONS and Fe_1Co_1-ONP.

Tuning oxygen vacancy on 2-D iron-cobalt oxide nanosheets through hydrogenation for enhancing oxygen evolution activity

Linzhou Zhuang[1], Yi Jia[2], Tianwei He[3], Aijun Du[3], Xuecheng Yan[2], Lei Ge[1], Zhonghua Zhu[1], and Xiangdong Yao[2*]*
[1]School of Chemical Engineering, the University of Queensland, Brisbane, 4072, Australia
[2]School of Natural Sciences and Queensland Micro- and Nanotechnology Centre, Griffith University, Nathan Campus, 4111, Australia
[3]School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology, Gardens Point Campus, Brisbane, 4001, Australia



In electrocatalytic water splitting to hydrogen and oxygen, the oxygen evolution reaction (OER) is the rate-determining reaction. To design a high-performance OER catalyst, the strategy of creating and adjusting the oxygen vacancy has demonstrated to be effective. Herein, a hydrogenation method is applied to treat a 2-D iron-cobalt oxide ($Fe_1Co_1O_x$-origin), aiming to controllably tune its oxygen vacancies. Notably, compared with $Fe_1Co_1O_x$-origin, the hydrogenated iron-cobalt oxide at an optimized condition of 200 °C and 2.0 MPa exhibits a remarkably improved OER activity in 1.0 M KOH (an overpotential of 225 mV at a current density of 10 mA cm^2) and rapid reaction kinetics (Tafel slope of 36.0 mV dec^{-1}). Its OER mass activity is 1.9 times of $Fe_1Co_1O_x$-origin at an overpotential (η) of 350 mV. Experimental results and density-functional theory (DFT) calculations reveal that the optimal control of oxygen vacancies on the 2-D $Fe_1Co_1O_x$ via hydrogenation can improve the electronic conductivity and promote the OH^- adsorption onto nearby low-coordinated Co^{3+} sites, resulting in a significantly enhanced OER activity.

Unlocking high silica bauxite ore reserves through process technology innovation

Hong Peng, Dilini Seneviratne, James Vaughan, The University of Queensland - Rio Tinto Bauxite & Alumina Technology Centre

Processing high silica bauxite is costly to the Bayer refinery. This is due to loss of caustic soda for re-precipitation of dissolved silicates from kaolinite and quartz and higher neutralisation costs due to the presence of sodalite in the bauxite residue. The aim of this project is to facilitate a technological breakthrough that will significantly enhance Australia's bauxite mineral reserves and support the potential to expand the alumina industry. This will be achieved through the development of a new, innovative silicate management technology for the processing of existing bauxite mineral deposits. Recently, we have made a breakthrough on how to control and enhance the digestion and precipitation kinetics of silicate species in bauxite which has been published in the journals or conference proceeding:

In the first investigation as shown in Figure 1, we conducted the thermal activation of bauxite ore samples by heating samples from 25-650˚C to monitor the phase transformation using the Rigaku *in situ* XRD facility. The results show the different transformation pathway for gibbsite phase in the bauxite compared with pure gibbsite phase only. Different mineralogy of bauxite samples also affect the temperature of phase transformation.

In the second project, silicate in Bayer liquor precipitates in the form of crystalline aluminosilicates or zeolites known in industry as desilication product. Crystallisation of this product is being investigated by the team under different operating conditions to identify avenues for recovering soda locked in this product. Qualitative and quantitative X-ray diffraction are currently being utilised to identify and measure different zeolite and bauxite mineral phases and investigate zeolite phase transformations over time as shown in Figure 2.

The project is funded by Advance Queensland Research Fellowship through Queensland Government and Rio Tinto as industry partner.

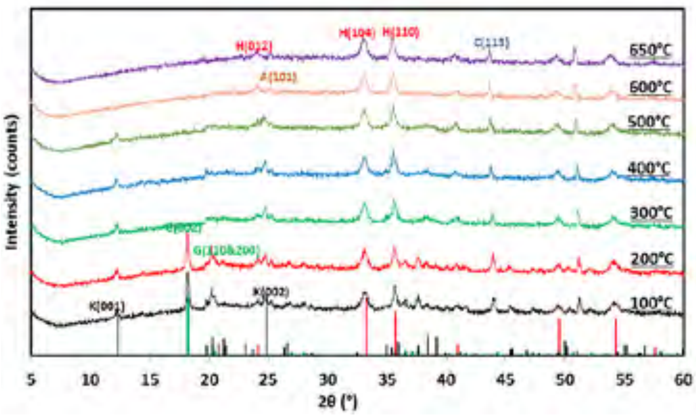


Figure 1: In situ XRD patterns of heat treated bauxite with increasing temperature (Black line(K): kaolinite; Red line(H): Hematite; Green line(G): Gibbsite; Brown line(A): Anatase; Blue(C): corundum).

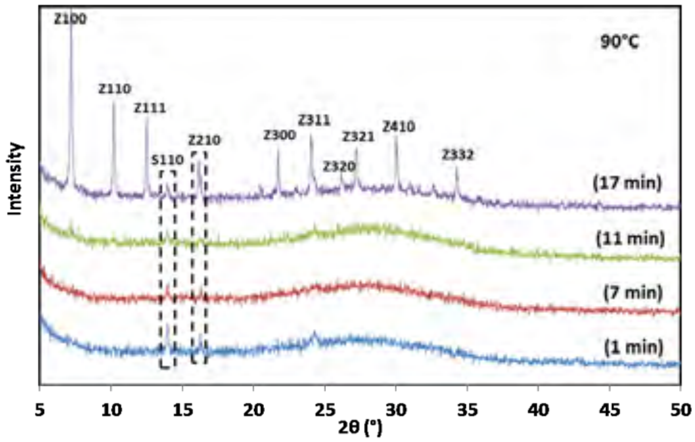
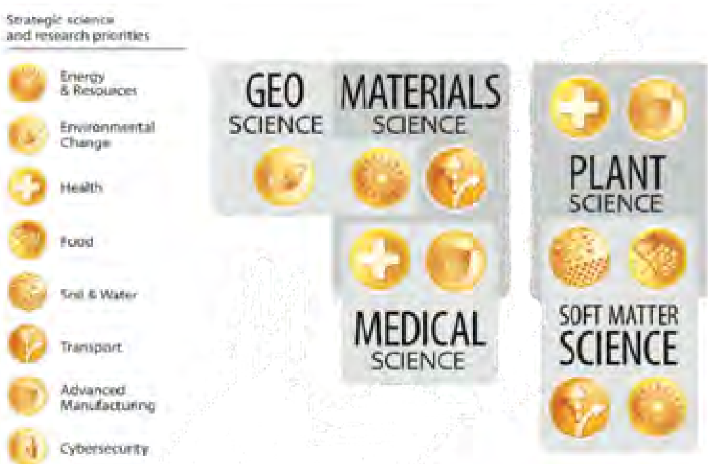


Figure 2. XRD patterns of solid samples as a function of time during amorphous formation and dissolution. Z = zeolite A, S = sodalite.



Looking to the future, CMM research will continue to contribute to strategic science and research priorities in the areas of geo, materials, plant, medical and soft matter science.


04

TRAINING, OUTREACH & EVENTS

In addition to its comprehensive instrument training timetable, both one-on-one and courses, CMM is committed to sharing its expertise via seminars, workshops, networking events and outreach activities.

Highlights in 2017 included participation at the World Science Festival and the Australian Microbeam Analysis Symposium, and the inaugural CMM User Assembly.

Occupational Health & Safety

In 2017 all CMM OH&S goals were achieved. CMM was audited by OHS Division. Auditors reported CMM demonstrated effective implementation of the UQ's health and safety systems in all audit criteria. All seven recommended improvements were achieved by the close of 2017.

Substantial changes to the workplace required modification and development of new safety systems. The Hawken refurbishment resulted in the closure of the Hawken facilities and opening of two additional laboratory sites. A record number of 472 inductions were undertaken in 2017.

247 individuals completed **472** laboratory inductions over **6** sites

300+ laboratory workers accessed CMM facilities

111 (100% approved, 68% audited) active risk assessments from CMM staff group

CMM Training workshops

In February a pre-conference Australian Microbeam Analysis Society (AMAS) one day workshop on cryo-SEM was run by CMM across the Hawken and IMB laboratories.

The workshop had the following aims: to provide information and guidance on the requirements to set up a state-of-the-art cryo-SEM facility; and to increase awareness of image and analysis artefacts associated with the technique. CMM staff experts presented to the seven local and interstate participants, a series of three 45 minute lectures: (1) An Introduction to Cryo-Scanning Electron Microscopy by Kim Sewell; (2) Biological Cryo-EM Techniques by Matthias Floetenmeyer; and (3) Cryo Preparation for cryo-FIB/SEM by Roger Wepf. Afternoon practical small group activities included Kim Sewell and Roger Wepf setting up and operating cryo-SEMs to image and analyse a diverse range of carefully-selected samples; and Matthias Floetenmeyer and Kathryn Green demonstrating advanced cryo-fixation techniques including high pressure and ethane plunge freezing – and much more. Participants left the workshop with an extensive amount of cryo-SEM related reference and video resources. The strong support of this inaugural (for CMM) cryo-SEM workshop by participants from other electron microscope facilities is evidence of the likely future growth of the discipline.

Further to these special workshops, CMM run group and individual training sessions throughout the year. In 2017 173 people attend 15 training sessions, with a further 365 people attending training workshops.

CMM outreach & events

Australian Microbeam Analysis Society (AMAS) Symposium 2017

The 14th Biennial Australian Microbeam Analysis Society (AMAS) Symposium was hosted by the Queensland University of Technology and The University of Queensland from 6-10 February 2017. The five day program, which included two days of workshops, featured a lineup of international speakers including Professor Silke Christiansen (Freie University, Germany) and Dr Ed Vicenzi (Smithsonian Institution's Museum Conservation Institute) and Masashi Watanabe, President of the Microanalysis Society USA and Director of the Electron Microscopy and Nanofabrication facility at Lehigh University (USA). The three keynote speakers were joined by nine invited speakers from Australia, Canada, Germany, Spain, UK, and USA.

A particular highlight of the symposium was an entertaining presentation on the *500 Years of Glass in 45 Minutes* by Andy McConnell, a world authority on glassware and BBC TVs first specialist recruited to Antiques Roadshow. Andy's expertise ranges from glassware of all types ranging from 1650 to present.

Workshops held on Monday 6 and Tuesday 7 February, included two hosted by The University of Queensland and CMM on *Focused Ion Beam Systems: Theory, Simulation and Application (FIB/HIM/SRIM)* undertaken by Dr Lena Wolff and Dr Hui Diao and *Cryo-SEM* delivered by CMM's Dr Kim Sewell.

One side of the two-story 'cube' showing the dinosaur landscape scene (left) and the interactive panels (right) at the QUT venue for the 14th Biennial Australian Microbeam Analysis Symposium.

CMM at the World Science Festival 2017

As part of the World Science Festival (WSF) at the Queensland Museum (QM, 25 and 26th March 2017), CMM presented a Microscopy and MyScope™ Outreach activity and display. A prominent backdrop feature of the display was a huge (10m long x 2m high) wall-mounted vinyl banner titled *The Incredible Power of Microscopy* that was conceived and designed by Roger Wepf. The banner had a 'Power of Ten' theme that illustrated the journey from Meter (m) to Pico-Meter (pm) and Quarks and, which linked appropriately to the nearby QM Large Hadron Collider display. A large activity station featured eight computers running the free online MyScope Outreach website developed by the Australian Microscopy and Microanalysis Research Facility (AMMRF) and FEI company and two benchtop scanning electron microscopes (SEMs) loaned from Hitachi Australia via NewSpec.

Technical aspects of the display were expertly organised and monitored by CMM's own IT wizard, Andrew Stark. The entire display ran reliably and efficiently off a single cached server PC and used very little bandwidth from a SIM i.e. 2.6 gB over the whole weekend. This IT setup meant that we were independent of the limited bandwidth public WiFi at the QM. Loops of interesting and exciting microscope images were run continuously via several Raspberry Pi mini-computers on several big screen monitors positioned at the top of the display. Andrew is happy to provide details of this relatively straightforward and mainstream setup (according to him, at least) to anyone who may be interested in a similar outreach presentation.

There were some 180 to 200 visitor or visitor group interactions, each of about 15 minutes duration, conducted on each of the two days of the display weekend. Visitors were guided through the use of the impressive Myscope Outreach Scanning Electron Microscope (SEM) simulator and allowed to experience the excitement of scientific discovery with real-world light and electron microscopy samples and activities. Over the weekend, expert CMM staff and volunteers (comprised variously of Roger Wepf, Andrew Stark, Caterina Cadaras, Heike Bostlemann, Bronwen Cribb, Rick Webb, Ron Rasch, Rob Gould, Matthias Floetenmeyer, Kim Sewell Ying Yu, Gordon King, and Eunice Grinan); and Newspec staff (Martin Cole) facilitated a range of engaging imaging activities involving USB light microscopes and the two Hitachi SEMs. The activities included high magnification light microscope and benchtop SEM viewing of biological samples such as food mould, native bees, butterfly wings, mother-of-pearl and gecko feet, and the use of X-ray microanalysis to quickly and safely determine the elements in gold, fool's gold and meteorite samples. Younger visitors were particularly keen to investigate and capture images of their own skin, hair and clothing using hand held USB microscopes. The large range of real and virtual microscopy options available to the display staff meant that interactions were able to be expertly tailored on-the-fly for visitors to accommodate specific interests and preferences. Overall, it was an extremely successful, although exhausting, two days of public outreach that CMM looks forward to repeating in 2018.

Frontiers in Microscopy and Microanalysis

The Frontiers in Microscopy and Microanalysis seminar series introduces students and staff to advances in microscopy and nanoscopy with an emphasis on light microscopy, electron microscopy and analysis, as well as x-ray microscopy and x-ray analytical methods. Both methodological and technological progress and applications in various scientific fields are discussed.

Highlights of the 2017 series are listed below.

» Prof. Rafal Dunin-Borkowski
Electron Microscopy at the Forefront-ERC Operation and Science

» Dr Yannick Schwab
Capturing rare cells in heterogeneous samples with Correlative Light and Electron Microscopy (CLEM)

» Professor Alex de Marco
Optimal FIB milling in life sciences and nanofab

» Professor Rob Parton, CMM
Quantitation in Biological Electron Microscopy

» Falk Lucas, ScopeM – ETH Zürich, Switzerland
PPMS in the real world

» Dr Miriam Lucas, ScopeM – ETH Zürich, Switzerland
3D CLEM: targeted volume SEM

» Antonin Doupal, TESCAN
Increasing the Performance and Analytical Power of FIB-SEMs

» Dr Felix Leyssner
NAP-XPS/SPM & EnviroESCA TM Systems

» Dr Sandrin Eeig (University of Tasmania)
Optimising EPMA MicroProbe Analysis

» David Hoyle (VIC Canada), Dr H Inada (Naka Japan), Dr T Yaguchi (Naka Japan)
Inauguration Seminar for our 2 new HT 7700 S/TEM from Hitachi

» Dr. Richard White
Recent Advances in Surface Analysis from Thermo Fisher Scientific

Inaugural User Group Assembly

CMM's commitment to research excellence has been constantly delivered upon for over 50 years at UQ. Sharing research outcomes through a program of outreach and engagement allows for knowledge transfer between CMM's analytical staff and end users.

Through 2017 CMM hosted a number of events and training programs to share knowledge and facilitate research discussion among users, encouraging new capabilities and collaborations.

CMM held its inaugural *User Assembly* in December 2017. The aim of the assembly was to create an environment for research stakeholders to present their research and provide an opportunity for networking.

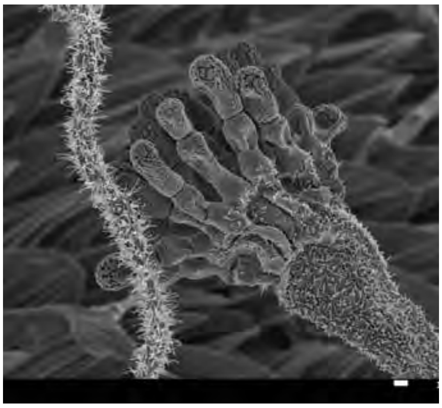
At the inaugural event, CMM Director, Professor Roger Wepf welcomed guests to UQ's Queensland Bioscience Precinct auditorium where staff, students, collaborators and guests heard a keynote address from Professor Refal Dunin-Borkowski, Director of the Institute for Microstructure Research and the Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons (ER-C), Forschungszentrum Jülich (Germany), who talked to the title *Electron microscopy at the forefront – ERC operation and science*. This keynote address was followed by seven CMM users discussing their own research, plus talks by CMM Laboratory Managers on their laboratories and facilities.

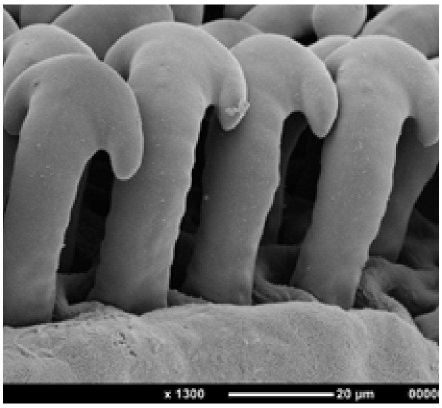
The December 2017 User Assembly was the first in what will become a flagship symposium event for CMM and its users.

Image of the month

In 2017 CMM continued it's Image of the Month competition. CMM clients enter the competition by submitting an image that they have taken on one of the instruments. The monthly winner has their image displayed on the banner of CMM's website and included in the online gallery. This is a great way to exhibit the images taken on CMM instruments and continues to build the connection between staff and clients.

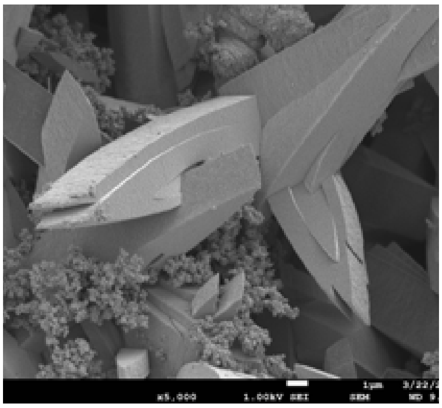
View our full gallery on https://www.flickr.com/photos/cmmatuq

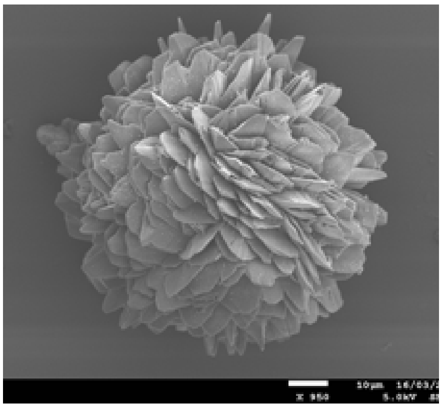




January Winner 2017 (left)
Image taken by CMM Affiliate Dr Bronwen Cribb on the JEOL7001 FE SEM. The hand-like structure is made up of fungal conidia (spores) at the end of a hypha. The fungus is growing on the surface of an insect antenna.

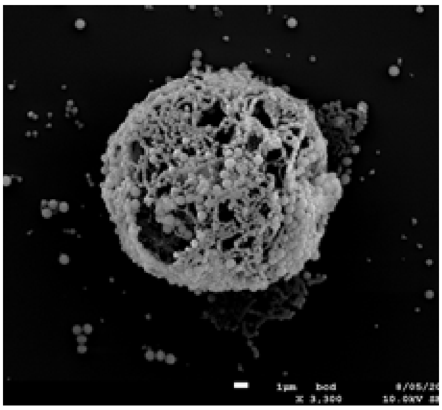
February Winner 2017
Image taken by Michael Tianyi Feng on the Jeol Neoscope JCM 5000. The image shows the cincinnuli (minute interlocking hooks) on the petasma (male genital) of a black tiger prawn. You can also see some bacteria attached on the surfaces of the cincinnulus.

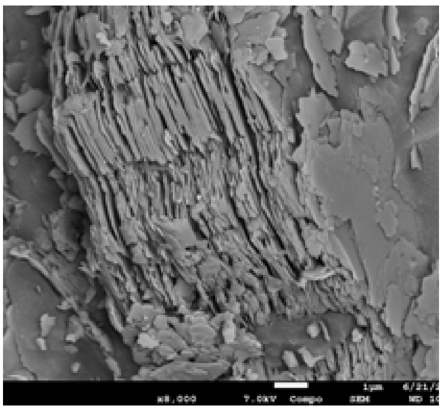




March Winner 2017 (left)
Image taken by Linzhou Zhuang on the SEM JEOL 7001F. It shows the morphology of cobalt-ABDC metal organic framework which is taken with the voltage of 5.0 keV, working distance of 10 mm and spot size of 8.

April Winner 2017
Image taken by Heike Bostelmann on the JEOL 7100. It shows intergrown blades of a mineral that formed in a system modelling copper mineralogy in complex weathering conditions.

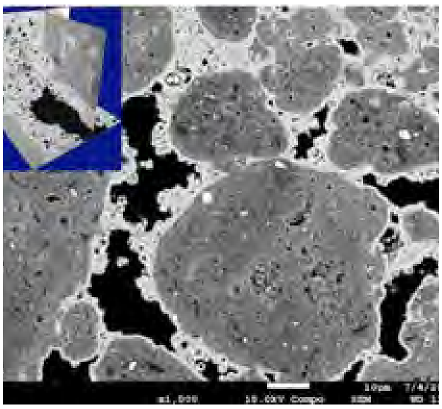


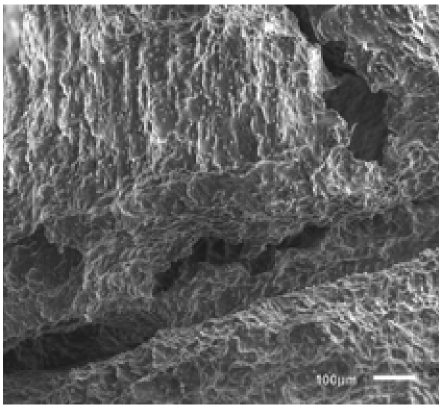


May Winner 2017 (left)
Image taken by Dr. Bogdan Donose on the JEOL 7001 FEG: "Colloidal bird's cage"- a silica nano-particles aggregate.

June Winner 2017
"Book of Clay Tablets" - a compositional back-scattered electron image of frozen sheets of kaolin clay taken by taken Di Liu on the JEOL JSM 7100F / Alto 2500 Cryo-SEM.

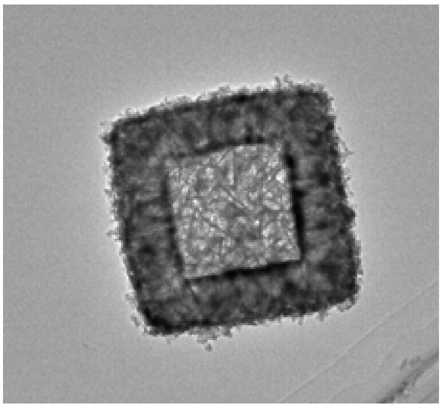
“Win a free Cafe Nano Coffee Card every month. Submit your image(s) and the CMM steering committee selects the winner of the month.”

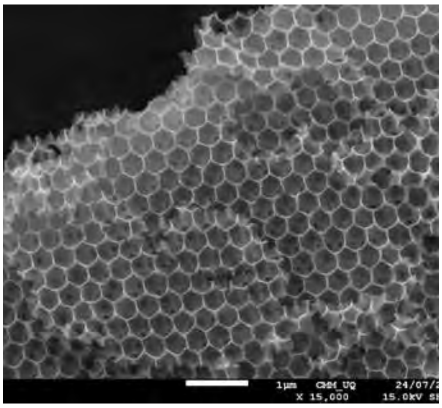




July winner 2017 (left)
Image taken by Alan Levett on the JEOL 7100. Microbial cement - Microorganisms within iron-rich environments may become encrusted in iron oxide minerals. The 3D model allows us to investigate the timing of fossilisation and indicates that microorganisms are preserved in separate generations. For example, the replication of microorganisms gradually infills the pore spaces between grains, creating a ‘microbial cement.’

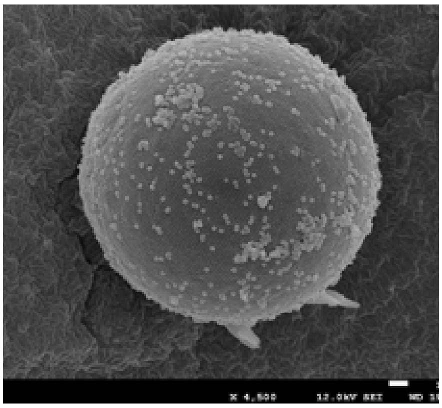
August winner 2017
Image taken by Akif Soltan on the JEOL 6610. It is the corrosion morphology (corrosion cavity to be precise) of an unalloyed Mg sample after 3 weeks of corrosion testing in NaCl solution.

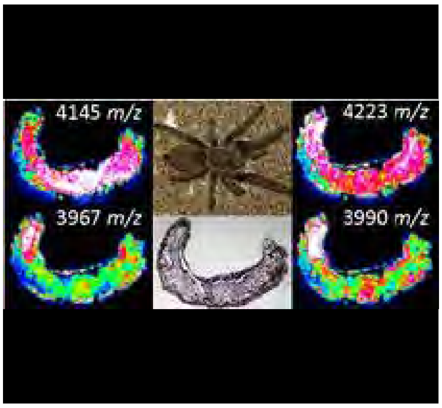




September winner 2017 (left)
Image taken by Yilong Yang on the JEOL 2100. It is the morphology of a ZIF-67 nanocubic sample after phosphidation. It shows a Co2P-nanosheet shell structure.

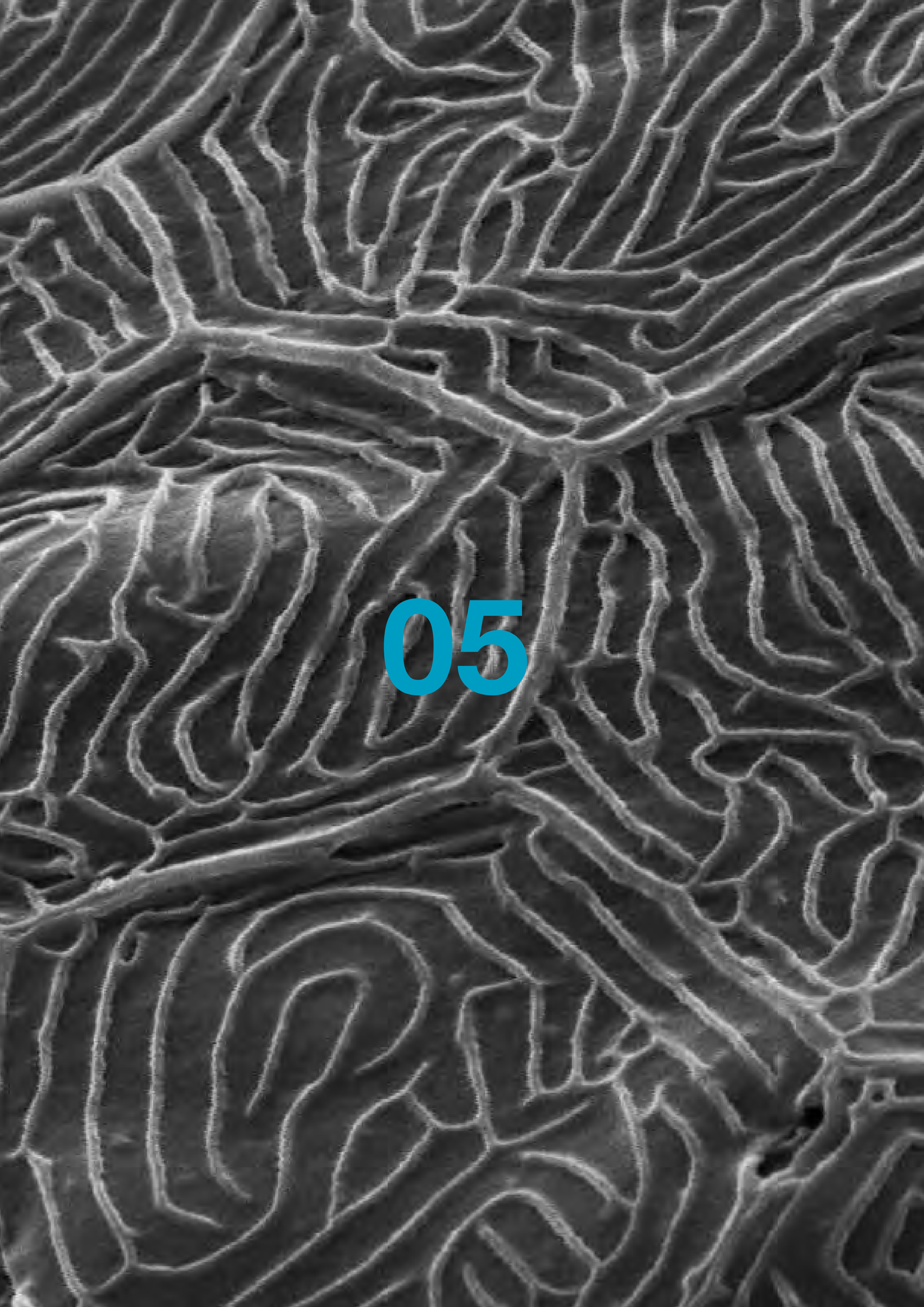
October winner 2017
This image was taken by Min Hong using the SEM JEOL 7001. The sample is the inverse opal photonic crystal designed for energy storage application.





November winner 2017 (left)
This image was taken by Nikhil Aravindakshan using the SEM JEOL 7001. The sample is a Photonic crystal bead where polystyrene nanoparticles self-assemble to form beads.

December winner 2017
This image was taken by Renan Castro Santana using MALDI imaging as a part of a study into the regeneration of venom, after venom exhaustion, by Tarantula Spiders from North Queensland. The spatial resolution was 40 um for this experiment



05

PUBLICATIONS

To keep an accurate record of research output that has invoiced CMM infrastructure and expertise, we ask that our users cite CMM facilities in their publications. This provides a useful overview and feedback on the requirements of researchers, allowing us to respond to user needs.

CMM affiliated publications

5 Book chapters

69 Bio/Med journal papers

15 Env/Geo journal papers

241 Phys Sci/Eng journal papers

11 Conference papers

Book Chapter

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06

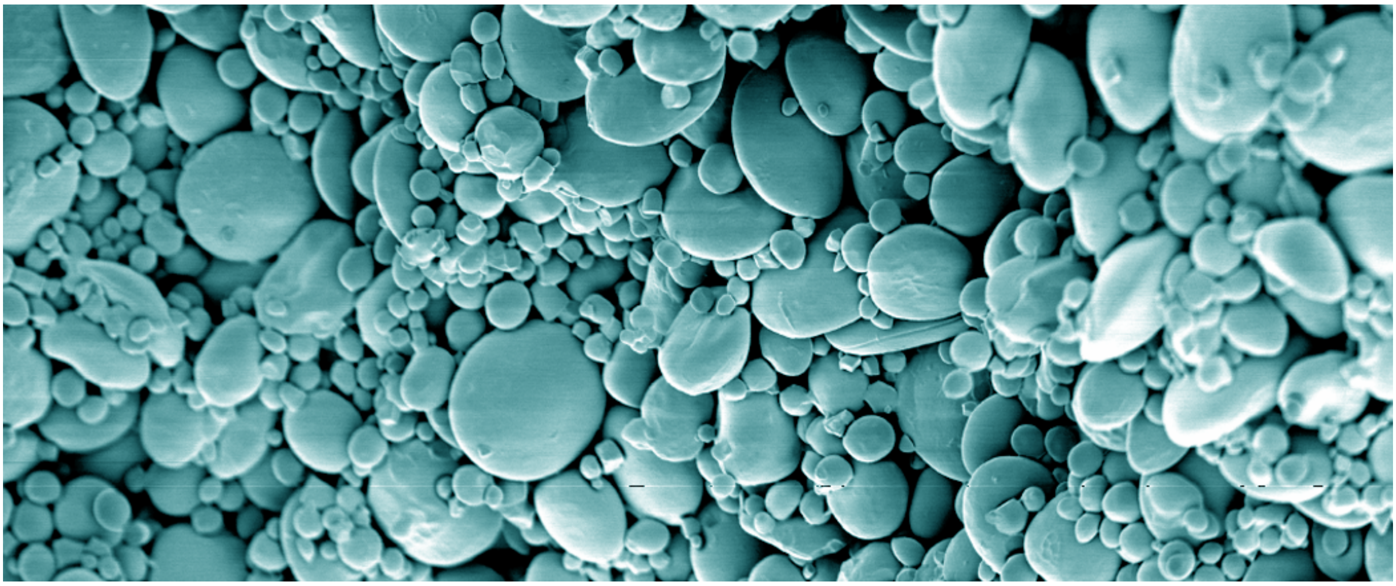
FINANCE

2017 Operational funding

REVENUE	
Fees and Charges	672,071
Other Income	32,831
Defined Central Funding Scheme	1,004,742
Operating Level Allocations	2,763,144
Executive Level Allocations	15,251
TOTAL REVENUE	*4,488,038*
EXPENDITURE	
Academic Salaries	1,031,497
General Salaries	1,456,004
Other Employment Costs	2,187
General Operating Expenses	239,070
Professional & Other Services	249,459
Equipment & Minor Works	1,376,060
Travel	64,744
Hospitality	20,321
Other Expenses	7,292
TOTAL EXPENDITURE	*4,446,635*
Operating Result	***41,403***

2017 Restricted funding

REVENUE	
Research Income	401,182
Investment	4,189
Other Income	8,532
Defined Central Funding Scheme	25,000
Operating Level Allocations	10,000
Executive Level Allocations	15,000
TOTAL REVENUE	*463,903*
EXPENDITURE	
Academic Salaries	72,149
General Salaries	263,135
Other Employment Costs	1,032
General Operating Expenses	7,543
Professional & Other Services	-
Equipment & Minor Works	109,616
Travel	10,213
Hospitality	-
Other Expenses	-
TOTAL EXPENDITURE	*463,687*
Operating Result	***216***



List of figure captions

GROUP PHOTO OF THE 4TH CMM TEAM RETREAT EVENT

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venom
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Front cover image taken by CMM Affiliate Dr Bronwen Cribb on the JEOL7001 FE SEM. The hand-like structure is made up of fungal conidia (spores) at the end of a hypha. The fungus is growing on the surface of an insect antenna.