ANFF

Australian National Fabrication Facility

10 years of ANFF

CASEBOOK 2017

Ten years of ANFF

• ANFF CEO Rosie Hicks (far left), with the ANFF Board Members (from left to right: Dr Robert Frater, Prof Chris Fell, Andrew Brawley, Dr Elaine Saunders, Dr Deborah Rathjen, and Dr Rowan Gilmore. Dr Colin White not pictured.)

A Decade of Achievement

A decade ago, a group of Australia's most distinguished nanotechnology researchers developed an investment plan for the Australian National Fabrication Facility (ANFF), one of the original nine research infrastructure facilities established under the Commonwealth's National Collaborative Research Infrastructure Strategy (NCRIS). It was a highly collaborative meeting and promised much for the future.

With financial support from Commonwealth and State Governments, CSIRO and participant universities, ANFF has grown to a $250 million operation to provide the infrastructure needs of more than 2,500 researchers who complete over 10% of Australian Research Council supported research and have been successful in launching a score of commercially successful enterprises.

ANFF's future lies in continuing to support cutting-edge research and in fostering the translational science and engineering necessary to take breakthrough science through to real benefit for mankind. This research embraces the great majority of Australian research priorities identified by the Commonwealth.

Please do take every opportunity to learn what each node is doing, whether this is through ANFF's Research Showcases and Casebooks, or by engaging in discussions with the many experts at the ANFF nodes about how your research infrastructure needs can be best supported.

The Board of ANFF, comprising senior industry figures, congratulates ANFF's management, Node Directors and staff on what has been and is being achieved and wishes ANFF's users good fortune in their research.

Emeritus Professor Chris Fell AM FTSE HonFIEAust CPEng
Chairman. Australian National Fabrication Facility

Ten years of impact

ANFF has turned 10. It's fantastic news, and a perfect opportunity to look back at our first decade of operations.

ANFF was established to provide access to micro and nanofabrication equipment, essential to Australia's scientific future. Simply creating a national network unlocked the potential of existing infrastructure, with the use of these facilities more than doubling in the first year. ANFF now plays a critical role in translating ideas into products and the development of tech-based start-ups.

We've become an established part of the scientific community. In the 2017 alone, ANFF has enabled more than 2,500 researchers from academia and industry to develop their various projects, resulting in 677 peer-reviewed publications.

2017 has also seen the welcome release of the Australian Government's 2016 Research Infrastructure Roadmap. The Roadmap identifies advanced fabrication and manufacturing as one of the nine priority areas in which Australia's internationally significant research underpins innovation, economic growth and societal benefit. New capital investment to enable ANFF to remain at the forefront of micro and nanofabrication is vital for our continued success in the next 10 years.

This year's casebook demonstrates the range of the research being conducted across the network – readers will have to forgive a bit of nostalgia, with a few pages dotted throughout to celebrate the past 10 years.

On a personal note, ANFF's first 10 years have been an amazing experience, as I'm sure the next 10 will be too.

I'm proud to say I've been here from the start.

Rosie Hicks, *Chief Executive Officer,*
Australian National Fabrication Facility

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NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

ANFF

Australian National Fabrication Facility Ltd
151 Wellington Road
Clayton VIC 3168
T: +61 3 9902 9619
E: info@anff.org.au
www.anff.org.au

Credits
Editor
Tom Eddershaw
Design
Peta Blackwell

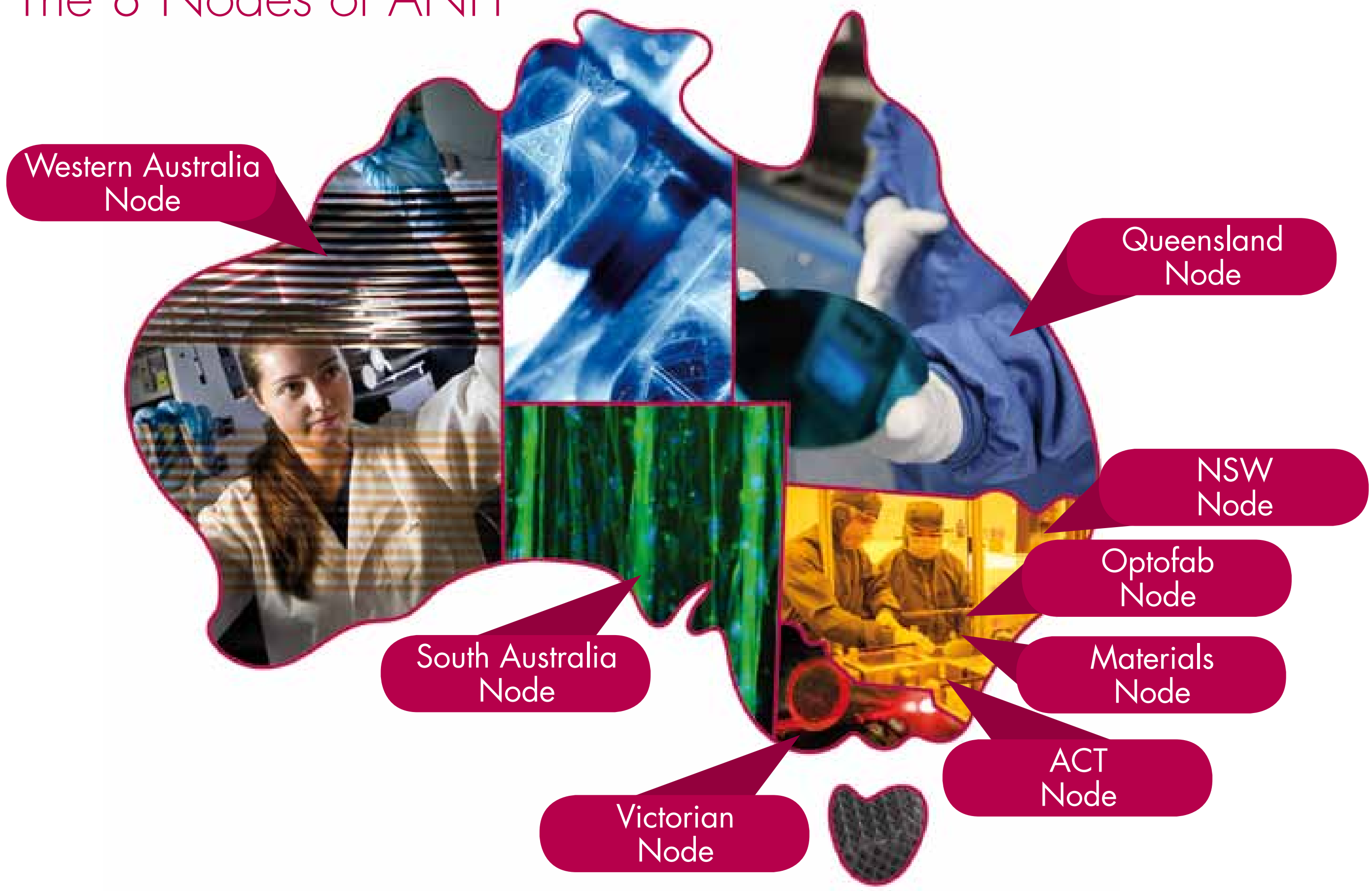
Snapshot of ANFF

ANFF was established under the Australian Government's National Collaborative Research Infrastructure Strategy (NCRIS).

ANFF's mission is to provide micro and nano fabrication facilities for Australia's researchers, SMEs and start-up companies.

Over 500 facilities are located across 21 institutions around Australia in a national network of 8 nodes. Each node offers complementary specialised manufacturing facilities supported by trained staff.

The 8 Nodes of ANFF



ANFF in numbers

2017 was yet another strong year for ANFF, here's a few of the stand out statistics.

24+ years

ANFF TOOLS WERE BEING USED FOR A TOTAL OF 215,625 HOURS, WHICH EQUATES TO MORE THAN 24 YEARS

677

ANFF HAS REPORTED 677 PEER-REVIEWED PUBLICATIONS

↑ 12%

THE ANFF USER BASE HAS RISEN BY 12% WHEN COMPARED TO 2016

2,969

A RISE OF NEARLY 30% SAW 2,969 PEOPLE TRAINED IN ANFF FACILITIES, UP FROM 2,285 LAST YEAR

↑ 5,000+

INDUSTRY USAGE OF ANFF HAS INCREASED BY MORE THAN 5,000 HOURS OF TOOL TIME

↑ 26%

870 COLLABORATIVE PROJECTS WERE REPORTED THAT ANFF WAS INVOLVED IN, UP FROM 689 LAST YEAR

Meet with ANFF in 2018

Throughout 2018, there's going to be a number of opportunities to engage with ANFF experts, away from the office. Here's a few highlights.

ICONN 2018

ANFF will be exhibiting at Australia's leading nanoscience and nanotechnology conference, ICONN 2018.

This event will focus on new materials, technology, medical advances, electronics, and photonics that rely on an understanding of the nano-world.

International Conference on Nanoscience and Nanotechnology
29 January – 2 February 2018
University of Wollongong, AUSTRALIA

ANFF Winter Schools around the country

There are now two ANFF nodes offering Winter Schools to provide students and researchers with an insight into what nanofabrication is capable of.

A mixture of talks, workshops and practicals give scientists of any level hands on experience in the lab and demonstrate how nanofabrication can help in a variety of applications.

Dates are yet to be confirmed, but contact either ANFF SA or ANFF NSW staff to find out more.

The 2018 Research Showcase

Keep an eye out for details for the 2018 Research Showcase, which, as always, will highlight some of the research enabled by the ANFF nodes around Australia.

Details will be announced around August 2018.

ANN Short Term Travel Grants

In 2018, researchers can take advantage of the Australian Nanotechnology Network (ANN) new grants system that will enable early career researchers and postgraduate students to travel to the centres within the Australian National Fabrication Facility (ANFF).

The grant covers up to $1,000 in travel and accommodation for successful applicants. To qualify for the grant, the applicant must: be a postgraduate student or early career researcher currently studying/working in Australia in the area of nanotechnology; be a member of ANN; and have documented support from Supervisor and ANFF Node Director/Manager.

Visit www.ausnano.net/content/ANFFshort_term_visits for more info.

ACT NODE

Research School of Physics & Engineering
The Stores, End of Garran Road
Australian National University
Canberra ACT 0200

Node Director: Prof Chennupati Jagadish
Email: chennupati.jagadish@anu.edu.au
Phone: +61 2 6125 0363

Facility Manager: Dr Fouad Karouta
Email: fouad.karouta@anu.edu.au
Phone: +61 2 6125 7174

• An ANU team has been investigating hBN thin films grown using MOCVD on a sapphire substrate. Credit: Dipankar Chugh

Fabricating a flexible future

A year-long investigation into hexagonal boron nitride (hBN) has seen Dipankar Chugh, a PhD candidate at ANU, optimise the production of flexible 2D materials.

The reliable fabrication of thin films of versatile semiconductors, such as hBN, is enabling the creation of new generations of flexible electronics. The resulting devices are finding applications in many areas including opto-electronics, wearables, and renewable energy.

With their huge potential beginning to be realised, it's now vitally important that the growth process is understood in order to improve the fabrication and capabilities of these devices.

Dipankar and his colleagues have been studying and optimising the growth of hBN on a sapphire substrate using ANFF ACT's state-of-the-art Metal-Organic Chemical Vapour Deposition (MOCVD) system.

MOCVD works by introducing precursor molecules into a reactor in the form of a gas, where individual molecules separate and begin to coat a heated substrate.

By breaking the fabrication process down, the group has been able to improve the crystallinity of hBN layer and minimised impurities in the deposited films – characteristics that are critical for many of the envisioned applications for hBN.

"Determining the right conditions for growing the crystal often involves optimising a lot of different parameters, such as temperature, gas flow rates, pressure, substrate pre-treatments etc.," Dipankar explained.

Triethyl boron and ammonia are introduced to the MOCVD reactor to provide the required boron and nitrogen to make a hBN layer – ideally the gases mix at the surface of the substrate to create a consistent layer. However, if these two precursors are added at the same time, they can react prematurely and fail to attach to the substrate surface.

The team found that flow modulation growth – introducing the two ingredient gases alternatively in short bursts – was a fantastic way to optimise the introductory phase. Extensive characterisation of each film, using techniques including x-ray diffraction, optical spectroscopy, and transmission electron microscopy, was conducted to evaluate material quality.

The next stage is to use the MOCVD system to investigate the growth of device structures, such as solar cells, photodetectors and laser diodes.

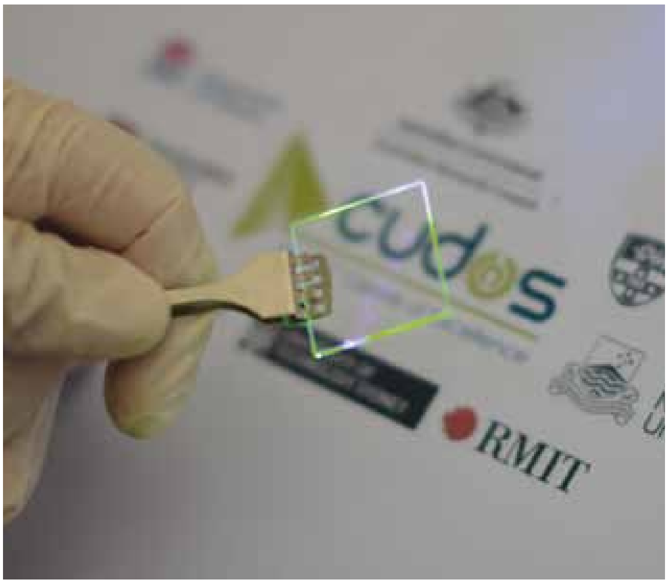
The light at the end of a 50-year tunnel

Australian National University (ANU) researchers have solved the 50-year problem of embedding nanocrystals into glass.

The crystals can amplify minimal amounts of light to create night vision glasses that are cheap, robust and available at a size that's practical for everyday use.

The research opens the door to car windscreens, conventional glasses, or camera lenses that allow the user see in the dark.

Conventional night vision takes a series of infrared photographs, converts them to an electrical current and then recreates the images in front of the wearer's eye using visible light.



• *Embedding nanoparticles in glass could enable widely useable night vision. Credit: Dragomir Neshev*

However, a team led by Professor Dragomir Neshev from ANU began investigating nanocrystals of a semiconductor material called aluminium gallium arsenide (AlGaAs).

The crystals absorb IR and emits visible light to passively reproduce the same effect as conventional night vision, but with greater efficiency, accuracy, and without requiring cumbersome packaging.

"We are currently working with a company leader in night vision to enable prototyping of the technology," Dragomir said.

It was theorised 50 years ago that III-V semiconductor crystals could be used to change the colour of light efficiently, but it's particularly difficult to grow high-quality crystals directly on glass substrates. This is largely due to the challenges of matching the crystal orientation of the nanoparticles with the orientation of the substrate.

The ANU team found a way to circumvent the issue.

Instead of growing the crystals directly on a glass substrate, the researchers creating them separately and then transferred them onto the glass substrate using the hot-embossing capabilities at ANFF ACT.

Samples were fabricated at ANFF ACT, working with staff to perfect the fabrication process. "Realising such samples can only be done at ANFF and this project is heavily reliant on ANFF," Dr Moshen Rahmani, the scientist who developed the fabrication recipe, said.

The team's fabrication process is already patented in the USA and Australia. With new potential applications being investigated, such as nonlinear holograms which could be used as security markers, or to increase the focus of light for microscopy purposes, it won't be long until these crystals are lighting up a range of industries.

Temperature dependant mirrors

ANU researchers have invented a material that can behave as a window or a mirror, depending on its temperature.

The new nanomaterials are thin, hundreds of layers of it can fit on the tip of a needle, and they can be applied to any surface.

The group created an array of nanoparticles on a thin film. The nanoparticles are disk-shaped, just hundreds of nanometres wide, and were fabricated using ANFF ACT's electron beam lithography and reactive ion etching equipment.

When heated or cooled, the optical properties of the nanoparticles change, meaning they can reliably and reversibly be manipulated to allow light to pass or reflect it.

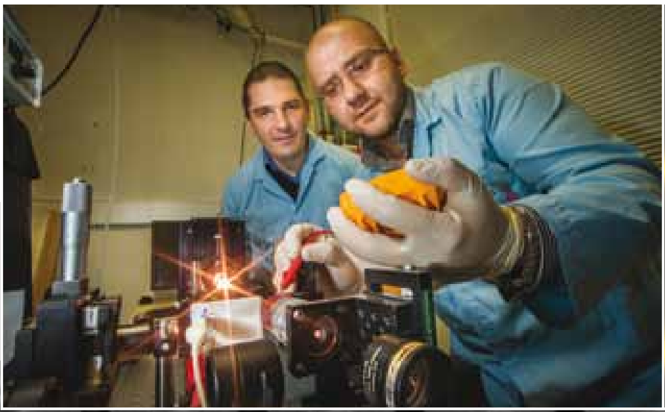
"By controlling the temperature of the nanoparticles, we managed to tune the refractive index of them. By employing this tunability we designed and fabricated resonant nanoparticles, which can act differently before and after heating," said Dr Mohsen Rahmani, lead author of the research and an ARC Discovery Early Career Research Fellow at the Nonlinear Physics Centre.

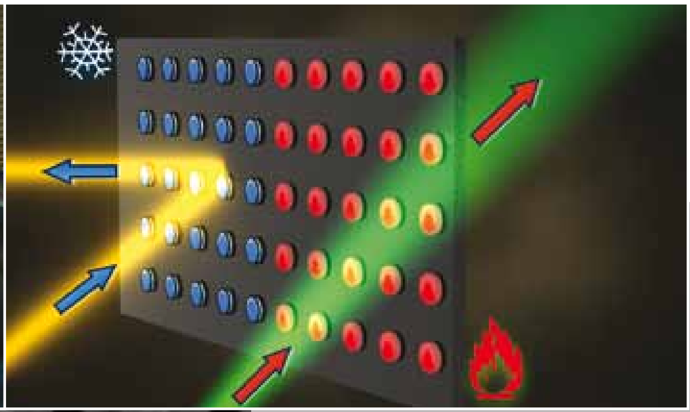
The team proved the concept using infrared light, commonly used in telecoms applications, and silicon nanoparticles that are lossless in this wavelength range.

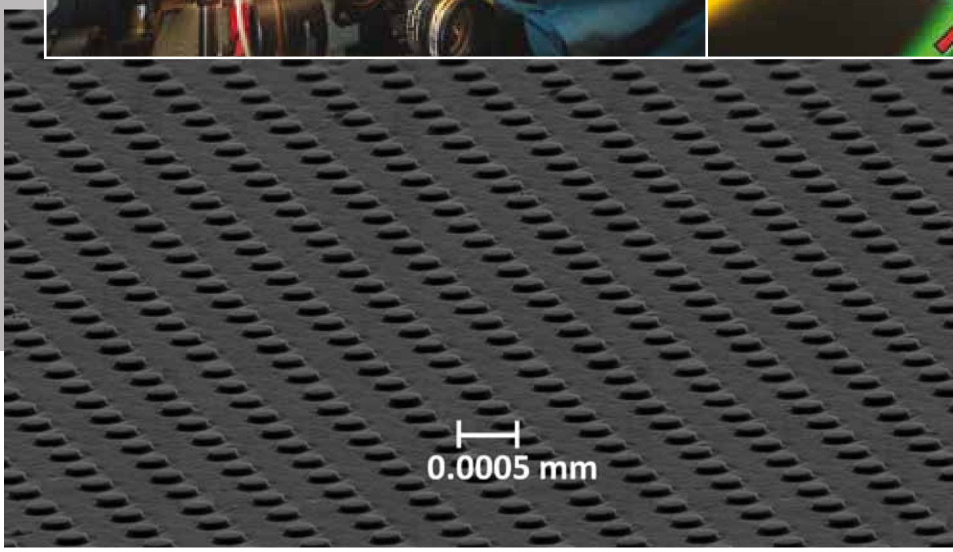
However, by tailoring the design and materials of the nanoparticles the concept can easily be adapted to work in other parts of the spectrum, including visible, which opens the technology up to a range of applications.

For instance, the invention could help to reduce the energy requirements of temperature control in buildings – the material could help keep a home cool on a hot day by keeping sunlight out, or help an office to warm up by letting sunlight in when it's cold.

The change is selective and localised, so the optical properties of portions of a window or surface can be changed independently. "Much like your car has a series of parallel resistive wires on the back windscreen to defog the rear view, a similar arrangement could be used with our invention to confine the temperature control to a precise location," said Dr Lei Xu, co-lead author of the research from the Nonlinear Physics Centre within the ANU Research School of Physics and Engineering.



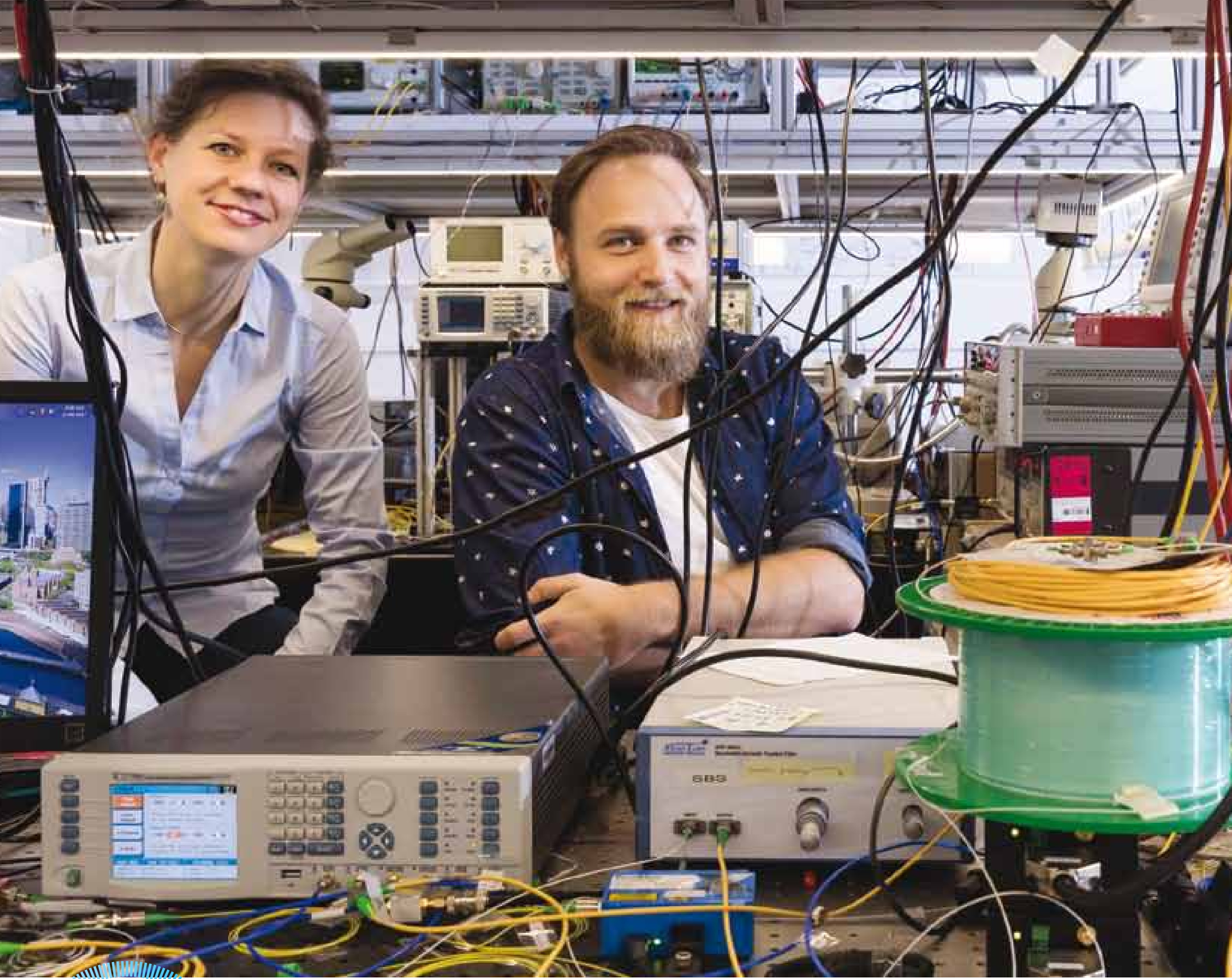




- Above Left: Mohsen Rahmani (Right) and Andrey Miroshnichenko (Left) have been investigating nanoparticles effects on light. Credit: Stuart Hay

- Above Right: A team from ANU have create a material that can selectively behave as a mirror or a window. Credit: Dr Mohsen Rahmani

- Left: Disk-shaped nanoparticles can reflect or transmit light depending on their temperature. Credit: Dr Mohsen Rahmani



Turning the volume up on

Photonic chips are capable of transmitting digital data at light speed. However, sometimes speed isn't the answer.

Photonic chips use light waves to carry information around a circuit, as opposed to electricity. The devices offer benefits to a range of applications, particularly in computing and communications, due to their high data transmission rate, efficiency, and low cooling demands.

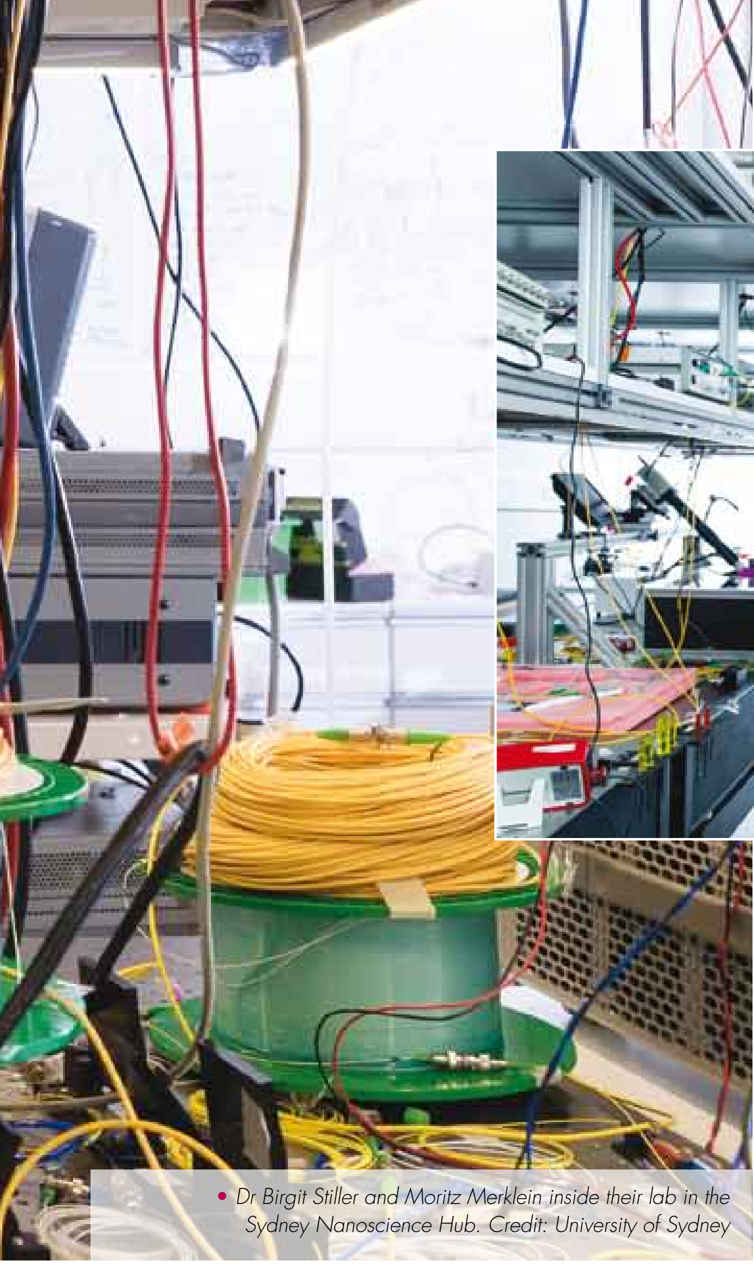
The high speed of light is well appreciated when sending data around the globe, but it becomes a challenge when processing data on a small chip.

Now though, a team at the ARC Centre for Ultrahigh Bandwidth Devices for Optical Systems (CUDOS) has created a chip that can momentarily pause digital information to be handled at a manageable rate.

"For these photonic chips to become a commercial reality, photonic data on the chip needs to be slowed down so that it can be processed, routed, stored and accessed," Moritz Merklein, one of the lead authors of the research and a University of Sydney doctoral candidate, explained.

By using the light signal to create an acoustic wave, the researchers have slowed the flow of information and provided more time for the processing, re-routing or synchronising of data streams. After a controlled storage time, the information carried by the acoustic wave is read out again, a new light signal is generated and sent on its way at full speed.

The team's chip features a spiralling waveguide which guides the light. When information-carrying light particles, called photons, enter the chip, a second light signal is sent



• Dr Birgit Stiller and Moritz Merklein inside their lab in the Sydney Nanoscience Hub. Credit: University of Sydney

• *Professor Benjamin Eggleton holding a photonic chip inside the Sydney Nanoscience Hub laboratory. Credit: CUDOS*

photonic chips

in from the opposite end that translates the optical wave to an acoustic wave. The two light waves meet in the waveguide and cause a phenomenon called stimulated Brillouin scattering (SBS), which causes the colliding photons to produce a lower energy photon and, more importantly, an acoustic particle called a phonon. The phonons are traveling much slower than the photons providing additional time to process or switch the data packets.

The phonons are then converted back to photons by introducing a "read" light pulse. When the "read" signal interacts with the phonons it generates a new light pulse, identical to the initial information-carrying signal, which then continues to travel down the waveguide and exits the chip.

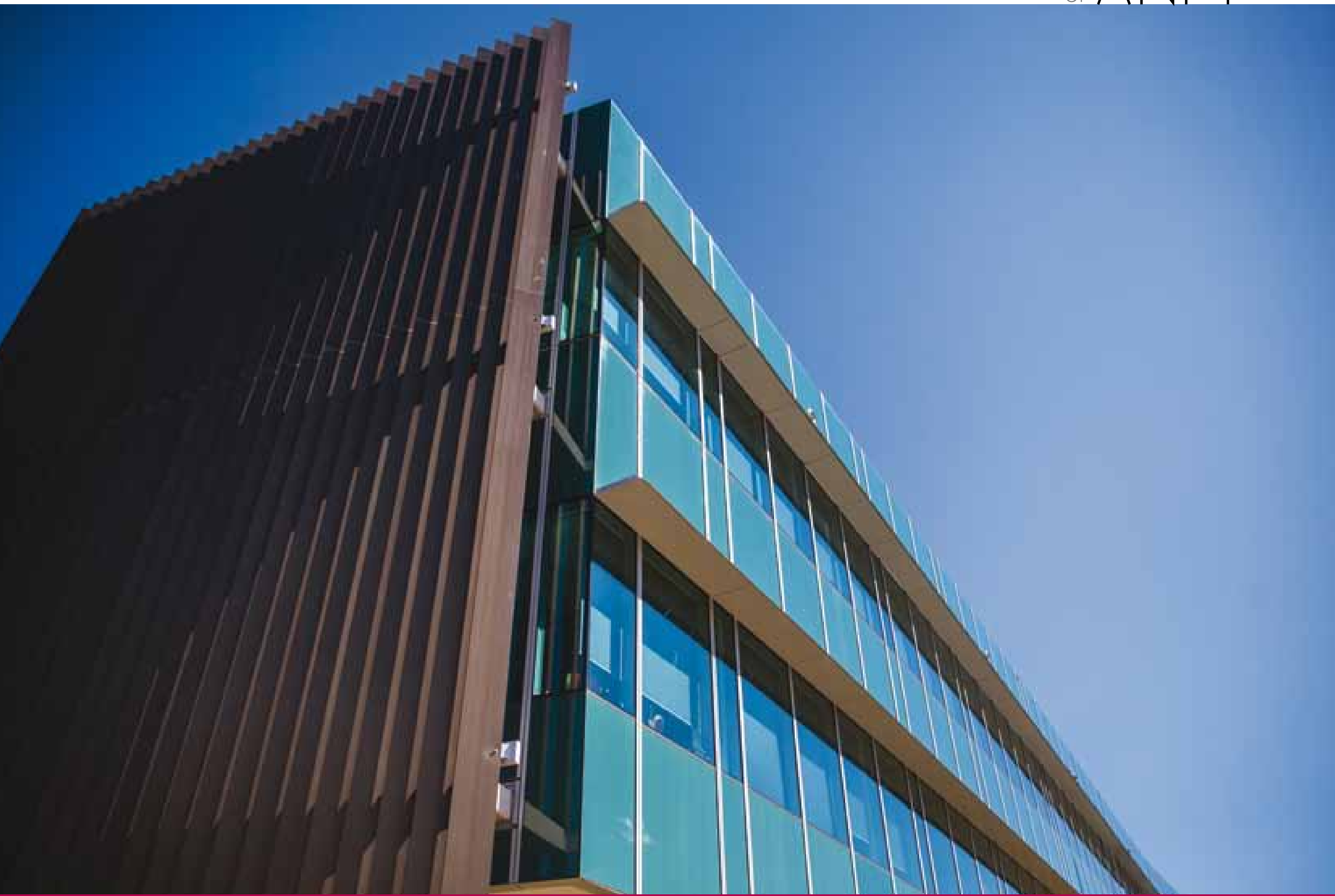
The entire process is over in nanoseconds but the added time is enough to interpret the information.

What's more, the system is not limited to a narrow bandwidth, unlike previous systems. "This allows us to store and retrieve information at multiple wavelengths simultaneously, vastly increasing the efficiency of the device," explained Dr Birgit Stiller, research fellow at the University of Sydney and supervisor of the project.

The project is part of a number of investigations CUDOS is conducting into the possibilities enabled by converting light to sound. So far, the team have used ANFF's facilities at the University of Sydney (Optofab Node), the Australian National University (ACT Node), and Swinburne University of Technology (Victorian Node), to help design, build and analyse a range of SBS-based chips.

CUDOS Director, ARC Laureate Fellow and co-author, Professor Benjamin Eggleton, said: "This is an important step forward in the field of optical information processing as this concept fulfils all requirements for current and future generation optical communication systems."

• *An illustration of the concept. The information-carrying light meets another pulse, causing an acoustic wave to be created. Credit: Moritz Merklein*



MATERIALS NODE

AIIM Facility (Building 231), Innovation Campus
University of Wollongong
Squires Way, North Wollongong, NSW, 2500

Node Director: Prof Gordon Wallace
Email: gwallace@uow.edu.au
Phone: +61 2 4221 3127

Facility Manager: Prof Peter Innis
Email: innis@uow.edu.au
Phone: +61 2 4221 3600

• *Printable solar cells could be produced for as little as $10 per square metre. Credit: Centre for Organic Electronics*

Printable POWER

• *Professor Paul Dastoor stands in front of his printable solar cells. Credit: Centre for Organic Electronics*

Professor Paul Dastoor and his team from the Centre for Organic Electronics at the University of Newcastle have developed a way of printing sheets of solar panels using a conventional printing press.

The technology was recently unveiled at Asia-Pacific's largest print industry exhibition, PacPrint. It's been gaining interest from large printing companies and printer manufacturers that could re-purpose their existing equipment to enter the renewable energy industry.

Using ANFF Materials' pilot scale printer, the team print an ink containing a blend of semiconducting organic electronic materials – making the ink electrically conductive and photovoltaic – on clear laminated sheets. Hundreds of metres of these sheets can be printed daily using ANFF's printer.

Once applied to commercial-scale printing presses this could be scaled up to kilometres. "If you had just ten of these printers operating around the clock, we could print enough material to deliver power to 1,000 homes per day," Paul said.

Once printed, Paul's sheets can be stuck to walls and roofs using velcro, and cost $10 per square metre.

Testing has found that the sheets produce power consistently, even under cloud cover. The material is so sensitive that it can produce small quantities of power under moonlight.

"On the back of five years of in-house development, all of the components of these advanced electronic inks are now synthesised at scale within our Centre for Organic Electronics using non-toxic carbon-based materials. These components are then used directly or further processed into water-based inks and paints," Paul added.

Paul and the team are currently working with global logistics solutions company CHEP to deliver a commercial scale pilot installation of organic printed solar on the roof of a service centre at the end of 2017.

• Dr Pia Winberg, founder of Venus Shell Systems, has been working with ANFF Materials. Credit: ACES

3D bioprinting has been embraced by the clinical community – while the emerging area is still maturing, its varied applications and tremendous promise has become well known.

The printing of biomaterials enables the fabrication of structures for use in wearable and implantable technologies for biomedical applications, including wearable energy and implants for tissue regeneration.

The ARC Centre of Excellence for Electromaterials Science (ACES) and ANFF Materials, based at the University of Wollongong's Innovation Campus, have now begun working with industrial partners to create a library of materials that make it commercially viable to print 3D structures for transplants, nerve or muscle repair and cartilage regeneration using the patient's own cells.

ACES, combined with ANFF Materials' expertise, has been leading the field globally in the area of bioprinting, and the pair are now playing a critical role in facilitating the transfer of knowledge to the commercial sector.

In June 2017, the Node unveiled a new reactor for processing biomaterials to be used in bioinks at larger scale, taking the ground-breaking research at ACES a step closer to industry.

The new capabilities will enable 50L reactions to produce kilograms of materials needed to formulate bioinks for 3D bioprinting of structures for cell transplantation, cartilage regeneration and wound healing projects.

"These new facilities will enable fundamental discoveries in biomaterials science to be applied in biological and clinical environments as quickly as possible," Professor Gordon

New materials to bring 3D bioprinting into the mainstream

Wallace, Director of ACES and ANFF Materials and 2017 NSW Scientist of the Year, said at the facility's opening.

The Centre's new equipment has been immediately put to work.

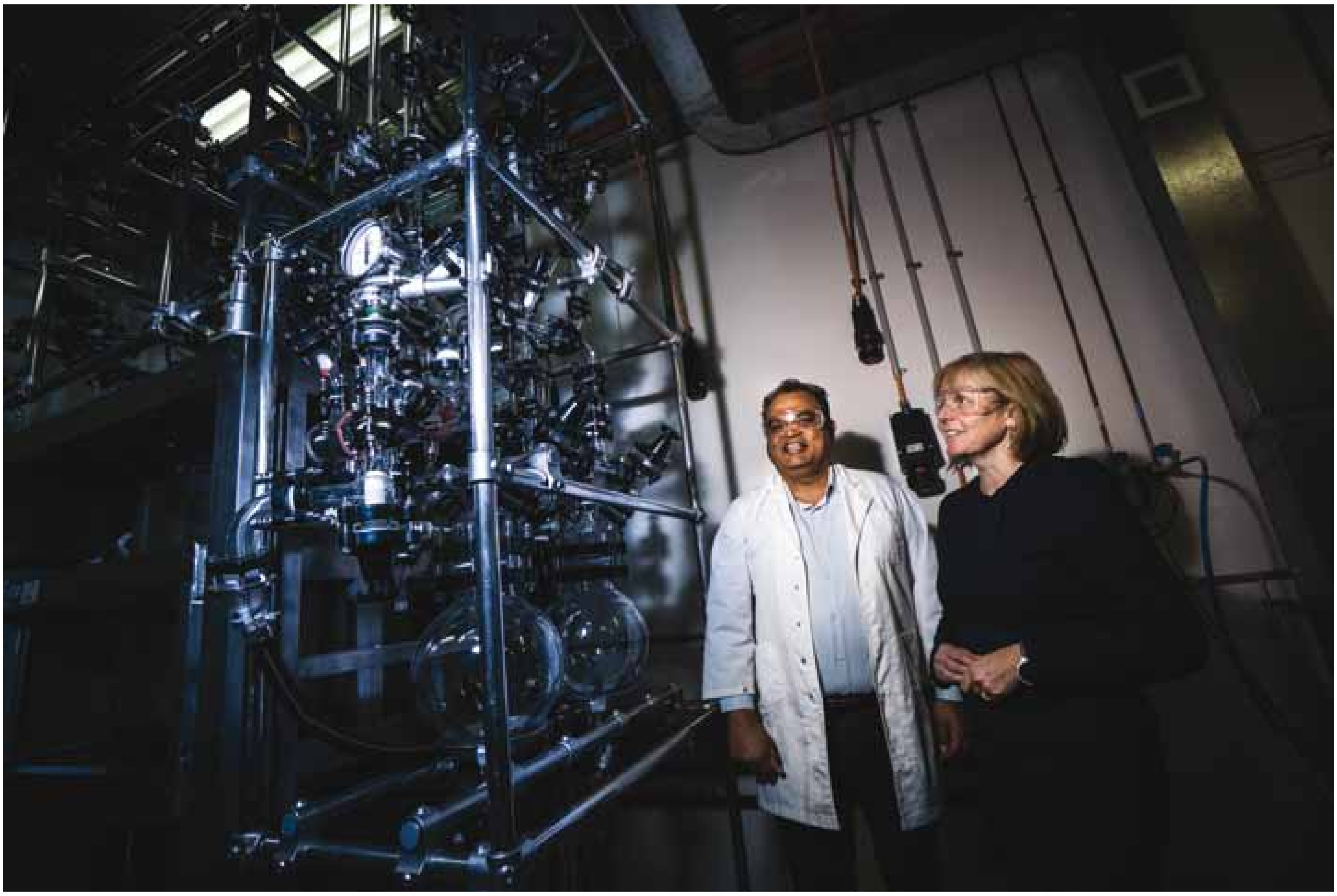
The team have developed molecular modification protocols that render commercially available gelatin as printable. Gelatin is a biomaterial that has proven to be a critical component of a bioink for 3D printing structures. The process has been scaled to allow for production of 5kg batches using the new 50L reactor.

These materials have been supplied to St Vincent's Hospital Melbourne for the BioPen project that involves 3D printing stem cells for cartilage repair and regeneration.

The materials have also been supplied to Australian Institute of Musculoskeletal Science to develop an in vitro model for the study of musculoskeletal tissue interactions.

Also at the Materials node, staff have been working closely with Venus Shell Systems, a seaweed producer based in Nowra, NSW to identify biomaterial that can be extracted from green seaweed and modified to be suitable for 3D bioprinting. The material has properties that are proving beneficial in wound healing applications.

• *Below: Dr Sanjeev Gambhir from ACES with ANFF CEO Rosie Hicks surveying the new 50L reactor. Credit: ACES*



3D printing a cure for diabetes

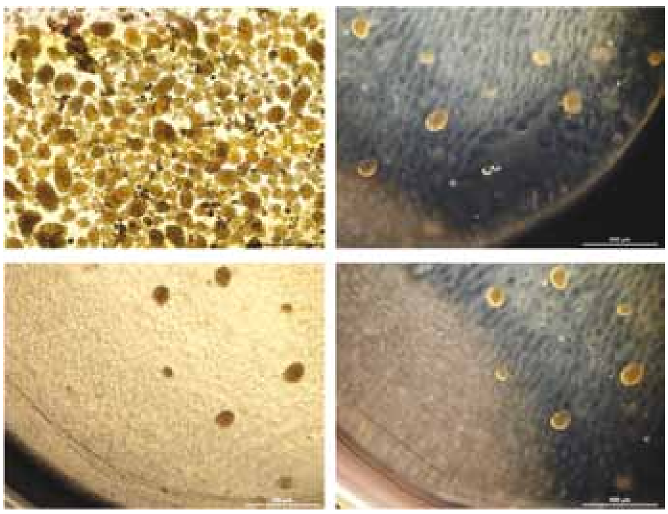
Researchers at the University of Wollongong have designed and built a customised 3D bioprinter capable of placing insulin-producing islet cells in a protective printed casing, ready for transplantation.

Transplanting islet cells offers a potential cure for type-1 diabetes – it's an approved treatment that has shown positive effects on a patient's ability to produce insulin. The problem is that poor grafting, immune reaction and rapid cell death post-transplant still limits the success of this treatment.

However, a customised benchtop printer has been developed at ANFF Materials that is capable of producing patient-specific implants which contain multiple biomaterials and cell types could change this.

"In collaboration with Professor Toby Coates' team at Royal Adelaide Hospital, we plan to improve the effectiveness of islet cell transplants by encapsulating donated islet cells in a 3D printed structure, to protect them during and after transplantation," Professor Gordon Wallace, ANFF Materials director, said.

The printed transplant material has the potential to reduce the likelihood of rejection as a patient's own cells could be used. Also, because multiple cell types can be printed in the same run, endothelial cells – essential for installing blood flow to the grafted islet cells – can be implanted, improving islet cell survival.



• *Mouse islet cells in a GelMa-based bioink. Credit: ACES*

• *Graphical representation of the target printed hydrogel scaffold structure containing patient islet and regulatory cells. Credit: ANFF Materials Node*

The printer is being delivered to the Royal Adelaide Hospital at the end of 2017 where researchers will use the technology to try to develop protocols aimed at improving the success of islet cell transplants.

"…we plan to improve the effectiveness of islet cell transplants by encapsulating donated islet cells in a 3D printed structure, to protect them during and after transplantation."
– Prof Gordon Wallace

The project called on the expertise in polymer modification, bioink formulation, additive fabrication hardware development, and biofabrication found within the ANFF Materials Node.

If successful, the method could provide a cure for all patients with type-1 diabetes. Even if a cure can't be reached, the technology could provide patients with a far more effective and readily managed way to control blood sugar, compared to traditional insulin injections.

Printable prosthetic ears

Quick, easy-to-produce and perfectly fitted prosthetic ears are now being developed, thanks to 3D bioprinting.

The project involves Doctor Payal Mukherjee and a team at the Royal Prince Alfred Hospital, Sydney, who have been collaborating with the Australian Research Council (ARC) Centre of Excellence for Electromaterials Science (ACES) and ANFF Materials at the University of Wollongong to produce a customised 3D printer and associated bioinks.

The printer, which will be installed at the Royal Prince Alfred Hospital in early 2018, creates a scaffolding to facilitate the growth of a new ear using the patient's own cells.

The 3D printed ears will be created for patients born with an ear deformity, such as a condition called microtia, where one ear requires total ear reconstruction.

To begin the fabrication process, the shape and fine features of the patient's opposite ear are captured by a scanner and turned into a computer model. From this CAD model, the team are able to print a 3D scaffolding structure that mirrors the opposite ear.

The final printed component is a softer gel-like material capable of facilitating cartilage growth from the patient's own stem cells or cartilage cells. The implant is inserted under the patient's skin giving the appearance of a matching ear.

The delivery and commissioning of the customised printer will require an intensive training program delivered by ANFF Materials Node staff – the Node will also continue to deliver biomaterials and bioink formulations to the hospital.

The Materials node is now also looking into commercial opportunities, including the supply of the specialised bioink and customised printer design.

• *Doctor Payal Mukherjee and Professor Gordon Wallace are developing 3D printed ears. Credit: ACES*

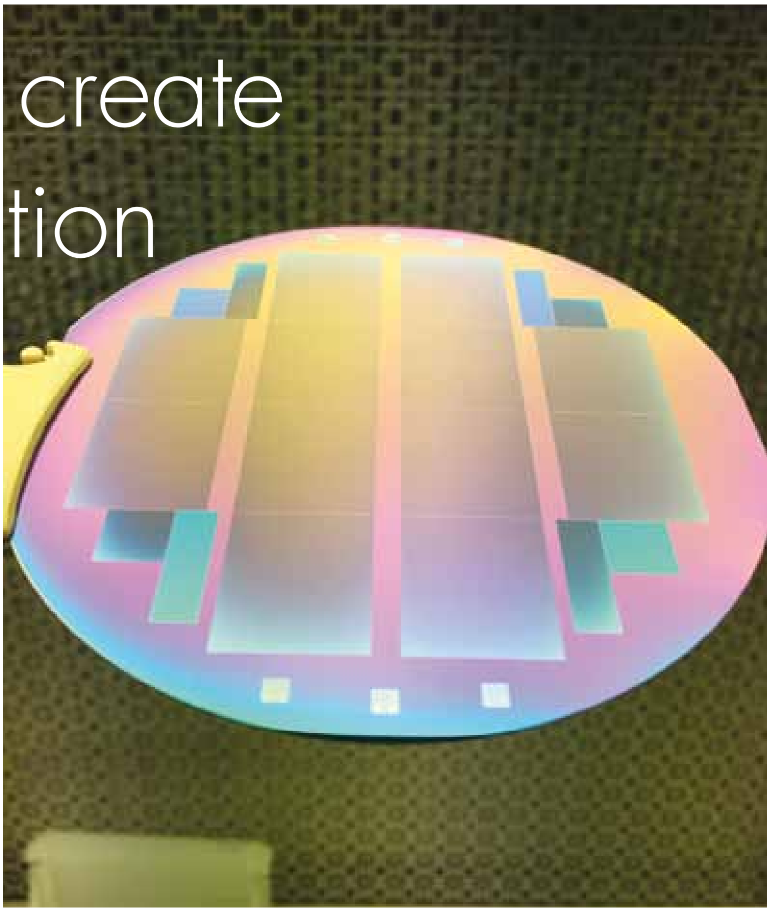
NSW NODE

Level 3 Newton Building
The University of New South Wales
Sydney NSW 2052

Node Director: Prof Andrew Dzurak
Email: a.dzurak@unsw.edu.au
Phone: +61 2 9385 6311

Facility Manager: Matthew Boreland
Email: m.boreland@unsw.edu.au
Phone: +61 2 9385 7845

A testbed to create a new generation of solar cells



• *Rear surface of a partially processed IBC wafer after thermal diffusion and oxide growth. The different doping across the wafer results in a variable oxide thickness, identifiable by the colorful pattern. Credit: Dr Michael Pollard*

Creating a new generation of thinner, more efficient solar cells just got easier, thanks to an international group of scientists that have created a testing platform to improve interdigitated back contact (IBC) cells.

IBCs are highly efficient when converting light to electricity. This is largely because all of the electrical contacts are moved to the rear of the device which clears the front surface of the cell and allows as much light as possible to be absorbed.

To push the efficiency and physical limits of these devices still further, coatings that contain nanophotonic structures are being investigated which enable thinner IBCs to be fabricated that can absorb larger amounts of light.

There are many proof-of-concept studies published for such coatings, but to date the research phase is slowing their progress to industrial scale deployment.

Now, a team led by Dr Michael Pollard, a researcher at UNSW, has created an IBC cell manufacturing process that creates a "blank canvas" on which researchers can investigate nanophotonic coatings.

While the team's process itself is not commercially viable, the nanophotonic surfaces that can be tested on them could eventually be scaled up to industrial levels.

The process allows creation of an IBC cell that can be thinned down to a selected target thickness and consistently reproduced, with the aim of developing coated devices that are not only more efficient, but lightweight and flexible too.

The team, which is spread across the University of New South Wales' School of Photovoltaic and Renewable Energy Engineering (SPREE), and the UK Universities of Warwick and Southampton, exploited ANFF NSW's photolithography capabilities, and the photovoltaic experience of PhD student Alexander To, to complete the project in just 6 months.

"The robust baseline process we have developed will enable researchers around the world to validate their designs and confirm efficiency improvements."

– Dr Tasmiat Rahman

"The robust baseline process we have developed will enable researchers around the world to validate their designs and confirm efficiency improvements," Dr Tasmiat Rahman, a researcher at the University of Southampton and lead author of the research, explained.

Seven nanophotonic surfaces are now in various stages of being trialed on these cells. Once proven, these tiny structures could make a big impact by ushering in a new generation of solar cells.

Organising neural networks on a chip

A University of Auckland team has built an organised network of human neural cells that could potentially unlock future treatments for neurological conditions.

The ongoing research, funded by The Royal Society of New Zealand's Marsden Fund, aims to build highly accurate, large-scale networks of human neurons on a chip which are electrically addressable at the single-cell level.

The technology could improve the understanding of neurological processes, such as learning and memory.

Associate Professor Charles Unsworth, Principle Investigator of the University of Auckland team, combined the group's recent breakthroughs in human cell patterning and ultra-sensitive electrode design with laser cell steering and laser ablative microsurgery to produce precisely defined circuits on chip.

The platform technology features a grid network on a chip with electrodes at each of the intersections. The team worked with ANFF NSW to manufacture this multi-electrode array. Neural cells are steered onto the electrodes where they are immobilised and coerced to grow.

As the cells grow along the grid lines, they connect to other cells to form a network. This rough web of cells is then pruned using laser microsurgery to produce an accurate grid, which can be stimulated and monitored at the single cell level.

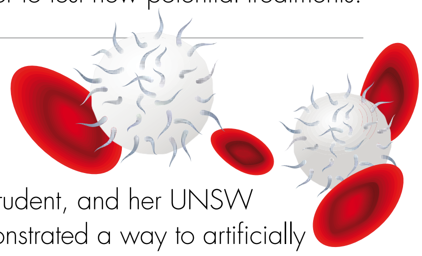
The platform will allow scientists to accurately track how electrical signals propagate from the single-cell level through to large network scales for the first time.

The technology will also provide a higher degree of control over the typical growth of neural tissue and provide improved experimental repeatability when compared to traditional, randomly cultured networks.

"We are extremely pleased with the results to date on the recordings from our human neural cells enabled by the chip platforms manufactured at ANFF NSW," Charles said. "These results have exceeded our expectations and have so far been of very high quality."

Charles and his colleagues are now investigating how to simulate neurodegenerative conditions on a chip, such as epilepsy and stroke, in order to test new potential treatments.

Back to blood's beginnings



A UNSW research group has demonstrated a way to create blood cells by recreating the conditions found in the embryonic circulatory system.

The process could provide a means to kickstart blood production in cancer patients following high intensity treatments such as chemotherapy.

White blood cells fight disease and are produced from blood stem cells found in a person's bone marrow. During chemotherapy, bone marrow can be eroded which can cause production of blood components such as white blood cells to decrease to dangerously low levels.

If researchers find a way to replenish the stem cells lost when bone marrow is damaged, patients would be able to begin producing white blood cells again to help fight against infections and disease.

The UNSW team is investigating the production of blood stem cells in an embryo, where they are produced by endothelial cells that line the circulatory system.

Jingjing Li, a UNSW PhD student, and her UNSW colleagues have now demonstrated a way to artificially recreate these embryonic conditions by creating a device that features a network of microchannels and microvalves.

The microchannels, produced using ANFF NSW's photolithography suite, mimic the blood vessels of the developing circulatory system and are coated with endothelial cells.

The microvalves are built using ANFF Q's microscale 3D printing tool, and enable the researchers to recreate the pulsed blood flow over the endothelial cells, and therefore trigger production of the stem cells.

Jingjing's work builds on research unveiled in 2016 by a team led by Professor Andrew Elefanty from the Murdoch Childrens Research Institute, Melbourne. Andrew and his colleagues demonstrated differentiation of stem cells into arterial cells using a series of chemicals and varying growth factors.

However, the UNSW team's method provides a chemical-free, flow-induced way to produce the blood cells. "The technology may lead to a better understanding of blood formation and may lead to the production of blood products in the future," Dr Robert Nordon, who led the project, said.

Providing portable pulsed lasers

The marrying of two long-term ANFF-enabled projects has allowed Zedelef, a UNSW spinout company, to produce a lightweight, powerful, pulsed laser that could improve light-based applications including lidar, spectroscopy, ranging, defence-related IR countermeasures, and communications.

Zedelef's project has yielded a proof-of-principle demonstration of a new class of portable, actively Q-switched lasers. Q-switched lasers are typically used when a series of laser pulses are required, rather than a continuous beam.

For instance, lidar – light-based radar that allows autonomous vehicles to navigate – uses a pulsed laser's reflection from an object to create a topographical map of an area. If the pulses have a high intensity, the reflected light is easier to detect.

"Every aspect of this project was conducted within the confines of ANFF… ANFF has provided both the equipment and staff support when appropriate."

– Prof François Ladouceur

The development of these lasers was conducted by Zedelef staff in collaboration with researchers from UNSW and Macquarie University, and supported by ANFF NSW and Optofab engineers.

The work succeeded by combining two technologies developed independently within ANFF. The first is a class of chip lasers based on direct-write waveguides which produce highly homogeneous laser light, fabricated at Macquarie University.

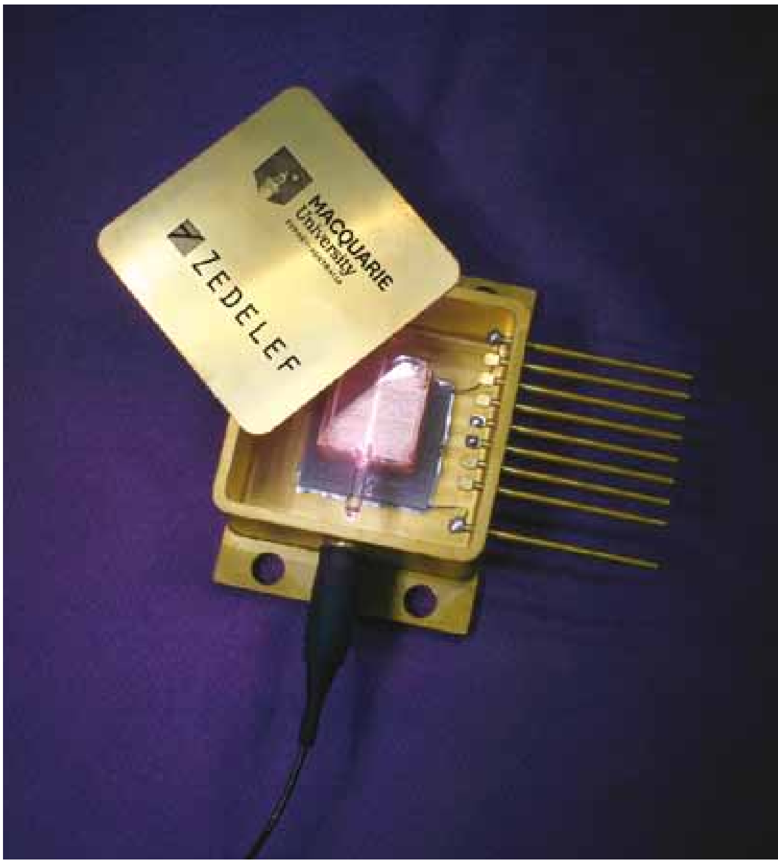
The second development was the use of ferro-electric liquid-crystal cells to control the pulse rate, originally developed for sensing applications at UNSW.

Pulsed laser beams are created by rapidly turning the laser on and off. Zedelef used the liquid crystal cell to act as a switching mechanism – applying a voltage to the cell reorients the liquid crystal molecules, so the cell can either allow light to pass or block it, ultimately controlling the rate of the laser pulse.

The combination of these two compact technologies has yielded the ability to produce a Q-switched laser small enough to be used for hand-held operations, in stark contrast to current bulky and energy-consuming alternatives.

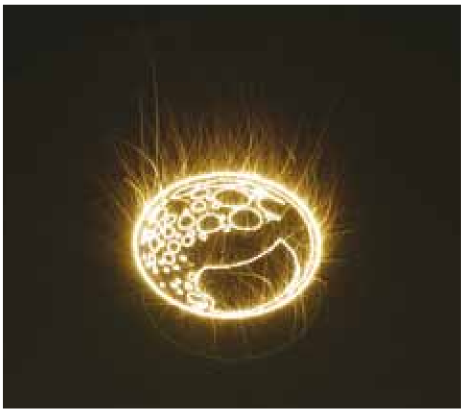
"Every aspect of this project was conducted within the confines of ANFF," Zedelef's CEO and Founder, Prof François Ladouceur, said. "From the development of the original technologies – specifically chip lasers and liquid-crystal cells – to their combination into the final proof-of-principle, ANFF has provided both the equipment and staff support when appropriate."

In collaboration with other industry partners, Zedelef is now working to take its proven concept and develop prototypes that can be demonstrated to potential customers.



• *Zedelef have developed a Q-switch by combining ANFF-enabled projects. Credit: Christoph Wieschendorf*

PHOTO HISTORY OF ANFF



3D Printing the ANFF logo

2013 AusMedtech Workshop Speakers, Prof Gordon Wallace, Prof Tanya Monro, Prof Yonggang Zhu

Facility Managers meeting, 2013

2014 Annual Research Showcase, at the Australian Academy of Science

2011 US-Australia Enabling Technologies Meeting, held in Melbourne

ANFF exhibition at the CUDOS Showcase

Groundbreaking ceremony for the Melbourne Centre for Nanofabrication, ANFF's headquarters

ANFF's opening ceremony, October 2008

Minister Simon Birmingham and Dr Stephen Bremner inspect the MBE equipment at UNSW as it was unveiled

Senior Officials on Global Research Infrastructures (GSO) at the Melbourne Centre for Nanofabrication

ANFF staff exhibit at Parliament House, 2014

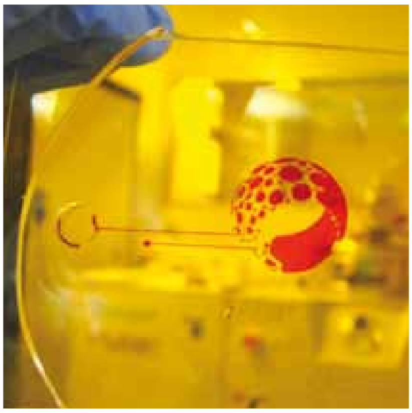
Launch of the Metal-Organic Chemical Vapour Deposition capabilities at ANFF ACT

ANFF Chairman, Professor Chris Fell (Right) signs an MoU with MacDiarmid Institute for Advanced Materials and Nanotechnology Director, Professor Thomas Nann

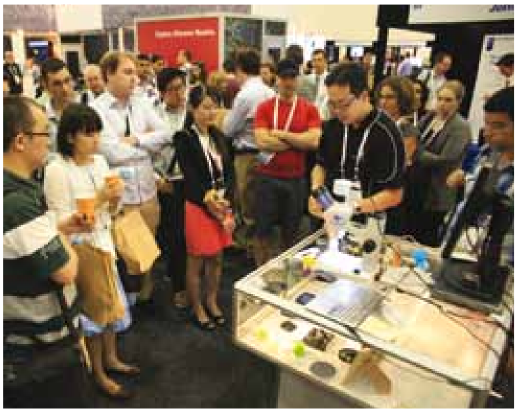
International Advisory Committee: Prof Gabriel Aeppli, ETH Zürich; Prof Harold Craighead, Cornell University; Prof Jim Williams, ANU (Chair)

ANFF and AMMRF share a booth under the NCRIS banner

The opening of the Australian Hearing Hub at Macquarie University, home to the ANFF OptoFab Node



The ANFF logo as a microfluidic device



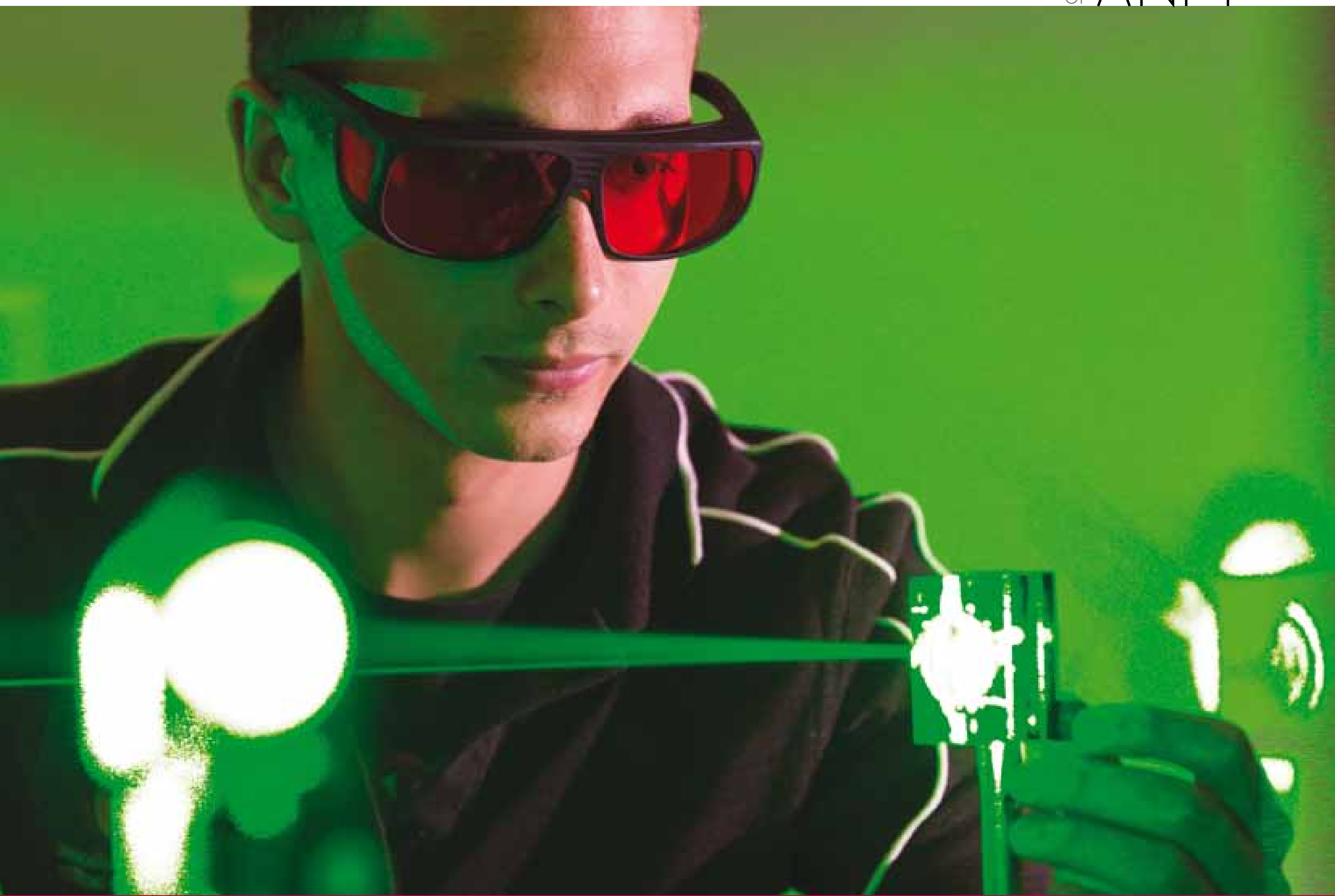
Demonstrating microfluidics at ICONN 2014

The first Frater awards in 2012

2016 US-Australia Enabling Technologies Meeting, held in Sydney

The 2014 inaugural ANFF SA Symposium and Winter School.

Official launch of the Optofab Node, 2013

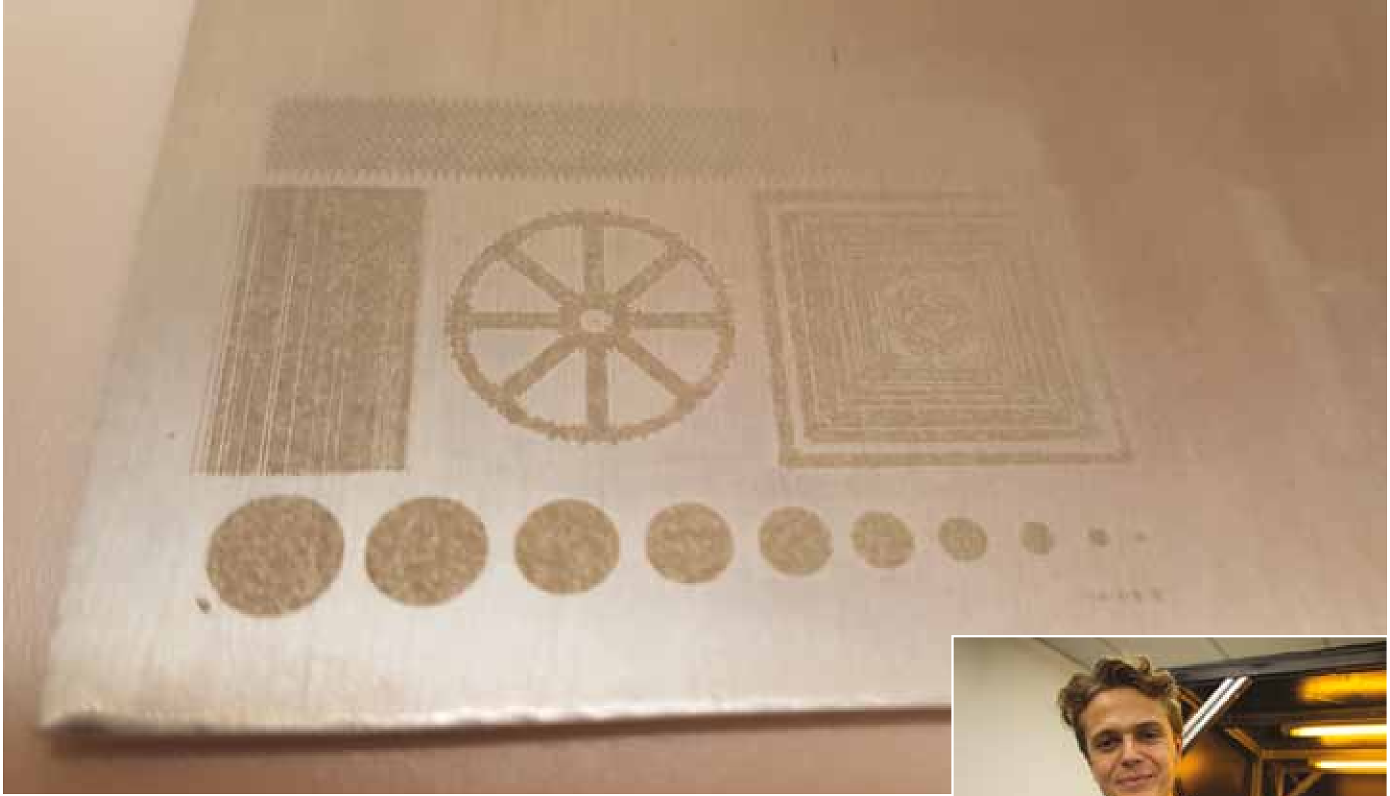


OPTOFAB NODE

Australian Hearing Hub (Building W1A)
Level 4, 16 University Avenue
Macquarie University, North Ryde
NSW 2109

Node Director: Prof Michael Withford
Email: michael.withford@mq.edu.au
Phone: +61 2 9850 7056

Facility Manager: Dr Benjamin Johnston
Email: benjamin.johnston@mq.edu.au
Phone: +61 2 9850 8960



Reducing drag with microfabrication

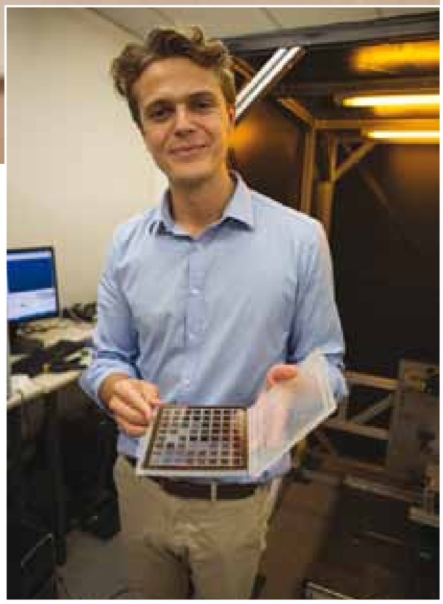
Henry Bilinsky, founder and CEO of MicroTau, has found a means to reduce drag across an aircraft's surface by 6%, using a process conventionally used for manufacturing computer chips.

MicroTau, based at a facility in Sydenham, NSW is now working with the US Air Force to turn his proven "Direct Contactless Microfabrication" concept into an everyday reality.

Inspired by the topography of shark skin, the addition of 25 micron-tall ridges called riblets, spaced 50 microns apart, to an aircraft's surface has been found to improve airflow over a surface. Applying this to aircraft could reduce carbon emissions, while saving airline operators billions by improving fuel efficiency.

Riblets have been known to reduce drag for decades, and that adjusting the size and spacing of the ridges can tailor the phenomenon to different applications such as aircraft, submarines or high-speed trains. However, it's only been achieved through expensive processes until now.

MicroTau has now demonstrated that a modified lithographic technique can reliably create the ridges.



• *Henry Bilinsky has developed a way to improve air flow over solid structures. Credit: Henry Bilinsky*

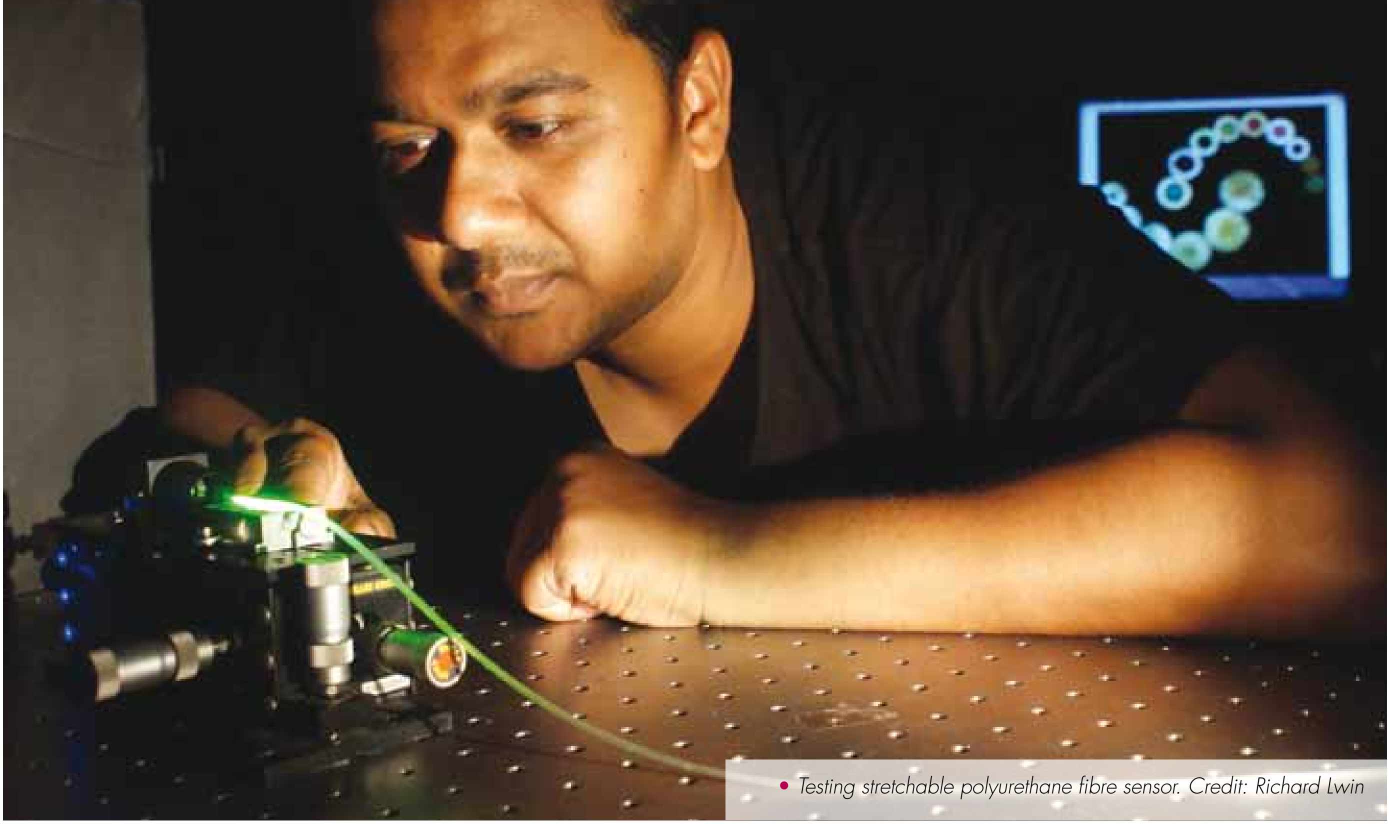
It's a process that's quick, scalable, cheap, and can be used on existing aircraft.

It's done by shining UV light through a photomask, made at ANFF Optofab, onto a UV curable coating applied to the aircraft's surface. The photomask casts a shadow onto the coating, so the UV light cures only the riblet structures. Once the uncured coating is removed, the riblet structure remains. By adapting the photomask, the riblets can be tailored to specific applications.

"Having a world-class facility that can design and print these components on your doorstep is incredible and the OptoFab team were really helpful throughout," Henry said.

Lockheed Martin conducted wind tunnel testing on MicroTau's panels and found they reliably reduced skin friction drag by 6%, equating to a 2% or greater reduction in fuel consumption.

"The global commercial airline business spends about US$170 billion a year on fuel, producing some 780 million tonnes of CO_2. If we are able to realise that 2% saving there is a very clear economic and environmental benefit," Henry said.



• *Testing stretchable polyurethane fibre sensor. Credit: Richard Lwin*

A whole new meaning to smart casual

The NSW Smart Sensing Network (NSSN) has been working with ANFF Optofab to create smart fabrics that could warn the wearer of impending heart attacks.

The team have proven the concept that cheap, micrometre-wide polyurethane fibres are sensitive enough to detect fluctuations in the wearer's vital signs. They're now working to connect the fibres with the outside world and weave them into fabrics.

The NSSN created 150μm polyurethane optical and electrical fibre sensors using the specialty fibre draw facilities at the University of Sydney.

The draw tower pulls out long, thin strands of the plastic that is affordable and widely available to form fibres that are flexible and durable. The fibres can be woven into traditional fabrics to manufacture smart clothing.

The fibres can be deformed as a heart beats, creating measurable changes in the light or current that is passed through them.

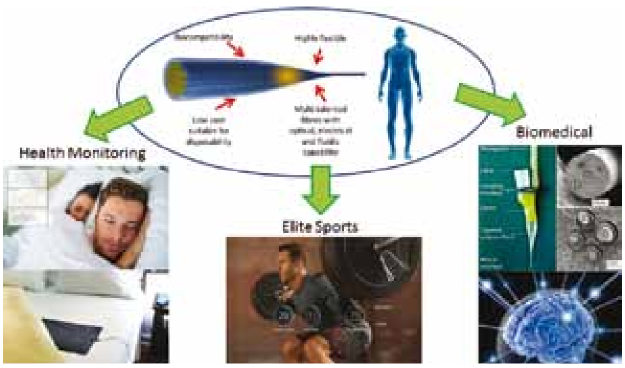
Testing showed that the fibres could monitor minute deformation forces of around 0.09N with a sensitivity of 23.3dB/N.

The capability of these fibres has attracted the interest of health, sports, and wearables industry players that have seen the clear benefits of the technology, especially when combined with other smart devices.

For instance, if the heart rate begins to show warning signs of a heart attack an alarm could be sent to health care professionals via a linked smartphone, with data about the wearer's location and provide information about recent heart activity.

The material the sensors are made from is very low cost which suggests that once commercialised, they'll quickly find a home in the retail wearables monitoring market, with a particular focus on fitness. Pairing smart shirts with the smartwatches now being widely used to monitor professional and amateur athletes' progress would provide an incredible amount of information to a user.

The team is now working to develop a prototype consisting of a polyurethane fibre sensor embedded into a length of textile to measure movement, respiration, and heart rate under laboratory conditions.



• *The versatility of polyurethane fibre sensors allow them to be potentially used in the field of health monitoring, elite sports and biomedical industry. Credit: Richard Lwin*

Taking the internet to a new dimension

By creating intricate chip-based 3D photonic circuits Macquarie University researchers and spin-out company, Modular Photonics, are breathing new life into fibre optic networks.

Fibre optics are able to transfer large amounts of information over huge areas but soon data demand will exceed what the current networks are capable of. With more than 20 billion devices predicted to be connected to the internet by 2020, generating global traffic of 200 exabytes per month, there's a clear need to push these fibre optic networks further.

Integrated photonics circuits are the backbone of fibre optic networks. They separate out different light signals, distributing incoming packages of information like an air-traffic controller. To do this the circuits use a series of channels called waveguides that carry light through the chip to a selected output.

Due to traditional manufacturing processes which are confined to creating waveguides on the surface of a glass substrate, conventional photonics circuits are limited to just two dimensions.

The Macquarie University researchers, led by Professor Mick Withford, have used novel manufacturing techniques to break free from the surface using Optofab's laser inscription microphotonics facility that focuses laser light at a specified distance into the glass to selectively modify material.

What's more, Modular Photonics' devices can boost the current legacy fibre-optic links by simply adding a novel circuit to either end of the fibre.

"For the first time, these 3D circuits unlock access to the many degrees of freedom of a photon for scaling the fibre optic transmission capacity and avoiding the capacity crunch," Dr Simon Gross, a research fellow at Macquarie, said.

These 3D optical chips already enable a thousand-fold increase in data rate across legacy fibre infrastructure found in large buildings, campuses, hospitals, and shopping centres.

The team are now testing over large distances in collaboration with NICT, Japan and the Nokia Bell Labs, United States. In mid 2017, these chips enabled data transmission across 3,500km with a record-high efficiency over distance (31,500 bits/s/Hz x km).

Fibre sensors are heating up heavy industries

The Institute for Photonics and Advanced Sensing (IPAS) at the University of Adelaide is developing optical fibre-based, high temperature sensors for Mitsubishi Heavy Industries.

The technology builds on optical fibre sensors that were originally developed for deployment in smelters. This novel temperature sensing solution can take multiple, simultaneous readings in a smelter in locations where this was not previously possible.

By distributing Fibre Bragg Gratings (FBGs) throughout a micro-structured optical fibre, the team has created an affordable sensor that can measure up to 1,300°C.

The FBGs are a series of nanometre holes drilled into the core of the optical fibre that reflect specific wavelengths of light. When the glass heats up the spacing of these gratings changes very slightly, thus reflecting a different wavelength of light. By monitoring this change in reflected wavelength, a reliable and highly accurate measurement of temperature can be produced.

"We have utilised the Optofab facilities at both the University of Adelaide and Macquarie University within the construction of project outputs," Tim Nelson, Project Manager at IPAS, said. The gratings are written by focusing Optofab Macquarie's femtosecond laser, which creates a series of laser pulses spaced femtoseconds apart, onto the core of fibres that were produced using Optofab Adelaide's optical fibre facility which heats a glass block before pulling it out into long, flexible, but robust strands.

"This new collaboration represents international recognition for the quality of the research and development we are doing, and the difference these emerging disruptive technologies like photonics can make to businesses' bottom lines," Professor Andre Luiten, Director of IPAS, said.

The collaboration also brings new photonic sensing technology to MHI products, which is hoped to lead to significant improvements in operation and new business opportunities.

QUEENSLAND NODE

Level 2 AIBN, Building 75, Room 266
University of Queensland
Queensland 4072

Node Director: Prof Justin Cooper-White
Email: j.cooperwhite@uq.edu.au
Phone: +61 7 3346 3858

Facility Manager: Dr Jane Fitzpatrick
Email: j.fitzpatrick1@uq.edu.au
Phone: +61 7 3346 3460

Grow-your-own miniature hearts

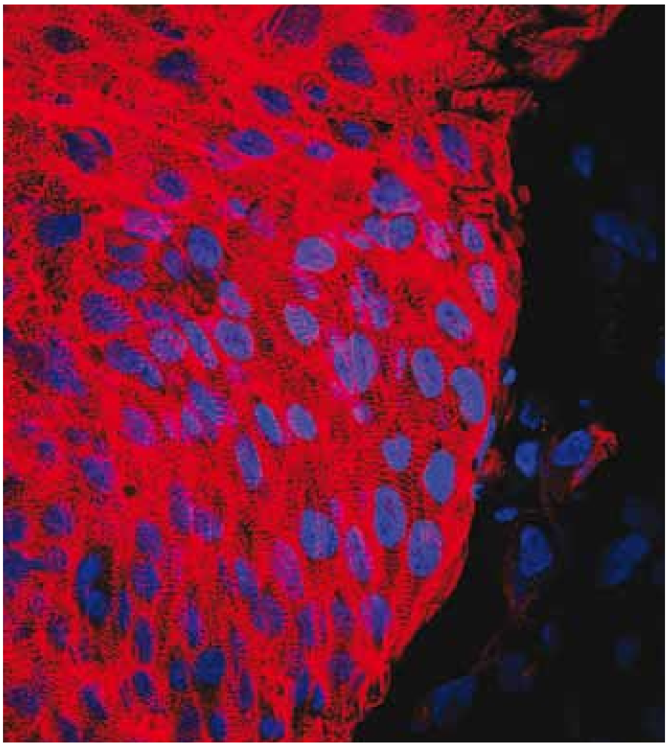
Dr James Hudson and a team from the University of Queensland have created a device that provides researchers with easy-access to tissue that models cardiovascular diseases and could help discover new therapies for patients.

By automatically assembling cardiac cells, the device creates cardiac organoids that behave like a scaled-down model of a heart. It provides researchers with an all-in-one testing package that only requires the addition of a cell-matrix mixture, cell culture medium and video imaging for monitoring.

Cardiac organoids are used by medical researchers to study the heart in realistic environments, without needing an actual human subject. They can be used to test treatments or to study mechanical effects known to cause heart failure. However, the fabrication of these organoid test beds in traditional formats is laborious, time-consuming, and requires a high level of training.

"Working with ANFF enabled us to complete this project effectively, as our lab members could try different geometries and fabrication techniques."
– Dr James Hudson

The UQ team have simplified the fabrication process of the organoids. Its technology, called the Heart-Dyno, comprises two posts and a cell culture well that are engineered to facilitate the automated growth of a cardiac organoid. The device can also induce mechanical stresses on the tissue and provide physical analysis of the organoid as it contracts and pulls on the posts.



High magnification confocal image of cardiac cells (red) in a human cardiac organoid. Credit: Richard Mills

The NHMRC and National Heart Foundation-funded team required ANFF Q's SU-8 photolithography techniques to make a mould for the post inserts. "This was technically challenging at the start because the posts have a high-aspect ratio of 700μm high with a 200x500μm base for our Heart-Dyno device features," James explained.

"Working with ANFF enabled us to complete this project effectively, as our lab members could try different geometries and fabrication techniques so that we can now produce the Heart-Dyno with >99% success and reproducibility," James said.

The researchers are now collaborating with industry partners to discover new therapies for patients with heart failure. They also want to commercialise the Heart-Dyno plates to make this culture system accessible to researchers in academia and also industry.

With easy-access to cardiac organoids, medical researchers can quickly investigate more treatments in greater depth.

"We have also fabricated multiple organoid types in our device (cardiac, skeletal muscle, and neural) so we believe that this culture device may also be useful to researchers outside of the cardiovascular field," James added.

Storing solid hydrogen for energy applications

Hydrogen is naturally abundant, volatile gas at room temperatures – but when used as a fuel source it produces no pollution, making it a favourite of those investigating a clean energy future.

A team from the the University of Queensland's Nihon Superior Centre for the Manufacture of Electronic Materials (NSCMEM) and Kyushu University, Japan, is helping to overcome the issue of safely storing the volatile gas and efficiently retrieving it when it's needed.

The researchers have taken steps towards developing a viable hydrogen fuel cell by realising that it's easier to collect stored hydrogen when there are defects within the storage device.

The team is investigating solid-state gas storage – a safer, more practical, and potentially less energy-intensive mechanism to store hydrogen compared to conventional alternatives that include compressing the gas or cryogenically cooling it.

Binding hydrogen atoms to a metal alloy keeps them in a solid state. Once bonded, the hydrogen is retained in a stable crystalline structure, where it waits until it's retrieved.

Retrieval brings problems of its own. It requires energy – often either heat or electrical – to release hydrogen from its binding. The more energy that's required to remove the hydrogen, the less efficient the entire system becomes.

Using ANFF Q's Differential Scanning Calorimetry capabilities, the team monitored the temperature required to break the hydrogen free from samples of magnesium-nickel, an appealing storage material due its high storage capacity, low cost, and availability.

One finding of the team's research is that the areas of the storage medium containing defects release hydrogen at temperatures at least 100°C lower than those regions with no defects. This information arms cell manufacturers with a means to reduce the energy required to withdraw hydrogen from storage, improving efficiency and making the process easier.

"This research has been funded by a Brisbane-based hydrogen storage company, Hydrexia Pty Ltd., to further the understanding of their proprietary materials in order to improve the system performance outputs such as faster hydrogen uptake/release rates, lower operating temperatures, and more," Xuan Quy Tran, a scientist at NSCMEM and lead author of the research, said.

• *Scaled Biolabs CEO Drew Titmarsh holds one of the startup's microfluidic chips produced at ANFF Q. Credit: Scaled Biolabs*

Running 10,000 experiments in parallel

Having successfully spun out of the University of Queensland in 2016, US-based Scaled Biolabs has begun unlocking new cell therapies using its miniaturised cell culture lab that runs nearly 10,000 experiments in parallel.

The company's device is now being used by industrial customers in the cell therapy and immuno-oncology sectors, enabling the rapid development of medical treatments.

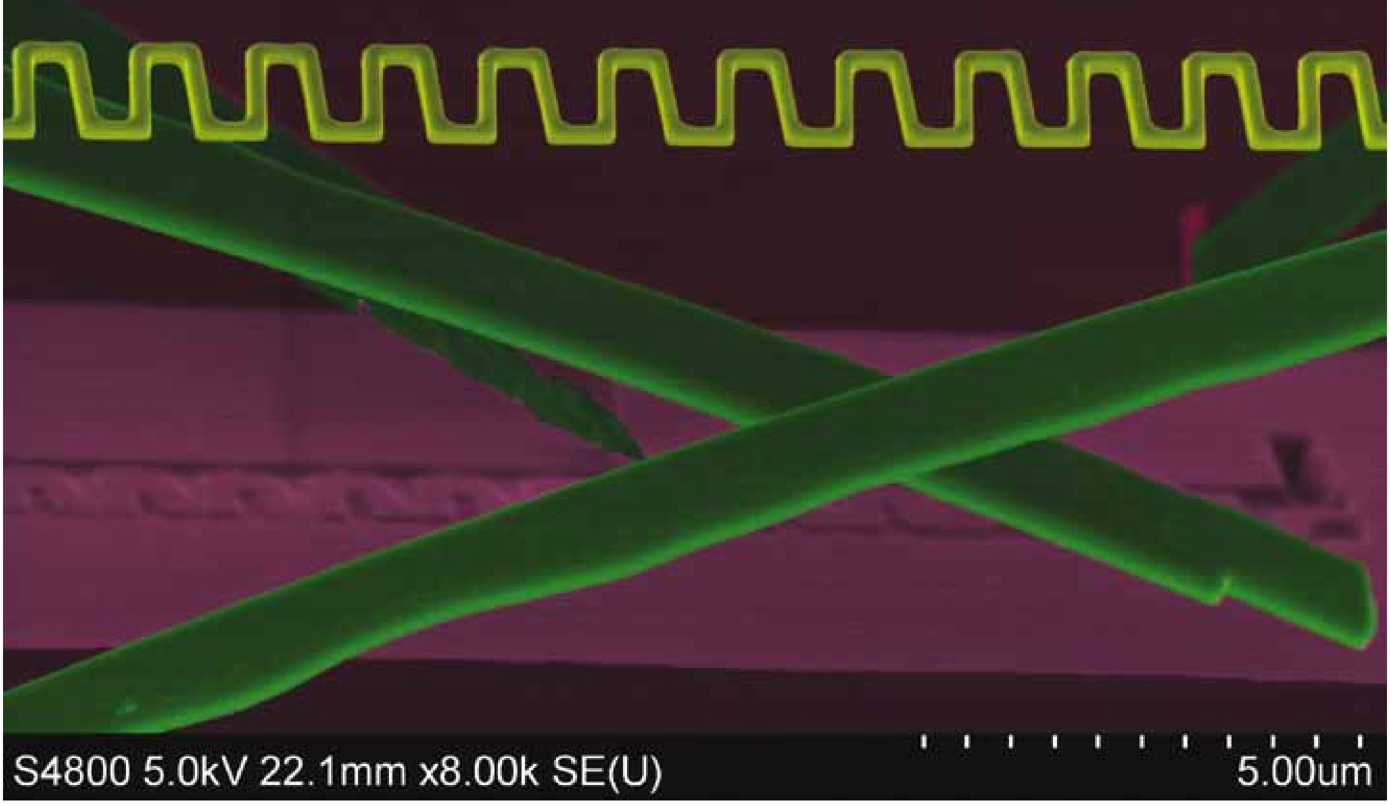
Within the device, high-density arrays of wells are seeded with cells and then dosed with various concentrations of factors. The results can then be easily scanned and interpreted giving vastly more data than conventional assays, meaning manual experimentation can be vastly accelerated. The chips also provide the benefit of conducting experiments under flow conditions, which gives better insight into the natural cellular processes at play.

Because of the huge number of simultaneous experiments the technology conducts, researchers are able to screen varying parameters, such as drug compounds and concentrations, all at the same time.

Scaled Biolabs' platform also requires at least 10 times less test material than conventional systems, and processes it at a much faster rate. This helps to reduce cost and bring new treatments to market in a fraction of the time it takes conventionally.

The platform has been supported throughout its entire journey by ANFF Q, from the initial concept through to the point where the company is providing devices to be used on client samples. Mask writing, photolithography, optical surface profiling, soft lithography, 3D printing, and confocal microscopy capabilities were all used throughout the research phase of these devices.

The company is continuing its work with ANFF Q to automate its technology and to add computational support.



• *Above: A SiC nanospring demonstrating the capability of strain-engineering in epitaxial SiC. Credit: Hoang-Phuong Phan*

Australia has taken the lead in producing SiC sensors

Griffith University's Queensland Micro and Nanotechnology Centre (QMNC) is combining high-quality silicon carbide (SiC) nanofilms with MEMS devices to produce robust sensors for harsh environments.

The world-leading quality of the Centre's SiC layers has revealed material properties that can be used in a new generation of miniature sensors. Once incorporated into MEMS-based devices, a plethora of applications open up.

Their single crystal, nanometre-thin films can be applied to silicon wafers that are 300mm in diameter, and feature an ultra-smooth surface roughness of less than 0.5nm. The films were grown using ANFF Q's low-pressure chemical vapor deposition (LPCVD) reactor at 1,000°C.

The SiC samples have demonstrated a piezoresistive characteristic that provides 15 times more sensitivity to mechanical stresses than metals. They remain sensitive at 400°C, making them ideal for sensing applications in harsh environments.

"With the platform technology for batch fabrication of SiC-MEMS/NEMS transducers, we can produce tens of thousands of micro sensors on a single SiC-on-Si wafer," Professor Nam-Trung Nguyen, a researcher at QMNC, said.

"This high throughput will significantly reduce the total cost of the sensors and is relevant to a wide range of applications. Especially sensing in harsh environments, such as those in mining, automotive, defence, and power industries, this will allow a quick penetration into the commercial market," he continued.

QMNC is the only research centre in Australia with the capability of growing high-quality SiC nanometre-thin films, but the researchers there have maximised their outcomes through numerous inter-institutional collaborations. This includes work with UQ on SiC-on-glass waferbonding, with University of Tokyo on SiC piezoresistive effects, and with Stanford University on bulk SiC-based sensing devices.

The work has been largely conducted at ANFF Q using equipment for microprocessing that ranged from chromium mask production at UQ to SiC-on-Si growth and SiC micro-machining at Griffith.

"The support from ANFF and our industrial partner SPT in establishing world-class micro/nanofabrication facilities in the Queensland node was an important factor, which led to the success of this project," Nam-Trung said.

Adding nanomaterials to improve lubricants

The quest for an environmentally friendly substitute to oil-based lubricants has led a University of Queensland team to investigate nano-additive water-based alternatives.

The use of nanomaterials in a water-based solution opens the door to tailored, environmentally friendly lubricants with parameters that can be modified to meet the requirements of a particular application.

The group, led by Professor Han Huang, a researcher at UQ, investigated both zero dimensional (0D) aluminium oxide nanoparticles and two dimensional (2D) graphene oxide sheets as additives.

When these novel lubricants were investigated for their effects on friction and wear, it was found that the lubricating mechanisms were directly related to the intrinsic properties of the nano-additives.

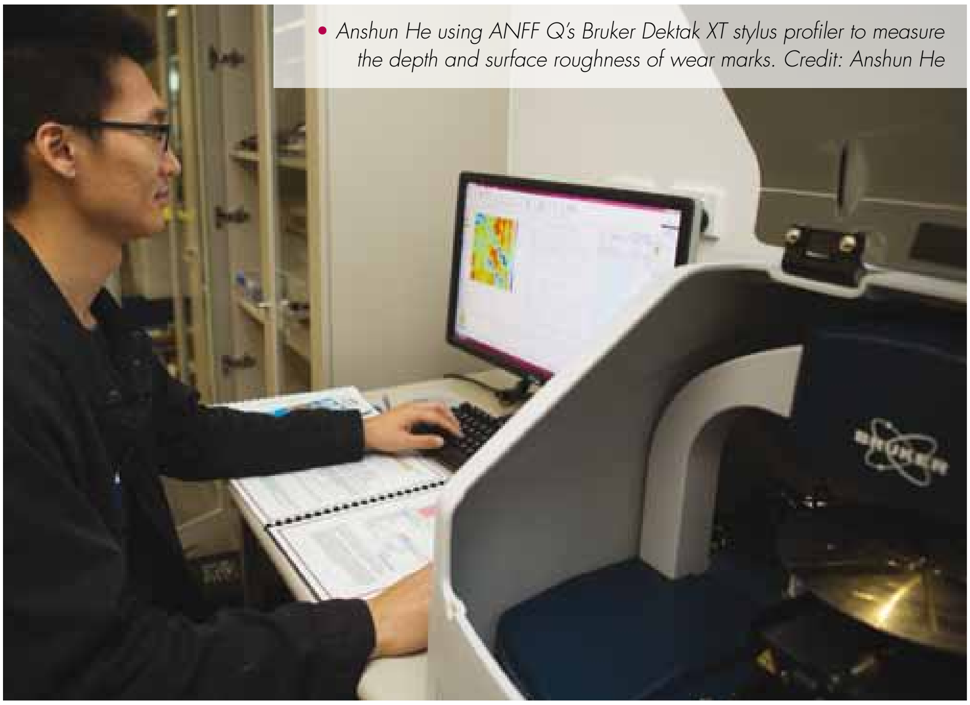
The team's analysis revealed that the aluminium oxide particles create an anti-frictional thin film on the surface of a material and demonstrated strong anti-wear characteristics, meaning they could operate as a lubricant for an extended period of time. For the graphene oxide sheets, it was sliding of the individual layers on top of one another that helped to ease friction.

Initial characterisation of the lubricants was conducted at ANFF Q.

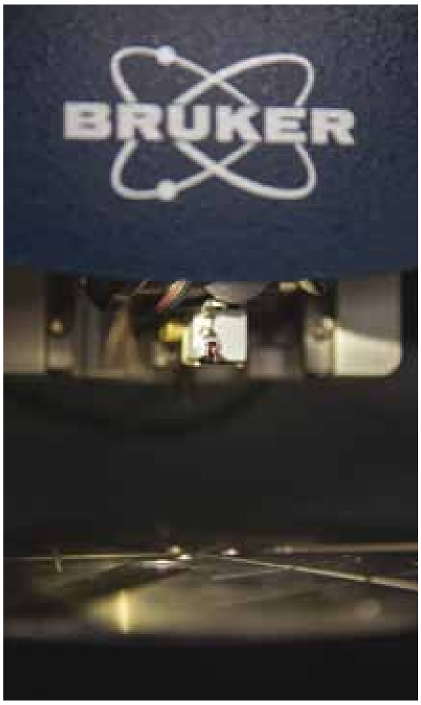
The lubricants were then tested by analysing their effect on the wear of two surfaces rubbing together. After testing, the worn surfaces were examined using instruments at ANFF Q, including the Node's stylus profiler and confocal microscope to determine the depth and surface roughness of the wear marks.

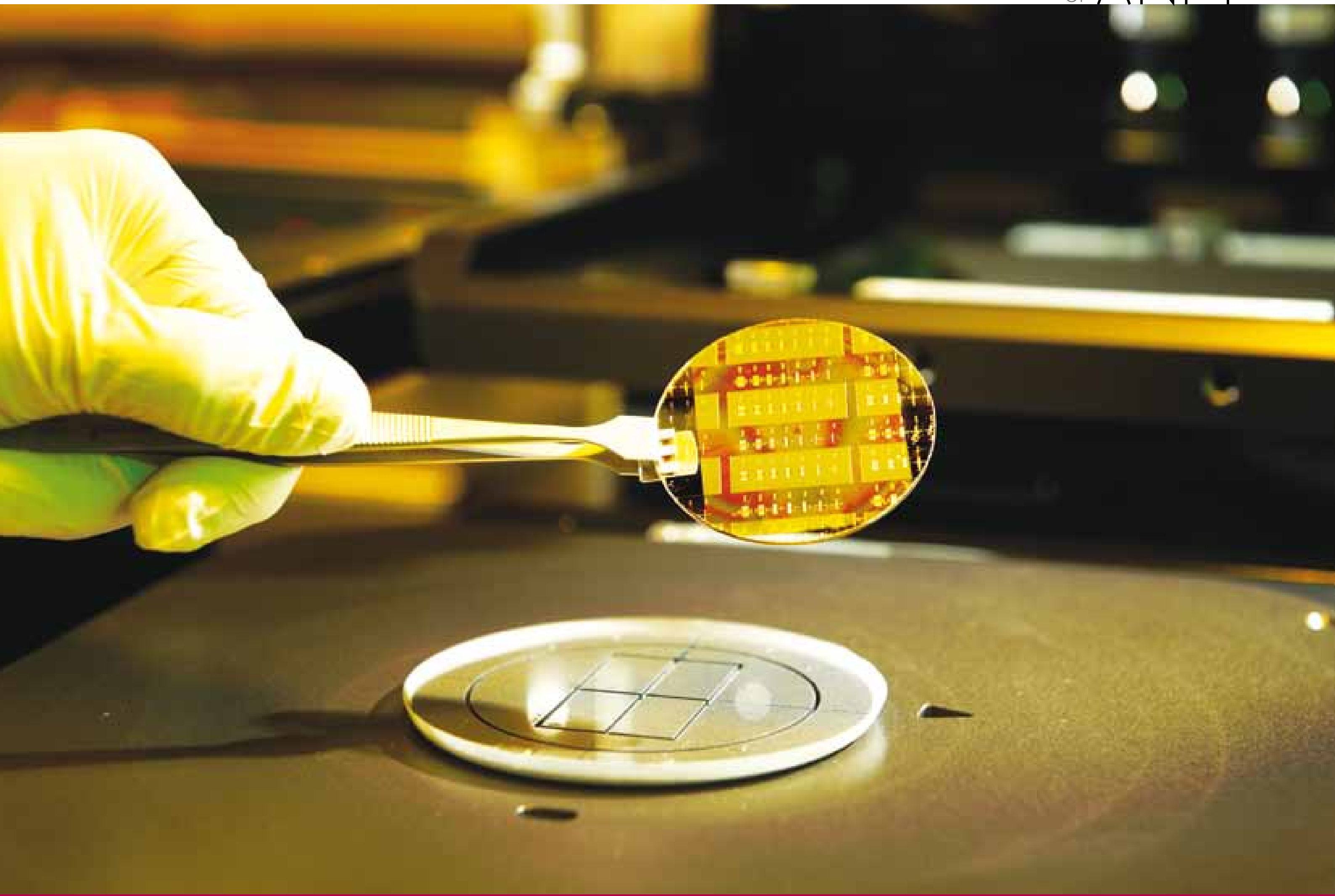
"Our research leads to deeper understanding on the behaviour of nanostructures in water-based lubricants during mechanical movements involving friction and wear," Han said. "The research results opened the door to meet the demands of replacing oil-based lubricants with environmental compatible and economical water-based ones in broad manufacturing industries."

The team are now investigating the potential of other nano-materials. The researchers will be focusing on combining both 0D-2D to see if both types can work together. By expanding the work to include a range of 0D and 2D materials, the team hope to build a library of additives to suit any application.



• Anshun He using ANFF Q's Bruker Dektak XT stylus profiler to measure the depth and surface roughness of wear marks. Credit: Anshun He



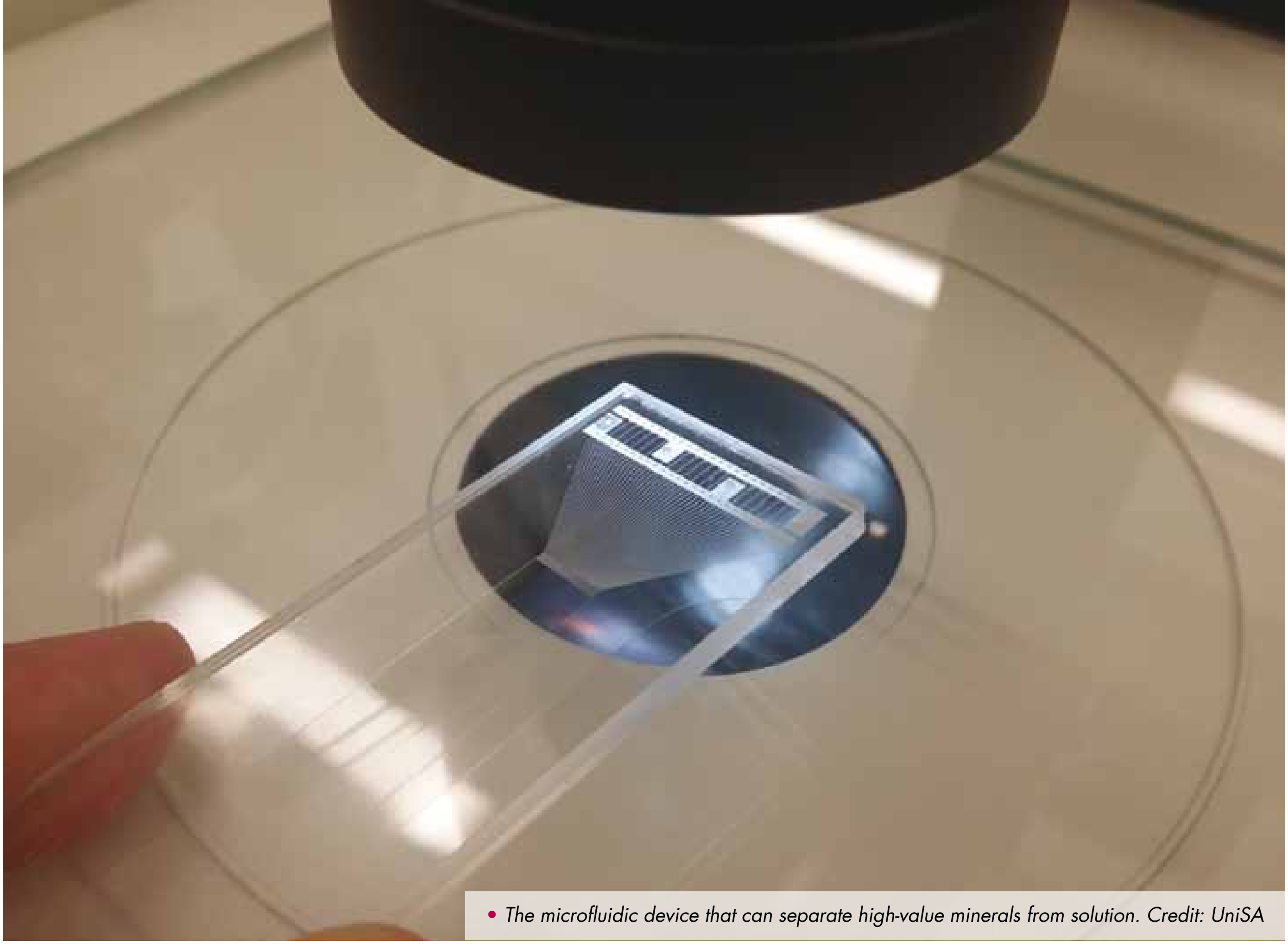


SA NODE

Future Industries Institute
University of South Australia
Mawson Lakes SA 5095

Node Director: Dr Craig Priest
Email: craig.priest@unisa.edu.au
Phone: +61 8 8302 5146

Facility Manager: Mr Simon Doe
Email: simon.doe@unisa.edu.au
Phone: +61 8 8302 5226



• The microfluidic device that can separate high-value minerals from solution. Credit: UniSA

Chip-based high-value mineral extraction

Researchers at the University of South Australia's Future Industries Institute (FII) have developed a faster, cheaper, and safer way of refining high-value metals by exploiting microfluidic chip technology.

The approach has been demonstrated for platinum and rare earth elements over the last 5 years and now the group is scaling up to handle commercial volumes.

Recycling precious metals is often achieved by dissolving valuable waste or ore in highly acidic water, then using a specific chemical to selectively react and extract the valuable metal into an oil.

The oil containing the valuable metal is then separated from the water which carries away everything else, but this can be difficult because droplets are formed during mixing and coalescence, which can be slow or completely fail for complex extraction systems.

To speed things up, the team designed a new microfluidic chip which forces many streams of water and oil to flow parallel to one another, achieving rapid extraction without a slow phase separation step.

The valuable metal effectively "changes lanes" from stream to stream like traffic on a microfluidic freeway, usually within just a few seconds of contact. UniSA's new chips allow 20 times higher throughput than previous chip designs.

"The ANFF SA facilities helped the team transition from an 'idea' through 'proof-of-concept' and now exploring higher TRL (technology readiness level) testing and manufacturing," A/Prof Craig Priest, Project leader, Senior Research Fellow at UniSA's Future Industries Institute, and ANFF SA Director.

Modelling of the microfluidic chip was conducted using ANFF's Design House suite of software. The chips were fabricated in ANFF SA and Optofab laboratories using photolithography, etching, laser milling and thermal bonding of glass.

"ANFF SA's micro-injection moulding and micromilling capabilities will be critical in the development of the next-generation prototype and developing methods that are suitable for mass manufacturing," Craig added.

Opening the gateway to in-home health care for post-acute patients

A global search for a "well-connected organisation" to develop an innovative microneedle technology has led InnaMed founder and CEO Eshwar Inapuri of Palo Alto, California to ANFF SA.

The combination of ANFF SA's valuable Design House software with access to specialist staff proved irresistible to Eshwar. He was confident he had found the right team to develop his connected blood-testing platform, HealthScale, which will remotely monitor post-acute patients after their hospital discharge.

With a background in biomedical solutions and hardware, Eshwar recognised an opportunity for painless microneedle technology to be incorporated into a medical device that could be used to deliver in-home health care. Not only could it help save the lives of chronic heart failure patients, but significantly reduce the billion-dollar healthcare costs (estimated at US$13,000 per person or more than US$17 billion annually in America) associated with avoidable hospital re-admissions.

Utilising the capabilities of ANFF SA's flagship Kira CNC Micro Milling Machine, micro machining technologist Mark Cherrill has provided expert advice to help achieve the rapid turn-around of Eshwar's HealthScale prototype.

Eshwar said the expansive reach of ANFF SA and its collaborative approach were unlike anything he had ever experienced anywhere else around the world.

"It's hard to find such a well-connected organisation in America that is willing to get things done quickly. ANFF SA has really proven to be a one-stop shop for us," said Eshwar.

"Without doubt, ANFF SA has been the right fit for our organisation. From the helpful faculty and researchers at the University of South Australia, right through to the flexible and problem-solving team who treat your project as their own. Our experience has been the best."

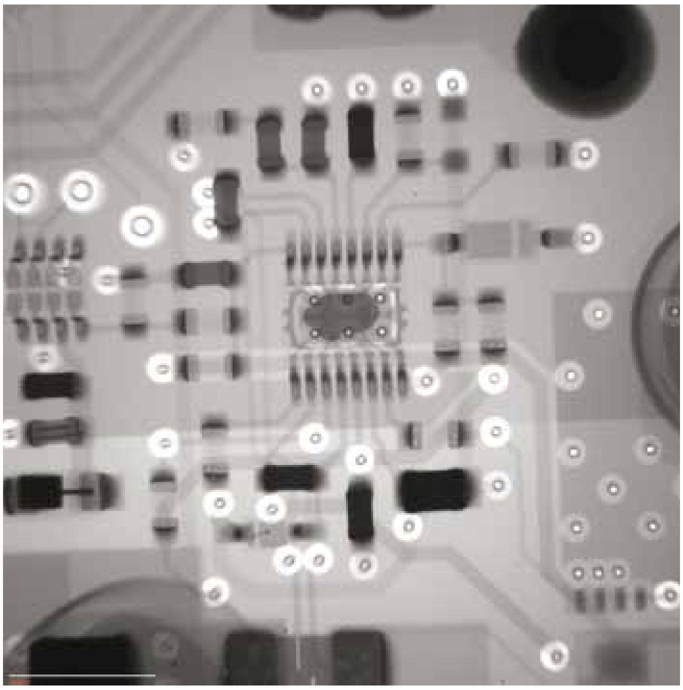
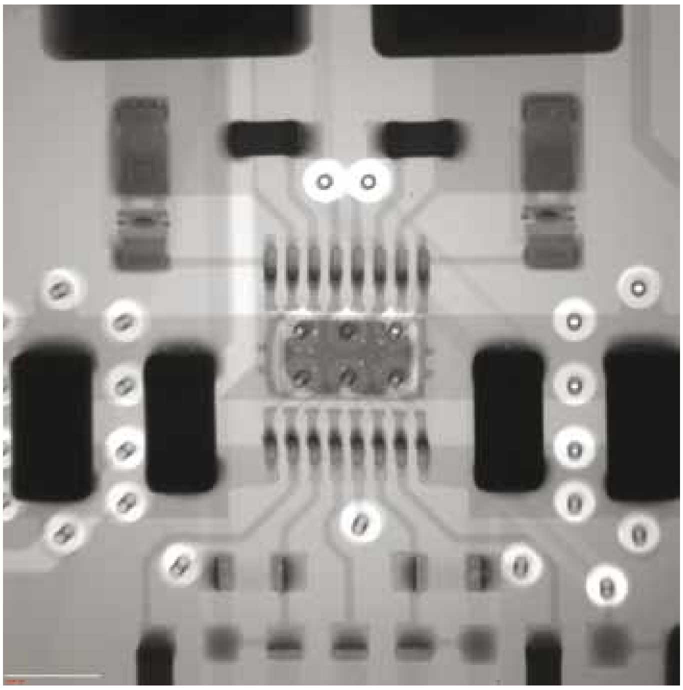
The HealthScale device is designed to empower high-risk patients for self-managed care. Simple and effective microneedle technology draws just four drops of blood painlessly into a test card. The test card is then placed into the device and within five minutes meaningful test results are delivered to the user and their medical specialists will be monitoring the results for preemptive intervention.

• *HealthScale, developed with ANFF SA, is a microneedle technology that provides in-home health care. Credit: InnaMed*

"Without doubt, ANFF SA has been the right fit for our organisation. From the helpful faculty and researchers at the University of South Australia, right through to the flexible and problem-solving team who treat your project as their own. Our experience has been the best."
– Eshwar Inapuri

"It is exciting to see Australian and international companies increasingly rely on ANFF to realise their next-generation technologies," said Dr Craig Priest, SA Node Director. "I'm particularly proud of the professionalism and skills mix in our ANFF SA team that consistently delivers world's best outcomes. It makes all the difference."

Having delivered outstanding results with HealthScale, Eshwar has recently chosen to re-partner with ANFF SA for the design and development of another novel medical device.

• *Examples of X-ray tomography images. Credit: UniSA*

Providing non-destructive testing to Australian industries

Non-destructive analysis of miniaturised electronic components has connected a South Australian manufacturer, CircuitWorks Australia, with X-ray tomography available at ANFF SA.

Circuitworks Australia is a global distributor of high quality and reliable electrical components. The company produces customised products for customers, taking projects from initial design to the assembly line.

CircuitWorks director, Bevan Illman, made contact with ANFF SA seeking to inspect the internal circuitry of a micro-sized printed wire assembly (PWA) without destroying it.

Microelectronic components can be as small as a speck of dust with intricate embedded features meaning Bevan was unable to simply "take a look under the hood" of the PWA.

Through his intimate knowledge in the design and manufacturing processes of these miniaturised devices Bevan knew he required a specialised X-ray machine and an experienced tomographer.

Using ANFF SA's state-of-the-art, high-resolution 3D Micro-XCT equipment, a thorough investigation and analysis of the PWA was undertaken, without the need to perform a destructive cross-section analysis.

With no sample preparation, the ANFF SA Micro-XCT equipment enables high-resolution imaging of samples including biological networks, porous geological cores for petroleum industry, and semiconductor packages down to submicron levels. In many cases, it is possible to draw a conclusion based on 3D X-ray micrographs without the need of destructive physical cross sectioning.

For Bevan, the resulting 3D images of the PWA revealed unique and valuable 'inside information' to the manufacturing team and the client.

"The 3D X-rays provided by ANFF SA proved an extremely reliable method to perform a detailed evaluation of the PWAs," Bevan confirmed.

"Based on ANFF SA's comprehensive reports and imaging, our client began extensive electrical simulation and testing of the PWA," said Bevan. "As a result, our client modified the printed circuit board in the PWA and manufacturing proceeded. Everyone is happy!"

ANFF SA Facility Manager, Simon Doe is pleased to see a well-respected local manufacturer benefit from ANFF SA's unique capabilities.

"Our 3D Micro-XCT offers high-resolution imaging of microstructures inside tiny components," said Simon. "This is one of many ways that ANFF SA is supporting advanced manufacturing innovation in Australia."

• Scott McCormick worked with ANFF SA during his PhD to develop a testing method for nanoparticles.

On-chip screening of nanoparticle toxicity

A device capable of testing nanoparticles for toxicity is being developed in South Australia to protect the health and safety of the public and the manufacturing industry.

The use of nanoparticles in applications like healthcare, chemical synthesis, disinfection, and energy is growing rapidly. Yet, every new particle must be safe and effective, putting pressure on current testing protocols that are costly and slow.

Using ANFF SA's world-class equipment and facilities, a team of University of South Australia (UniSA) and Monash University researchers are prototyping a miniaturised cell-laden microfluidic device to accelerate testing of nanoparticles for toxic effects.

The device exploits laminar flow to guide cells and nanoparticles to microscale testing sites within a channel. These locations can then be monitored over time, so that a single experiment can report many nanotoxicity test outcomes based on combinations of different cells and particles.

PhD student Scott McCormick has anchored viable white blood cells and skin cells in a microchannel, and studied the effect of flow on detachment. The study dovetails with the successful demonstration of a 5-channel screening chip, developed by Dr Tommy Tong, previously a researcher at UniSA, and now at Monash University.

The research team benefits from access to rapid prototyping capabilities, including ANFF SA's direct-write lithography which allows a quick transition from concept to laboratory testing.

"Access to ANFF SA's state-of-the-art fabrication equipment, facilities and highly skilled staff has been crucial to my work," said Scott. "ANFF SA allows my PhD training to include high-performance facilities and access to technical expertise."

It is hoped that further development of the concept will enable improved regulation and safety for the use of nanoparticles in consumer and industry applications. The concept may also improve personalised medicine by testing, for example, multiple chemotherapy drugs against a patient's cancer cells to find the most effective dosage prior to administering.

Making cell modification easier

Gene-modified cell therapy is evolving as a major new genre of medicine, offering cures to what are currently considered incurable diseases.

Now, an Australian startup called Indee Labs is simplifying the process of modifying cells to bring down costs of development and manufacturing and make the therapy available to everyone.

Gene-modified cell therapy typically involves modifying the DNA of individual T-cells – an essential part of the immune system – to target tissues such as tumours.

T-cells naturally attack infections within the body but by modifying their genetic code, they can be tailored to target diseases they wouldn't typically recognise. As the cells stay in the body and reproduce, they can keep fighting long after the initial treatment.

The first therapies are beginning to pass the medical approval process and could begin hitting the market before the end of 2017.

The current production method involves directly injecting each cell with a virus that engrains itself in the cell's DNA. The technique is difficult, expensive and slow preventing widespread adoption of the treatment.

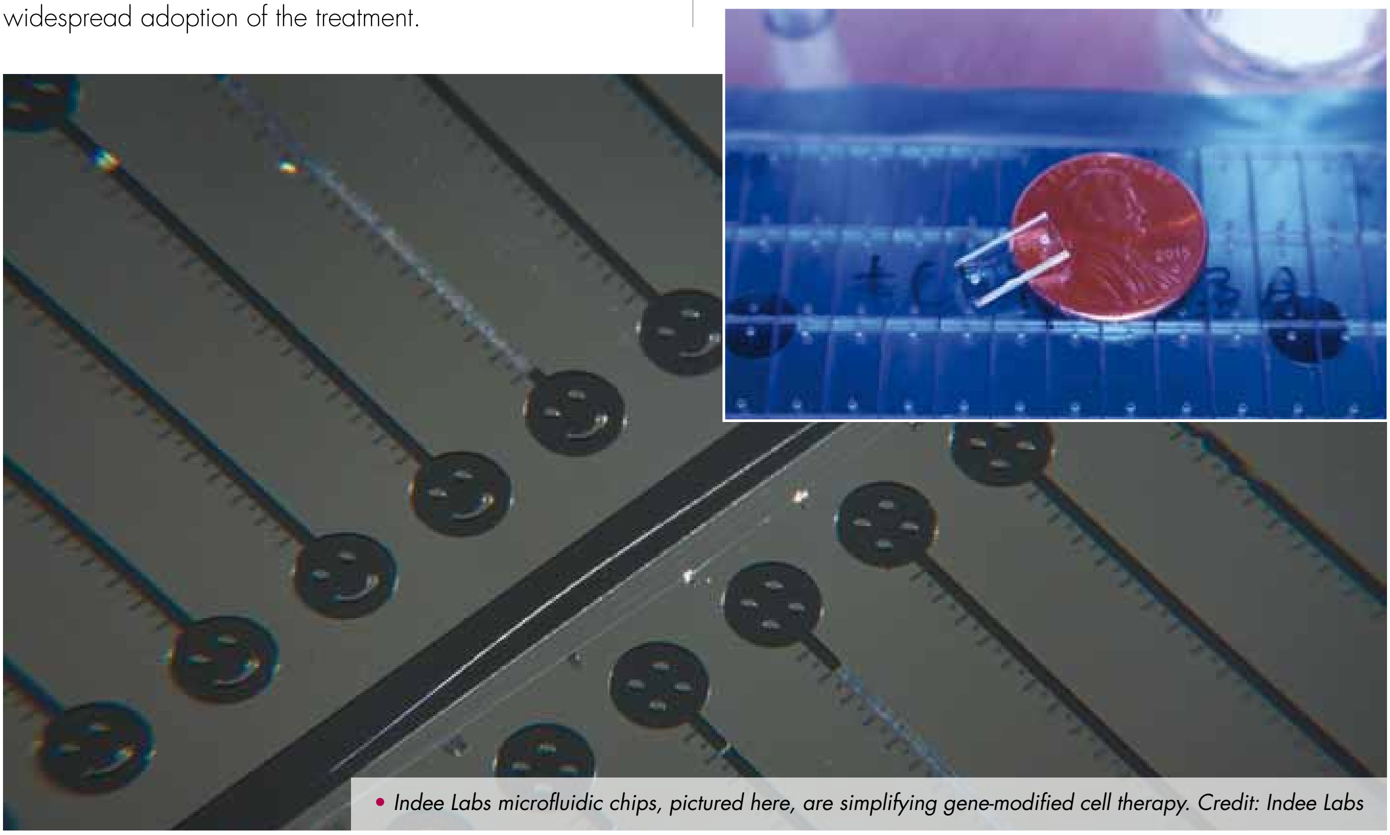
Indee Labs has been working with ANFF SA since 2014 to simplify the process. The company has developed a microfluidic device which uses fluid dynamics to force genetic material into a cell without the risks associated with viral vectors.

A mixture of T-cells and the desired genes is placed in the microfluidic chip. The mixture passes through turbulent regions within the device which disrupts the cell's membrane, allowing the genes to enter. The membrane then heals itself, encasing the new genetic information which modifies or engineers the cell to attack a specified disease.

The technique provides a scalable alternative to direct injection that offers cost benefits and reduces processing times.

The device has been shown to efficiently modify cells *in vitro* or in a petri dish and the technology is under evaluation by publicly-traded companies in the United States. Indee Labs has received approximately AU$2M in investment to develop the technology and has been recognised by a number of US and Australian organisations including the White House Cancer Moonshot Taskforce, AFOSR, AusTrade, Jobs for NSW and QB3@953 among others.

"I moved to Silicon Valley after receiving our first round of investment thinking Silicon Valley knew how to etch a silicon wafer," Dr Ryan Pawall, Indee CEO, said. "Less than a week later I called Simon instead. Nobody does micro- and nano-fabrication quite like Simon Doe and Craig Priest at ANFF SA."



• *Indee Labs microfluidic chips, pictured here, are simplifying gene-modified cell therapy. Credit: Indee Labs*

Ten years of ANFF

Year	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Number of Users	360	803	920	1,283	1,812	2,000	2,189	2,673	2,640	2,962
User Hours	10,897	31,375	37,610	54,530	84,948	101,841	128,282	192,639	201,592	215,625

Ten years of hard work

Five board members sat for our first Annual General Meeting. Four of those members are still with the Board today, including inaugural chair, Dr Bob Frater and current chair, Prof Chris Fell. Our annual staff development awards, the Frater Awards, are named in honour of the inaugural chair.

Seventeen node staff names were listed in our first Annual Progress Report in 2007/08, that has grown to 119 names in our 2016/17 Annual Progress Report.

2017

- Silicon Quantum Computing spinout founded with $83 million funding from Australian and New South Wales governments, Commonwealth Bank Australia, Telstra Corporation and UNSW Sydney
- Australian Nanotechnology Network announces Short Term Visit fund for early career researchers to travel to ANFF nodes

2016

- Scaled Biolabs receives backing from Indie Bio to miniaturise combinatorial multiplexing of reagents for use in pathology labs or cell manufacturing processes into a microfluidic device
- Modular Photonics presents its devices at ECOC 2016, one of the world's largest optical communications conferences

2015

- ANFF signs MoU with New Zealand's MacDiarmid Institute for Advanced Materials and Nanotechnology
- Radulock founded on a novel method for making high-pressure connections for microfluidic devices

2014

- Inaugural ANFF SA Winter School, offering hands on training in micro and nano fabrication techniques
- ANFF Design House launched

2013

- Red Chip Photonics founded on novel chip-based lasers

2012

- Inaugural Frater Awards to provide staff with personal development opportunities
- AquaHydrex founded, providing storable energy from water and sunlight

2011

- Inaugural ANFF research showcase, 'Fabrication 2020', held in Melbourne
- Inaugural US-Australia S&T Joint Commission Meeting held to develop new collaborative ties in Nanotechnology between the US Air Force (USAF) and Australia
- Vaxxas founded on microneedle technology

2010

- ANFF VIC celebrates opening of Melbourne Centre for Nanofabrication
- First ANFF one-day short course in nanofabrication held at ICONN 2010
- ANFF WA established as ANFF's eighth Node

2009

- ANFF's first spin-out, Kiriama founded

2008

- First ANFF acknowledgements appear in peer-reviewed journals

2007

- ANFF Limited established
- First ANFF Nodes established

VIC NODE

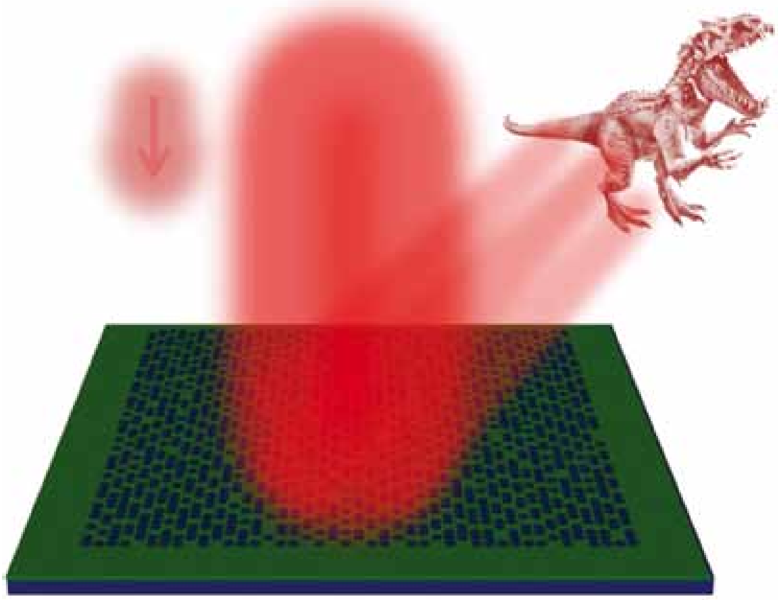
Melbourne Centre for Nanofabrication
151 Wellington Road
Clayton VIC 3168

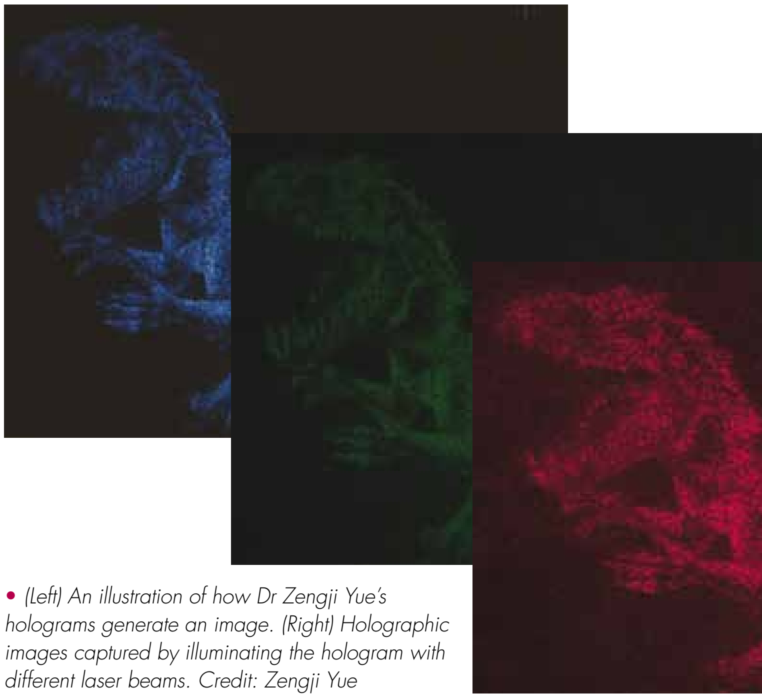
Node Director: Prof Nico Voelcker
Email: nicolas.voelcker@monash.edu
Phone: +61 3 9902 9097

Facility Manager: Dr Paul Spizzirri
Email: paul.spizzirri@monash.edu
Phone: +61 3 9902 9653

General Manager: Dr Sean Langelier
Email: sean.langelier@monash.edu
Phone: +61 3 9902 4100

Ultrathin holograms open doors to 3D displays





• *(Left) An illustration of how Dr Zengji Yue's holograms generate an image. (Right) Holographic images captured by illuminating the hologram with different laser beams. Credit: Zengji Yue*

A team led by Professor Min Gu from RMIT University and the Beijing Institute of Technology has fabricated the world's thinnest hologram – it could revolutionise the way we interact with everyday technologies.

The team's research, published in *Nature Communications*, takes a step closer to three-dimensional (3D) displays for smart devices by reducing physical dimensions of a hologram to the nanometre scale.

Holograms are the result of shining light on a recorded interference pattern to recreate a seemingly 3D object within a film. An interference pattern is created by light being split into two and travelling different paths of varying length, which causes a phase difference in the light resulting in peaks and troughs of intensity when the beams are recombined.

Since the 60s it's been common practice to use a process called computer-generated holography (CGH) to create the patterns that induce the holographic effect. This can in principle be applied to technologies including smartphones.

However, holograms have to be thick enough to allow enough time for the phase difference to become noticeable so the physical size of holograms (between micrometre to millimetres) makes this currently impractical.

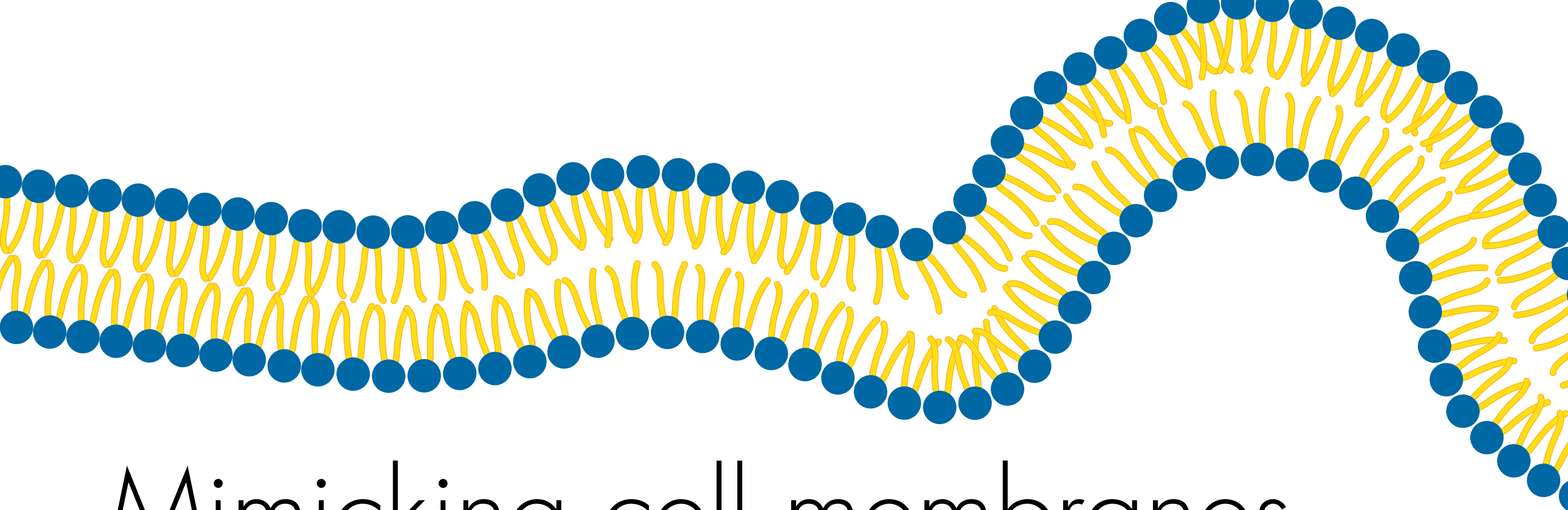
The paper's lead author, Dr Zengji Yue, explained that to reduce the depth the team began working with antimony telluride (Sb_2Te_3) that had been laser etched to feature the desired interference pattern.

Sb_2Te_3's refractive index at the surface is far lower than within the body of the material which means the new film acts as a resonance cavity – light is bounced between the surfaces, exaggerating the phase difference.

The team worked closely with Dr Lachlan Hyde, a Senior Process Engineer at the Melbourne Centre for Nanofabrication to use atomic layer deposition (ALD) as the basis to fabricate the Sb_2Te_3 hologram film.

The result is a 60nm thick film, orders of magnitude smaller than previous holograms, that produces the holographic images.

Considering most of the processes are scalable, the new holograms could be produced on a large scale. The next step is to create smaller pixels to increase the resolution of the images, and to investigate dynamic displays.



Mimicking cell membranes

A Swinburne University of Technology researcher has taken big steps towards reliably modelling cell membranes. The process could help to improve biosensor technologies and drug delivery techniques.

Cell membranes are the interface between the interior of a human cell and the outside environment. The membrane is made of from an organised lipid molecule structure known as a lipid bilayer.

The membrane plays an important role in transporting molecules in and out of the cell so studying them enables researchers to improve the understanding of drug pathways into human cells.

The problem is conducting research on real cell membranes is challenging as they are complex and variable environments.

Supported lipid bilayers (SLB) can be used to reliably replicate membranes and they can be created by collapsing spherical lipid bilayers onto a support surface. However, reliably collapsing the spheres has proven difficult – the process is complex and the relationship between the surface chemistry of the support material and the lipid spheres is poorly understood.

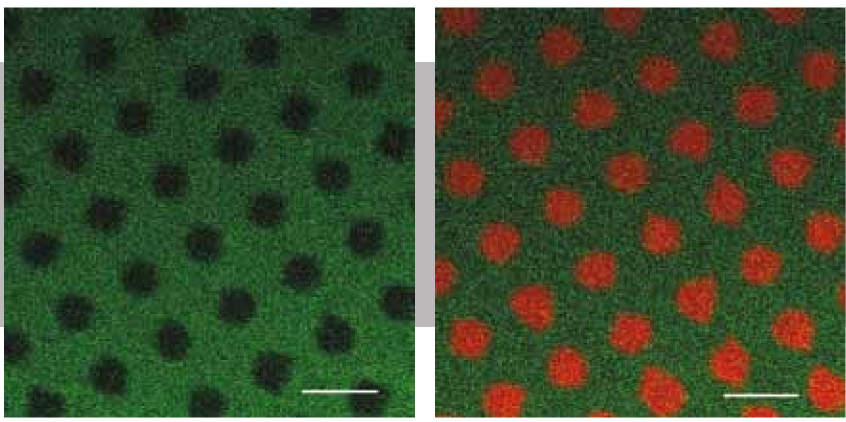
Dr Hannah Askew began investigating how different surface chemistries and acidity or alkalinity could influence the creation of SLBs during her PhD project at Swinburne University of Technology.

Using ANFF VIC's plasma polymerisation capabilities at Swinburne and the node's characterisation equipment at La Trobe University, Hannah applied coatings of acrylic acid (ppAAc), allylamine (ppAAm) and ppAAc/ppAAm patterns to support materials to vary their surface properties. A photolithography mask manufactured at the OptoFab node, enabled the creation of the ppAAc/ppAAm patterns.

Hannah found that the lipid spheres stuck to ppAAm irrespective of pH. However, when coated with ppAAc, pH could be used to control the behaviour of the spheres at the surface. When ppAAm and ppAAc regions were deposited on the same surface in a pattern, a hybrid SLB was produced with both rigid and fluid lipid bilayer regions.

The patterned coating combined with careful use of pH enabled the spatial control of both lipid location and mobility.

This outcome contributes to the development of increasingly complex cell membrane models which can be used in a variety of industries to investigate processes such as drug-membrane interactions and to develop improved biosensing platforms.



• *Confocal microscopy image of a patterned surface of ppAAc circles (stained red) on ppAA (stained green). Scale bar = 20μm. Credit: Hannah Askew*

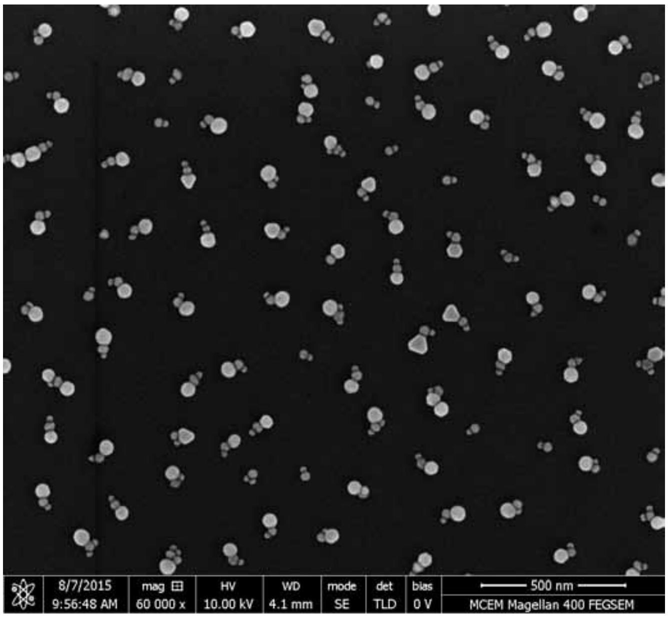
Automatic assembly of nanoparticle-based lenses

A team of researchers has created a scalable production method for a class of nanoscale lenses using the electrostatic forces between charged nanoparticles, enabling wider application of the technology.

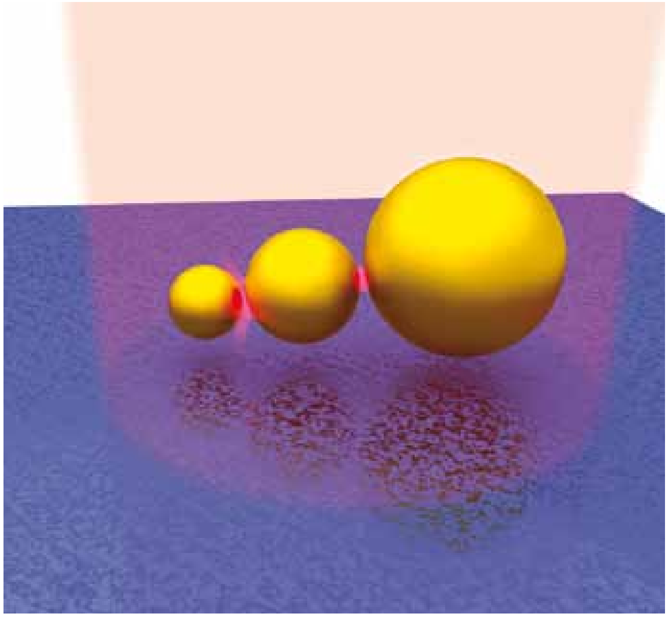
These nanolenses use the gaps between triplets – or trimers – of different sized nanoparticles to focus light.

They are showing enormous promise in a range of optical and sensing applications due to their miniscule size and very high field enhancement. However, an expensive and laborious production process has limited their widespread uptake.

Dr Julian Lloyd, lead author of the research, and his colleagues' method uses induced electrostatic forces to self-assemble the gold nanoparticle triplets. The process was developed at Monash University, Monash Centre for Electron Microscopy and the Melbourne Centre for Nanofabrication, ANFF VIC's flagship facility and ANFF's headquarters.



• *Dr Julian Lloyd has devised a scalable method to produce trimers capable of focusing light. Credit: Julian Lloyd*



• *An illustration of the trimers focusing light. Credit: Soon Hock Ng*

The method enables production of these trimers with a more than 60 per cent yield, quantities that have never been achieved before, and removes the need for expensive "top-down" fabrication techniques traditionally used that inhibit the scalability of the fabrication process.

Julian's trimers are short strings of nanoparticles 20nm, 30nm and 50nm in diameter. In his paper published in *ACS Nano*, Julian explains that by placing differing surface charges on the nanoparticles, the structures draw themselves into place.

Using a positively charged substrate as a base, the team add a number of negatively charged 30nm particles which neatly distribute themselves across the surface. Positively charged 20nm particles are added, each attracted to a 30nm particle, before a solution of positively charged 50nm particles is introduced. The particles align themselves because the 20 and 50nm particles repel each other, whilst both being drawn towards the centre 30nm particle.

"We can control the distance between individual trimers and also improve the trimer yield by tuning the surface charges," Julian explained.

"As the whole assembly method relies on electrostatic interactions, it was vitally important to know the surface charges of the different components," he continued. "The surface charge measurements were taken at the Melbourne Centre for Nanofabrication using the Centre's Zeta sizer and a Zeta potential analyser."

• *Growing diamond at the MCN. Credit: Alastair Stacey*

Australia's first superconducting diamond

In an Australian first, a Victorian team of researchers has created superconducting diamond.

Diamond is already nature's super material. It's the hardest naturally occurring substance, a fantastic thermal conductor, and it doesn't corrode. Adding superconductivity to this list of characteristics is an exciting prospect for a new class of highly robust devices.

It is also potentially a step towards a material that can exhibit absolutely no electrical resistance at room temperature – a holy grail of materials science. According to Professor Marvin Cohen, an award-winning theorist from the University of California at Berkeley, diamond could be the material that makes this possible.

However, producing superconductivity in diamond at any temperature has proved elusive, there's only a select group of international labs capable of doing it at all.

But now a team from the University of Melbourne has joined the fold, thanks to research conducted by Masters student Yi Jiang, led by ANFF VIC Technology Fellow Ambassador Dr Alastair Stacey and supported by the ARC and USA's Air Force Office of Scientific Research (AFOSR).

The team demonstrated that adding a dose of boron – a process called doping – causes diamond to show superconducting properties at temperatures around 2K.

To do this, the team harnessed diamond chemical vapour deposition capabilities available at ANFF VIC's flagship facility, the Melbourne Centre for Nanofabrication, that are capable of introducing boron while diamond is being grown.

"The investment by ANFF in a state-of-the-art facility for the growing of high quality, ultra-pure, single crystal diamond films – and in particular the investment in a high purity boron doping line into the reactor – is a big part of what made this research possible," Alastair said.

Even at these low temperatures, superconductors are incredibly useful for applications including range finding and monitoring low-intensity light sources.

The team's boron-doped diamond will now be used as the base material for a range of new sensors including SQUIDS (for magnetic field sensing) and single photon detectors, as well as in integrated diamond quantum photonic devices.

Nanofibre facemasks provide a breath of fresh air

Deakin University's Institute of Frontier Materials (IFM) has been working with Xinau Technology to develop a new type of nanofibre facemask that will replace traditional microfibre-based equivalents.

Air quality is on the decline in huge areas of the developed and developing world. The International Energy Agency attribute an estimated 6.5 million deaths per year to indoor and outdoor air pollution – it is reportedly the fourth largest threat to human health, after high blood pressure, dietary risks, and smoking.

Pollutants that measure less than 2.5 microns (PM2.5) are a particular concern, their small size means they are able to penetrate deep into the lungs.

Facemasks are now commonly used in heavily affected areas, but conventional microfibre masks either don't provide the necessary filtration or block airflow too heavily, making it hard to breath.

"ANFF VIC's needleless electrospinning machines at Deakin University made it possible to process large-size nanofibre nonwoven sheets with consistent structure."

– Professor Tong Lin

As "smog seasons" become a regular occurrence, cities such as Beijing, China are seeing a huge number of residents turn to expensive, high-end masks to help them breathe easy.

A team at the IFM are now using ANFF VIC's electrospinning equipment to create nanofibre-based masks that are drastically better at stopping inhalation of PM2.5 particles, and provide very little breath resistance. The pilot electrospinning machine is able to prepare 2-metre-wide nanofibre sheets in a continuous manner and has a production capability of up to 1,000m^2 per day.

• *Nanofibre facemasks offer comfort and safety benefits, protecting the wearer from pollution. Credit: Tong Lin*

"When a layer of nanofibre nonwovens is inserted into conventional facemask, the breath resistance did not increase much, however the capture efficiency for PM2.5 was significantly improved," Professor Tong Lin, leader of the team at Deakin University, said. This means the team can make the filtering material thinner and more breathable, while still stopping up to 95% of airborne pollutants.

The key component to maintain high PM2.5 filtration efficiency is the nanofibre sheets, which are highly porous and have a large surface area.

"ANFF VIC's needleless electrospinning machines at Deakin University made it possible to process large-size nanofibre nonwoven sheets with consistent structure," Tong continued. "It also allows you to adjust the fibrous structure by changing the operating parameters such as voltage, spinning distance and polymer components."

The team are currently working with Xinau to commercialise the technology.

WA NODE

School of Electrical, Electronic
& Computer Engineering
Room 4.17, M018,
The University of Western Australia
35 Stirling Highway, Crawley WA 6009

Node Director: Prof Lorenzo Faraone
Email: lorenzo.faraone@uwa.edu.au
Phone: +61 8 6488 3104

Facility Manager: Prof Mariusz Martyniuk
Email: mariusz.martyniuk@uwa.edu.au
Phone: +61 8 6488 1905

MEMS-Metamaterials: Tuning in to long-wavelength terahertz radiation

Research conducted at the University of Western Australia and the Australian National University has provided a foundation for a new generation of detectors for dangerous substances, airport security scanners, as well as for exploring novel types of short range communications.

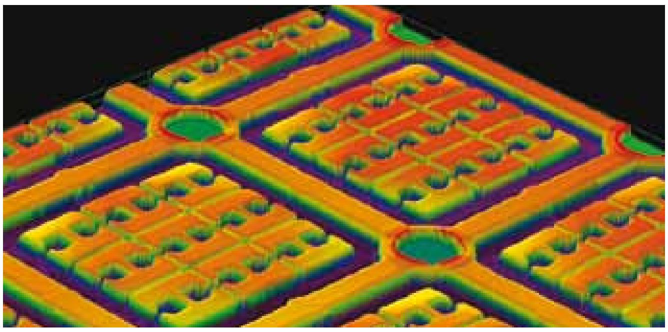
The technology can controllably absorb, reflect or transmit infrared and terahertz light. It's adaptively controlled and can be rapidly adjusted to scan a range of spectral signals.

Proving this concept is vital for future low-cost miniature devices for spectroscopic, spatial, and temporal manipulation of infrared and terahertz waves.

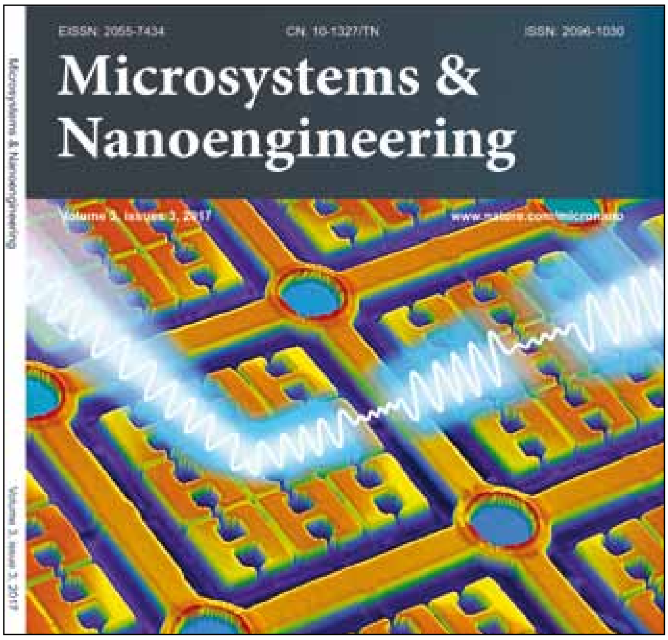
Terahertz and infrared light is widely used in a variety of applications including security screening and communications. To improve current technologies, materials with a strong and tunable response are desired.

The team – led by Ilya Shadrivov (Australian National University) and Mariusz Martyniuk (University of Western Australia) – worked with ANFF WA and ANFF ACT to fabricate and characterise a microelectromechanical system (MEMS)-based metamaterial.

MEMS devices are miniature mechanical devices that can be moved in a number of different axis by applying a small voltage.



• *Ilya Shadrivov worked closely with ANFF WA and ACT to characterise MEMS-based light sensors. Credit: UoW*



• *Ilya's research was published in Microsystems and Nanoengineering. Credit: Microsystems and Nanoengineering*

The team took this established technology, which consisted of a silicon nitride membrane and placed "meta-atoms" that absorb the light on top.

The completed device can control and tune how much terahertz or infrared is absorbed by varying the height of the MEMS surface above the ground plane.

"Our MEMS structure modulates absorption, leading to modulation of local temperature in the surface below. This can be used for substantial enhancement of the sensitivity when you measure this change of temperature," Ilya explained.

This demonstrated performance is a stepping stone towards development of a unified technology to manipulate infrared and terahertz waves, with far reaching applications in security, imaging and communications.

• *MEMS devices featuring light-sensitive meta-atoms. Credit: UoW*

Calcium detection using ISFET devices

A new class of devices developed by Professor Giacinta Parish and her team at the University of Western Australia is providing the most sensitive measurements of calcium ions to date.

The sensor uses a highly selective and sensitive transistor made of a semiconductor called aluminium gallium nitride (AlGaN) to detect calcium ions. It can be used in conjunction with other types of sensors to create devices that screen for a number of ions or pathogens.

Calcium monitoring is vital to applications including blood monitoring, water-network maintenance, food processing, chemical oceanography and agriculture.

For instance, water hardness can cause numerous problems in industrial processes and households, at a heavy cost. Dissolved calcium salts are the primary reason for scaling in pipes and water heaters, which can result in entire systems needing to be replaced.

Monitoring calcium ion concentration in the blood can highlight deficiencies that could cause conditions such as muscle and nerve tightening and osteoporosis. Calcium is also essential for many biological functions including the creation of bones and teeth, the movement of muscles, neural and intracellular signalling, and many enzyme-based processes.

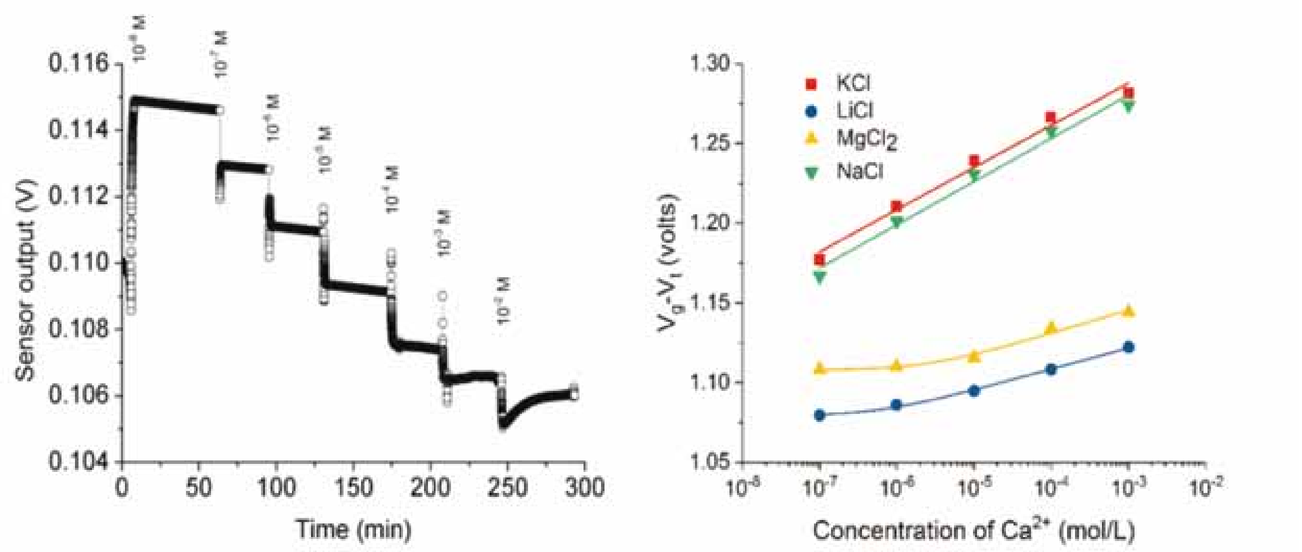
Traditionally atomic absorption spectrometry (AAS) is used for quantifying calcium content. However, sample preparation for AAS is tedious, the technique is expensive and not suitable for in situ real-time monitoring, and the equipment is bulky.

Giacinta's device is instead based on ion selective field effect transistors (ISFETs) and offers advantages over traditional AAS, such as better portability, lower cost, and excellent selectivity. The team fabricated its devices at ANFF WA, using the Node's lithography suite to fabricate layers of AlGaN on a sapphire substrate.

The device comprises a chamber in which to place a sample with electrodes on either side. When the desired ions, in this case calcium, are present in the sample the circuit is completed and a voltage is able to pass through. More calcium means more electricity, which allows the device to calculate the concentration of the ion in the sample.

The result is a highly specialised sensor that non-destructively analyses samples and is capable of detecting very low concentrations of calcium. Testing showed that Giacinta's devices offer the lowest reported detection limit for reference electrode free Ca^{2+} sensors.

Further studies of this technology can be expanded by integrating an array of sensors with membranes of different composition onto a single chip to detect various chemicals simultaneously.



• *Left: sensor response over time for AlGaN/GaN sensor with calcium membrane to changes in Ca^{2+} concentration*
Right: changes in effective equilibrium gate potential with changes in Ca^{2+} concentration. Credit: Giacinta Parish

Unlocking infrared with X-RAYS

• *The ANFF WA MBE Lab. Credit: Imtiaz Madni*

University of Western Australia (UWA) researchers have been working to improve future infrared detectors by investigating the fundamental fabrication process of light-sensitive materials.

Detectors are reliant on photosensitive semiconductor crystals, the quality of which dictates their ability to detect light. To achieve a near-perfect crystal structure, improved fabrication processes and in-depth analysis of the crystal quality is essential.

Dr Imtiaz Madni and his colleagues from UWA theorised that they had identified a substrate on which to grow infrared-sensitive films of mercury cadmium telluride (HgCdTe) that would improve its performance as a detector at significantly reduced cost.

The proposed substrate was gallium antimonide (GaSb) – it possesses a similar crystal arrangement to HgCdTe which makes it an ideal crystal seed to grow thin films of the photosensitive material.

The team used ANFF WA's molecular beam epitaxy (MBE) suite to create their samples. The process deposits incredibly high-quality films of material so that almost every atom is located in the correct position, and the crystals are aligned in the correct orientation.

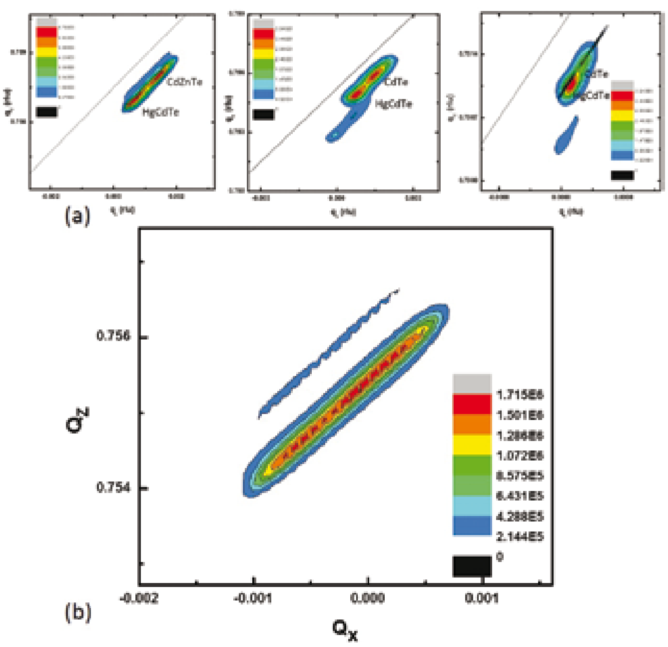
MBE aims a beam of atoms or molecules at a substrate in an ultra-high vacuum, effectively spray-painting the substrates surface with a thin film of the desired material. The process lays material down slowly to allow each atom to find its correct position, typically at a rate of around 8Å (0.8nm) of material per second.

Because crystal quality is so vital to the performance of the sensor, the team required high-resolution mapping of the internal structure of the material.

"We applied a sophisticated experimental technique for X-ray reciprocal space mapping to study the strain-relaxation in HgCdTe layers grown via MBE on conventionally-used lattice matched CdZnTe substrate as well as the promising alternative substrate, GaSb," Imtiaz explained.

The technique involves shining X-rays through the material, which causes a diffraction pattern of the X-rays that is specific to the crystal orientation. By tilting the material and recording the changes in the diffraction pattern, any variations in the structure can be highlighted. The group turned to the Panalytical Empyrion X-ray diffraction mapping equipment available at UWA, operated by ANFF and the Australian Microscopy and Microanalysis Research Facility (AMMRF), a fellow NCRIS-funded organisation.

The use of inexpensive GaSb as a substrate was demonstrated to result in the growth of high-quality HgCdTe crystal – therefore, significantly reducing the cost of high-performance infrared detectors.



• *X-ray reciprocal space analysis of (a) HgCdTe grown on CdZnTe, and alternative substrates GaAs and GaSb, (b) HgTe-CdTe superlattice material with 3 nm and 2 nm thickness of bilayers respectively. Credit: Imtiaz Madni*

Extending infrared detection

Infrared imaging provides a means to see in obscured environments by using parts of the light spectrum invisible to the eye.

Infrared technology is best known for its applications in the defence industry, where it's used to help soldiers and pilots to see in the dark or through smoky environments, but there's also a myriad of uses in industrial imaging, space exploration, environmental monitoring, and communications.

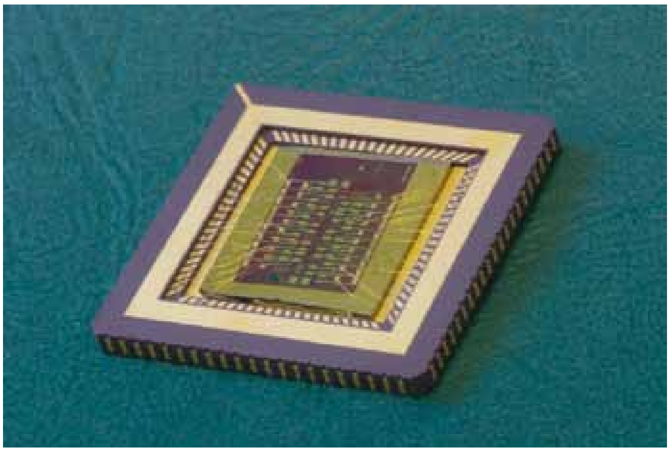
As researchers and manufacturers strive for more detailed images and better clarity of vision, they're pushed ever further into the extended parts of the infrared spectrum.

Scientists and engineers are starting to use a region of the IR spectrum referred to as the extended shortwave IR region (eSWIR). This part of the spectrum provides clearer images compared to other parts of the IR spectrum and makes it easier to recognise shapes – thus providing a tactical advantage.

The project has yielded fundamental insights into how current is carried through HgCdTe, directly aiding the development of infrared detectors.

Particularly in infrared imaging, sensitivity of a detector is vital. Most applications of infrared imaging occur out in the open where it's impractical to artificially illuminate the scene – this means the sensors are reliant on naturally occurring illumination from the environment, often from moonlight or heat so there's not an enormous amount of photons that can be detected.

Sensors work by monitoring the change in electrical properties of pixels as they are hit by photons. The electrical variation in the pixel is dependent on the intensity of the light hitting that part of the sensor – by mapping these variations it's possible to create an image. It is therefore critical to



• *15 Tesla super-conducting magnet at ANFF WA used in this research. Credit: Hemendra Kala*

• *Left: An infrared sensor being analysed at ANFF WA. Credit: Mariusz Martyniuk*

understand how electrons move within the sensitive material to make more efficient detectors.

However, because sensors are specific to certain bands of the light spectrum, currently used sensors for commonly used short-wave IR (SWIR) detection fail to detect eSWIR light. This means researchers are having to investigate new materials that are sensitive to this untapped light and develop an understanding of how to improve the device's electrical performance.

All of this has driven Selex ES, a UK-based world-leader in infrared detector technology, to work with ANFF WA to investigate the characteristics of a class of mercury cadmium telluride (HgCdTe)-based semiconductor materials. This class is particularly sensitive to eSWIR when doped.

Selex ES provided samples, and the WA Node contributed its experimental and technical expertise in the electrical characterisation of a range of doped semiconductor materials to assist the company in realising this new class of infrared detectors.

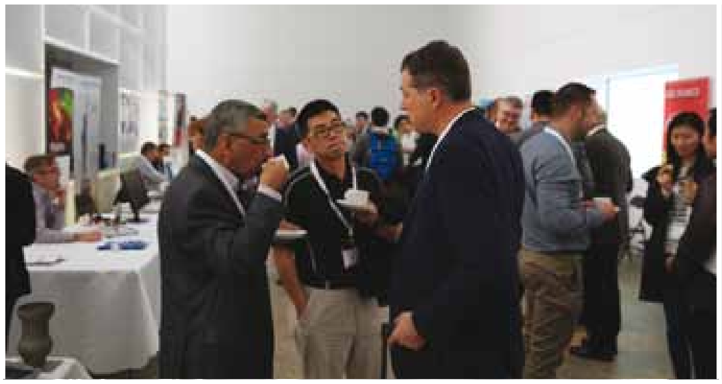
Resistivity and Hall-effect measurements were conducted using the 15 Tesla superconducting magnet at ANFF WA. The analysis and modelling was led by Dr Gilberto Umana-Membreno, a Senior Industry Support Engineer at ANFF WA, who is a leading expert in the field of electronic transport characterisation of semiconductors.

The project has yielded fundamental insights into how current is carried through HgCdTe, directly aiding the development of infrared detectors capable of higher performance and efficiency when compared to state-of-the-art equivalents.

2016 ANFF RESEARCH SHOWCASE

MIND THE GAP

The 2016 ANFF Research Showcase was held at the Australian Synchrotron, Melbourne. The event was focused on how ANFF and its users are helping to cross the gap between academia and industry. Here's a collection of photos taken at the event.







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