THE AUSTRALIAN NATIONAL FABRICATION FACILITY

ANFF

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National Research Infrastructure for Australia
An Australian Government Initiative

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The production of the 2020 Casebook comes amid the turmoil of the COVID 19 pandemic, a time that has seen the importance of research, development, and commercialisation of technologies thrust to the fore.

The creation of new revenue streams and businesses based on new technologies, novel manufacturing and new employment have rightly become central pillars of the Commonwealth Government's strategy for economic recovery.

These activities place ANFF, our NCRIS colleagues, and our clients at the heart of Australia's innovative future, and we stand ready to enable the Nation to capture the benefits of its investments in research at all levels of technology readiness.

However, it's only through sustained support that organisations such as ANFF can be ready to provide the flexible capability required to secure Australia's future. As such, the Board of ANFF thanks NCRIS for its continued support and funding, and expresses enormous appreciation to the institutions that have housed ANFF facilities and provided matching funds to enable the purchase of cutting-edge equipment.

Due to this support ANFF has been able to pivot to provide for emerging needs, and our ability to do so has been demonstrated throughout the COVID crisis. ANFF Nodes have continued to offer safe services with experienced technologists providing clients with outcomes and training. ANFF's strong backing of COVID-related projects has seen us assist Australia's immediate response, and the realisation of new research.

Despite COVID, the past year has seen the almost 3,000 users of ANFF facilities produce a steady stream of high-quality science and engineering that has enabled Australia to claim world leadership in a number of areas. Some are described in this Casebook which I strongly commend to you, and I speak for the Board when I thank all of those associated with the Facility for their substantial contributions in recent years and the many users of ANFF for their presentation of so many interesting fabrication challenges.

While the future seems turbulent, the appointment of our new CEO, Dr Ian Griffiths positions us to provide calm and efficient assistance to our clients as they travel the many paths towards commercialisation. We therefore look ahead with excitement and resolve as we continue to enable the research that will allow Australia to thrive.

Emeritus Professor Chris Fell AM FTSE HonFIEA ust CPEng
ANFF Chairman

As I complete my first year as CEO of ANFF I reflect on how much has changed so quickly. In late 2019 the executive team started to review and refresh the organisation's strategy documents. The focus was around maintaining our research infrastructure excellence and starting to consider how best to support the vast amount of industry engagement and commercialisation activity that is based on the use of our tools.

When COVID 19 caused lockdowns and the Nation's supply lines became stressed or inactive, ANFF pitched in and excelled to the best of our abilities. We manufactured, tested and supplied personal protective equipment items for front line workers at no cost. We accelerated a number of projects that have relevance to infectious diseases by significantly reducing cost and lending all of our engineering talent and tools to the cause. I would like to thank NCRIS and the Department of Education, Skills and Employment (DESE) for supporting ANFF and the new mode of operating. I would also like to thank all the ANFF staff members that went above and beyond to help when the Nation needed it most.

As supply lines reopen and lockdown restrictions ease, we have moved back to normal operations but in a new era – this era has a new energy for sovereign capability and rebooting the Australian Economy. A new focus for ANFF strategy became clear.

We need to use our tools and talent to directly support research and research translation in industry sectors that we already have a good track record. These are additional efforts that will add to our core remit of providing Australian innovators with access to world-class research infrastructure, but we are going to be both proactive and aggressive in putting added focus into the areas that we can do the most good – Healthcare and Biotech, Space and Defence and Renewable Energy.

We will augment the ANFF team to facilitate this focus and also to better integrate with other industry groups and strategic partners. We will also be keeping a close eye on promising home-grown technology that would benefit from additional support. As such ANFF and its University partners can together nurture these emerging technologies and companies through the valley of death. It's a role that ANFF is in a unique position to play.

As you will see in the ANFF Casebook we're doing some incredible things and as we move forward we will continue to add value to the Nation. Now is an exciting time to be in ANFF.

Dr Ian Griffiths
ANFF CEO

CONTENTS

This Casebook features stories split into three sections: Excellence in research; Capturing the Benefit; and Establishing industries. Flagship Focus pages take a look at some of the most unique capabilities available through the ANFF network.

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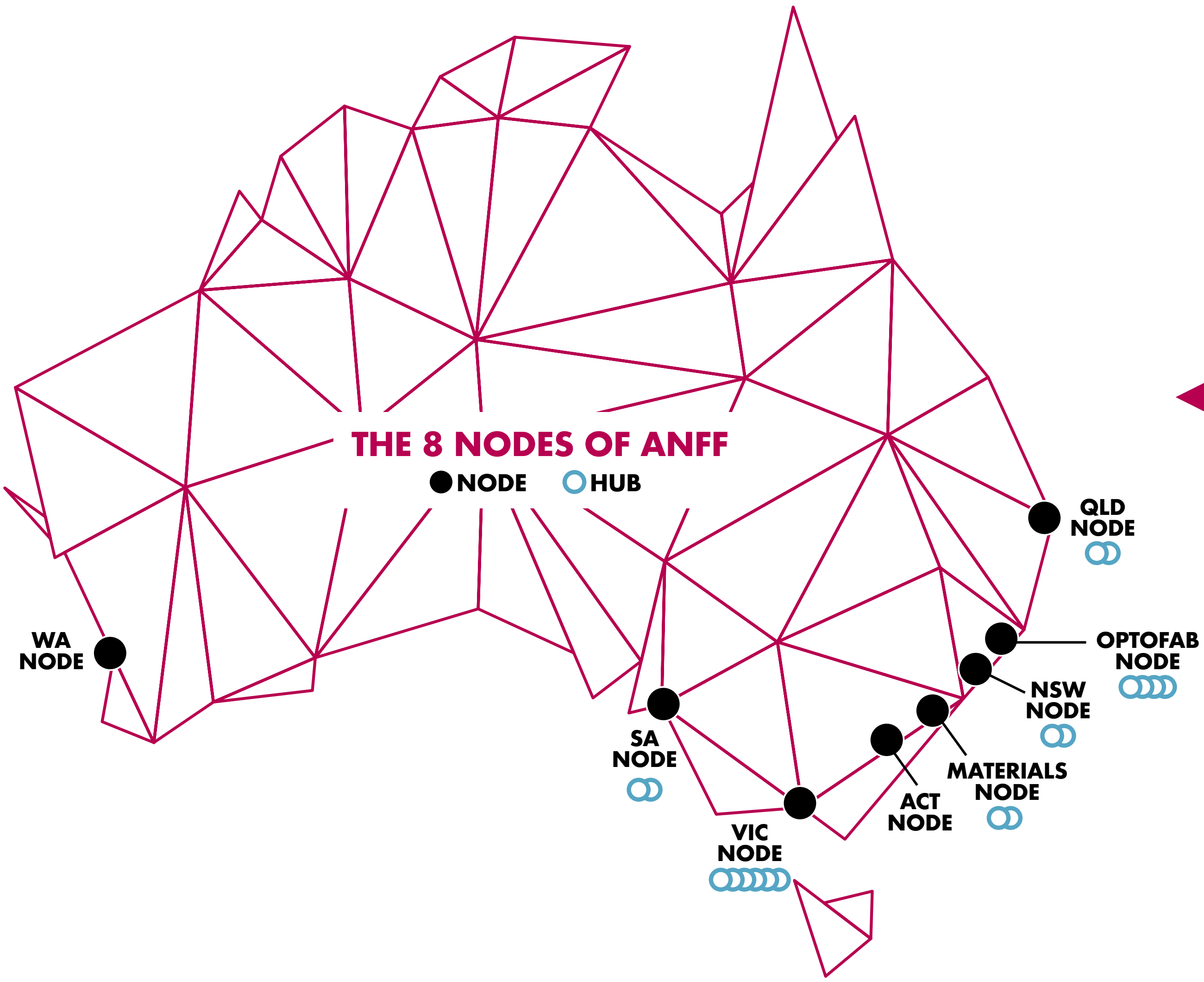
SNAPSHOT OF ANFF

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 tools 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.



ANFF IN NUMBERS

FY2020 was yet another strong year for ANFF, here's a few of the stand out statistics.

2,936

clients helped – average time on equipment per user exceeded 60 hours

20+ years

ANFF tools were being used for a total of 178,162 hours, equivalent to more than 20 years

+$50m

Funding injected into ANFF by Federal and State Governments as well as our Member Institutions

808

ANFF was acknowledged more than 808 times in publications in 2019

2,500+

More than 2,500 on-tool training sessions were conducted

130

There are now 130 ANFF experts to assist the Australian research community

EXCELLENCE IN RESEARCH

ANFF's equipment and expertise enables research excellence, we do this by making cutting-edge capability suites, world-class engineers, and supporting infrastructure available to all.

Ensuring our capabilities are world-leading allows us to support early stage research projects that provide the foundations of future products, jobs, and businesses, as well as providing immediate benefits to Australia, economically or otherwise.

This section of the Casebook presents a small sample of the hundreds of projects that ANFF helps on a yearly basis that exhibit excellence in research.

SUPERPOWERED STITCHES

Medical sutures could provide a conduit to deliver anti-inflammatory treatments directly into damaged tissue. Recent research has demonstrated that drugs can be drawn along the threads of the stitches themselves before being widely dispersed into soft tissue models.

This enticing approach to targeted wound treatment has recently been trialled by researchers from the ARC Centre of Excellence for Electromaterials Science (ACES) utilising electricity, standard sutures, anti-inflammatory medicines and a hydrogel testbed.

The team, led by Professor Brett Paull and including scientists from ACES' University of Tasmania (UTAS) and University of Wollongong (UOW) sites, has shown that their electrofluidic method allowed the drug to spread across the full 3D space of the testbed, and after two hours of electrical stimulation, over 80 per cent of the drug was retained within the target area.

To provide effective delivery of treatment in this way, medicine needs to travel quickly along the suture, but then slow down once it arrives in the target tissue to allow uptake of the drug into the body.

Professor Paull and his colleagues have shown that their electrofluidic approach enables them to vary the speed that bioactive molecules are carried along a typical absorbable suture by employing an electric field to manipulate the medicine.

Most water-soluble species carry some sort of charge and will therefore migrate towards either positive or negative electrodes when exposed to an electric current.

The principle of driving medicine along a fibre using a current in this way has been demonstrated previously, but it's never been tested in a biological model. To see if the approach could work in the wild, the ACES researchers turned to ANFF Materials experts to create a testbed tissue using a hydrogel called GelMA.

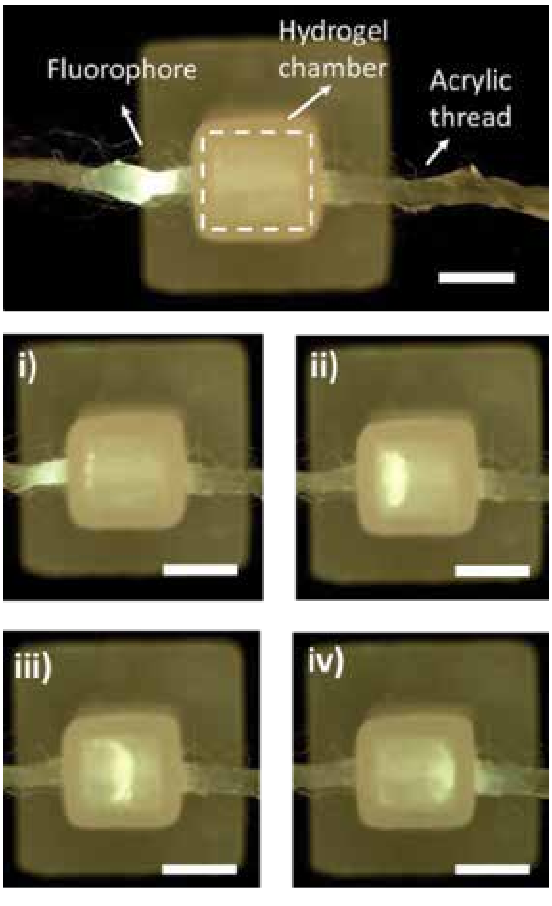
GelMA is a fantastic replica of natural tissue – it's made of denatured collagen, a protein vital to building connective tissue within the body, and can be cured to varying degrees by exposing it to different amounts of UV light to produce different mechanical properties.

Using this highly accurate model allowed the researchers to investigate aspects of how the delivery approach could work with live cell cultures.

The researchers use the electrophoresis phenomenon to drive bioactive molecules rapidly along the thread towards the desired distribution area by placing electrodes at either end of the suture and passing a small current through it. Once within the target tissue, the current is dropped, causing the flow to slow and allowing uptake of the drug into the biological model. Once the required time has passed, the current is ramped up again to sweep out the remaining bioactive and potentially any resultant cell metabolites of interest.

"The fascinating aspect of this work lies within its simplicity," Professor Paull said. "We can actually be highly quantitative in delivery of these bioactive species using some very simple materials, and not only deliver from A to B, but anywhere in-between"

"Our work, supported by ANFF Materials, showed that more than 80 per cent of the anti-inflammatory stayed within the hydrogel, and therefore indicates distinct promise for use in real tissue. We look forward to taking this research further."



ELECTROFLUIDICS CAN ALLOW FOR STRATEGIC DISTRIBUTION OF ANTI-INFLAMMATORY DRUGS.
Credit: Brett Paull

NOVEL DEVICE DETECTS PRE-ECLAMPSIA BIOMARKERS

Australian researchers are prototyping an affordable device capable of diagnosing pre-eclampsia within half an hour.

Approximately 76,000 pregnant women and 500,000 babies die from pre-eclampsia across the world every year. Women in developing countries are seven times more likely to suffer from the condition due to delayed diagnosis and a lack of access to hospitals.

Causes of pre-eclampsia are not entirely understood, but if left untreated it can lead to blood clots, organ failure, and death. Rapid, affordable, and accurate diagnostic tools are therefore essential in aiding treatment.

Now, a hand-held diagnostic device being developed by Professor Benjamin Thierry, Dr Duy Tran and a team from the University of South Australia's Future Industries Institute (UniSA FII) has shown it could pose a solution.

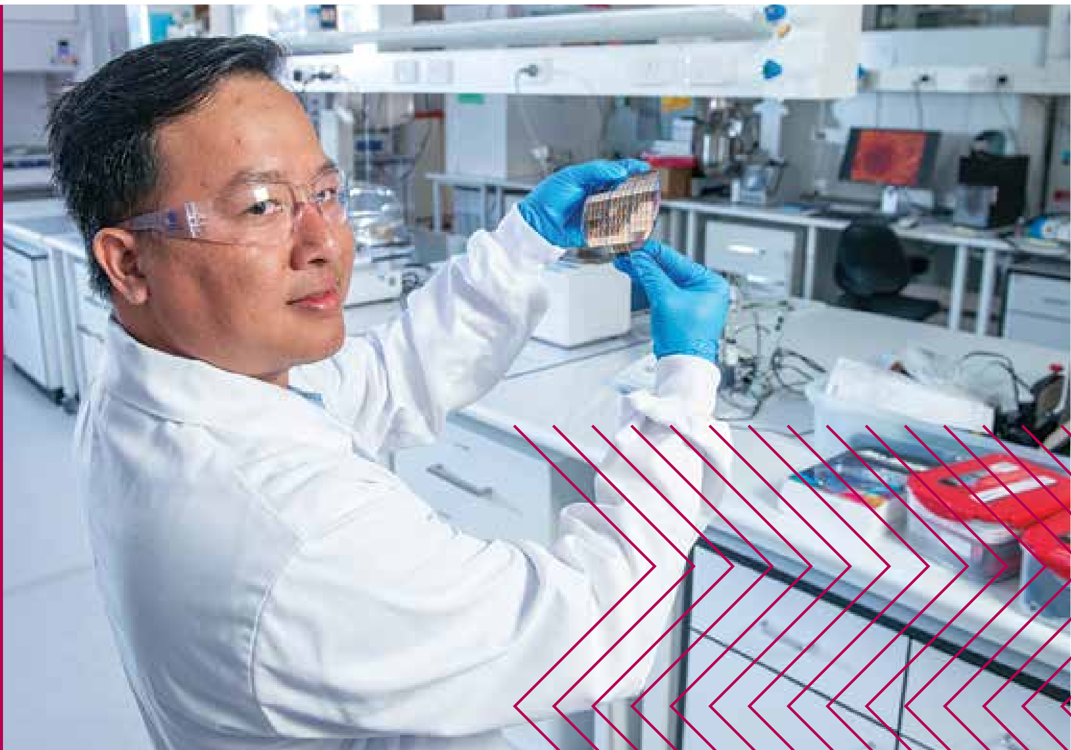
The affordable technology is already showing promising signs during early testing – a prototype developed by Dr Tran and PhD student Ms Thuy Pham has been successfully validated on four women with confirmed pre-eclampsia, and there are plans for further trials to be conducted in the Royal Womens Hospital (Melbourne) and Vietnam in the near future.

The team's new tool utilises a sensor developed at ANFF-SA, where Dr Tran has been harnessing the Node's technical expertise and its lithography and sputtering equipment to fabricate and fine-tune the device.

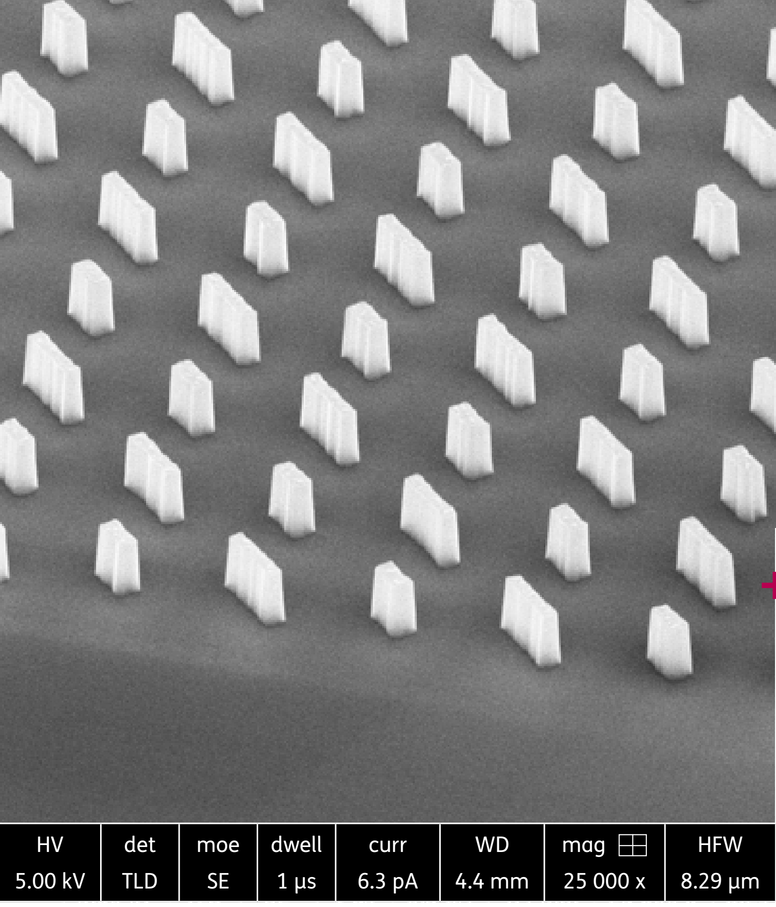
The sensor works by placing a droplet of the patient's blood onto a sensitive area of the device. This area contains receptors specific to pre-eclampsia biomarkers – if present, the biomarkers bind to the receptors and change the flow of electricity across the device. By monitoring these fluctuations in current, the presence and approximate quantity of pre-eclampsia biomarkers can be confirmed, allowing doctors to quickly react and mitigate the potentially life-threatening symptoms. Because the level of biomarkers can be detected, the severity of the condition can also be determined.

With support from the ARC Centre for Bio-Nano Science (CBNS), Dr Tran has built on local expertise to integrate his sensing technology within cost-effective and easy-to-operate diagnostic devices that can be operated with minimal training by nurses and other primary healthcare providers in regional and remote communities, both here in Australia and worldwide.

The next generation of the device is currently being developed with the support of the Medical Device Partnership Program (MDPP) as a handheld analyser unit with single-use disposable sensing cartridges, anticipated to be manufactured for as little as two dollars.



DR DUY TRAN HAS BEEN WORKING WITH ANFF-SA ON A LIFE SAVING DIAGNOSTIC TOOL.
Credit: Brenton Edwards



ARRAYS OF NANOFABRICATED STRUCTURES ENABLE RESEARCHERS TO HARNESS NOVEL OPTICAL PROPERTIES. *Credit: TMOS*

TMOS LIGHTS THE WAY

Researchers at the ANU-led ARC Centre of Excellence for Transformative Meta-Optical Systems (TMOS) are producing the light-based technologies that are needed to meet the evolving demands of Industry 4.0.

TMOS researchers are developing the devices that are expected to unlock widespread use of holographic displays, artificial vision, wearable medical devices, and ultra-fast WiFi whilst also laying the foundations for many more applications that are yet to be imagined.

The aim of TMOS is to develop ultrathin devices that create, manipulate, and detect light. These platforms are part of a movement towards meta-optical components that use nanofabricated structures to control light in ways that go beyond what is achievable by traditional approaches to photonics.

The team's latest ANFF-enabled research, led by the group of Professor Andrey Sukhorukov, drives the development of novel meta-optical devices for quantum applications.

The specific design by PhD student Shaun Lang is tailored for manipulation of entangled photons. These paired particles can be used to deliver the potential of quantum computers and to transmit unbreakable messages across incredible distances.

The entanglement principle is a quantum phenomenon that sees pairs of particles such as photons becoming twinned so that any changes made to one partnered particle is exhibited by the other. Theoretically, this connection remains regardless of how far apart the particles are, even if they're separated to opposite sides of the universe.

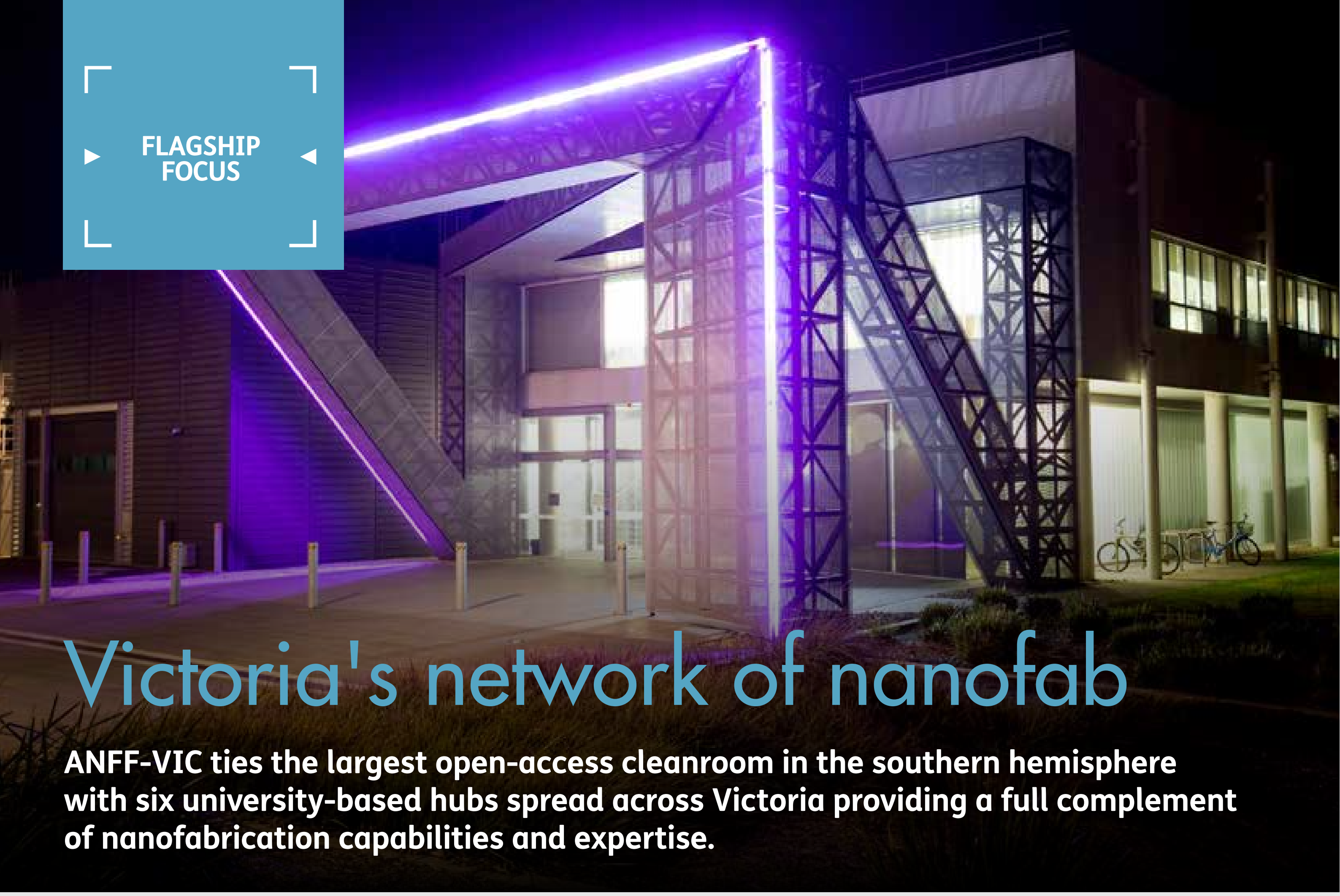
The project shows a way to change the polarisation of two photons simultaneously, which can accordingly modify the degree of quantum entanglement, an operation essential for a range of quantum protocols.

The research demonstrates a use of an array of structures called nanoresonators, which are features that measure 100 times smaller than a human hair. They resonate differently depending on the incoming light polarisation across a particular range of wavelengths.

Importantly, the optimisation of the arrangement and dimensions of the individual nanoresonators, which in combination form an ultrathin metasurface, allows the implementation of multiple controllable transformations of photon polarisations with a single device.

The metasurfaces were fabricated at ANFF-ACT using electron beam lithography and inductively coupled plasma etching, creating silicon nanostructure arrays with a thickness of 800 nm, optimised for operation around the 1,550 nm wavelength range which is compatible with the telecommunications industry. "The advanced equipment and dedicated staff at ANFF enable the fabrication with remarkable quality down to nanoscale," said Dr Jihua Zhang, a postdoctoral fellow working on quantum metasurfaces.

"This topic is an important part of the research mission in TMOS. Through ANFF-ACT and other sister nodes, we aim to develop the science and technology of meta-optics into novel devices and translate them into practical applications such as holographic displays, wearable optical sensors, remote sensing and imaging," said Prof. Dragomir Neshev, director of TMOS.



FLAGSHIP FOCUS

Victoria's network of nanofab

ANFF-VIC ties the largest open-access cleanroom in the southern hemisphere with six university-based hubs spread across Victoria providing a full complement of nanofabrication capabilities and expertise.

The Node spans the University of Melbourne; Deakin University; La Trobe University; Swinburne University of Technology; Victoria University; RMIT University; the CSIRO; and the unique Melbourne Centre for Nanofabrication (MCN), which is hosted by Monash University.

MCN is home to ANFF's national headquarters. The ISO9001-certified Centre is a world-class, purpose-built facility boasting state-of-the-art cleanrooms (class 10,000 and class 100), and reconfigurable biochemistry, microscopy and PC2 labs. These specialised work environments house top-of-the-line micro and nanofabrication equipment and precision measurement instrumentation.

Imminent arrival of the fabled Phabler

The latest flagship tool to be added to the MCN's suite of world-class capabilities is the Phabler 150, manufactured by Eulitha, which provides unprecedented ability to print high-resolution periodic nanostructures in a low-cost photolithography system.

The Phabler is similar to a conventional mask-aligner where a photoresist coated wafer is put in proximity to a mask and exposed by a beam of UV light, but thanks to the manufacturer's breakthrough PHABLE exposure technology, the resolution is no longer limited by diffraction.

Through a collaboration with La Trobe University, MCN has secured this tool to address a substantial need for rapid high-resolution, large area patterning techniques. This need is arising due to advances in the field of 2D metamaterials with related applications in diverse areas such as bio-sensing, nanophotonics, plasmonics, nanomagnetism, and more.

Acquisition of the Phabler has been driven by research being conducted at the La Trobe Institute for Molecular Sciences (LIMS). The institute is focused on the development, translation, and commercialisation of technology with a focus on health and well-being and understanding disease. LIMS involves a broad collaboration of scientists that addresses key problems which will significantly benefit Australian society. Cross-disciplinary collaborations, high-impact innovations, and commercialisation will be strongly supported by this new MCN equipment.

The new tool will form part of the process chain for key technologies being developed by LIMS allowing them to establish pilot production at the MCN.

The next-level Nanofrazor

The MCN is home to Australia's first (and only) Nanofrazor, a lithography tool which is the result of more than 20 years of intensive research and development that started at IBM Research in Zurich and has been extended at the spin-out, SwissLitho.

The Nanofrazor instrument performs t-SPL, a 3D direct-write lithography technique that provides sub-10 nm lateral resolution with sub-2 nm vertical accuracy, all under ambient temperature and pressure conditions.

During patterning, a 1,000°C+ cantilevered tip made of doped silicon scans over the surface of a sample, and in so doing sublimates a polymer resist known as PPA leaving nanoscopic topologies in its wake. As a secondary benefit to the AFM-based technology the Nanofrazor is capable of acting as an AFM as well, enabling real-time feedback control of the writing process.

The process isn't reliant on an ion gun or electron beam, which is helpful when dealing with sensitive electronic materials. It operates at ambient temperature, pressure, low voltage, and under nitrogen atmosphere sidestepping the need for a costly and cumbersome high-vacuum environment.

The ease of use and high resolution means it is ideal for rapid fabrication of three-dimensional nanostructures needed to create novel proof of concept devices and components for nanophotonics, nanooptics, nanoelectronics, and plasmonics applications.

Fab Fibres at Deakin's IFM

At Deakin's Institute of Frontier Materials (IFM), ANFF-VIC provides access to a fibre processing line that allows researchers and engineers to produce or enhance the functionality of novel fibres. The fibre production suite includes melt extrusion, wet spinning, and fibre coating capabilities that range in size from small-scale benchtop to pilot-scale experiments, and are able to spin or coat a diverse range of synthetic and natural polymers with additives such as nanomaterials.

Harnessing this equipment enables outcomes such as work published by scientists from Drexel University and Deakin in March 2020 that demonstrated a new knitted supercapacitor architecture to enable wearable energy storage devices. The international team worked with ANFF experts to develop a method to fabricate large quantities of conductive fibres that could be used to produce energy storing textiles to power devices such as flexible electronic components and smart garments.

ANFF's equipment at the IFM was used to perfect and automate the fabrication process. Melt extrusion was used to produce a nylon fibre and the wet spinning line used to coat the nylon in a promising 2D nanomaterial (MXene) adding capacitive functionality, which were then knitted into supercapacitors.

Surface coatings covered at Swinburne

Swinburne University's Biointerface Engineering Hub is home to an array of polymer surface coating and surface analysis tools, including plasma polymerisation, dip coating and more.

The Hub houses six custom made reactors for plasma polymerisation (PECVD) and plasma treatment. PECVD produces thin films by fragmenting a selected molecule with a plasma and coating everything inside the reactor with it including the desired surface. It's possible to vary the chemistry of the film by changing the conditions within the reactor, and the thickness of the film can also be changed by controlling the deposition time.

The process is substrate independent, and deposits pinhole-free thin films in the range of <1-200 nm with specific functional groups on samples of up to 20 cm in diameter. The monomers it can lay down can modify chemistry, charge, hydrophobicity and hydrophilicity, biocompatibility, or even prevent biofouling and bacterial adhesion.

Gain a deeper understanding at La Trobe

ANFF-VIC's La Trobe hub housed within the Centre for Material Surface Science provides access to time-of-flight secondary-ion mass spectrometry (ToF-SIMS) analysis.

ToF-SIMS is a microprobe technique and can produce mass spectra from points or areas on a sample surface, molecular maps (2D) and depth profiles. The process provides detailed information about the molecular composition of a surface, including isotope information and molecular weight.

During a ToF-SIMS experiment, the sample is bombarded with a focused beam of high-energy ions which fragments material from the outer nanoscopic layers of a sample's surface. Some of these ejected fragments are ionised, and these so-called secondary ions are then analysed. The material emitted from the surface is passed through an electrostatic field, which uniformly accelerates all ionised particles towards a detector. Particles with different masses but the same energy will take different amounts of time to reach the detector, and it's by studying this time of flight that the ion's mass can be deduced, leading to the identification of what chemical it is.

Interfacing at RMIT

Within RMIT's Micro Nano Research Facility (MNRF) is a host of fabrication equipment with a particular focus on interfacing micro and nanotechnologies to the macro world.

The MNRF team provide access to a multi-functional 3D printer capability of printing polymers, ceramics and metals. This builds on and complements the Low-temperature co-fired ceramic (LTCC) facility at RMIT to enable rapid prototyping of sophisticated integrated ceramic packages for electronics, photonics, MEMS for extreme conditions, and biomedical implantation.

The suite of capabilities provides robust, compact, but highly flexible packaging so that ANFF users can ready their technologies for real world contexts such as standardised electronic, photonic, and fluidic interfaces.

Making and measuring at UniMelb

Through ANFF-VIC at the University of Melbourne's Materials Characterisation and Fabrication Platform (MCFP), clients can access a Zeiss ORION NanoFab, an advanced scanning ion microscope (HIM) that utilises an interchangeable dual-ion beam (helium and neon) for nanofabrication and sub-nanometre imaging.

The HIM excels at imaging surfaces with sub-nanometer resolution and high surface sensitivity, but it also offers unique nanofabrication capabilities. The neon beam can be used for micro/nano milling, after which, features can be refined using the helium beam. Complex patterns can be generated using the Nanopatterning and Visualization Engine (NPVE) interface, while a gas injection system (GIS) enables gas-assisted etching of silicon as well as ion-beam-induced deposition of tungsten and silicon dioxide. Nanoscale implantation studies using both beams can also be performed.

PERSONALISING NUTRITION

A wearable smart patch could deliver precision data to help people personalise their diets and reduce their risk of developing lifestyle-related chronic diseases like Type 2 diabetes.

The world-first personalised nutrition wearable being developed by Melbourne-based start-up Nutromics is designed to measure dietary biomarkers and send the information to an app, enabling users to precisely track how their bodies respond to different foods.

The pioneering technology will be designed and manufactured in Australia.

A collaborative team led by Nutromics, Griffith University, RMIT and manufacturer Romar Engineering, with support from the Innovative Manufacturing Cooperative Research Centre (IMCRC), is now researching and developing the required manufacturing capabilities to pilot manufacture the device.

Pre-diabetes is estimated to affect more than 350 million people globally; in the US and China alone, 1 in 2 adults are pre-diabetic or diabetic.

Nutromics co-CEO Peter Vranes said the smart patch leveraged emerging technologies to empower people to take greater control of their health.

"Being able to easily monitor key dietary biomarkers will give you the knowledge to personalise your diet to suit your own body, to get healthy and stay healthy," Vranes said.

Diabetes is one of the largest chronic health challenges globally. Without taking any action, up to 70% of people with pre-diabetes can go on to develop Type 2 diabetes within the next four years, but with early interventions and lifestyle changes, the condition is largely preventable.

The fabrication of sample collection will be led by Griffith University and Romar Engineering, with sensor integration and stretchable electronics fabrication undertaken at RMIT's Micro Nano Research Facility, an intrinsic hub of ANFF's Victorian Node.

Research Co-Director of RMIT's Functional Materials and Microsystems Research Group, Professor Sharath Sriram, said the smart patch combined a complex sensing platform and stretchable electronics for improved conformity to skin.

Professor Sriram said RMIT researchers would integrate the technologies in a prototype smart patch that could be cost-efficiently manufactured, and was designed with the end-user at front of mind. "This smart patch is a significant evolution in wearable health monitoring technology," he said.

Professor Nam-Trung Nguyen, Director of the Queensland Micro- and Nanotechnology Centre at Griffith University and Deputy Director of ANFF-Q, said the project was underpinned by the centre's past and ongoing fundamental research in microfluidics and wearable, implantable microsystems.

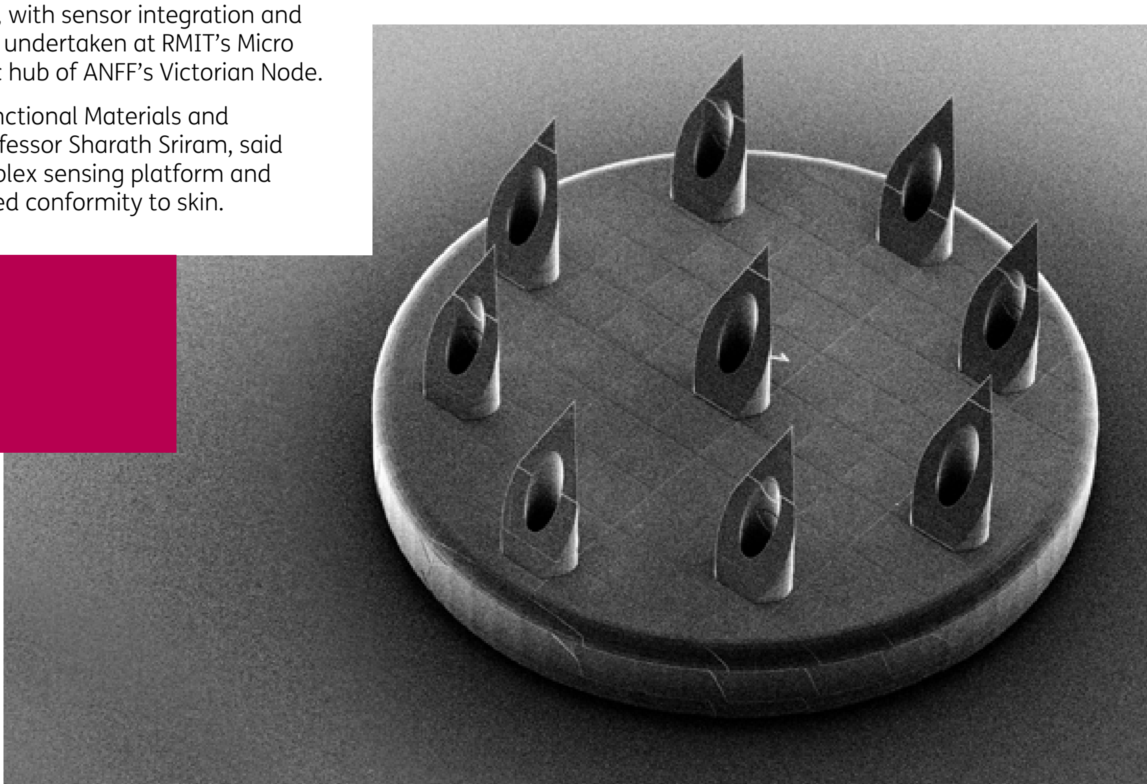
"One of the research pillars at the Queensland Micro- and Nanotechnology Centre is that we move towards the commercialisation and translation of our discoveries for the benefit of end users," he said.

"The project will benefit significantly from the recent addition of a femto second laser machining system funded by the ARC."

Alan Lipman, CEO of Romar Engineering, an established manufacturer of medical devices, said collaboration was the way forward for Australian manufacturing.

"Working with entrepreneurs, academics and researchers to develop new medical technologies is essential to maintain Australia's international competitiveness and to build a strong domestic manufacturing skills base."

THIS STORY WAS ORIGINALLY PUBLISHED BY GRIFFITH UNIVERSITY, FIND OUT MORE AT: NEWS.GRIFFITH.EDU.AU



AN ARRAY OF NEEDLES THAT COULD BE USED TO PROVIDE PERSONALISED DIETARY GUIDANCE, PRINTED USING ANFF-Q'S NANOSCRIBE.
Credit: Nam-Trung Nguyen

DANCING HELIUM

University of Queensland researchers are using a fluid that never settles to create quantum tornadoes on a chip.

The team, led by Professor Warwick Bowen has been working to understand and harness interactions between waves in superfluid helium and light. Their research leads on to new light-based technologies that require very little energy and are hypersensitive, while at the same time providing an insight into turbulent systems such as cyclones and interstellar objects.

Professor Bowen's research is centred on a raised silicon disk that was nanofabricated with help from ANFF-Q equipment and expertise. The structure's shape traps light at its edges, creating a cavity that can keep photons circling for a limited time.

This disk is then coated with superfluid helium – this is an approach unique to Professor Bowen's laboratory and the work builds on the team's previous endeavours that showed laser cooling can be used to sustain the temperatures required to keep the helium film in this superfluid state.

Superfluids are quantum liquids that are characterised by the fact that they have no viscosity, and flow without losing any energy. This means if a wave or a vortex starts in the superfluid, it won't ever stop of its own accord. In Professor Bowen's device, a superfluid acoustic wave is triggered to flow around the disks edge, travelling in the exact same space as the trapped light.

This colocation leads to the light interacting with the acoustic wave, which triggers a phenomenon called Brillouin scattering. The effect causes the light particles to be absorbed and re-emitted with lower energy. The energy difference is taken up by the acoustic wave, amplifying it. The result is in effect an incredibly low power, and low threshold type of laser for sound, rather than light.

This result can be harnessed to create ultraprecise sensors, ultranarrow light filters, low power devices, precision silicon chips, and more. Due to the forces at play, they are less susceptible to shock and vibration than their MEMS-based equivalents, and they could also have performance benefits.

Another bizarre behaviour of quantum liquids is that they can only carry integer circulation, which means they can only flow at fixed velocities. They can therefore be used to provide an absolute reference frame for acceleration measurement. This would allow a system to track its position without the need for satellites, making location pinpointing in submarines, in-door shopping centres, and underground far more accurate.

There's yet more novel effects to unlock however – Professor Bowen's devices can stir the superfluid helium to trigger vortices that will go on forever, and this provides a significant opportunities as a method to study turbulence. Professor Bowen said it was postulated more than 50 years ago that the turbulence problem could be simplified using quantum liquids.

"Our new technique is exciting because it allows quantum turbulence, which mirrors the sort of behaviour you see in cyclones, to be studied on a silicon chip for the first time," Professor Bowen said. The research also had implications in space, where quantum liquids are predicted to exist within dense astrophysical objects.

"Our finding allows us to observe this nanoscale quantum turbulence in the lab, and this research could help to explain how these objects behave," he said.

LIGHT, FANTASTIC:
THE PATH AHEAD FOR FASTER, SMALLER COMPUTER PROCESSORS

Australian and German physicists have developed a hybrid architecture to overcome some of the engineering hurdles that are slowing the uptake of light-based computing.

Light is emerging as the leading vehicle for information processing and telecommunications as our need for energy efficiency and bandwidth increases – developing affordable and scalable photonic chips is therefore essential.

However, there remain substantial engineering barriers to complete this transformation. Industry-standard silicon circuits that support light are more than an order of magnitude larger than modern electronic transistors. One solution is to 'compress' light using metallic waveguides – however this would not only require a new manufacturing infrastructure, but also the way light interacts with metals on chips means that photonic information is easily lost.

Now scientists in Australia and Germany have developed a modular method to design nanoscale devices to help overcome these problems, combining the best of traditional chip design with photonic architecture in a hybrid structure. Their research was in Nature Communications in May 2020.

"We have built a bridge between industry-standard silicon photonic systems and the metal-based waveguides that can be made 100 times smaller while retaining efficiency," said lead author Dr Alessandro Tuniz from the University of Sydney Nano Institute and School of Physics.

This hybrid approach, developed with assistance from ANFF-NSW University of Sydney Hub, allows the manipulation of light at the nanoscale, measured in billionths of a metre. The scientists have shown that they can achieve data manipulation at 100 times smaller than the wavelength of light carrying the information.

"This sort of efficiency and miniaturisation will be essential in transforming computer processing to be based on light. It will also be very useful in the development of quantum-optical information systems, a promising platform for future quantum computers," said Associate Professor Stefano Palomba, a co-author from the University of Sydney and Nanophotonics Leader at Sydney Nano.

"Eventually we expect photonic information will migrate to the CPU, the heart of any modern computer. Such a vision has already been mapped out by IBM."

On-chip nanometre-scale devices that use metals (known as "plasmonic" devices) allow for functionality that no conventional photonic device allows. Most notably, they efficiently compress light down to a few billionths of a metre and thus achieve hugely enhanced, interference-free, light-to-matter interactions.

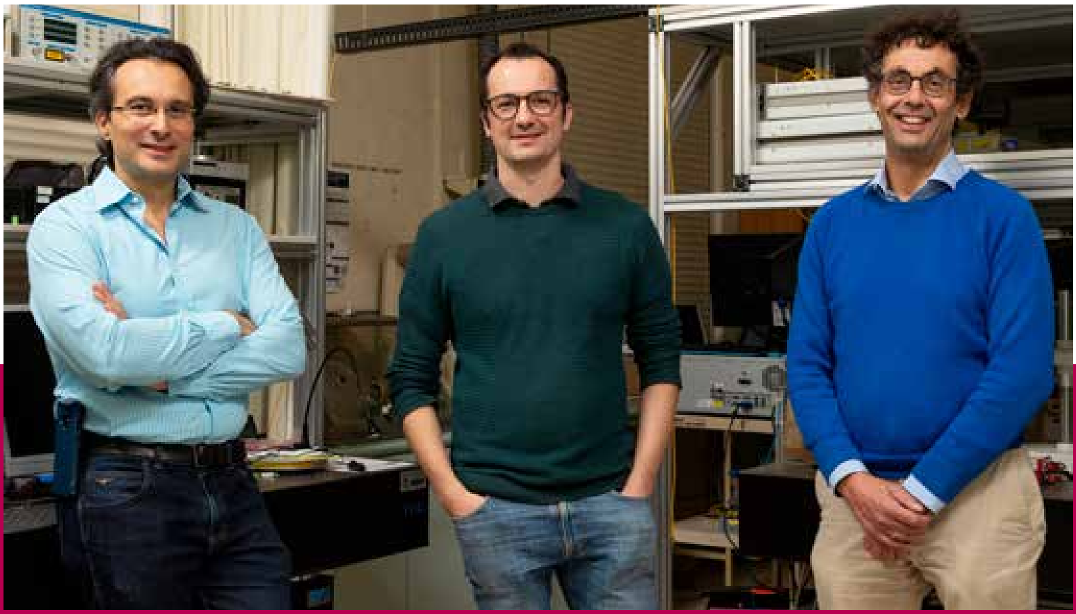
"As well as revolutionising general processing, this is very useful for specialised scientific processes such as nano-spectroscopy, atomic-scale sensing and nanoscale detectors," said Dr Tuniz also from the Sydney Institute of Photonics and Optical Science.

"We have shown that two separate designs can be joined together to enhance a run-of-the-mill chip that previously did nothing special," Dr Tuniz said.

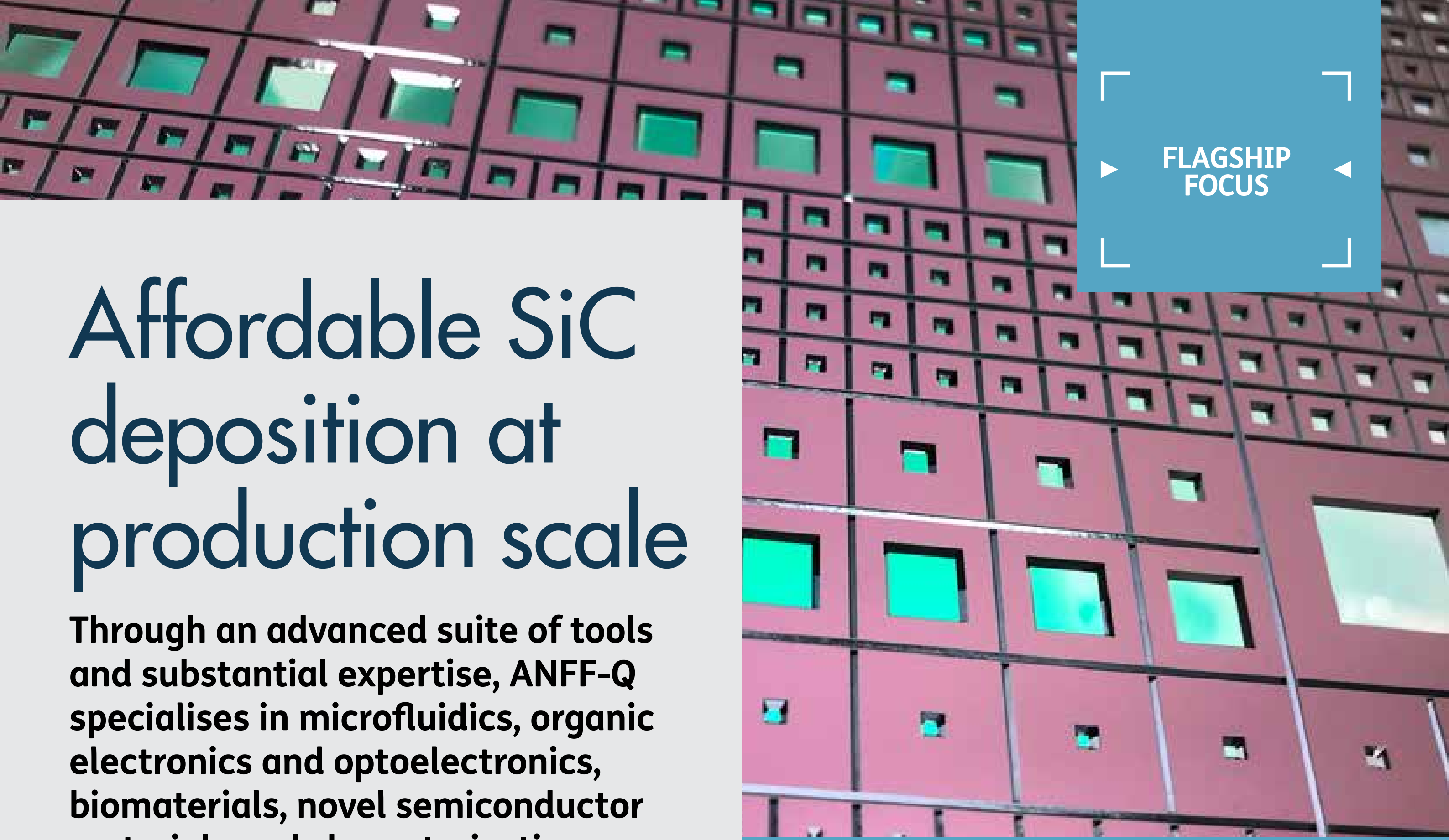
This modular approach allows for rapid rotation of light polarisation in the chip and, because of that rotation, quickly permits nano-focusing down to about 100 times less than the wavelength.

This story was written by Marcus Strom for the University of Sydney, originally titled: Light, fantastic: the path ahead for faster, smaller computer processors.

Find out more at **https://bit.ly/3jzYqSj**



(FROM LEFT) ASSOCIATE PROFESSOR STEFANO PALOMBA, DR ALESSANDRO TUNIZ, PROFESSOR MARTIJN DE STERKE.
Credit: Louise Cooper, USYD



Affordable SiC deposition at production scale

Through an advanced suite of tools and substantial expertise, ANFF-Q specialises in microfluidics, organic electronics and optoelectronics, biomaterials, novel semiconductor materials and characterisation.

The Node comprises four facilities, two at the University of Queensland and two at Griffith University.

Griffith's Queensland Microtechnology Facility (QMF) is home to novel epitaxial reactors that reduce barriers to adoption of Silicon Carbide (SiC) on Silicon (Si) for microtechnology.

The superior properties of SiC have the potential to revolutionise, enhance, and enable the performance of many devices. Physically, it is stronger, tougher and more robust than other materials commonly used in silicon device fabrication. Chemically it is inert, leading to excellent harsh environment and bio compatibility.

The reactor is capable of harnessing SiC at far lower costs and is therefore potentially unlocking the incredible performance benefits from utilising the material. The team use their reactor to deposit extremely high quality layers of SiC onto conventional Si wafers, combining the performance and price point benefits of each.

The team's production reactor was built by SPTS in Silicon Valley, a global production semiconductor equipment manufacturer, based on Griffith University IP. The unique process regime and system attributes of the tool targets the highest quality thin film deposition of SiC on Si wafers for MEMS, optical or any other product that can exploit the superior properties of SiC.

Key parameters are:

+ **Wafer size:** 2" up to 12" diameter
+ **Uniformity:** less than 1% thickness non-uniformity across the wafer
+ **Edge Exclusion:** 1 mm edge exclusion for film thicknesses up to 1 µm
+ **Standard Process deposition temperature:** 1,000°C
+ Double side deposition ensures wafers remain flat
+ Device fabrication at the QMF is on 150 mm wafers

Operating in a pressure regime between LPCVD and Molecular Beam Epitaxy the reactors enable exploitation of reactions that only occur at high vacuum. The special process gas handling produces high quality films with industry acceptable uniformity on large batches.

Applications:

+ Ultrathin (>40 nm) membranes used as supports for nano and bio analysis in high resolution imaging systems such as TEM or Synchrotrons
+ Harsh environments sensors
+ Optical devices
+ Biocompatible components such as wearable technologies and implantables

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AFM ON A CHIP

New developments from UWA are providing miniaturisation opportunities for one of the most widely used techniques for analysing nanoscale structures.

The UWA team has demonstrated a new approach that provides an alternative way to perform Atomic Force Microscopy (AFM), a characterisation technique used on a daily basis by those investigating the micro/nano world.

AFM relies on tracking the movements of an ultra-sharp tip that is fixed to a cantilever as it encounters nanoscale obstacles when scanned over a sample's surface.

In conventional AFM, these miniscule movements are followed by observing changes in direction of a laser beam that is reflected off the backside of the cantilever-mounted tip. As the cantilever deflects due to tip interactions with the sample, the beam is reflected in different directions – recording these changes allows the system to map the nanoscale landscape of a sample's surface, or to infer information about a sample's intrinsic properties such as stiffness, conductance, or magnetic properties.

This "free space optics" approach relies on optical leveraging and requires the laser beam to travel a significant distance before the tiny changes in path direction can be observed – the system has to be large enough to accommodate this.

The UWA team does away with footprint requirements of free space optics by harnessing the laser beam's ability to interact with itself.

Light is known to act both like a particle and like a wave. This latter behaviour means, much like waves in the sea, light waves can interfere with each other to cause amplifications or to cancel each other out.

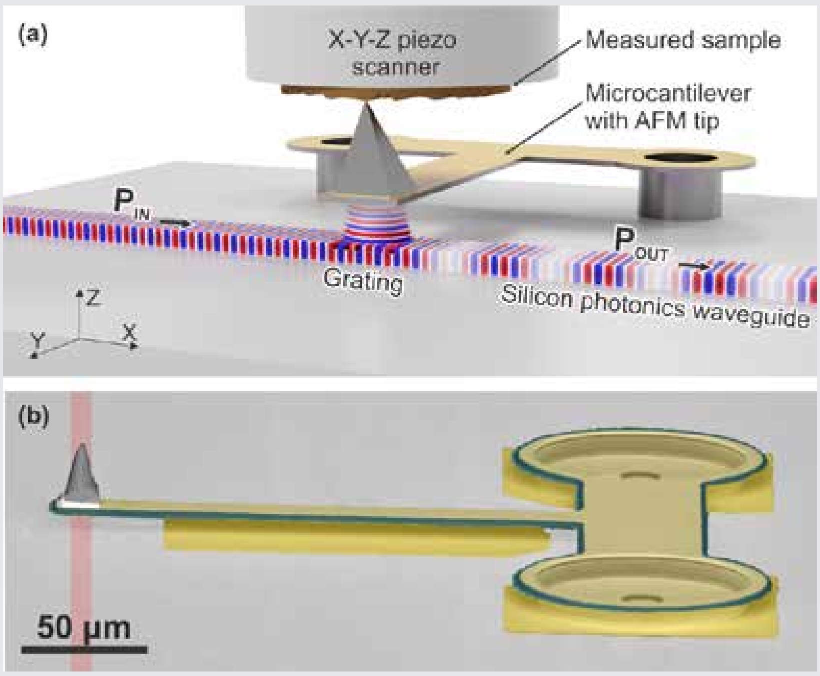
In the UWA system, a laser beam is passed very close to the cantilever in a light-carrying channel called a waveguide. A portion of the light is redirected out of this path, and aimed directly at the back side of the end of the cantilever. The light is reflected straight back into the original path of the laser beam where it's now becomes out of sync, causing it to interfere with the light that continued on directly – this causes vivid changes in the intensity of the waveguided light that can be easily monitored.

When the cantilever is moving up and down, the time taken for light to reach it and return to the typical path will change – if the cantilever is far away, the light will take longer to return, if it's closer the light returns sooner – and this causes measurable differences in the interference patterns. By monitoring these changes, the system can track the movements of the tip, and therefore infer the position of the cantilever-mounted tip and the scanned surface topology.

The result is an on-chip integrated system that needs far less space to operate, and that is less susceptible to outside influences. What's more, the componentry is made using well established fabrication practices making it affordable to produce at scale, and it can be easily retrofitted to existing systems.

The technology is well positioned for commercialisation, and the team's next steps are to continue to work towards this goal.

UWA RESEARCHERS HAVE MINIATURISED ONE OF THE MOST WIDELY USED ANALYSIS TECHNIQUES THROUGH WORK WITH ANFF-WA.
Credit: Michal Zawierta



DIAMOND ENCRUSTED SENSORS

An Adelaide artist has inspired a path towards rugged diamond-based magnetic field sensors that could be used in underwater monitoring, brain scanning, and mineral exploration applications.

A consortium of scientists had been trying to embed diamond into optical fibres when they realised that artist Karen Cunningham had shown them the way through her creative use of nanoparticles in blown glass.

The diamonds the researchers were using feature deliberate spaces and impurities in their crystal structure called nitrogen vacancy (NV) centres. These gaps have incredibly useful light-emitting properties that pose significant opportunities to sensing applications.

An NV centre emits red light at a particular wavelength if shone with a green laser beam, but if the centres are within a magnetic field the brightness of the emitted photons changes ever so slightly. Monitoring this variation can therefore indicate the strength of a magnetic field, providing an incredibly precise sensor. However, monitoring these subtle signals usually requires complex optical microscopes that are difficult to take into the field.

Professor Heike Ebendorff-Heidepriem from the University of Adelaide was working with a consortium led by Professor Brant Gibson from RMIT University to find a way to take NV diamond sensors out into the real world. The team, which also included researchers from the University of Melbourne, University of South Australia, and Defence Science and Technology Group, started embedding the diamonds into optical fibres that would both create a protective casing for the diamond and carry light towards a detector, providing a means to monitor magnetic fields found out of the lab.

However, there were obstacles to overcome. The fibre fabrication process requires a stage where the material is molten – this liquid glass is highly corrosive and rapidly degrades the diamond particles rendering them all but useless as sensors.

Because diamond burns at high temperatures, the team had been restricted to using unconventional "soft glasses" such as tellurite – these don't perform as well as conventional glass fibres and aren't as widely used in industry, but they are easier to process at lower temperatures. If the sensors were ever to be usable, a more robust glass would be required.

Another problem was that the haphazard distribution of the diamond particles – caused by mixing them into the molten glass – would end up blocking a lot of the light signals before they could be detected.

For more than ten years, the team had been trying to find a way around these issues.

But then, upon visiting Karen Cunningham ahead of an exhibition in Adelaide in 2017, Heike saw that the artist had managed to incorporate diamond particles into her art by sprinkling diamond across the surface of widely used silicate glass before manipulating the glass further.

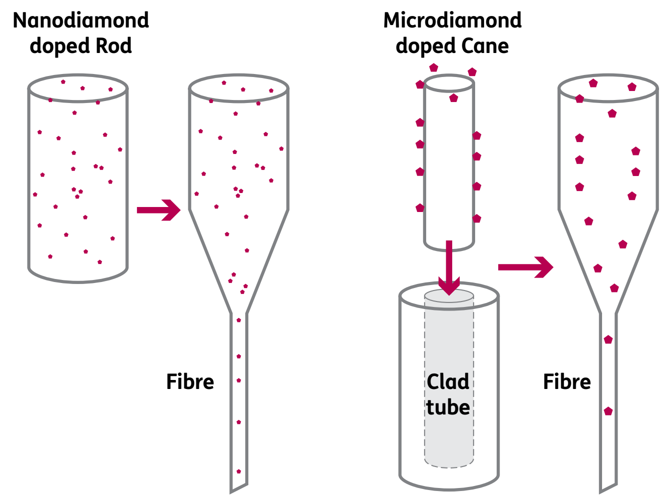
"For us, it was the lightbulb moment and we knew we had found a way make diamond sensors in more conventional glass fibres," Heike said.

It inspired Heike to invent an entirely new technique for introducing particles into optical fibres which she has named interface doping. To develop the technique, the team began working with ANFF Optofab's optical fibre specialists using silicate glass as a proof-of-concept towards a more robust fibre. Initially, a rod of silicate glass is produced and dip-coated with diamond particles. The diamond-encrusted rod is then inserted into a tube made of the same silicate glass and they are drawn out together to form the fibre. Once drawn out, the team are left with a ring of diamond particles that runs the length of the glass fibre.

But the artistic influence took the researchers further – Karen also utilised larger-than-typical diamond particles, measuring microns across instead of nanometres. The team also began using similar sized particles and found that they actually provided a higher level of sensitivity to magnetic field changes due to a higher concentration of NV centres in the bigger particles which provided a larger signal.

With this successful first step demonstrated, the consortium is now furthering their work by integrating diamond into conventional glass fibre types for future use within telecom networks.

NANO-DIAMOND IN VOLUME OF TELLURITE (ESTABLISHED PROCESS) | **MICRO-DIAMOND AT INTERFACE OF SILICATE** (NEW PROCESS)



FLAGSHIP FOCUS

Getting sensitive with ANFF Optofab

ANFF Optofab consists of Hubs at Macquarie University (headquarters), the University of Adelaide, the University of Technology Sydney, and the University of Sydney, but the Node comes together to provide a distributed one-stop-shop for fabricating optical and photonic devices.

The team offers specialist facilities to provide equipment and technical support to users in microprocessing, microfabrication and characterisation of fibre, planar or bulk materials that typically include silica, metals, ceramics, silicon, and polymers.

The Node's capabilities are regularly utilised to serve telecoms, biotechnology, biomedicine, microelectronics, optical sensing, industrial processing, and defence applications.

One of the most exciting applications of Optofab's extensive offering is to build fibre optic sensors. Here, light-carrying fibres are altered and adjusted to provide highly sensitive, flexible, efficient, and robust detecting devices that can be designed to suit a variety of uses.

From magnetic field sensing in mining, to temperature checking in furnaces, to monitoring the integrity of concrete in sewers, fibre sensors are being harnessed in ever more ambitious ways with an increasing amount of complexity and variation.

To investigate these new opportunities and to quickly capitalise on them fully, Optofab provides Australian innovators with access to expertise, unique infrastructure, and an established development pipeline.

CONTACT:

GET IN TOUCH WITH THE OPTOFAB TEAM TO FIND OUT MORE ABOUT THEIR PORTFOLIO AND WHAT THEY CAN DO TO HELP.

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Hub Manager: Luis Lima-Marques
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MAKING A FIBRE SENSOR

+

STEP 1. PRODUCE A PREFORM

A preform is typically a cylindrical block of glass that will later be stretched out to form a fibre. Preforms for most fibre materials are purchased as stock or manufactured with Optofab's help, before being processed to add capability. This may be done by drilling precise holes into the preform, or for more complex structures the preform is extruded through a die at high temperature and pressure. Both of these techniques can produce structured preforms that can be drawn out into fibres.

For relatively simple preform structures, the Optofab team at The University of Adelaide commonly use their high-precision ultrasound CNC for this purpose. Their DMG Ultrasonic 20 Linear provides 5-axis machining using diamond tooling that oscillates longitudinally while it spins to reduce processing forces and enable drilling, grinding and milling of brittle materials.

STEP 2. DRAW OUT FIBRE

The preforms are then drawn out on Optofab's Fibre Draw Tower, using furnaces to melt them at a specific temperature before pulling them out into long thin strands. This process may include multiple steps, but it will result in a fibre that measures around 125 µm in diameter.

The University of Adelaide team provide access to two draw towers, measuring four and six metres tall.

The 4 m soft glass drawing tower is capable of drawing preforms of 8 – 30 mm diameter and up to 230 mm in length into fibres of 100 – 400 µm outer diameter, with a RF furnace that provides temperatures between 200 – 1,200 degrees Celsius. A range of soft glasses and polymers can be drawn from this tower, and on-line coating of fibres with UV-curable polymers can also be performed.

The 6 m drawing tower enables the drawing of glass fibres in the temperature range of 1,800 – 2,200 degrees Celsius. This tower is capable of drawing preforms of 8 – 28 mm diameter and up to 1,000 mm in length into fibres of 100 – 300 µm outer diameter, and on-line coating of fibres with either UV or thermal curable polymers.

STEP 3. ADD FUNCTIONALITY

This is where the sensing fibre becomes tailored to its application – micro or nanostructures may be implemented, or coatings may be added to make the device sensitive to particular compounds.

The periodic troughs or holes required to produce a fibre Bragg grating can be quickly and easily built into the fibre using ANFF's laser processing suite at Macquarie University. A collection of pico-, nano-, or femto-second laser writing systems are available as well as a dedicated ultrafast laser system customised to suit exactly this purpose. This process may happen before or after drawing of the fibre, depending on the desired outcome.

Alternatively, the team at Optofab in Adelaide offer the capability to create and lay down functionalised coatings to add fluorophores that emit light when a specific analyte is present, or other desirable properties can be introduced to the fibre. Either the tip or the length of the fibre may be coated using the surface functionalisation capabilities available at the University of Adelaide's ANFF Hub.

STEP 4. PACKAGE THE SENSING FIBRE

If the optical fibre is sensitised for a target analyte, it is then packaged so that it can operate robustly in its intended environment and be integrated with optical interrogation equipment. The University of Adelaide hosts the full suite of equipment required to produce field deployable sensors.

The first step is to cleanly cut ("cleave") the specialty optical fibre and splice it to industry standard optical fibre. Optofab has a range of equipment suitable for cleaving and splicing even the most challenging and unique specialty optical fibre sensors.

The second step is to suitably package the optical fibre sensor for its environment. An example is to encapsulate the optical fibre into high temperature metal, metal ceramic or silicon carbide sheaths for use at high temperature. The facilities at the University of Adelaide include a HEPA filtered cleanroom for assembly.

In other applications, the package can also form part of the transducer required to generate a sensor response. At Macquarie University, fit-for-purpose packages are firstly designed using CAD before the final product is produced in titanium on a SLM metal printer.

CAPTURING THE BENEFIT

ANFF captures the benefits of research conducted in our laboratories and cleanroom spaces by assisting in the commercialisation of technologies that directly and indirectly benefit the people of Australia.

The next section overviews some of the spinouts, start ups and products that are approaching commercialisation – these are the projects that are starting to enhance our economy.

SKIN-DEEP SENSING

A new sensor from QLD-based company, WearOptimo, could provide medical professionals with a tool to forecast which COVID-19 patients are on the path to severe respiratory distress allowing earlier, more appropriate treatment.

The company's platform technology looks just below the skin for certain biomarkers or proteins that can provide invaluable clues as to the health of a patient. The device is applied as a wearable sticker that can be worn for days while suppling constant information to health professionals.

The device, classed as a microwearable, features a series of microstructures that reach a hair's width into the skin. This approach isn't invasive enough to require any kind of formal procedure for it to be applied, but, by delving just below the skin, the patch can gain access to the rich source of biomarkers present inside of the body. Once the information is accumulated, it is sent to a medical professional's smartphone or computer.

The company is already developing two types of sensor based on this platform – the first provides hydration information by looking for clues in the conductive properties of the skin's interstitial fluid, while the second searches for key biological signals of disease.

This second application has recently generated a buzz due to the fact that it could be used to help predict if a patient with COVID-19 is likely to require intensive care.

The patch can monitor how a patient's immune system is reacting to the disease by measuring levels of a protein called IL-6. This inflammatory cytokine is produced by the body to help tackle infection but can cause damage to organs and tissue when too much of it is produced.

Early research has linked IL-6 to a variety of poor outcomes including inflammatory pneumonia, it's been identified as a key discriminator between those COVID-19 patients who progress to critical illness or death and those who do not. The levels of IL-6 are typically very low in healthy people but the amount in the body can rise by 10 to 100 times in COVID-19 patients who go on to become the most critically ill – it's part of what is termed a "cytokine storm".

The device provides real-time monitoring of a patient's IL-6 levels, over hours or days if necessary. "Continuous monitoring of IL-6 will yield insights into the systemic proinflammatory response, and inform on the risk of imminent cytokine storm, empowering clinicians to make improved management choices earlier, streamlining decisions to treat with IL-6 inhibitors," Dr Anthony Brewer, Head of Research and Development at WearOptimo, explained. "This will have the beneficial effect of conserving global stocks, as well as reducing off-target side effect profiles in those unnecessarily treated."

The team have been working with ANFF experts in ACT, Queensland, and Victoria over a number of years to develop the sensor's platform architecture, utilising a plethora of cleanroom-based nanofabrication techniques.

WearOptimo is continuing to develop this innovative sensor and are preparing for human trials.

WEAROPTIMO'S WEARABLE SENSORS ARE WORN AS PATCHES AND DELVE JUST BELOW THE SKIN TO ACCUMULATE INFORMATION.
Credit: WearOptimo

GOING NANO FOR MAXIMUM IMPACT

A new way to solve a major problem in miniaturised sensors is at hand.

A major stumbling block in the race to provide comfortable and effective health monitoring is the need for miniaturisation of a large number of components, and to integrate them into a stand-alone sensing system. The finished device needs to still be sensitive enough to measure the small but significant changes that can indicate something important.

For the huge number of systems that measure changes in light to track health, this miniaturisation is particularly challenging given that the core components are typically some sort of light source or lamp, and a sensor that can detect light returning from the sample. Both are traditionally relatively large and require bulky cooling systems to ensure the accuracy of the overall system.

A team at ANU, led by Professor Lan Fu has harnessed the unique properties of nanowires and coupled them with a metasurface to create a system that can detect changes in refractive index in a device a fraction of the size currently available.

Her ANFF enabled technology uses controlled growth of nanowire arrays with uniform triangular shapes to create an LED capable of producing infrared light. This LED nanowire array is then topped by a fabricated metasurface. The light emission from the nanowire LEDs resonates with the metasurface resulting in a device that is 10,000 times smaller than similar current approaches and that can also tune the properties of the output light.

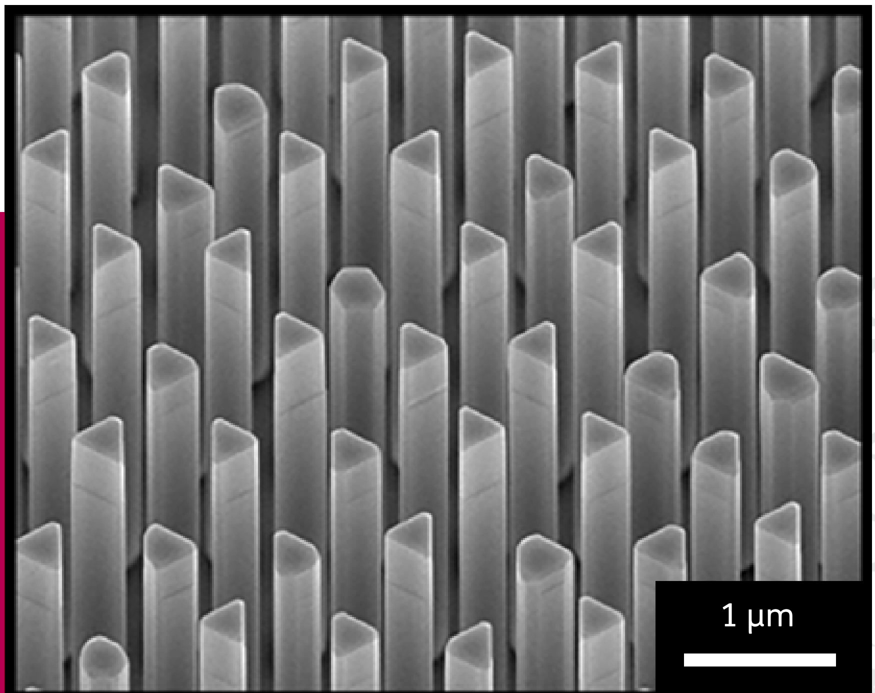
Biosensing occurs when specific markers or biomolecules bind to the metasurface, which changes the refractive index of the material at that point – this can be detected with ease resulting in a measurement that can be used to monitor a variety of health conditions.

This technology has an impressive potential to improve efficiencies in a number of applications. Nanowires are promising building blocks for the next generation nanoscale semiconductor electronics, photonics and optoelectronic devices. Their nanoscale one-dimensional geometry leads to novel optical and electrical properties desirable for applications such as LEDs, lasers, photodetectors, solar cells, and biosensors.

“Not only do these nanowires act as important foundations for high-performance active devices, but they also have the great potential for development of the miniaturised photonic systems such as the nanowire LED/Metasurface integrated biosensors,” explained Professor Lan Fu.

The ability of groups like these to take theoretical simulations and transform them into testable devices is a core function of the ANFF. The availability of the expertise and the equipment required to bring this research towards a fruitful outcome benefits all sectors of the Australian research and development ecosystem.

This work is supported by the ARC Centre of Excellence in Transformative Meta-optical Systems (TMOS) and aligns with the ANU Grand Challenge, Our Health in our Hands providing a holistic approach to understanding one’s own health through new science and technology.



ARRAYS OF TRIANGULAR NANOWIRES CAN BE USED TO CREATE LEDS.
Credit: Lan Fu.

PRINTED SOLAR CELLS WEIGH JUST 300G PER METRE, AND CAN BE FIXED IN PLACE WITH DOUBLE-SIDED TAPE.
Credit: UoN

SHOW AND SOLAR CELL

A team of University of Newcastle researchers has been showing off their ultra-light solar cells that are produced at a rate of hundreds of metres a day using ANFF Material's roll-to-roll printing capabilities.

With two at-scale projects now completed, the team are investigating the best ways to get their technology into the market, and have been in discussions with the print industry both locally and internationally regarding scale up.

The production principle is relatively simple. The technology required for printing the panels is essentially the industry standard, but instead of ink and paper, a photovoltaic liquid and a plastic substrate are used. This means that as the world sees the decline of the printing industry, struggling factories could be quickly repurposed to start printing solar panels.

The research team, led by Professor Paul Dastoor from The University of Newcastle's Centre for Organic Electronics, recently completed a public demonstration of what the panels are capable of by powering a light display in Sydney's north shore. Their flexible printed panels were attached to the curved overhead structure of a covered walkway, powering the entire 35 m display.

This is off the back of an incredibly successful proof-of-concept trial in partnership with logistics giant, CHEP, that is perhaps a more accurate example of how the panels can demonstrate their worth in the future. The panels have been on the roof of CHEP's pallet reconditioning facility in the Hunter Valley for almost 2 years now – their efficiency has dropped in line with expectations, but by and large, they show little to no visual degradation and have been capturing energy the entire time.

It will be installations such as across the roofs of large facilities or even along the sides of roads in remote areas that these panels will be best used – where they really come to the fore is affordable scalability and minimal weight.

Using ANFF Materials' roll-to-roll printing suite, the team are already capable of printing 100's of metres per day at very low cost – once manufacturing is scaled up, this could be closer to kilometres of power-grabbing panels a day, allowing the sheer quantity of the sheets to overcome the differences in efficiency with commercially available alternatives.

They also weigh just 300g per metre, a fraction of conventional panels that weigh in at about 15kg per metre. These new panels are so light and thin that they can be fixed in place with double-sided tape, allowing them to be used almost anywhere there is a surface to stick them to.

The printed panels currently have a life span of about two years, with water being the primary cause of degradation over time – but they should not be considered as disposable. The constituent materials are fully recyclable, so after their relatively short life span, they can be reused in new panels and start "catching rays" all over again.

The next step for the team is an ANFF-supported infrastructure expansion, and continued development of the materials to produce a new set of higher performance materials to push the technology even further.

MODULAR PHOTONICS GROWING AT LIGHTSPEED

Modular Photonics' awards cabinet is now bulging – 2020 has seen the company's ANFF-enabled photonic chip continue to gather interest and recognition, with prizes adding to a growing list of successful installations.

Modular Photonics' chip allows for legacy fibre optic systems to have extra life squeezed into them by adding a whole new dimension. These novel components can be retrofitted to existing fibre optic links by simply adding a novel circuit to either end of the fibre, providing thousand-fold increases in data transmission speeds.

In October, the company was recognised with a 2020 Cabling Installation & Maintenance (CIM) Platinum Innovators Award. Platinum awards go to products, projects, and programs that are deemed by CIM to be superb, offering groundbreaking approaches, or establishing new levels of performance.

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.

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.

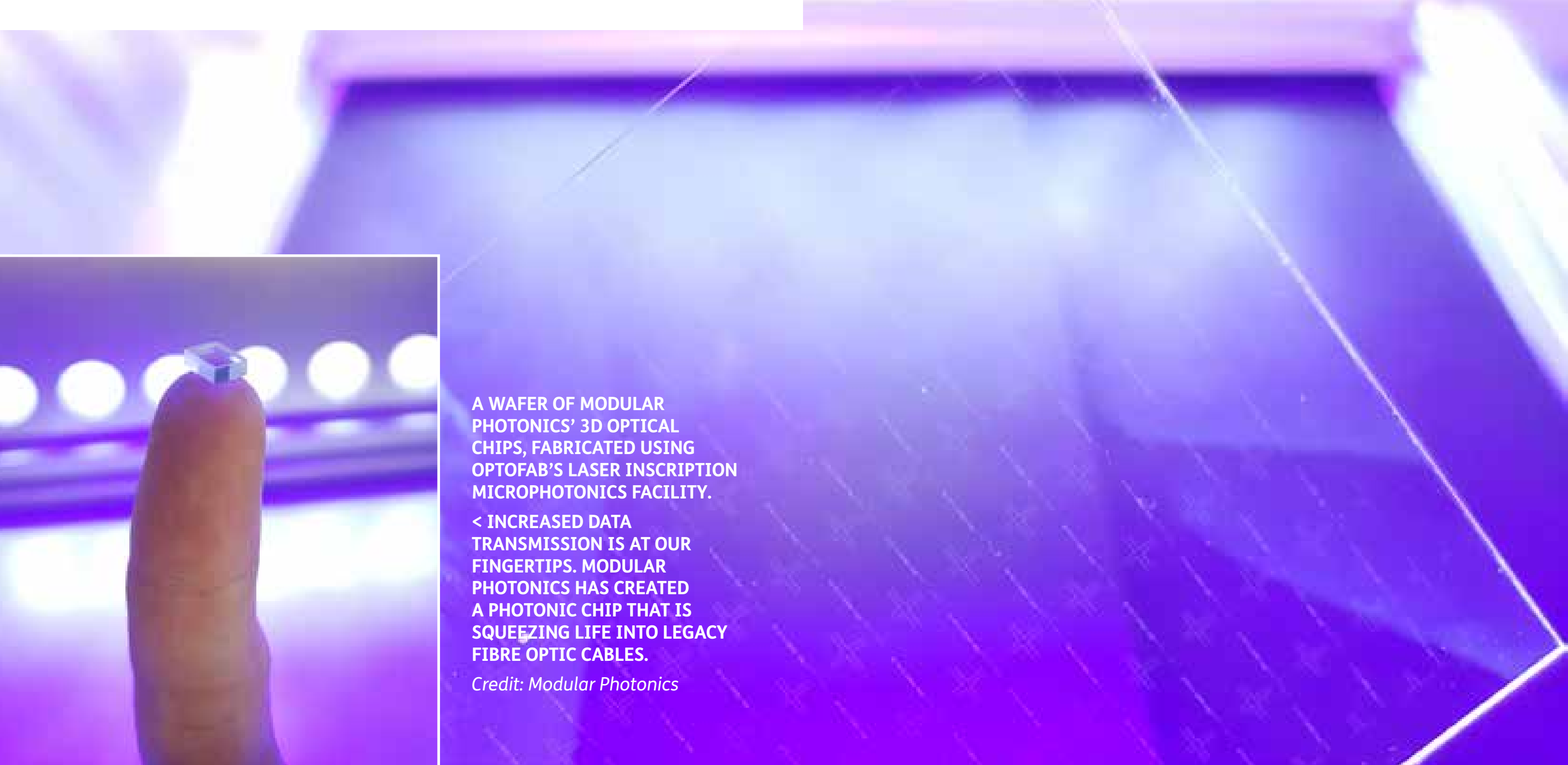
Due to traditional manufacturing processes which are confined to creating waveguides on the surface of a glass substrate, conventional photonics circuits are limited to just two dimensions.

Professor Mick Withford and Dr Simon Gross worked with ANFF Optofab to develop a modular 3D optical chip that could provide faster data rates across legacy fibre infrastructure found in buildings, campuses, hospitals, and shopping centres. They used Optofab's laser inscription microphotonics facility that focuses laser light at a specified distance into glass to selectively modify material. The team used this process to create waveguides within a glass block that move out of the 2D plane and to open up three dimensions of data transmissions.

The resulting device allowed existing infrastructure to provide data rates of more than a thousand times larger than they were capable of before the chip was added. Modular Photonics was spun out from Macquarie University based on this novel device, and the company has been gathering interest ever since.

The first trials of Modular Photonic's technology saw installations at the Sydney Olympic Park and in local schools. Placement of the OMPlex modules took only a matter of hours, and the systems have been boosting performance flawlessly for over three years.

With the latest successes providing a sound foundation, the company has recently hired a new staff member to join their R&D department. The team are working with NSW Exports and Austrade to grow an international distribution network to include India, Malaysia, Middle East, and the UK – building on a list of established distributers in China and Japan – and are solidifying plans for scale up as part of a foreshadowed step change in sales that will see them become independent.



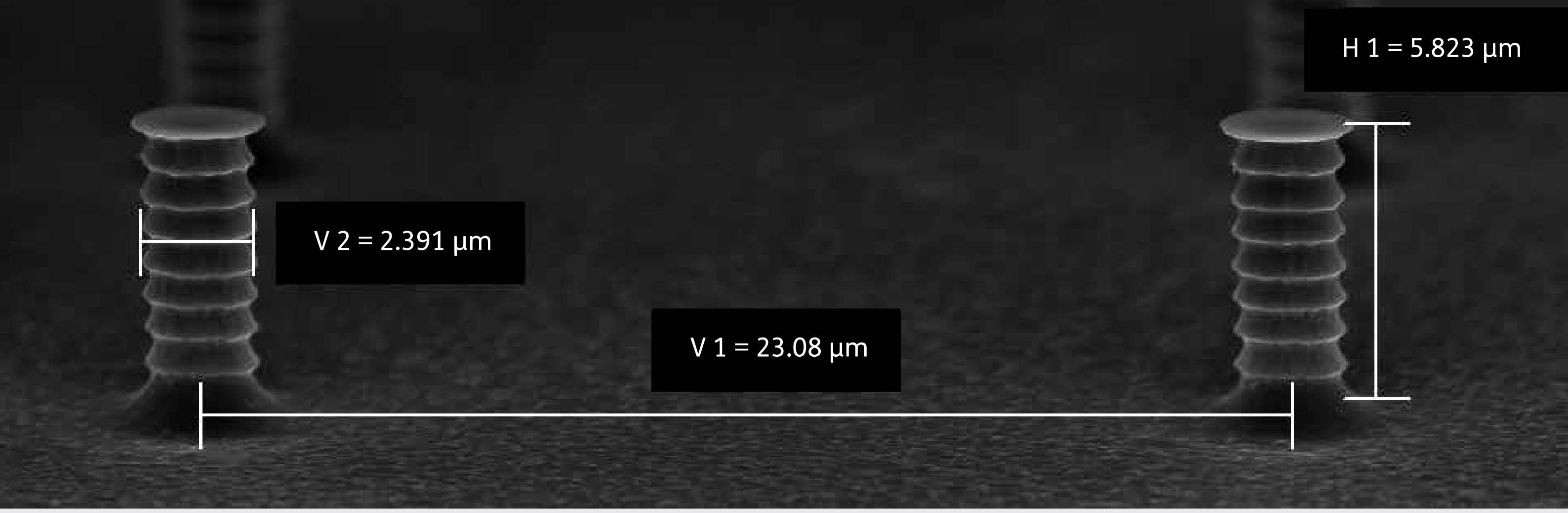
A WAFER OF MODULAR PHOTONICS' 3D OPTICAL CHIPS, FABRICATED USING OPTOFAB'S LASER INSCRIPTION MICROPHOTONICS FACILITY.

< INCREASED DATA TRANSMISSION IS AT OUR FINGERTIPS. MODULAR PHOTONICS HAS CREATED A PHOTONIC CHIP THAT IS SQUEEZING LIFE INTO LEGACY FIBRE OPTIC CABLES.

Credit: Modular Photonics

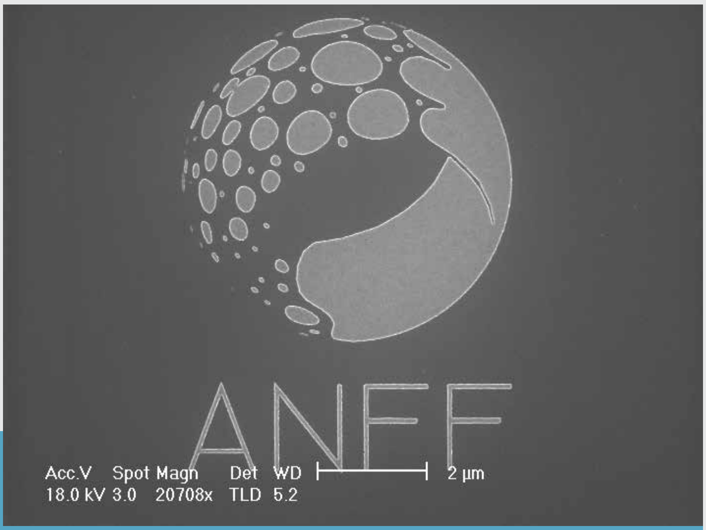
High resolution patterning with ANFF-NSW

FLAGSHIP FOCUS



ANFF-NSW is split between the University of New South Wales (UNSW) and the University of Sydney. The research disciplines supported by both sites is broad, encompassing quantum computing, biomedical devices, nanophotonics, medical detectors and photovoltaics.

ELECTRON BEAM LITHOGRAPHY ALLOWS FOR THE CREATION OF NANOSCALE STRUCTURES AND PATTERNS.
Credit: ANFF-NSW



ANFF-NSW equipment at the University of Sydney forms part of the Research and Prototype Foundry (RPF), a Core Research Facility based at the Sydney Nanoscience Hub. The RPF enables the development of optical chips, electronic devices and new quantum technologies via outstanding lithography, etching, deposition, and metrology capabilities.

ANFF's site at UNSW is home to the capabilities required to create both Si-MOS and GaAs devices with sub-50 nm feature sizes routinely produced using the hub's suite of high-resolution electron beam lithography (EBL) systems.

The EBL process provides incredible patterning resolution that can create structures that measure less than 10 nm in size.

The technique uses a highly energetic, tightly focused electron beam. The beam is scanned over a sample coated with an electron-sensitive resist to draw the desired pattern, before the sample is then developed in an appropriate solvent to reveal the fabricated structures. This then acts as a mould for subsequent pattern transfer techniques such as dry etching or metal lift-off.

ANFF's site at UNSW plays host to two EBLs, an FEI Sirion and Raith 150 TWO, which are used to expose substrates up to 2 inches, and 6 inches respectively. The Raith can stitch fields to allow for processing of large patterns, and features a Fixed Beam Moving stage that allows stitch free exposure which is especially beneficial for fabricating waveguides when even the smallest misalignment of stitched fields results in signal loss. The tool also features Automated Height Sensing mode that allows for micro adjustment in the focal point of the beam to be made during exposure.

The vast range of uses of this process include nano-electronics, photonics, plasmonics, nano-fluidics, MEMS, x-ray and neutron optics.

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SUPER SPINIFEX

UQ researchers are commercialising a class of reinforcing nanofibres that have the potential to create an entirely new industry in rural Queensland.

This UQ team, led by Professor Darren Martin, has demonstrated a highly efficient way to extract cellulose found in the cell walls of spinifex grass and turn it into cellulose nanofibres (CNFs).

These novel nanofibres can be used to significantly reinforce products ranging from condoms to concrete, possessing Kevlar-like properties that add significant strength to a material while only adding a fraction of a percent by weight.

The spinifex grass that the fibres derive from is found across large swathes of Australia's outback. The harvesting and early stage processing of this grass is already providing substantial employment and wealth opportunities for Indigenous people in remote areas, as well as increasing involvement of Indigenous people in materials science.

For more than seven years, the UQ team has been collaborating with the Dugalunji Aboriginal Corporation (DAC) – a Traditional Owner business located in Camooweal, QLD – and the organisation has been responsible for the upstream processes of raw spinifex grass ever since.

Facilitated by ANFF and UniQuest, the UQ researchers and DAC are now working with industrial partners to develop this platform technology further and to secure investment as the fibres gather commercial interest.

Reinforcing fibres such as these are typically mixed into a bulk material to improve its strength before being turned into a product. The UQ fibres can be used to prepare stronger rubber, allowing for medical gloves to be made thinner while maintaining their strength; to reinforce paper to better withstand recycling processes and allow for increased reuse; and to be mixed into cement to reduce the amount of material required to construct a building, reducing both costs and environmental impact in the process.

The early stages in producing the UQ CNFs is to breakdown the spinifex by washing, drying, and grinding down the grass to produce a fine powder. Next, the nanofibres are extracted by pulping the powder before hitting it with mechanical energy to separate the CNFs from the mixture, a process called mechanical fibrillation.

As well as being highly efficient, this production process also provides environmental benefits – there's no need for harsh chemical treatments to deconstruct the spinifex grass and release the cellulose nanofibrils, while the total energy used is also less than that required to produce similar wood-derived CNFs.

The team worked with ANFF at the University of Queensland to characterise the properties and morphology of various grades of CNFs as well as to understand how the fibres worked to reinforce the bulk materials. Professor Martin and the UQ researchers also worked with ANFF's fellow NCRIS-funded colleagues at Microscopy Australia (MA) who provided assistance on a variety of advanced characterisation techniques.

The results from this work showed that these spinifex CNFs have a high length to width ratio, and therefore a high surface area to volume ratio. This makes them very attractive as a strengthening agent because they can provide reinforcement at very low loadings. The team has also identified that due to their processing technique, their CNFs contained higher levels of flexible "hemicellulose" plant cell wall component, and so tend to be longer and tougher than alternative CNFs that can be derived from wood, for example.

The team's horizons continue to grow as new opportunities and applications are found and seized upon. Their next steps include aiming to scale up production towards 10's or 100's of kilograms per day to meet growing demand.

DERIVATIVES OF SPINIFEX GRASS COULD SOON BE USED TO REINFORCE A VARIETY OF COMMERCIAL PRODUCTS.
Credit: Darren Martin

NEW ERA IN X-RAY IMAGING

In-depth imaging is now available on the move thanks to Adelaide-based medical device manufacturer, Micro-X, which has commercialised a new way of producing x-rays.

The ASX-listed company is harnessing two dimensional materials and advanced manufacturing practices to create a far smaller and less power intensive x-ray emitter that reduces overall system footprint and opens it up for portability.

Micro-X's lightweight systems are already being sold across the world, with two new product lines based on this proprietary technology. The newest product, the Rover, received FDA approval in July 2020, and by the end of September the company has secured a $1.4m contract for supply of the mobile x-ray imaging system.

The company has also been named as a Finalist in the Innovator of the Year category of the 2020 SA Science Excellence and Innovation Awards in recognition of the development and commercialisation of this ground-breaking technology.

X-ray imaging is vital to medical professionals to look inside the body without the need for an operation. It relies on the production of x-ray light which is absorbed in different amounts by different tissues, producing a silhouette that can be used to identify broken bones, abnormal tissues, and far more.

To create these x-rays, an electron beam is required to inject enough energy into a target material to make it emit the essential light – this takes place in a component called an x-ray tube.

In a traditional system a metal filament is heated to "boil off" electrons to form the electron beam, but this is incredibly inefficient and results in large amounts of excess heat being generated. To dissipate the heat, conventional x-ray tubes are usually surrounded by a heavy oil-bath, which adds significant weight to the system, thus limiting its overall design and portability.

Micro-X's core technology does away with the need for bulky heat sinks by making it far easier to create the initial electron beam. The company's x-ray tubes use a proprietary carbon nanotube (CNT)-based field emitter to produce electrons.

The CNTs that form the core of these emitters are sheets of graphene that are rolled up to form cylinders – they are far more willing to release electrons than the traditional metal filament and will do so without the need for significant heating, removing the need for oil baths and allowing for miniaturisation of the entire system.

This emitter is manufactured at Micro-X's Tonsley production facility, and is central to two new product lines launched by Micro-X – the DRX-Revolution 'Nano' which is now operating in hospitals in 14 countries, while the 'Rover' mobile x-ray unit for deployed military hospitals was recently launched and will be sent to a number of Pacific Island nations.

The company's interdisciplinary team started developing their CNT technology in 2017, with assistance from Flinders University, the University of Adelaide, the University of South Australia and ANFF-SA. As the project grew the extended national ANFF network has become part of Micro-X's supply chain, with the OptoFab Node in NSW currently producing some critical tube components.

Ready to take on new challenges, Micro-X has joined the Australian Stroke Alliance to help develop a lightweight mobile computed tomography (CT) scanner 'Ring Scanner' to enable lifesaving diagnostic imagers to be fitted into every ambulance providing stroke diagnosis at the point-of-care.

DR STEVE TREWARTHA AND CAITLIN WOUTERS SHOWING ONE OF MICRO-X'S NOVEL X-RAY TUBES AT THEIR TONSLEY PRODUCTION FACILITY.
Credit: Micro-X

MUPHARMA'S BRIGHT FUTURE SEEN CLEARLY

An exciting Melbourne start-up has developed a highly novel non-invasive device that could avoid the need for intraocular injections to deliver drugs to the eye.

This non-invasive technology promises a safer, more comfortable, and convenient treatment option for the tens of millions of people across the world that are affected by retinal blood vessel diseases, such as Macular Degeneration and Diabetic Macular Edema.

Invented by Mark and Harry Unger through their startup MuPharma Pty Ltd together with ANFF-VIC Director, Professor Nicolas Voelcker, the technology has now successfully completed proof of concept trials at the Monash Biomedical Imaging Centre; work funded by the Medical Devices Partnership Program Victoria (MDPP Vic), supported by LaunchVic.

The conventional treatment for retinal diseases involves regularly injecting drugs with a hypodermic needle directly into the vitreous jelly that fills the back of the eye. This procedure can be uncomfortable, painful, and disruptive to the patient whilst also adding risks of infection, retinal detachment, and increased pressure within the eye.

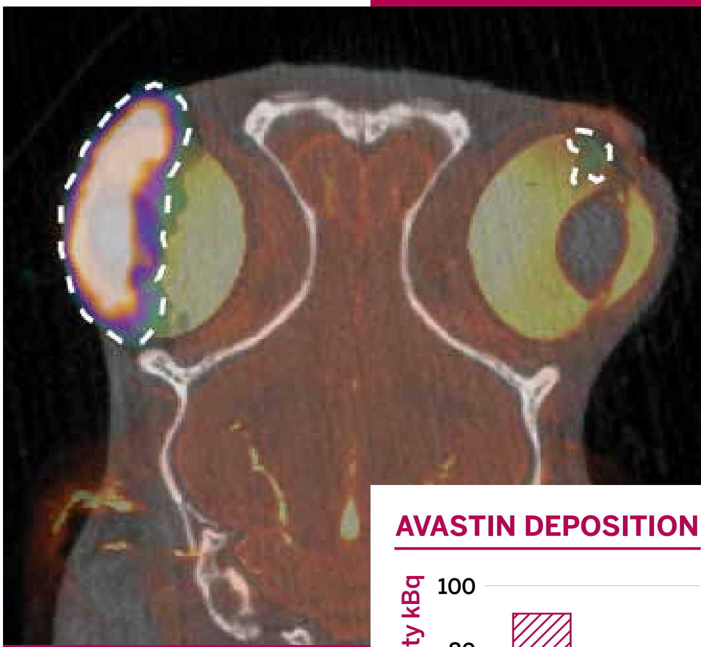
Instead of using a needle and syringe, MuPharma's new approach uses an ultrasound-based, handheld device that is loaded with a routinely-injected drug. The treatment is administered by briefly holding the device against the eye to enable the drug to pass through barrier tissue at the surface. The eye's natural blood supply then carries the medicine to the diseased retinal areas.

The process is over in a matter of minutes, eliminates the major risks associated with intravitreal injections, and is likely to require less drug per treatment than conventional injection procedures. In contrast to existing alternatives, MuPharma's treatment doesn't necessarily need to be administered by an eye specialist and patients could potentially drive and work shortly afterwards. This all combines to provide patients with a convenient, comfortable, and painless treatment option.

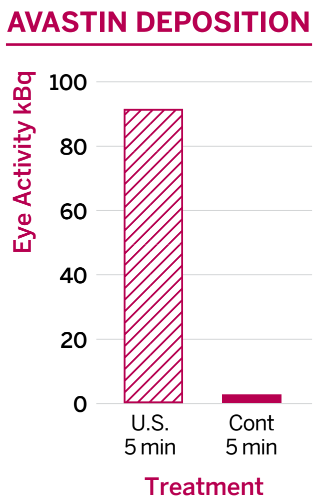
The technology continues to be refined with help from ANFF-VIC, where development has been underway for almost a decade. Engineers at the Melbourne Centre for Nanofabrication (MCN) have iteratively prototyped and characterised the device's essential components, worked with third-party product designers, hosted a "live-in" intern, and assisted with the proof of concept testing. This included cutting edge characterisation of device core operating parameters and loading and release profiles.

Follow on testing conducted by the Monash Biomedical Imaging Centre was able to validate that the MuPharma device could non-invasively deliver a significant amount of Avastin (a large antibody conventionally delivered by intraocular injection) to the eye relative to controls. Further advanced testing is currently underway.

The potential of the device has already been recognised by MDPP Vic, who have supported the device's development and brought together a team of consulting experts which MuPharma's founders can call upon.



AVASTIN DELIVERY BY MUPHARMA'S DEVICE DRAMATICALLY ENHANCED EYE DEPOSITION. DEPOSITION OF RADIOACTIVE AVASTIN OUTLINED IN WHITE DASHED LINE. LEFT EYE WAS ADMINISTERED AVASTIN BY ULTRASOUND DELIVERY FOR 5 MINUTES AND THE RIGHT EYE WAS ADMINISTERED AVASTIN WITHOUT ACTIVE ULTRASOUND FOR 5 MINUTES. THE GRAPH SHOWS THE DIFFERENCE IN RADIOACTIVITY DEPOSITED AT THE EYE 90 MINUTES AFTER APPLICATION.



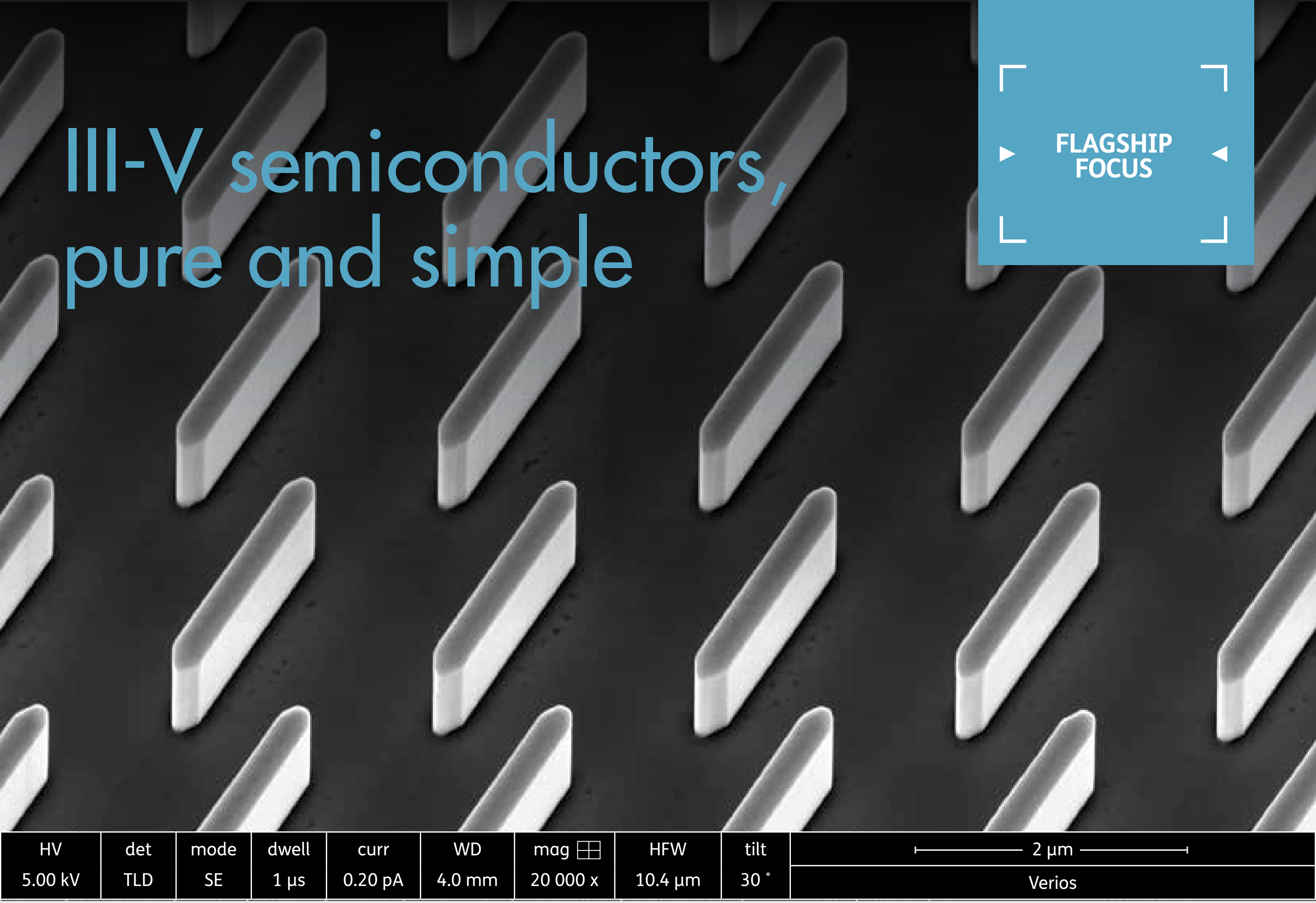
As commercialisation of the technology continues, the Ungers are working with experts at the MCN and MDPP, as well as with a team of drug delivery specialists led by Professor Nicolas Voelcker to optimise the device.

"The last year or so has seen our device's development sprint forward despite a global pandemic," said Mark Unger, Managing Director of MuPharma. "This progress wouldn't have been possible without the support of ANFF, the MCN, as well as MDPP Vic and our research collaborators in the Voelcker Group.

"Now, having extensively demonstrated the capabilities of our technology, we're excited to continue working with these groups to bring our device to market and providing patients with retinal diseases a means of treatment that eliminates regular intravitreal injections."

III-V semiconductors, pure and simple

FLAGSHIP FOCUS



ANFF-ACT, located at the Australian National University, provides a range of capabilities and services for the fabrication of photonic devices, specialising in the growth of III-V and nitride semiconductor materials.

ANFF-ACT works closely with two renowned research groups based at ANU's Laser Physics Centre and the Department of Electronic Materials Engineering. These groups bring expertise in the capabilities of ion implantation, etching, and optical characterisation.

Amidst the world-class capabilities sits the team's three Metal-Organic Chemical Vapour Deposition (MOCVD) reactors which are unique. They've been customised to provide the perfect conditions for the growth of III-V and nitride compound semiconductors to produce 2D and 3D nanostructures including nanowires, quantum dots, and quantum wells. A large number of materials can be produced with precise control of composition and strain, allowing precise bandgap tuning.

MOCVD or Metal-Organic Vapour Phase Epitaxy (MOVPE) is an epitaxial technique widely used for the growth of semiconductor materials. The main distinction of MOCVD from other CVD techniques is the ability to grow monocrystalline layers/structures on a substrate, where the substrate serves as a seed crystal.

The principle behind this technique is the pyrolysis of compound gaseous precursors, one for each atomic group, with the subsequent growth of the layer with the required material composition on a substrate. Material growth is carried out at temperatures much lower than the melting point of the material, resulting in atomically smooth surfaces and abrupt interfaces.

ANFF-ACT's MOCVD systems can deposit on wafers measuring 3 x 2 inches, and typical substrates materials include InP, GaAs, InAs, GaP, Si and sapphire. Common devices that are being developed while using these tools include LED, LD, photodetectors, III-V MEMS technologies for an array of end applications.

The three systems are:

+ **MOCVD1** – AIXTRON 3x2FT CCS (Close-Coupled Showerhead) MOCVD system for growth of III-V (III-As, III-P, III-Sb) semiconductor structures. Epitaxial growth of III-V (arsenide, phosphide and antimonide based materials) 2D and 3D nano/microstructures.
+ **MOCVD2** – AIXTRON 200/4 horizontal flow MOCVD system for growth of III-V (III-As, III-P, III-Sb) semiconductor structures. Epitaxial growth of III-V (arsenide, phosphide and antimonide based materials) 2D and 3D nano/micro structures.
+ **MOCVD3** – AIXTRON 3x2FT CCS (Close-Coupled Showerhead) MOCVD system for growth of III-N (nitride) semiconductor structures. Epitaxial growth of III-N (nitride based materials) 2D and 3D nano/micro structures.

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HOMEGROWN PLATFORM TO MAKE DIAGNOSTICS EASY

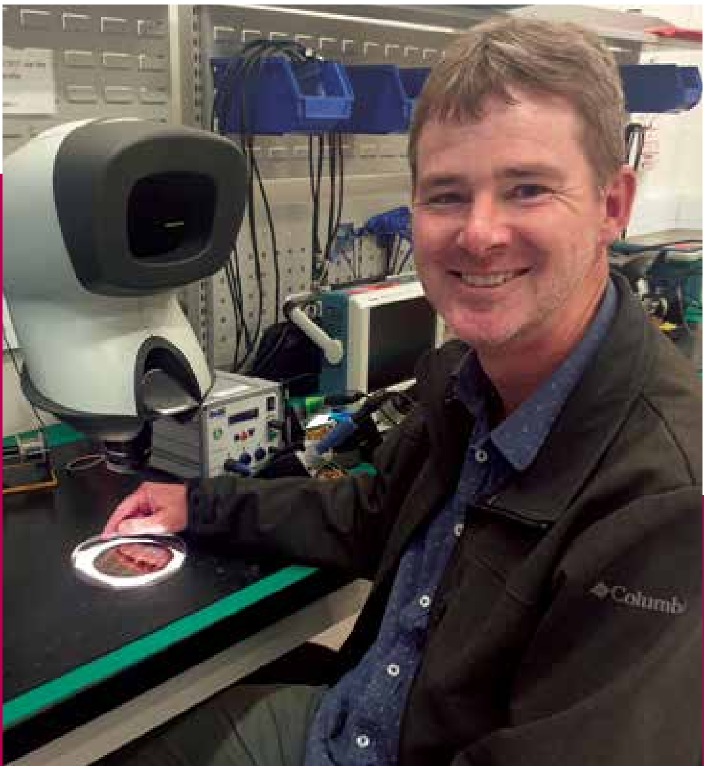
NSW-startup Kimiya is developing a homegrown technology platform aimed at making diagnostic testing quick, easy and accessible.

The COVID-19 crisis has thrust the need for rapid diagnostics into the general consciousness, publicly demonstrating that time-to-result can be critical to suppressing outbreaks and minimising associated health, social, and economic impacts.

Kimiya's efforts are aimed at bringing the benefits of Nucleic Acid Testing (NAT) to the frontline. NAT is widely used in centralised testing facilities and considered the gold standard for COVID-19 diagnosis, as well as for many other ailments.

The company's system is intended to be placed at the point of care, which is particularly useful given the large percentage of Australia's population that live in rural and remote areas. The aim is for the entire testing process to be conducted within a portable system, with a positive or negative outcome being confirmed within the hour. This would provide a drastic timeline improvement on the current pathology workflows which can take days once transport of samples is taken into account.

Once completed, Kimiya's technology could provide General Practitioners with the means to quickly identify common conditions and prescribe an accurate course of medicine instead of resorting to broad-spectrum antibiotics while awaiting results.



KIMIYA'S CO-FOUNDER, MATTHEW WORSMAN, IS USING MICROFLUIDICS TO MAKE A NAT DEVICE THAT IS PORTABLE, SIMPLE TO USE, AND PROVIDES SAMPLE-TO-ANSWER RESULTS.
Credit: Matthew Worsman

In addition to slowing the rise of antimicrobial resistance, this means that patients are almost instantly able to begin recovery with a more targeted treatment. It also reduces the demand on the resources of centralised testing facilities as they aren't constantly processing routine conditions, allowing them to better provide their specialist services to those that need it most.

NAT detects the presence of a target virus or bacteria by investigating whether a sample contains strands of DNA or RNA that are specific to the particular pathogen. In the specific case of COVID-19 for example, the procedure would seek out the presence of SARS-CoV-2 viral RNA. If SARS-CoV-2 viral RNA is in the sample, the patient is suffering from COVID-19, if it's not, the patient is considered clear of the condition.

The NAT approach initially involves taking a sample from the patient, then breaking it down to release genetic material associated with all of the human cells, bacteria, or viruses that are present. Target biomarkers are then replicated to make them easier to find before the mixture is passed through a sensing component that confirms whether they are present or not.

It's central to the goals of the company's co-founder, Matthew Worsman, to not just make the product portable enough to install in doctor's surgeries or remote locations, but also to be simple to use, and provide sample-to-answer results. To do this, they're utilising ANFF-NSW expertise and capabilities to develop a silicon-based microfluidic architecture that will be at the heart of the company's technology. The resulting lab-on-a-chip will perform the amplification and detection processes that are key to NAT diagnostics.

Mr Worsman explained, "Given the level of sophistication envisaged, Kimiya has a way to go but with ANFF-NSW support for COVID-19 related development work, the team aims to achieve results to boost the technology readiness level significantly in the coming months."

PHOTONIC SWITCH ON THE RIGHT TRACKS

A photonic switch developed by Perth-based researchers has been backed by UWA to help it reach its commercial potential.

In late 2019, Associate Professors Mariusz Martyniuk and Gino Putrino, and Professor Dilusha Silva from UWA's Microelectronics Research Group, were awarded a Pathfinder grant of up to $25,000 to build and test a prototype light-coupling switching device at UWA.

The UWA team has taken a Micro-Electro-Mechanical Systems (MEMS)-based approach – these devices feature micron-sized movable parts that are used to perform an array of tasks such as sensing movement or temperature in a smartphone.

The team's technology could help meet the ever-increasing need for faster network speeds by improving information transfer in light-based devices, providing system performance benefits while reducing energy costs. The novel design of the team's MEMS-based approach requires minimal energy consumption and is economic to manufacture using conventional fabrication processes.

The ability to redirect light signals is essential to many established photonic practices, such as fibre optic cable networks, but is also vital to new and emerging applications including photonic-based computer chips and photonic integrated chips. In all of these applications, rapid redirection of light between outputs allows for incredible speeds of data transmission.

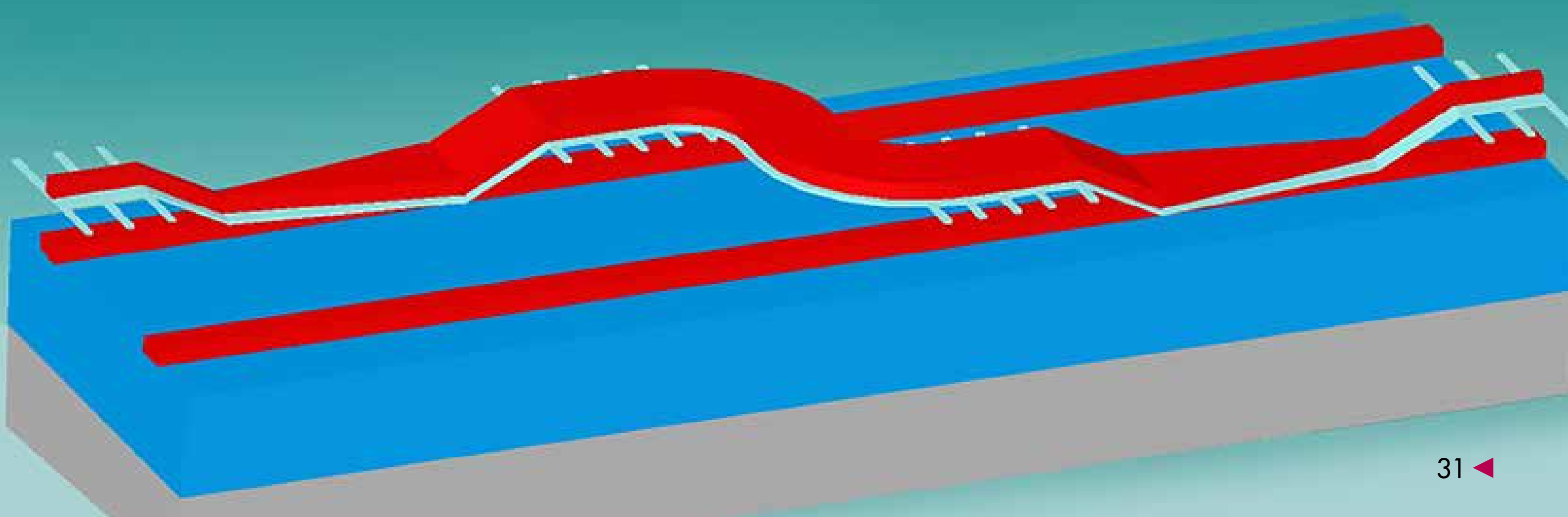
In this case, a MEMS approach is used to switch light from one channel to another in a similar fashion to how trains change between tracks via a railroad turnout. Light signals enter the device through an ordinary waveguide, but are then coupled to a suspended waveguide that can either carry them on the same course, or can "change between the tracks", redirecting the flow of information to another output.

The switching is entirely controllable through electronic signals, and the changes happen almost instantly. Importantly, this is achieved with a fraction of power in comparison to current commercial technologies.

"If the predicted 'low loss' of light in our new design can be demonstrated, it offers the potential for efficient and economic control of on-chip light propagation, enabling a wide range of applications from high-speed optical communications to ultra-low power signal processing," Assoc. Prof Martyniuk explained.

"The Pathfinder funding along with additional and significant contributions from our industry partner and the DST Group goes a long way to being able to test whether the design works as well as we think it will," Assoc. Prof Martyniuk said. "The MEMS fabrication capabilities and know-how available at ANFF-WA are the enabling factors in this project, and are essential to the past and future successes of this project."

DESIGN FOR OPTICAL SWITCHING BETWEEN TWO ON-CHIP WAVEGUIDES USING A SUSPENDED MEMS BRIDGING WAVEGUIDE ACTUATED INDEPENDENTLY OVER EACH OF THE ON-CHIP WAVEGUIDES.
Credit: MRG

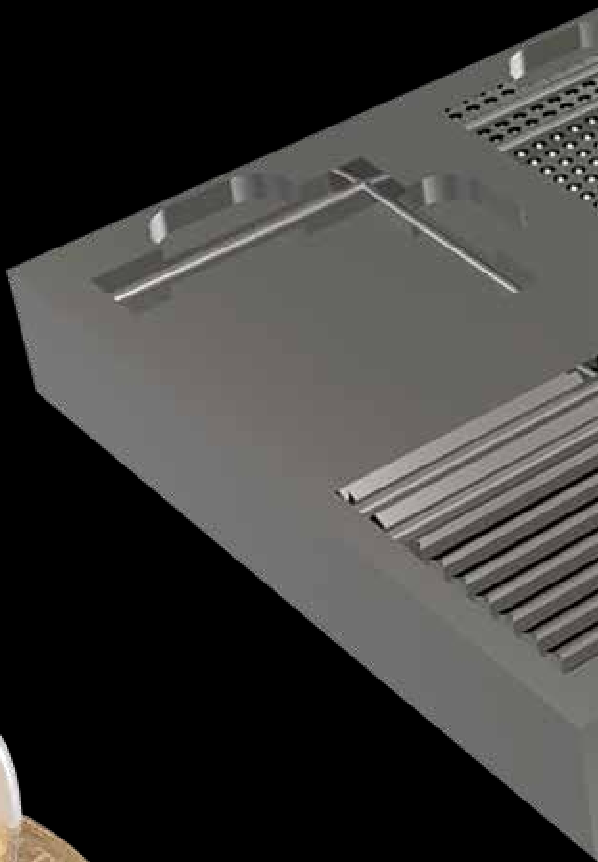


FLAGSHIP FOCUS

Micromilling at ANFF-SA

Split between the University of South Australia and Flinders University, ANFF-SA provides access to cutting-edge equipment and expert staff specialising in microfluidics, organic electronics, biomaterials, novel semiconductor materials and characterisation.

The Node houses state-of-the-art photolithography, micromachining, hot embossing and bonding, micro-injection moulding, plasma etching, thin film coating, fluidic simulation, and advanced characterisation in ISO Class 5 & 6 cleanroom environments.

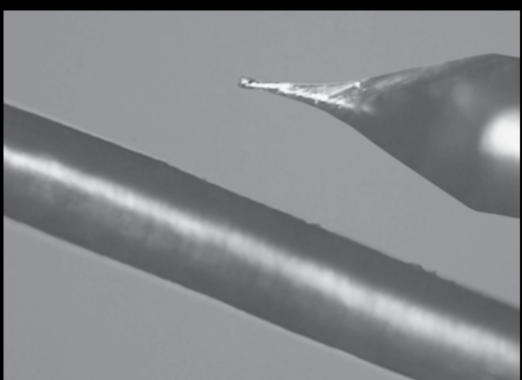


CNC Milling on the microscale

One of the exciting and unique capabilities of the ANFF-SA Node is its micromilling CNC equipment, the cutting-edge Kira SuperMill 2M. This process offers precision machining capabilities at amazing resolutions for researchers, academics and industry requiring microscale devices and is the only one of its kind in the Southern Hemisphere.

The Kira removes material using a rapidly rotating machine head that is programmed by a CAD model. ANFF-SA has a choice of eight machining heads that measure as little as 5 µm across and rotate at up to 160,000 rpm, allowing the team to process features ranging from centimetres to micrometres. The tool utilises 3-axis simultaneous movement with a positional accuracy of 10 nm in a temperature-controlled environment to achieve three-dimensional machining of microstructures that are almost too small to be believed.

To optimise the geometries of the project and minimise iteration costs, ANFF-SA offers access to finite element analysis, computational fluid dynamics simulation capabilities as well as a suite of micro and nano inspection equipment including X-ray CT and laser confocal microscopes, helping clients save critical time and money.



LEFT: A COMPARISON OF ANFF-SA'S 5 µm MACHINE HEAD WITH A ~88 µm HUMAN HAIR.

RIGHT: MILLED PARTS ON A $2 COIN.

Credit: ANFF-SA

TOOL SUMMARY +

Function:
High accuracy milling with ultra-fine finish

Uses:
Directly machined channel geometries, features for micro injection and PDMS casting moulds and fine finishing of 3D printed parts.

Key Features:
+ positional accuracy of 0.01 µm (or 10 nm)
+ automatic tool changer - eight tools
+ cutting tool diameter down to 5 µm
+ 200 mm machining envelope
+ 50,000 rpm electric and 160,000 rpm air spindles

Material:
Polymers (such as PEEK, Teflon, PMMA) and metals (aluminium, stainless steel, hardened tool steel and titanium)

Scale:
One-off parts and low volume

Tolerance:
Submicron accuracy

ESTABLISHING INDUSTRIES

Maintaining a strong economy depends on both supporting established industries and creating entirely new ones.

This section looks at researchers that are arming businesses with the means to do old jobs in new ways, or those that are forging entirely new paths to create new opportunities.

UWA RESEARCH MOVES UP THE FOOD CHAIN

A research project to develop a portable sensor capable of assessing food quality has won the Buy West Eat Best Kim Chance Fellowship Award from the WA State Government.

University of Western Australia PhD student Jorge Silva was awarded the Fellowship in late 2019 for his research project to develop low-cost spectroscopic infrared scanning technology to assess food quality.

The Kim Chance Fellowship Award was established in recognition of Mr Chance's devotion to agriculture, and for his tireless support of farmers, the wider agricultural sector and regional communities.

The $10,000 fellowship, funded through the WA Department of Primary Industries and Regional Development, allowed Jorge to travel to the University of Georgia, USA in early 2020 to gain hands on experience in food quality and safety assessment using infrared scanning technology.

Jorge's innovative ANFF-WA-enabled work that helped to secure the award is aimed at developing a portable spectroscopy system for monitoring the quality of food across the supply chain. The project will improve the quality control measures used to detect faecal contamination in poultry and surface contamination on vegetable crops by looking at two narrow spectral bands centred at 517 nm and 565 nm.

The approach first involves the use of two cameras to calculate the volume of chicken using stereo estimation. Stereo estimation, which is a form of artificial binocular vision, compares the distances of an object from the two cameras to generate a disparity map. This map then allows the system to estimate the volume of the detected object – in this case chickens. The result is a contact free approach to classify chicken by size that can happen inline during processing.

At the same time as classifying the chicken, the cameras capture spectral faecal matter signatures using a narrowband optical filter, one tailored to the 517 nm band, while the other is specific to observe 565 nm light. The amplitude of spectral signal allows the system to observe whether faecal matter is present – if there is any, alarm bells start ringing.

The approach has potential to be modified for use in other farming applications. This is possible considering that many spectral features of plants and minerals can be detected within the visible and near infrared bands that can be detected using CMOS cameras commonly found in smartphones and computers.

Preliminary trials will be undertaken with poultry within the next two years, with the aim of having the technology to market within four to five years.

UWA PHD STUDENT JORGE SILVA, RECIPIENT OF THE BUY WEST EAT BEST KIM CHANCE FELLOWSHIP AWARD, WITH AGRICULTURE AND FOOD MINISTER ALANNAH MACTIERNAN AND BUY WEST EAT BEST PROGRAM MANAGER MELISSA WORTHINGTON.
Credit: UWA

STORING SUNSHINE IN A BOTTLE

ANFF-enabled researchers at ANU have created a record-breaking device that uses sunlight to harvest hydrogen.

This exciting research is a major step in the pursuit of a clean-power economy, and aligns closely with the Council of Australian Governments (COAG) Energy Council's national hydrogen strategy.

Many countries have recognised the incredible potential of hydrogen as a clean source of energy – it's a transportable, exportable clean fuel with a high specific energy density, and efficiently produces electricity when consumed in a fuel cell, producing water as the only byproduct.

While it's the most common element in the universe, hydrogen is oddly difficult to gather efficiently. Most of the Earth's hydrogen is bound up in in molecules like water, it can be separated and collected but this requires energy.

A promising mechanism for hydrogen harvesting is by splitting water in a process called electrolysis. The process uses electricity to break apart water into hydrogen and oxygen, the hydrogen can then be captured, stored, and used as a fuel source as and when it's needed.

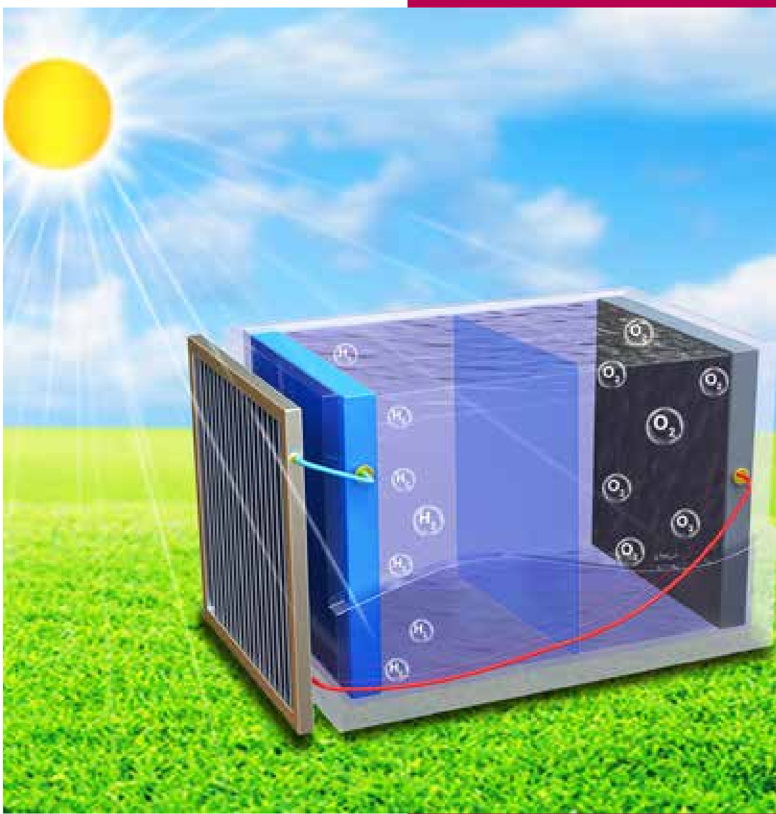
Electrolysis requires power and until now this has meant pulling on the national grid, requiring a great deal of additional infrastructure and resulting in a lot of lost energy, reducing overall efficiency.

However, the ANU team has now demonstrated record-breaking conversion efficiencies of hydrogen harvesting by creating a standalone system that powers itself. They've introduced a tandem solar cell system that feeds electricity directly into a water-splitting chamber and removes the need for external power sources.

"To produce hydrogen in the past, solar plants had to produce electricity which is then used to electrolyse water to produce hydrogen. Our new method is more direct, making it more efficient," lead author of the research, Dr Siva Karuturi said.

The team worked with ANFF-ACT to build two interlinked solar absorbers capable of generating the required energy levels to separate hydrogen. The first cell is made of a perovskite material, these are considered to be some of the best performing photovoltaic materials available and allows the team's device to accumulate part of the power required for the electrolysis process. Then, a second silicon photoelectrode kicks in to supply a sufficient voltage to allow the splitting to begin.

This direct solar-to-hydrogen approach has unlocked record-breaking conversion efficiencies of 17.6%, nearing the performance of current rooftop solar panels. The team's planned steps could see them reach the 20% efficiency mark before the end of 2021, paving the way for cost-effective green hydrogen production.



DIRECT SOLAR POWER IS UNLOCKING EFFICIENT CAPTURE OF HYDROGEN FOR ENERGY APPLICATIONS.
Credit: Siva Karuturi.

"Significant cost benefits could be achieved through the use of the solar-to-hydrogen approach," says Dr Karuturi, "as it avoids the need for added power and network infrastructure necessary when hydrogen is produced using a traditional electrolyser. By avoiding the need to convert solar power from DC to AC power and back again, in addition to avoiding power transmission losses, the direct conversion of solar energy into hydrogen can achieve a higher overall efficiency for the total process."

While they begin taking steps towards higher efficiencies, Dr Karuturi and the team will also look to incorporate cheaper materials to further reduce costs of the technology.

LIGŌ TO LEAD THE WAY

A lifechanging product being developed in Sydney could revolutionise the way we approach wound repair, while also placing Australia at the forefront of the burgeoning regenerative medicine industry.

This new platform, codenamed Ligō from the Latin 'to bind', is a novel 3D bioprinting technique from fast-growing start-up, Inventia Life Science. The technology builds on a treatment that would see a surgeon begin treating a burn victim within 20 minutes.

The company's proprietary technique offers so much promise that in July 2020 the Government's BioMedTech Horizons program announced it will inject $1m in funding to take the device into first-in-human clinical trials within two years.

The procedure involves taking a small section of the patient's skin, extracting the skin cells and 3D printing them directly into the wound within a supporting gel where they can begin to encourage faster healing with less scarring.

The project brings Inventia Life Science together with world-renowned skin surgeon and former Australian of the Year, Professor Fiona Wood who pioneered the 'spray-on skin' technique to treat skin burns. Her work demonstrated that by introducing healthy skin cells such as keratinocytes, fibroblasts, and melanocytes, healing time and scarring can be reduced, improving patient outcomes and satisfaction.

The Ligō is a continuation of this spray-on skin technique that would see the recovery-enhancing skin cells encapsulated within an optimised microenvironment as they are efficiently applied to the wound.

This work is based on tried and tested technologies within Inventia's existing product lines. The company's commercially available Rastrum is used to bioprint three-dimensional tissue samples to provide researchers with highly accurate tissue testbeds for new medicines and cosmetics.

The Rastrum lays down cells into ordinary well plates with a gel that forms a supportive scaffold. This allows the cells to proliferate in three dimensions and more accurately represent real tissue. The results offer a cheaper, more repeatable, and more attractive option when compared to the use of live animals for testing.

This principle of laying down cellular material along with a chemically curable hydrogel is the core principle behind the Ligō, but instead of printing within a well plate, it will be used to directly treat acute wounds.

The procedure involves taking a small skin graft, extracting the skin cells and combining them with a bioink within the operating theatre. This mixture is then printed directly into the wound by a robotic device where it forms a gel. Suspending these cells in a gel creates an optimal environment to encourage the cell regeneration.

To aid the development of the project, the team brought in the bioprinting expertise of Professor Gordon Wallace as they work towards new printing techniques and bioink formulations that will enable the application of skin cells within a hydrogel structure. The majority of the work to translate the biomaterials to clinic is taking place at TRICEP, using ANFF Materials' equipment and expertise.

SMARTCRETE CRC RECEIVES FUNDING

In March 2020, the Hon Karen Andrews announced $21 million in funding for the ANFF-supported SmartCrete CRC, which aims to reduce the cost of concrete and improve productivity of one of the most heavily used building materials in the world.

Concrete might not seem glamourous to an outsider, but its use underpins much of the infrastructure needed for the modern world.

SmartCrete plans to guarantee the long-term viability of concrete infrastructure in Australia by pursuing three major program initiatives – providing new engineering solutions, improving the sustainability and environmental attributes of cement structures, and by creating technologies that allow better management of concrete assets.

The CRC will be particularly relying on ANFF equipment and expertise to assist its pursuit of novel sensing components that can be built into concrete structures such as skyscrapers and sewers. The improved information provided by these sensors will mean that fewer people have to enter dangerous environments and ensure long-term accurate monitoring of a structure's integrity.

One of the most advanced projects in the SmartCrete portfolio is a corrosion monitoring device being developed by Macquarie University researchers. This sensor tracks damage to the walls of a concrete sewer by feeding out information about the temperature and humidity in the sewer headspace allowing engineers to predict when interventions will be needed.

These sensors are based on mature Fibre Bragg Grating (FBG) technology and made by creating arrays of microscale features in commercially available fibre optic cables. The team, led by Dr Martin Ams, creates the sensing elements using a femtosecond laser that is part of ANFF OptoFab's laser machining and inscription suite.

When light is passed down the fibre, these gratings reflect a precise wavelength that is dependent on the spacing of the features. If the size of the fibre were to change, perhaps contracting due to the glass becoming colder, the distribution of these features alters with it and therefore a different wavelength is reflected. The device is consequently able to observe changes in the integrity of the concrete by monitoring the variations in returning light.

Devices of this type have already been installed at a number of Sydney Water wastewater treatment plants and have shown a lifetime exceeding 14 months, outperforming conventional electrical sensors which only survive a number of days in these harsh environments.

Dr Martin Ams said: "SmartCrete CRC will provide an avenue for increased uptake of such sensors, especially into the concrete sector, with asset management being the forefront research program to capitalise on their advantages."

"With funding secured, we now plan to drive down the cost of the sensor interrogation system and roll out sensing installations not only throughout Australia's concrete wastewater network but also across other concrete-based industries."

Deposition with atomic precision

FLAGSHIP FOCUS

ANFF-WA is hosted at UWA within the Microelectronics Research Group (MRG), part of the School of Engineering.

ANFF-WA WORKS CLOSELY WITH RESEARCHERS AT THE CUTTING EDGE OF MEMS TECHNOLOGY.
Credit: MRG

MRG is the only II-VI infrared material research group in Australia, which allows ANFF-WA's engineers to provide unique expertise on the fabrication of infrared devices built using materials such as mercury cadmium telluride (HgCdTe). The teams expertise is aimed at a diverse range of applications including imaging, infrared spectroscopy, remote sensing, optical communications, meteorology and space situation awareness for both civilian and military uses.

Recent years have seen a significant investment in the Node's Molecular Beam Epitaxy (MBE) lab, which is home to a customised Riber 32P MBE system.

Molecular Beam Epitaxy is a deposition technique that allows for crystals to be grown with extremely high purity. The process allows for subnanometre control over crystal structure and film thickness as it's grown, as well as for the positioning of dopants within the material.

A series of molecular beams are directed onto a heated crystalline substrate. Upon arrival on the substrate, the molecules in the beam bind, forming a new crystal layer. The entire growth occurs in an ultra-high vacuum and there is no chemical mixing before the beams reach the substrate surface. Therefore, the quality of MBE produced material is all but perfect.

ANFF-WA's system features a series of in-situ tools, such as reflection high-energy electron diffraction (RHEED), ellipsometry, pyrometry and an accuflux meter to allow observations and analysis during growth. This adds a further level of precision and control to the growth process. The in-situ monitoring results combine to provide an extremely effective method to grow high-purity HgCdTe materials, leading to the development of new infrared sensors.

The excellent equipment and expertise available at ANFF-WA has allowed for the full fabrication of high performance infrared focal plane arrays (IR FPA) for the first time in Australia, illustrating the international relevance of ANFF.

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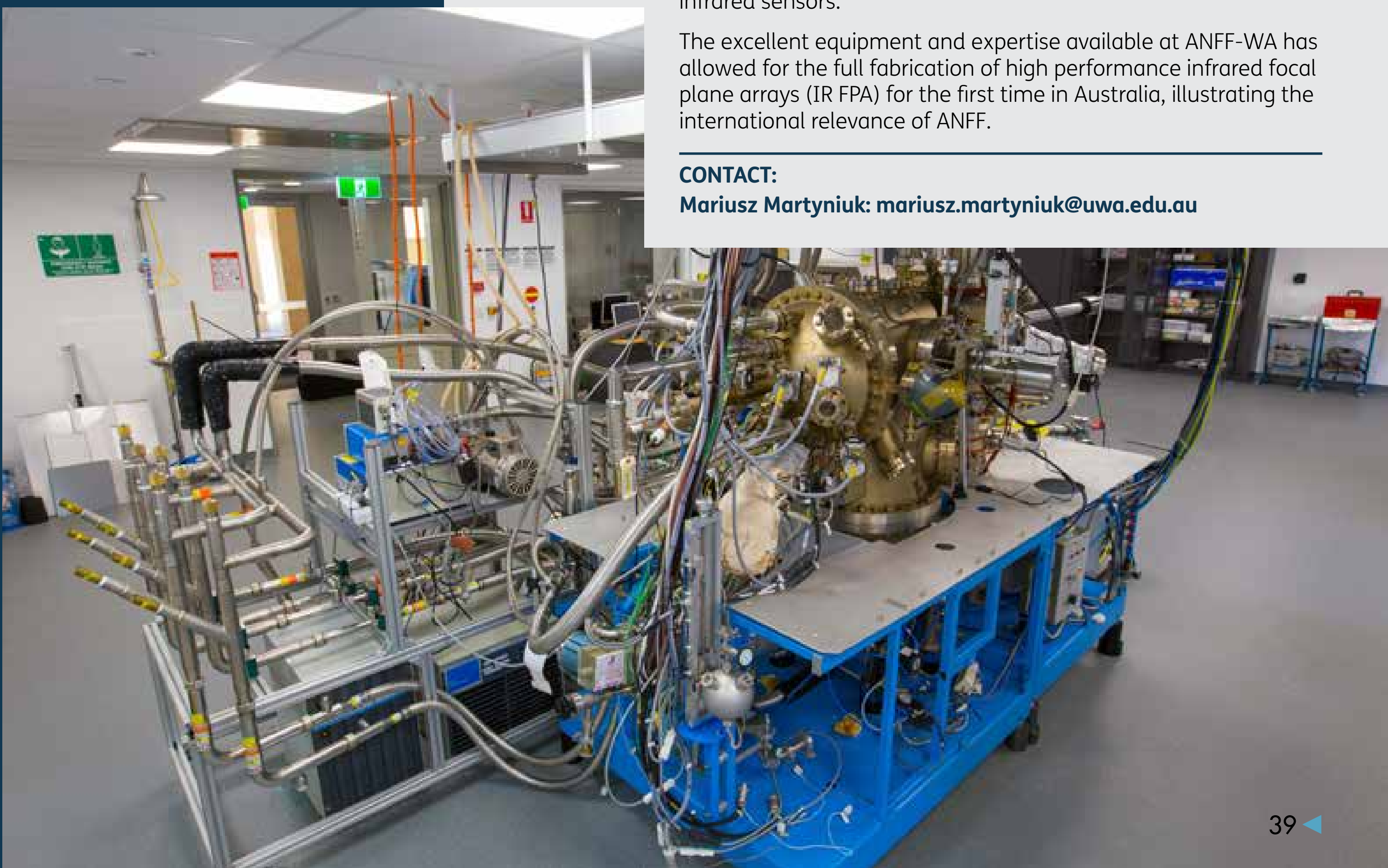


ECOFRIENDLY PESTICIDES GET AN EFFICIENCY BOOST

Researchers from the University of Queensland have paved the way for wide use of high-performance ecofriendly pesticides by encasing them in nanoparticles, making them sturdier and stickier.

Biopesticides, such as spinosad, are a new generation of pesticides that are showing promise in the livestock industry by posing a triple threat. Their production has less effect on the environment, they're made from natural products, and they have been demonstrated to be highly effective at dealing with cattle pests such as ticks in laboratory settings.

Unaided however, spinosads quickly degrade in sunlight and can be easily washed away by rainfall – this means that they become largely ineffective within in a week in the field, making them prohibitively expensive and impractical as they would have to be reapplied every few days.

Inspiration was needed and it came to Jun Zhang and a team at the University of Queensland who looked at naturally occurring particles like pollen, bacteria, and viruses that use a spikey outer shell to latch on to animal hides. The team produced their own prickly nanoparticles, and loaded them with pesticides.

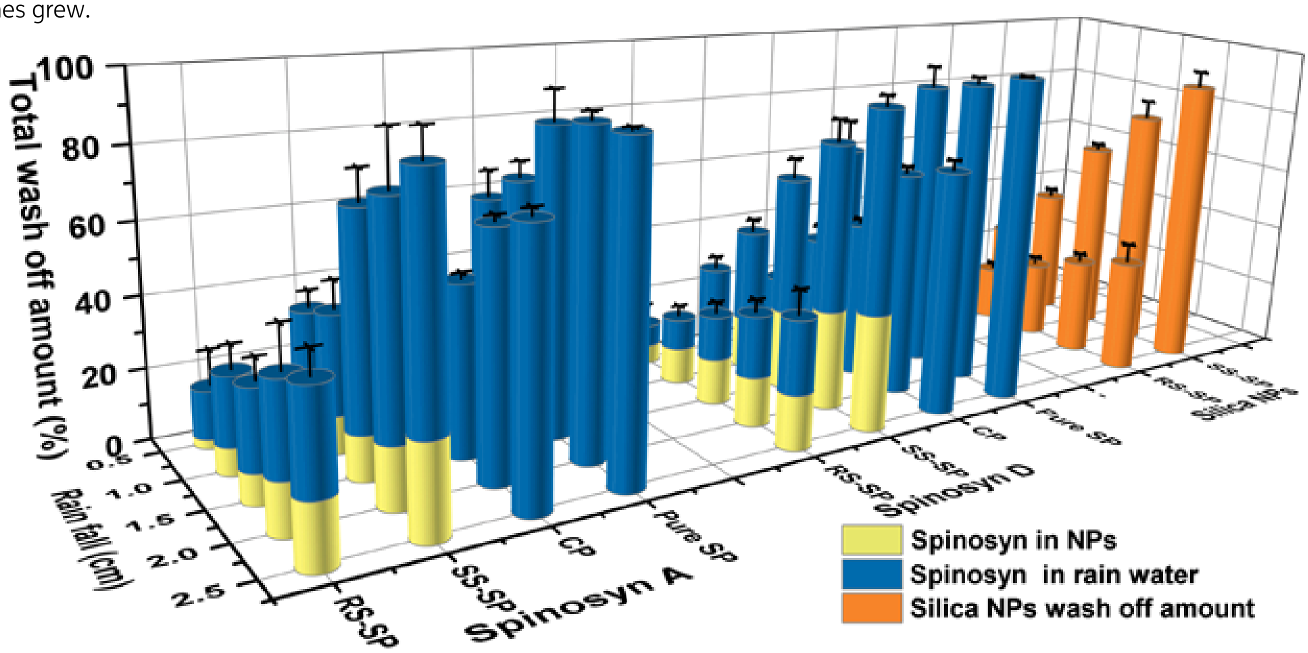
Nanoparticles can be fabricated in a number of ways, depending on the properties required and the materials used. They can be created by simply spraying tiny droplets of molten material into a cooling bath, much like miniature musket bullets; or by coating a seed particle with material, similar to how pearls form.

In this instance, a resin core is used as a base to grow a layer of silica on the surface. When the resin is removed, a hollow shell remains. The resin was also instrumental in allowing the spikes to form on the outer edge of the shell, providing support as the delicate spines grew.

Once these nanoparticles are produced, they are mixed in with the spinosad solution in a vacuum which allows solvent to be evaporated away at temperatures that won't damage either the pesticide or the particles. By reducing the mixture in this way, the nanoparticles adsorb the pesticide leaving them loaded and ready for application.

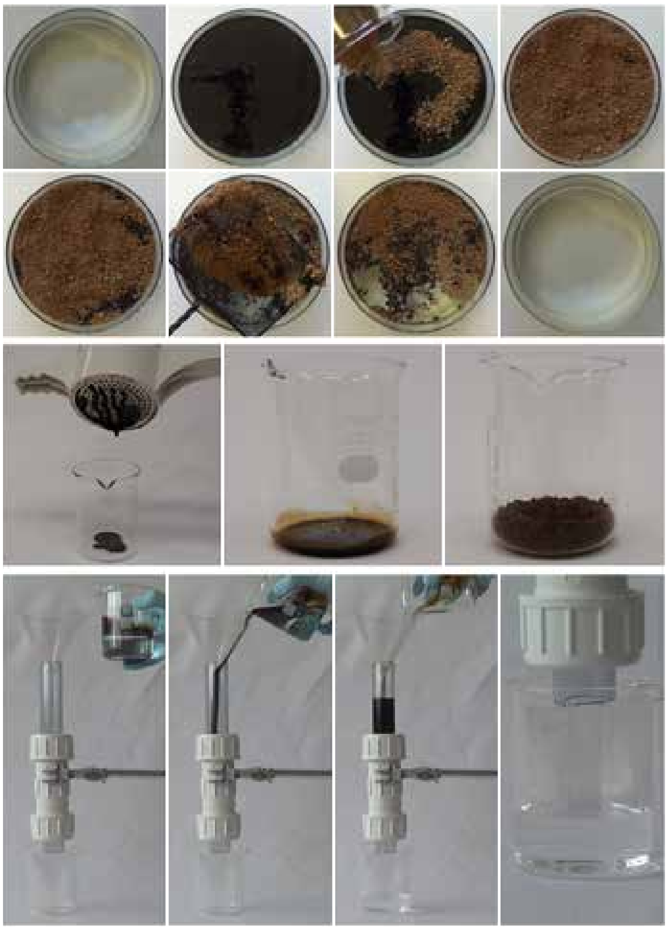
The team then had to see how their new nanospinosad particles performed. To understand the adhesive qualities, they worked with ANFF experts at UQ to perform fluorescent confocal microscopy. Their nanospinosad was labelled with a green fluorescent probe, which was then used to keep track of the distribution of the particles latched on to ticks. "In the field" testing was then simulated by coating a cattle hide with nanospinosad and exposing it to conditions such as wind, sun and rain in the lab and in open air.

The research demonstrated that their work had paid off, with the particles both protecting the biopesticide from sunlight and improving its ability to latch on to cattle hides and pests. In fact, due to its improved adhesive capabilities, the team's nanospinosad outperformed benchmark commercial spinosads by killing more ticks, and also showed a 10-fold increase in photostability compared to the off-the-shelf products in simulated field conditions. The result is an effective, ecofriendly pesticide that doesn't need to be reapplied on a weekly basis, saving time, energy, money and the environment in a single shot.



A WONDER MATERIAL MADE FROM WASTE

In February 2020, Clean Earth Technologies (CET) signed an agreement with Flinders University to produce commercial quantities of an environmental wonder material.



Developed by Associate Professor Justin Chalker and his team at Flinders University, this novel polymer is made exclusively from waste materials and is capable of pulling oil from the oceans or mercury from the water supply, while also enabling near complete recapture of the pollutants.

CET, a Singaporean company, has now established a manufacturing facility in South Australia that is capable of producing 1 tonne of the key material per day, and the first shipments have already been delivered to clients.

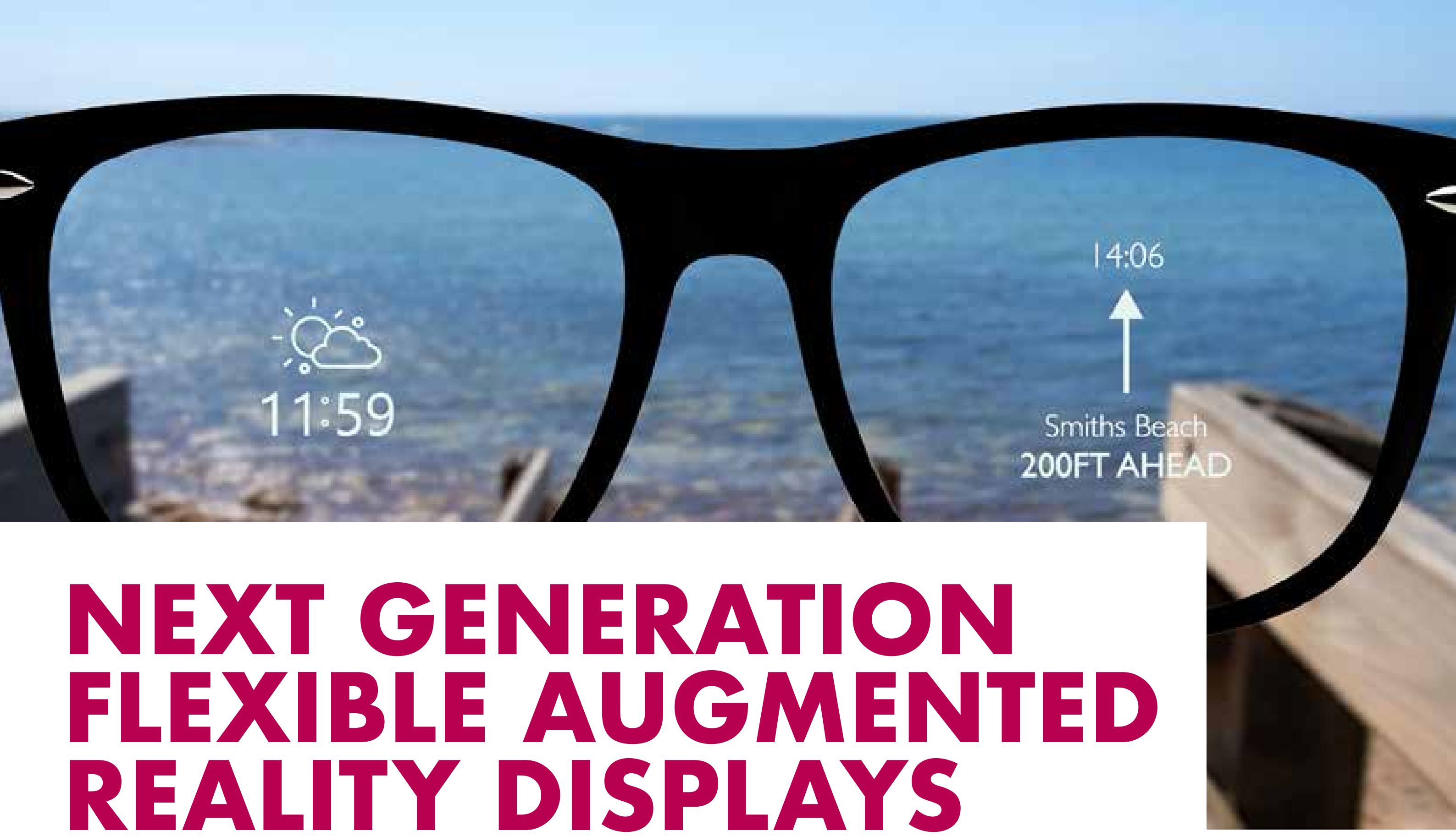
The polymer is made from sulphur and cooking oil, by-products of the petroleum and food industry that are abundant, affordable, and would otherwise go unused. "There's something particularly fitting about making an oil or mercury-binding polymer in a single, solvent-free step, in which every atom in the polymer is derived from industrial waste," Dr Chalker said.

The team has already demonstrated that the buoyant material can be used to extract spilled crude oil from the oceans, or mercury from air, water, and soil. Once saturated it can then be rung out to enable efficient recapture of the contaminants, before being used again and again. With multiple environmental applications, the novel polymer can be used in either a powdered form or packed into a filter, depending on the remediation required.

ANFF-SA's Tip Enhancing Raman Spectroscopy (TERS) system, which provides non-destructive mapping and imaging, was critical to understanding how the material behaves when absorbing pollutants, and therefore in assessing the various environmental applications of the polymer. "ANFF-SA's TERS system confirmed the presence of a key structure [repeated S-S bonds] which makes up the backbone of the polymer, and was able to confirm that a thin film of oil remains bound to the polymer after the oil is recovered" said Dr Chalker. "This answered our fundamental question about how the oil interacts with the polymer."

As progress continues, additional modifications to the SA manufacturing plant are ongoing to increase the capacity and automation, and the Chalker Lab continues to collaborate with CET as the facility is developed. The team are also working closely with ANFF-SA's experts to develop new commercial products that use the polymer.

A WONDER MATERIAL AT WORK. PROFESSOR CHALKER'S NOVEL POLYMER DEMONSTRATING ITS OIL ABSORBING ABILITIES IN POWDER OR FILTER FORM.
Credit: Justin Chalker



NEXT GENERATION FLEXIBLE AUGMENTED REALITY DISPLAYS

Augmented Reality (AR) is being brought out of science fiction and into real-world applications, generating a market that has the potential to grow to US$100 billion by 2024.

Jarvish, a Taiwanese AR smart-wearable manufacturer, has partnered with the University of Melbourne and Melbourne Centre for Nanofabrication (MCN) to prototype a small, lightweight AR system that can be integrated into regular-sized spectacles, military goggles, or motorcycle helmets.

AR is an emerging technology that enables the seamless overlay of reality with computer-generated virtual images in such a way that the virtual content is aligned with actual objects. The main part of any AR device is a display through which a viewer can see both the digital and real worlds simultaneously.

The technology is already enabling crossover between the real and the virtual in the medical sector where it's allowing for image-guided surgeries to be performed, and also by providing in-depth training scenarios for new students through surgical simulations. It's also seeing growing usage in applications found in industrial design, consumer electronics, education, and the entertainment industry.

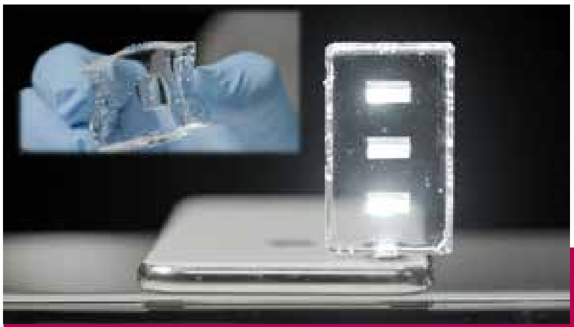
While the premise is promising, current systems utilise a glass-based technique to deliver images to the eye. The approach demands bulky optical cables and a micro-display to be integrated into the viewing glass on either side of the line of sight for both eyes – this makes the system large and blocks peripheral vision. The result is an uncomfortable device that can also cause eyestrain, traits that have unsurprisingly hindered widespread adoption of AR in most applications.

To allow use of this futuristic technology to spread, Jarvish collaborated with The University of Melbourne and the MCN to develop a flexible AR display prototype that is capable of being incorporated into more ergonomic systems. Specifically, they've worked with experts at the Melbourne Centre for Nanofabrication to embed micro and nanostructures on a flexible PDMS base and incorporate it into a system that resembles ordinary spectacles.

Within Jarvish's device, a flexible multilayer guide carries light towards an array of air-filled micro and nano structures that form a pixel array. A computer-generated image is produced by a micro-display located in the frame of the device and is carried by the flexible waveguide into the pixel array. Here, the image is reflected out of the system and towards the eye, resulting in the desired effect of a virtual world overlapping the real one.

MCN's photolithography, metal evaporators, high resolution 3D printing capabilities and the Centre's PDMS lab were all used widely during development, while a number of ANFF experts were closely involved in the fabrications of the working prototypes.

The company has filed a patent on this technology "Light Guiding Apparatus and Guiding Method Thereof" with the Australian Patent Office on 7 September 2020, and has been accorded Australian provisional application No. 2020903198. The prototyping is ongoing, with further development of the device being undertaken with a view towards mass production.



JARVISH IS DEVELOPING ERGONOMIC AR TECHNOLOGIES USING NANOFABRICATION.
Credit: Jarvish

FLAGSHIP FOCUS

TRICEP flexes bioprinting muscle

The ANFF Materials Node, based at the University of Wollongong (UoW) and the University of Newcastle (UoN), specialises in application areas including 3D printing, bioprinting, and 2D printing of organic electronic devices such as sensors and solar cells.

In 2018 the Node's UoW team became an establishing partner of the Translational Research Initiative for Cellular Engineering and Printing (TRICEP). This Wollongong-based collaborative centre combines the research prowess of ARC Centre of Excellence for Electromaterials Science (ACES) and UoW with ANFF Materials' world-leading fabrication expertise and equipment.

The result is an innovative hub that combats significant clinical challenges by providing startups, institutions and industry with the opportunity to collaborate with leading researchers as they develop the 3D bioprinting technologies that are revolutionising the world of medtech.

Bioprinting takes the principles of 3D printing but uses biological and biofriendly materials instead of plastics or metals – it promises to provide truer-to-life tissue models for testing purposes, or even print entirely new body parts for transplant. The practice often involves creating a scaffold to support living cells and to allow them to proliferate as they would do so in the body.

In its first few short years, ANFF-enabled projects at TRICEP have included the development of:

+ **3D REDI**, a bioprinting platform aimed at educating the next generation of biofabricators and serving as a biomaterials research tool;
+ **3D PICT**, a customised 3D printer to distribute three different cell types throughout a multi-material structure developed in collaborative venture with Prof Toby Coates and his team at the Royal Alfred Hospital; and
+ **3D ALEK**, a customised multi-materials biofabrication 3D printer that utilises a specialised bioink developed and built by ACES researchers at the University of Wollongong (UOW) and the Australian National Fabrication Facility (ANFF) to assist in the regeneration of cartilage for use in reconstructive ear surgery.

If you would like to find out more about bioprinting, TRICEP, or ANFF Materials, please contact the Materials Node through:

Peter Innis
innis@uow.edu.au

Due to a need for constant access to ANFF's open access capabilities, experts and equipment from ANFF Materials have been embedded in TRICEP, and are now underpinning the development of some of the most promising bioprinting technologies that the world has to offer.

The ANFF/TRICEP partnership creates new opportunities to fast track new innovations and products to market. It does this by leveraging local, national and international industries as well as start-up entities to provide access to personnel and world-class infrastructure. The initiative houses a range of additive manufacturing technologies, including the highest resolution metal printer in Australia and the country's leading biofabrication capability to develop biomaterials. The well-credentialed team are able to identify and customise materials and fabrication protocols to produce specialised 3D printing devices and bioinks to treat specific medical conditions.

QUANTUM TECH IS TAKING EFFECT

The quantum sector is nearing the tipping point of its transition from R&D into real-world applications. Sydney's "Quantum Harbour" is leading the way with its critical mass of world-class researchers and infrastructure, ready for the next leap in quantum technology.

Quantum technologies are starting to mature at an incredible rate and are already beginning to generate economic outputs. These entirely new classes of devices are erupting, and they're all based on harnessing the bizarre behaviours that are exhibited in the sub-atomic world.

While the realisation of quantum computers is perhaps synonymous with quantum technologies, the application of quantum effects stretches far further. The field is already starting to transform electronics, communications, and sensing, and will create new markets, new applications and new jobs in Australia – most of which are yet to be imagined.

The CSIRO's Quantum Technology Roadmap, published in May 2020, predicted just how large this fledgling industry is going to be. The report states that the quantum technology industry could be worth over $4 billion in revenue for Australia by 2040 and create 16,000 new jobs.

With new companies setting up shop and a slew of research outcomes taking humankind ever closer to this technological revolution, Sydney in particular has become an essential contributor in the global pursuit of quantum tech.

The past decade has seen Sydney turn into a veritable playground for those that are working to deliver functional quantum computers. The city is host to a potent mixture of brilliant scientists and engineers that are supported by local authorities and institutions, all underpinned by a focused network of open access research infrastructure. The results have meant Sydney can entice some of the greatest minds in the field to its labs.

However, the rapidly growing demand for experts is starting to outweigh the supply. Yet again Sydney's universities are stepping up to the plate to create a workforce focused on this burgeoning economy and securing Australia's share in this billion-dollar industry to be.

Grow your own genius

In July 2020, UNSW announced it will become the first university in the world to offer a Bachelor of Quantum Engineering degree.

The course covers a range of quantum technologies including nanoelectronics, microwave engineering and quantum technologies for advanced sensors, secure communications and computing.

World-leading expert in quantum engineering and long-term ANFF-NSW client, UNSW Scientia Professor Andrea Morello, has been the driving force behind the new degree. He believes an undergraduate offering in quantum technology is essential to building a world-class quantum workforce in Australia.

"As it stands, there simply aren't enough qualified engineers to fill the jobs needing quantum skills in Australia – or anywhere in the world, in fact," Professor Morello said. "Developing and applying the cutting-edge technologies in these fields demands a deep understanding of their quantum nature. Moreover, this understanding can also be used to develop devices and capabilities that have no precedent, like quantum computers and quantum secure telecommunications. This is why we created the new degree."

Starting in Term 3 2020, the UNSW course will train students in advanced electronics and telecommunication engineering, specialising in how to design and control complex quantum systems.

The course complements a PhD-level offering already available through the Sydney Quantum Academy (SQA), a joint venture between Macquarie University, UTS, UNSW, and the University of Sydney, with funding from the NSW State Government.

SQA brings together leaders in the field to build Australia's quantum economy through the provision of education and training programs, collaborative research, industry development, investment attraction, and promotion of the benefits and implications of quantum technology.

The Academy unites budding quantum scientists and engineers with a mixture of ANFF-enabled world-leading researchers. These include the likes of the University of Sydney's Professor David Reilly, and UNSW's Professor Michelle Simmons, Professor Andrea Morello, and ANFF-NSW Director, Professor Andrew Dzurak.

Fabricating the future

Underpinning any leap in quantum technology is a need for world-class nanofabrication. Without the ability to build at the nanoscale, researchers and engineers would be unable to induce the quantum phenomena used to create these critical technologies that are vital to Australia's economic future.

Through use of ANFF-NSW's specialised fabrication facilities at UNSW and the University of Sydney, the last year alone has seen great bounds taken towards new quantum technologies, in particular in quantum computing.

Quantum computers pose significant improvements over conventional computers for particular applications due to their ability to process incredible amounts of information simultaneously. This is possible due to a fundamental change in hardware.

To store information in binary code, conventional computers utilise on/off switches called transistors to represent 1s and 0s. Quantum computers instead use qubits that contain quantum systems held in a delicate balance somewhere between the two – the result is that instead of being a 1 or a 0, qubits can be both at the same time.

The benefit becomes clear when many qubits are used together. For example, a quantum computer with just 300 qubits would be able to store more numerical values than there are atoms in the universe. Classical systems would need to become overwhelmingly large or be given incredible amounts of time to achieve things that quantum computers could process with relative ease.

But this delicate superposition of quantum states requires impressive fabrication capabilities to build and maintain their integrity, and the hurdles to engineering these solutions are still many.

Handling the heat

One such obstacle is creating a qubit that operates at practically obtainable temperatures – until this year the silicon-based qubit approach that Professor Andrew Dzurak and his colleagues at UNSW are working towards required temperatures at close to absolute zero to maintain coherence.

However, in March, ANFF-NSW-enabled research published in Nature by an international team led by Professor Dzurak, demonstrated a qubit architecture that could operate at higher temperatures than ever before – their proof of concept device therefore provides a way to reduce the cost of cooling by orders of magnitude.

The team's design allows the devices to operate at temperatures around 1.5K, an increase of 15 times that of previous architectures. "This is still very cold, but is a temperature that can be achieved using just a few thousand dollars' worth of refrigeration, rather than the millions of dollars needed to cool chips to 0.1 Kelvin," explained Professor Dzurak.

There are other hurdles to overcome in advancing this technology, but handling the heat is one of the largest and Professor Dzurak's work provides an enormous step in the right direction.

What's more, the device is produced using conventional fabrication techniques meaning it can be replicated in existing semiconductor 'chip' foundries. As with the majority of the work conducted by Professor Dzurak's team, these devices are built with ANFF-NSW's Silicon-MOS fabrication line, using similar processes to those currently used to produce conventional computing components. This means there are already production lines in place that can be adapted to produce the new quantum computing components at scale, using existing semiconductor foundries once these devices are perfected.

This ready-for-industry mindset is essential for rapid and more affordable uptake of quantum computing. Established businesses such as Microsoft – which is racing towards the realisation of quantum computers through their extensive work with ANFF-NSW at the University of Sydney – are heavily involved the pursuit of quantum computers, and it's becoming easier to see what the production pipeline will look like.

However, it's not just computing giants that are on the chase, and Sydney-based organisations are emerging in the field to take a slice of the action. One fine example is Silicon Quantum Computing Pty Ltd, which launched in May 2017 with over A$83 million of capital funding from the Australian Commonwealth Government, UNSW Sydney, the Commonwealth Bank of Australia, Telstra Corporation and the State Government of New South Wales. The company was established to commercialise silicon qubit research from the Australian Centre of Excellence for Quantum Computation and Communications Technology (CQC2T).

Archer takes aim

Another of these newer players is Archer Materials, an ASX-listed company focused on pursuing novel uses of advanced materials to develop new streams of revenue.

Archer has been working with ANFF's micro and nanofabrication experts at the University of Sydney for over a year as they pursue a carbon-based approach to building a qubit.

In June, Archer demonstrated conductivity in its prototype qubit component for the first time, a significant milestone in the company's pursuit of developing quantum computing technologies.

This development involved preparing and analysing the conductivity of the prototype with nanometre precision. Dr Martin Fuechsle, Archer's Manager of Quantum Technology, worked with specialist technical staff based at the University of Sydney's Research and Prototype Foundry (RPF) to prepare the sample and then perform the conductance analysis.

On the back of this achievement, Dr Fuechsle explained that the company can now continue along its technical development roadmap towards a working qubit prototype. He said: "As part of this developmental process, we will continue to use the RPF facilities at USyd, as well as lab facilities at collaborating institutes, such as UNSW in Sydney and EPFL in Switzerland. Our next experimental efforts will focus on controlling the electron spin state on individual qubit components using single carbon nanospheres."

Only time will tell

As to how and when quantum computing will become a part of everyday life, only time will tell, there's still a plethora of obstacles to overcome before the full scope of the picture comes into focus. However, with the breadth of activity occurring in ANFF-enabled labs, with an increase in expertise provided by UNSW and SQA programs, and with the continued support of the city's universities and Government, one near certainty is that Sydney will be at the heart of it all.

Credit: RPF ANFF-NSW

ACCESSING ANFF

PRINCIPLES

- The Australian National Fabrication Facility (ANFF) provides access to nano and microfabrication facilities to all Australian researchers;
- ANFF seeks to encourage collaboration in research;
- The ANFF Access and Pricing Policy is intended to ensure that there are as few barriers as possible to accessing major infrastructure for those undertaking meritorious research;
- The Policy has been developed to ensure open and transparent access to the facility for all Australian researchers;
- The procedure for all users accessing a Node will be as equitable as possible.

ACCESS STEPS

ANFF's goal is to have a new user being able to use a tool within 2 weeks of contacting the network.

CONTACT ANFF → **DISCUSS PROJECT WITH ANFF AND ESTABLISH PATHWAY** → **ACCESS PROTOCOLS** → **EXPERT-SUPPORTED TOOL USAGE OR FEE FOR SERVICE** → **ACHIEVE PROJECT OBJECTIVES** →

PRICING STRUCTURE

The ANFF recognises three classes of user:

1. **PhD students;**
2. **Publicly funded researchers, including University researchers; and**
3. **Industry users.**

Pricing for public sector researchers is based on marginal costs only. A full listing of costs for each Node, including consumables, is given in the Access and Pricing Policy (**www.anff.org.au/access/access-pathways**).

ACKNOWLEDGEMENTS

Users are asked to acknowledge the program in papers as follows: “This work used the [NODE] node of the NCRIS-enabled Australian National Fabrication Facility (ANFF)”.

The ANFF logo (available from the website) should be included on the acknowledgements slide of a presentation.

FEEDBACK

All feedback should be reported to the relevant Facility Manager and Node Director for discussion at the Node’s Access Committee meeting. Further comment can be passed directly to ANFF HQ by contacting **info@anff.org.au**.

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Contact info@anff.org.au for general enquiries, or get in touch with any of our staff to start discussing your project.

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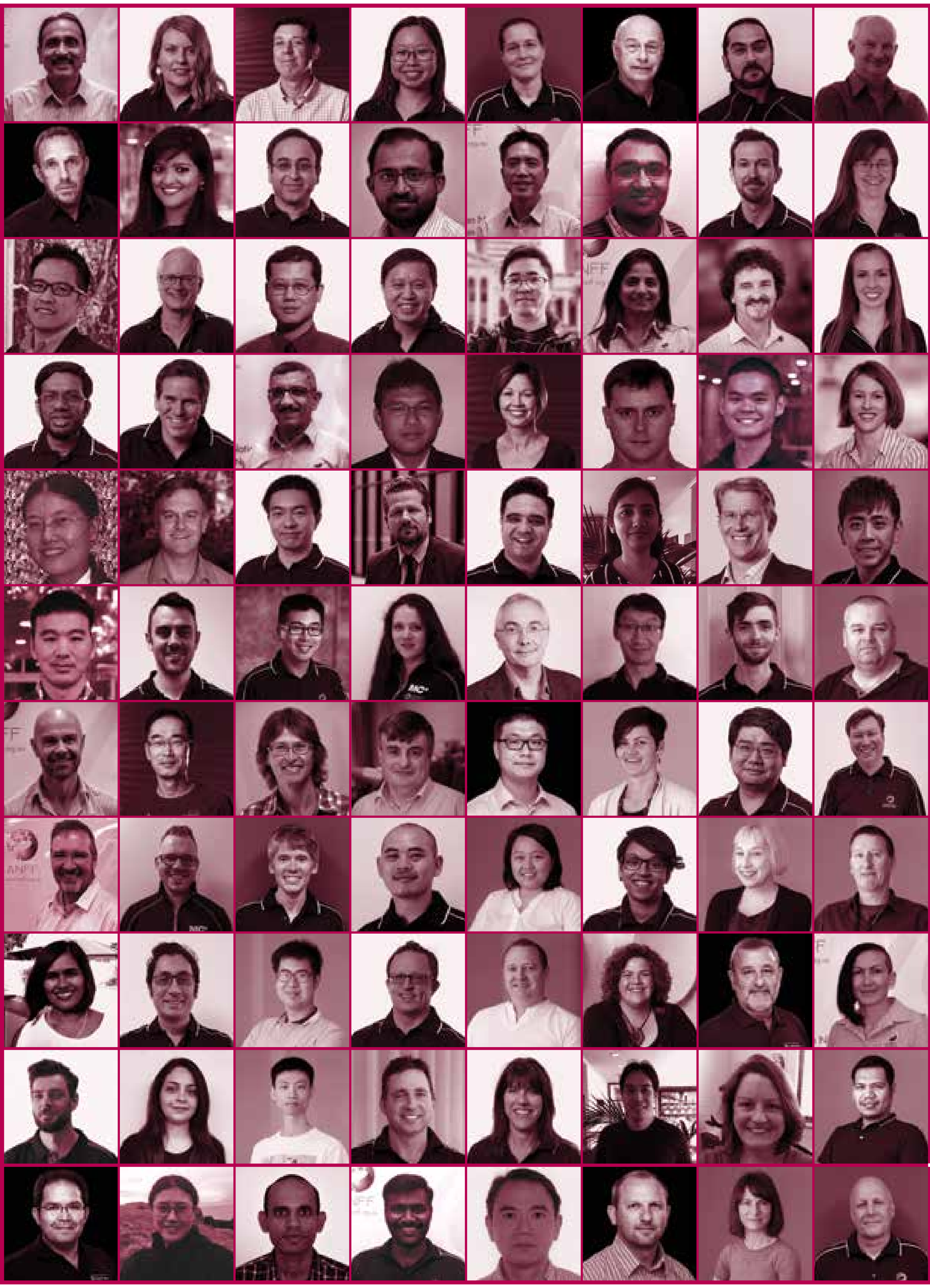

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