ANFF

Australian National Fabrication Facility

BUILDING COMPETITIVE ADVANTAGE

A CASEBOOK

CONTENTS

WELCOME

Rosie Hicks,
Chief Executive Officer
Australian National Fabrication Facility

3D-printed scaffolds for the regrowth of severed nerves, the manufacture of environmentally friendly materials to clean up oil spills, and the development of an artificial photosynthesis device that converts carbon dioxide into fuel are all projects carried out using ANFF facilities. These examples demonstrate the role that nanoscience and nanotechnology have to play in addressing the societal challenges facing Australia.

ANFF was established to support the research and development of new nano-fabrication technologies. By linking laboratories that provided a toolkit for the nanoscience research community, ANFF has formed an integrated network of technical staff and researchers that supported the research of 2000 researchers during 2012/13. The availability of ANFF facilities has a profound effect on research programs in nanotechnology supported by the Australian Research Council.

Australian R&D achievements made possible through ANFF are extensive. These are generating a high volume of meritorious research outputs including highly skilled graduates trained in nanofabrication techniques.

The facilities are essential for participation in a global nanotechnology market. Industry uptake of nanotechnology and the ability to innovate must be underpinned by world-class research.

ANFF delivers a national competitive advantage to researchers: the ability to access a resource of more than 500 facilities and matching academic and technical expertise in solving research problems. With many of the research projects that were initiated during ANFF's infant years beginning to mature, devices and prototypes that address real-world problems are being developed using the latest science.

ANFF provides an interface to the university system that efficiently supports the translation of these devices and prototypes into societal benefits by engaging with industry. During the last year, ANFF use doubled among researchers working on industrial R&D projects and start-up companies.

We present this collection of case studies to illustrate opportunities that are emerging from the university sector in the field of nanotechnology. These opportunities provide the beginning of a new industry that will drive productivity and economic growth while addressing many of the societal challenges facing the nation in the decades to come.

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A polymer embedded with a fluorescent dye. These materials are being used to make fluorescent optical fibres in developing a new generation of solar cell. Credit: OptoFab Node, University of Sydney.

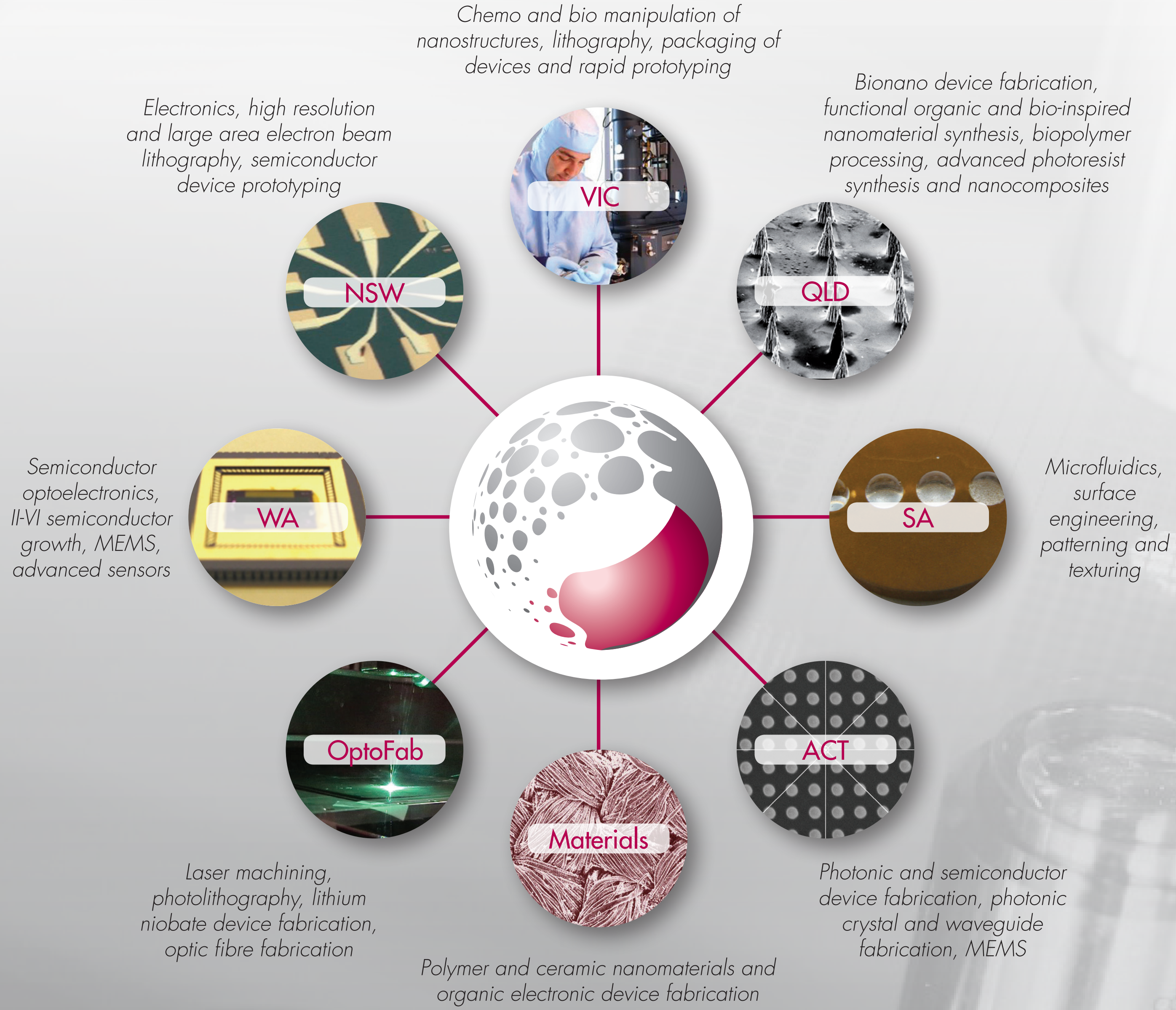
SNAPSHOT OF THE ANFF 2012 – 2013

ANFF

The Australian National Fabrication Facility (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.

Over 500 facilities are located across 21 institutions around Australia in a national network of eight Nodes. These Nodes are operated by facility managers and their respective teams of dedicated technical staff who provide a critical mass of technical and academic expertise specific to core themes in nanotechnology.



Supporting Australian Researchers

Academic or industrial researchers can engage with ANFF for access to facilities, training on fabrication techniques, access to Australia's top researchers for collaboration, or to engage in industrial R&D projects.

In 2012–13 ANFF supported researchers by:

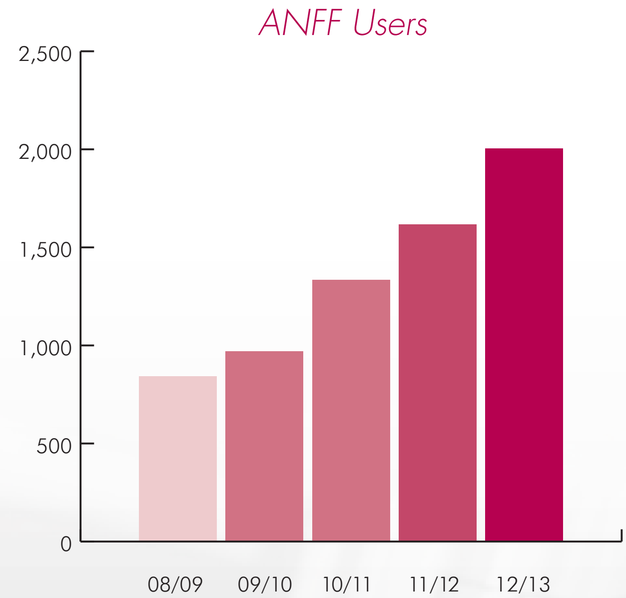
Providing access to fabrication facilities:
101,841 tool hours were used in fulfilling the needs of over 2000 researchers; a number that has grown consistently since ANFF's establishment.

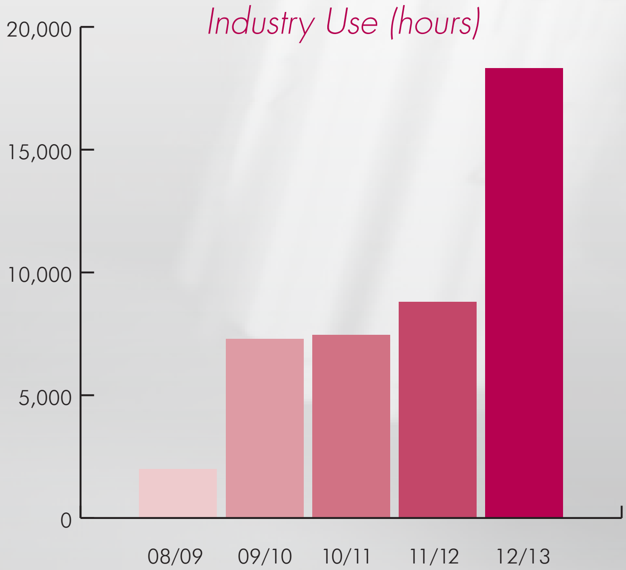
Providing training on fabrication techniques:
958 one-on-one training sessions were provided to ANFF users, and an additional 1538 were trained in 150 courses and seminars.

Inspiring collaborations:
496 academic papers or other research outputs were generated from collaborative projects.

Supporting industrial R&D projects:
ANFF use for industrial projects grew 108%, and now represents 18% of ANFF's total facility time.

> *On behalf of the ANFF network, we present just a few case studies demonstrating Australia's strength in nanotechnology research: a national competitive advantage that may lead to a new Australian industry to drive economic growth in the decades to come.*





ANFF's facility managers: the heart of the ANFF National Network. Credit: NSW Node, University of NSW.

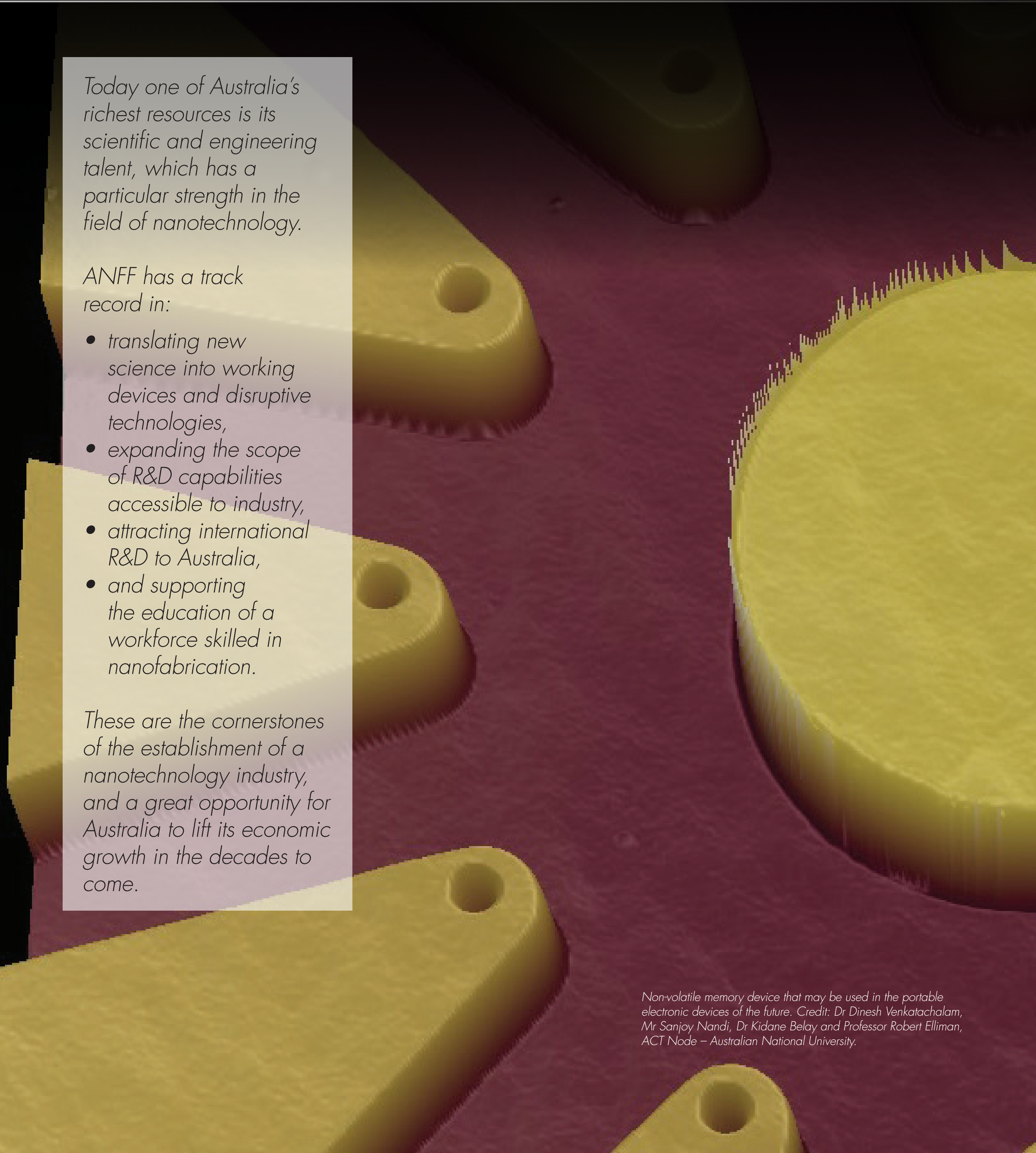
BUILDING AUSTRALIA'S COMPETITIVE ADVANTAGE

Today one of Australia's richest resources is its scientific and engineering talent, which has a particular strength in the field of nanotechnology.

ANFF has a track record in:

- *translating new science into working devices and disruptive technologies,*
- *expanding the scope of R&D capabilities accessible to industry,*
- *attracting international R&D to Australia,*
- *and supporting the education of a workforce skilled in nanofabrication.*

These are the cornerstones of the establishment of a nanotechnology industry, and a great opportunity for Australia to lift its economic growth in the decades to come.



Non-volatile memory device that may be used in the portable electronic devices of the future. Credit: Dr Dinesh Venkatachalam, Mr Sanjoy Nandi, Dr Kidane Belay and Professor Robert Elliman, ACT Node – Australian National University.

SMALL MUSCLES TO HAVE BIG IMPACT ON SMART CLOTHING

Dr Javad Foroughi and Professor Geoff Spinks, Materials Node — University of Wollongong

A new artificial muscle could make intelligent textiles that automatically react to environmental conditions like heat or sweat.

The hybrid yarn muscles are based on carbon nanotubes — hollow cylinders just one carbon atom thick. On their own, carbon nanotubes are about 10,000 times smaller than the diameter of a human hair but they can be 100 times stronger than steel.

Researchers at the University of Wollongong, part of the Materials Node of ANFF, combined the nanotubes with a wax material similar to household candles; the result being a single thread of yarn around 10 times smaller than the diameter of a human hair, which can lift over 100,000 times its own weight and generate 85 times higher mechanical output that natural skeletal muscles.

Professor Geoff Spinks and Dr Javad Foroughi carried out the research through the ARC Centre of Excellence for Electromaterials Science (ACES) as part of a team spread across four continents.

Professor Spinks said: "When heated, either electrically or with a flash of light, the wax in the yarn muscles expands, causing a contraction of the nanotube yarn."

Unlike other artificial muscles, the hybrid yarn muscles are fully dry so actuation can be triggered from changes in environmental temperature or the presence of chemical agents, making them perfect for use as self-powered intelligent materials.

Using facilities housed at the Materials Node, the team can move to the next exciting step of weaving, sewing, braiding and knitting the hybrid yarn muscles.

"The yarns could be used to create intelligent fabrics that can open and close the porosity of the fabric to allow heat in or keep it out, or release moisture," said ACES researcher and fabrication expert Dr Foroughi.

Dr Javad Foroughi (left) and Professor Geoff Spinks (right).

"Other applications for the yarns could include robots, catheters, micro-motors, tuneable optical systems and even toys."

ANFF would like to congratulate the team for their publication in the prestigious journal *Science* and on Dr Foroughi receiving his 3-year fellowship from the Australian Research Council to develop intelligent fabrics.

PROVIDING A COMPETITIVE ADVANTAGE FOR AUSTRALIAN START-UP COMPANIES

Zedelef, VIMOC Technologies, AquaHydrex

In recent years ANFF has demonstrated how it can support projects to make a smooth transition between academic research and university spin-out companies. Zedelef, Vimoc Technologies, and AquaHydrex are three examples of companies who would not be able to conduct their R&D operations locally without the support of ANFF.

Zedelef

Zedelef is a University of New South Wales (UNSW) spin-out company with a promising optical sensor technology.

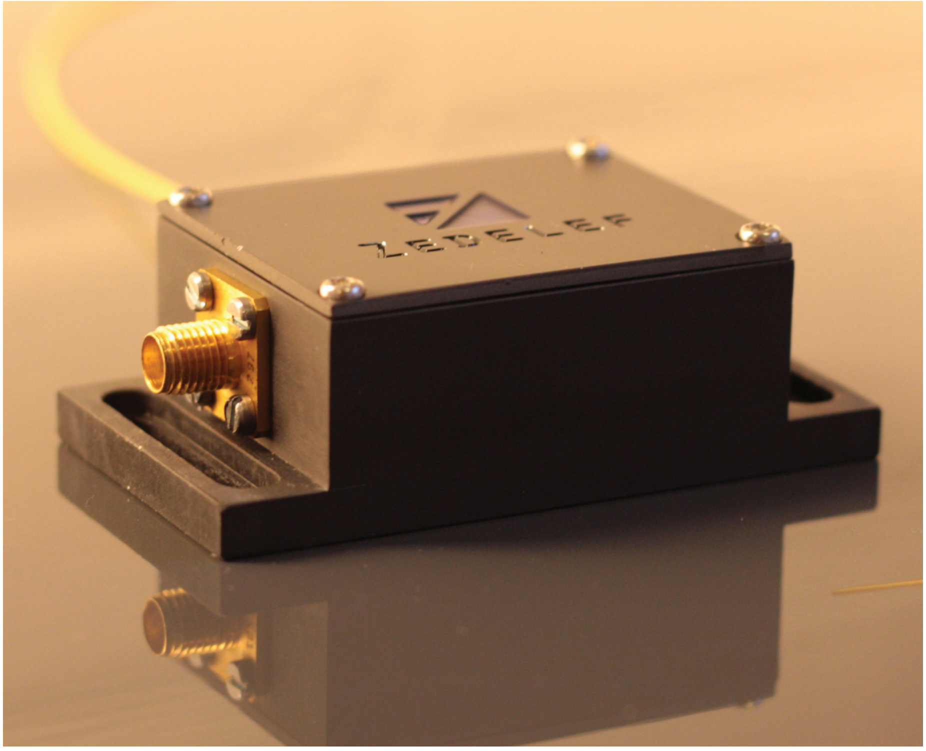
Professor Francois Ladouceur and his UNSW colleagues Dr Zourab Brodzeli and Dr Leonardo Silvestri are the founders of the start-up, which is commercialising a new optical fibre based sensor that could have applications for the oil, gas, and electricity industries.

Their device, a sensor that is fabricated onto the tip of an optical fibre, converts electrical signals from devices such as microphones and pressure sensors so they can be read optically.

Zedelef have raised their first round of funds successfully securing both private investment as well as a Commercialisation Australia grant. In July this year, they were awarded an ARC linkage grant of $320,000 to work on an underwater surveillance and ocean-monitoring network with the defence company Thales Australia.

This fundraising effort follows the team declining a $10 million offer from Chinese investors to move offshore, opting instead to pursue their start-up dream in Australia.

Professor Ladouceur said; "Working with ANFF we will be able to establish our R&D operations locally without asking investors to fund significant capital infrastructure. This strengthens our value proposition to local investors and has given us the flexibility to turn away from the Chinese offer."



Zedelef's optic fibre sensor. Credit: Camelia Tiplea.

VIMOC Technologies

In September 2013, VIMOC Technologies launched a project with ANFF to develop a 3D-integrated computing server-on-a-chip. It aims to solve the problem of next generation's Big Data being too big.

VIMOC will initially be working with ANFF in developing various aspects of the chip design, which is distinct from regular chips in that the transistors and communication systems are stacked in three dimensions, rather than two. This first stage is underway with the support of NSW Government Techvouchers grant.

"This is an exciting project from a semiconductor perspective because it addresses the problem of having too many components crammed into a two-dimensional chip layout," said Professor Andrew Dzurak, Director of the NSW Node of ANFF.

The VIMOC project has already drawn the attention of the international technology community to Australia. It has won major sponsorship from billion-dollar global software firm Cadence Design Systems, and has attracted interest from tech giants Oracle, Amazon, Broadcom, Huawei and CountryTell.

Tarik Hammadou, VIMOC Technologies Co-founder and CEO, commented, "It is thanks to ANFF that we are able to develop this technology in Australia and not in Silicon Valley in the USA."

AquaHydrex

In December 2012, a group including researchers at the ANFF Materials Node secured a Commercialisation Australia grant and a venture capital investment from True North Venture Partners to form a spin-out company named 'AquaHydrex.'

AquaHydrex is the culmination of years of research that has taken place within the ARC Centre of Excellence for Electromaterials Science (ACES), as well other Australian Research Council (ARC) supported projects at Monash University.

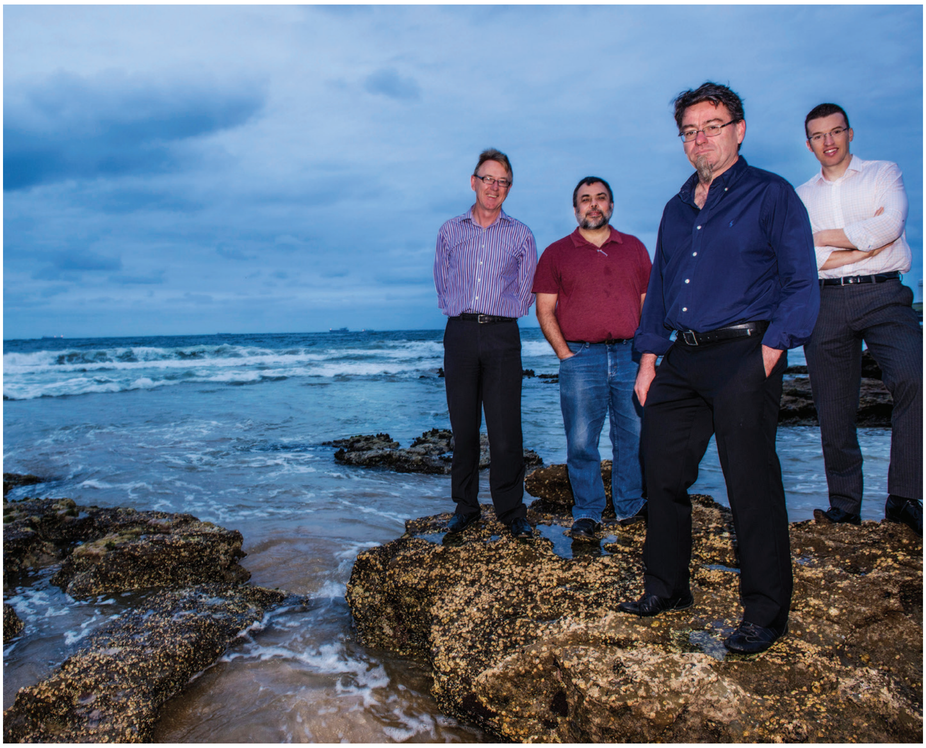
The technologies being commercialised involve novel catalytic processes that enhance the efficient electrolysis of water to produce hydrogen. A second set of technologies are inspired by photosynthesis to assist the production of oxygen gas from water under sunlight. The company plans to remain embedded in the ACES and Materials Node.

Materials Node Director Professor Gordon Wallace said: "This new investment holds the future promise of a major technological and social impact, with accompanying benefits to Australia.

Together with ANFF we aim to build the skills and infrastructure required to translate our research into commercially viable opportunities."

True North Venture Partners leads a $300 million venture capital fund that seeks to identify disruptive innovations and work with management teams to build companies for the long-term in the areas of energy, water, waste, and agriculture.

According to Steve Kloos, Partner at True North Venture Partners, "AquaHydrex is an example of the interesting and globally relevant innovation in Australia and we look forward to partnering with the AquaHydrex team."



AquaHydrex participants (from left to right): Professor Douglas MacFarlane (Monash University), Professor Gerhard Swiegers (IPRI Senior Researcher), Professor Gordon Wallace (IPRI Director), Dr Paul Barret (UniQuest, Commercialisation Manager for Physical Sciences). Credit: University of Wollongong.

VIMOC Technologies are designing a 3D integrated chip. Credit VIMOC Technologies

WITH WORLD-CLASS RESEARCH COMES WORLD-CLASS GRADUATES

Dr Jarryd Pla, NSW Node — University of NSW

ANFF provides more than just fabrication facilities; it also provides specialist training and support for Australia's research students as part of its mandate to support world-class research.

Dr Jarryd Pla is one research student who embraced all that ANFF has to offer during his PhD studies.

Jarryd started his PhD in 2009 at the University of NSW in the Centre for Quantum Computation and Communication Technology (CQC2T). Like many such research centres, the NSW Node was established along-side CQC2T to build on their existing expertise through the provision of new facilities and technical staff with complementary knowledge.

Jarryd describes his project: "The goal was to develop a quantum bit (or qubit), which is the basic unit of a quantum computer, using the same techniques employed by silicon computer chip manufacturers today.

By chance this was one of the Centre's key projects to work on. It was a very ambitious project, and not knowing how ambitious it actually was, I jumped at the opportunity. There were many late nights in the lab and sacrificed weekends."

Under the guidance of ANFF–NSW Node Director Professor Andrew Dzurak and CQC2T Project Manager A/Professor Andrea Morello, Jarryd made the first giant leap towards a working silicon quantum computer. They fabricated a device that demonstrated the ability to detect the direction electrons spun around a phosphorous atom — they could read 0 or 1. This work earned Jarryd and the team a publication in the prestigious academic journal *Nature*, recognition seen by most scientists as the pinnacle of any research career.

Little did Jarryd know that this was just the beginning.

In October 2012, Jarryd was again published in *Nature*, this time as lead author, after successfully manipulating (or writing) the spin of the phosphorous atom

Dr Jarryd Pla (centre) with Professor Andrew Dzurak (left) and A/Professor Andrea Morello (right), at a UNSW press conference in October 2012 annoucing their findings published in Nature.

and thereby demonstrating the first single atom quantum bit in silicon.

Jarryd had concreted his reputation in the international science research community, having achieved a goal so highly prized by researchers around the world that many believe it will be as significant as the discovery of the semiconductor transistor in 1947. This news made national and international headlines that extended as far as the New York Times.

In April 2013, with only weeks left before Jarryd was to hand his PhD thesis in to the UNSW Graduate Research School, Jarryd's work was published a third time in *Nature*. This time it was for the demonstration of a quantum bit using the nuclear spin of the phosphorous atom, providing a significantly more accurate read-out of the device.

Professor Dzurak commented on the significance of this finding: "We achieved a read-out fidelity of 99.8 per cent, which sets a new benchmark for qubit accuracy in solid-state devices.

The accuracy of the UNSW team's nuclear spin qubit rivals what many consider to be today's best quantum bit — a single atom in an electromagnetic trap inside a vacuum chamber. The development of this 'Ion Trap' technology was awarded the 2012 Nobel Prize in physics."

Jarryd's work has turned the revolutionary concept of a quantum computer from science fiction into a real possibility. With the support of ANFF and CQC2T, Jarryd has begun his research career with a CV full of accomplishments that few academics will see in their lifetime.

In May 2013, Jarryd took up a Post Doctoral Fellowship at the University College London where he will continue work in quantum computation.

NASA CONNECTS DOWN UNDER FOR GROWTH OF CARBON NANOTUBES

Dr Lachlan Hyde, Victorian Node — Melbourne Centre for Nanofabrication

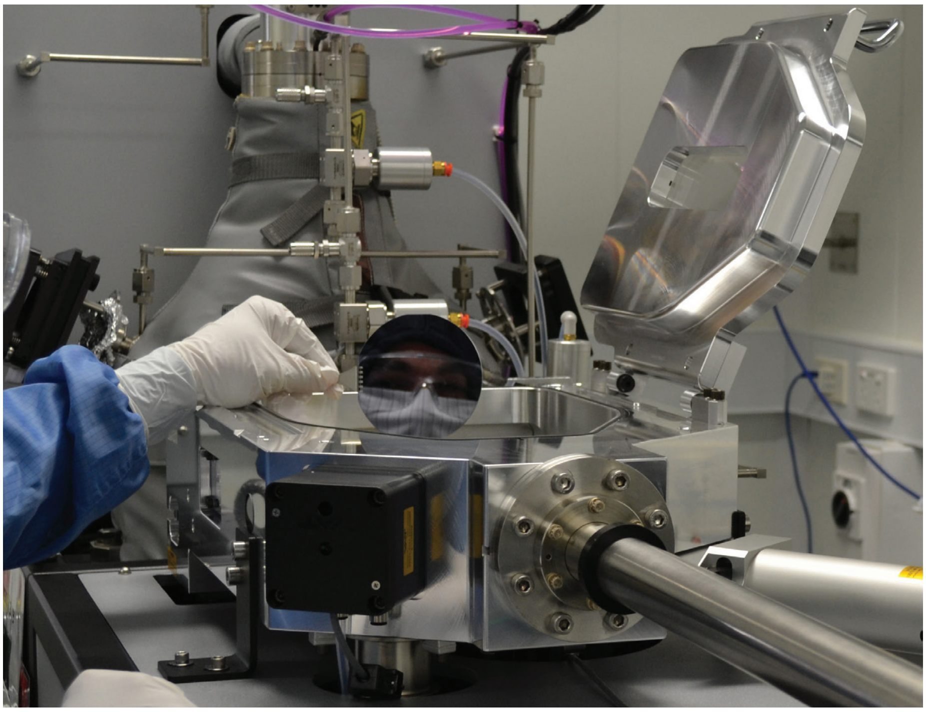
Coatings of nanotube forests developed by NASA are the blackest materials ever measured, which has great importance for many scientific uses. The NASA team has worked for several years to make their formulation black over a wide spectral range, and improve the robustness and the number of materials to which the nanotubes can be applied. With some assistance from the Melbourne Centre for Nanofabrication (MCN) — the Victorian Node of ANFF — NASA is further developing carbon nanotube technology for use on parts with complex shapes.

Principal Investigator John Hagopian and co-investigator Vivek Dwivedi of the NASA Goddard Space Flight Center are using Atomic Layer Deposition (ALD) to deposit layered thin-films suitable for carbon nanotube growth on intricate parts.

To gain the highest sensitivity and consistent measurements, carbon nanotubes must be evenly deposited across the surface of the detection component. This requires a highly uniform foundation layer, commonly a film of nanoparticles or iron oxide, to support growth of the carbon nanotubes. This is difficult to achieve using deposition techniques such as sputtering or evaporation because corners and crevasses are left uncoated and there is a large variation in the thickness of the coating. ALD is one technique that can coat all surfaces of an intricate object in a highly controlled and uniform layer.

The NASA researchers worked with MCN's operating expert in ALD, Lachlan Hyde, to perform a number of iterations for ALD growth of iron thin films. Characterisation by Hyde using the MCN's spectroscopic variable angle ellipsometer allowed the film thickness and uniformity to be optimised on test wafers.

The NASA team were provided with development samples, their intricate part containing an ALD grown film, as well as a detailed report on the process, including development recipes and analysis of ALD film growth. Hagopian and Dwivedi have since conducted trial production of carbon nanotubes on these wafers at NASA.



ALD Facility at the Melbourne Centre for Nanofabrication. Credit: Victorain Node - MCN

"We have successfully performed growth on two development samples with an ALD iron catalyst from MCN and the nanotubes have properties very similar to those grown using electron beam deposited catalysts," said Hagopian.

"Both their ALD process development and characterisation capabilities are world-class. We intend to continue our collaboration and look for additional opportunities to leverage their capabilities to increase our speed of technology development."

OPTIC FIBRE SENSORS: AN AIRCRAFT WING THAT KNOWS WHEN IT IS CORRODING

Mr Roman Kostecki and Professor Tanya Monro, OptoFab Node — University of Adelaide

Aircraft wings with built in corrosion detectors could save millions in maintenance and increase the safety of aircraft.

This is one of many technologies evolving from a new generation of sensors made from optical fibres that are being developed at the OptoFab Node of ANFF.

New applications for these optic fibre devices include: structural stress sensing, virus detection for diagnostics, bacterial detection for water quality monitoring, and sulphate detection to monitor wine fermentation.

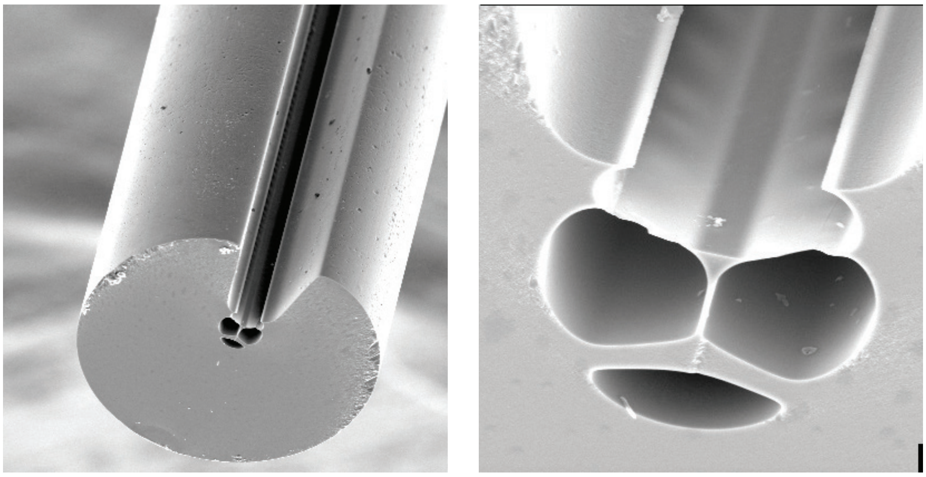
Professor Tanya Monro, from the Optofab Node of ANFF and Director of the Institute for Photonics and Advanced Sensing (IPAS), describes the technology:

"Most people are familiar with optic fibres with a circular cross section transmitting light without any loss for data communication.

Optic fibres used for sensing are often micro or nanostructured and coated with materials that respond when the light comes into contact with a range of chemical or biological markers, which can easily be detected."

The team at IPAS initially developed a variety of sensors using microstructured optical fibres made from soft glass. However, these fibres are not suited to the harsh environment in aircraft wings.

The team at IPAS has provided a critical step towards solving this problem. At the Australian Institute of Physics conference last December, PhD student Roman Kostecki presented microstructured optic fibres fabricated from silica glass, a material robust enough for corrosion sensing applications. These fibres were made using recently commissioned OptoFab capabilities: the ultrasonic milling and optical fibre draw tower facilities located on the University of Adelaide campus.



A microstructured optic fibre used for sensing. Light travels down the centre section. The slot at one side of the fibre allows the outside environment to interact with the light — this is the basis of the sensor. Credit: University of Adelaide.

"These findings and our new capabilities mean we can start to apply our sensors to real world problems," said Professor Monro.

"Aircraft, for example, could contain these fibres so lasers could be fired along them to detect aluminium ions as an indicator of corrosion.

At the moment you have to routinely pull the plane apart to visually inspect it for corrosion, so there's a lot of lost flight time and costs."

While still believed to be several years away, the team will continue developing the aircraft corrosion application of this work with their partners at the Defence Science and Technology Organisation.

Australia should look forward to seeing many other home grown sensing technologies evolve from ANFF and IPAS in the years to come.

AUTOMATICALLY TINTING WINDOWS: ELECTRO-OPTICAL DEVICES BASED ON CONDUCTING POLYMERS

Professor Gordon Wallace, A/Professor Peter Innis, Materials Node — University of Wollongong

Windows that can be tinted electronically — a platform technology that could change architecture and the automotive industry forever — have been developed at the ANFF.

The Materials Node developed the auto-tinting glass using scalable processes amenable to the fabrication of large panes. This will one day allow high-rise building windows, car windscreens, or rear vision mirrors to adjust their tint according to the time of day or level of privacy with the flick of a switch.

The technology is similar to the well known "Smart Glass" that becomes opaque when a voltage is applied, with the difference that it remains transparent when it is tinted.

Prototype windows were made at the Materials Node using in-house expertise in polymers, electrochromic materials and electrochemistry. ANFF facilities were used to deposit a clear electrically conductive electrode (indium tin oxide), an electrochromic layer (a conductive polymer), and a proprietary electrolytic layer responsible for the tinting.

"One of the most significant aspects of this work has been engineering the layers such that they can be made using scalable processes," said A/Professor Peter Innis, Materials Node Facility Manager at the University of Wollongong.

Electronically tinting windows might one day be used in high rise buildings.

"The conductive polymer and electrolytic layers we engineered can either be spray painted or printed directly onto a surface. This allows larger areas to be processed, overcoming a major problem that has restricted other's attempts at fabricating self-dimming windows to areas millimetres in size."

This work is the result of a successful ARC industry linkage project that ANFF has supported. It has produced yet another disruptive technology that is expected to change the market for architectural glass, and automotive mirrors and windows.

MAKING SUPERMAN REDUNDANT: OPTOFAB NOW MAKES DIAMONDS

Dr Peter Ha, Ms Jana Say, OptoFab Node — Macquarie University

If you thought Superman was strong, meet Dr Peter Ha of OptoFab. Peter now makes diamonds with his own hands, and a little help from the newly installed Chemical Vapour Deposition (CVD) facility at Macquarie University.

Diamond is the strongest and hardest material known to man and has the highest thermal conductivity. It is also a semiconductor, fluorescent and biocompatible. This unique combination of properties has led to diamond based technologies solving more problems than Superman ever could, without failing at the sight of kryptonite — did I mention it is chemically inert?

Peter and the team at OptoFab can produce diamond as particles or films. Unlike many other diamond production systems, the films produced from the CVD system can evenly coat all surfaces including complex object such as bearings.

"Some of the first diamonds we grew were in the form of powders," said Peter. "We have developed many processes to grow various types of continuous films, such as optical windows or hard, low friction coatings for mechanical parts."

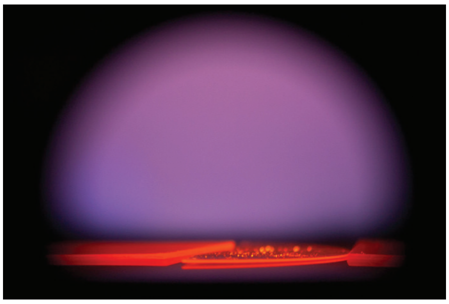
On the high-tech end of the application spectrum, Jana Say from Macquarie University used fluorescent diamonds for her medical research.

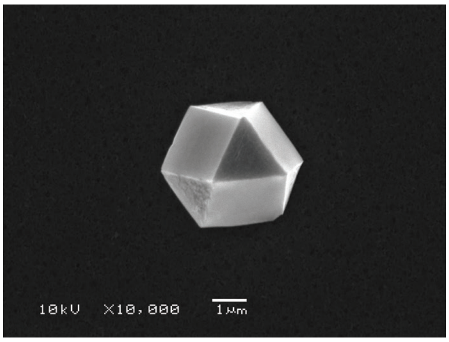
Jana describes her project: "Our nano-diamonds have what we call nitrogen-vacancy centres — the things that make the diamonds fluoresce. These diamonds can be used to probe how the body and cells work to help better understand a variety of diseases including cancer. The advantage of using diamonds over other nanoparticles is their durability and biocompatibility. Other materials tend to lose fluorescence quickly and can be toxic so they destroy the living cells we are trying to analyse."

While it is early days for the facility, Peter is preparing to support other applications for diamond, including:

- Grinding media — diamond powders made with the CVD can be used with OptoFab's high speed ball mill for very fine grinding of other materials.
- Biomedical implants — applying a diamond coating makes them biocompatible. For applications such as joint replacements they also take advantage of the low-friction and low-wear properties the coating provides.
- Biosensors — conductive diamond is an ideal material as both an electrode and a platform to support living cells.
- High power electronics — diamond semiconductor devices can tolerate high currents and can be used at elevated temperatures.
- High performance heat sinks — diamond can cool devices up to three times more efficiently than copper heat sinks.
- Optoelectronics — diamonds can be used as a light source or as wires (waveguides) for optical circuits.

Peter and the team at OptoFab look forward to helping researchers uncover the full potential of diamond based technology in solving some of the biggest problems industry and society is facing today.





Top: Wafer in the diamond CVD chamber. Bottom: An individual diamond crystallite. Credit: OptoFab Node — Macquarie University

A NEW MANUFACTURING TECHNOLOGY FOR POINT-OF-CARE DIAGNOSTIC DEVICES

Mr Ryan Pawell, University of NSW and Dr David Inglis, Macquarie University
ANFF NSW Node and AMMRF UNSW Node — University of New South Wales

Point-of-care diagnostics (POCDs) will help to revolutionise modern health care. With the use of POCDs, tests that would otherwise need to be analysed at a hospital or pathology lab can be performed locally at either medical clinics by your GP or even in the comfort of your own home. Being more accessible, cost effective, and much faster due to on-site testing, POCDs could improve or even save the lives of many thousands of people through the early detection of a wide range of medical conditions.

There are currently a large number of POC technologies evolving from laboratories around Australia. The resulting POCDs will be able to rapidly detect everything from cancer to infectious diseases including the flu.

In simple terms, POCDs are a laboratory-on-a-chip. This has been made possible through the combination of micro-fabrication technology (used for decades in the semiconductor industry) and nano-biotechnology, which has been used to scale down the diagnostic processing onto a chip, resulting in technology that is typically cheap enough to be disposable.

While much of the current work in this field is focused on new functionality, Ryan Pawell, a PhD student at UNSW, is focused on the manufacture of microfluidic devices.

Ryan Pawell describes his PhD project: "The aim of my PhD is to develop microfluidic medical devices for less than $1. Ideally, this would reduce the cost of healthcare in the developed world and disseminate state-of-the-art medical technologies into the developing world.

I have taken the basic design of a microfluidic device that separates red and white blood cells for diagnostic purposes and manufactured it via hot embossing in a hard, stable and cytocompatible plastic. Devices made using this process offer numerous advantages including: lower cost, higher speed of manufacture, longer shelf life and higher burst pressure.

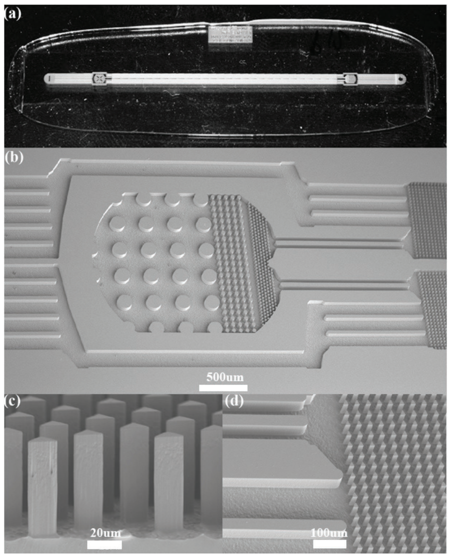
During Ryan's project, he has used facilities at both the ANFF and the Australian Microscopy & Microanalysis Research Facility (AMMRF) located at the University of NSW.

"My core laboratory work involves replicating these designs in plastics and investigating how the robust plastics allow for improved fluid flow rates. The facilities at ANFF allowed us to overcome mold fabrication challenges with their deep-reactive ion etching (DRIE) service. We then used the DRIE molds to emboss devices that were later characterised using electron microscopy," said Ryan.

"The University of NSW is a one-stop microfluidics shop. We can send device designs to the ANFF for deep-reactive ion etching, and then verify our embossing process with equipment at the Electron Microscope Unit (AMMRF) in a neighboring building. Having such a broad range of facilities on campus allows us to quickly iterate between designs without having to share information with additional 3rd parties. Ultimately, this has sped up the development of our manufacturing process significantly."

After examining the commercial value of the process, the UNSW technology transfer office — New South Innovations (NSi) — filed a provisional patent on the intellectual property (IP). This IP is available for free and with minimal paperwork through NSi's Easy Acces IP program on the basis that the licensee intends to put it to good use.

Both ANFF and AMMRF look forward to continued work with Ryan and his research. We are also excited by the potential involvement of industry partners which could facilitate the mass manufacture of these POCDs, which will benefit the healthcare industry and the developing world.



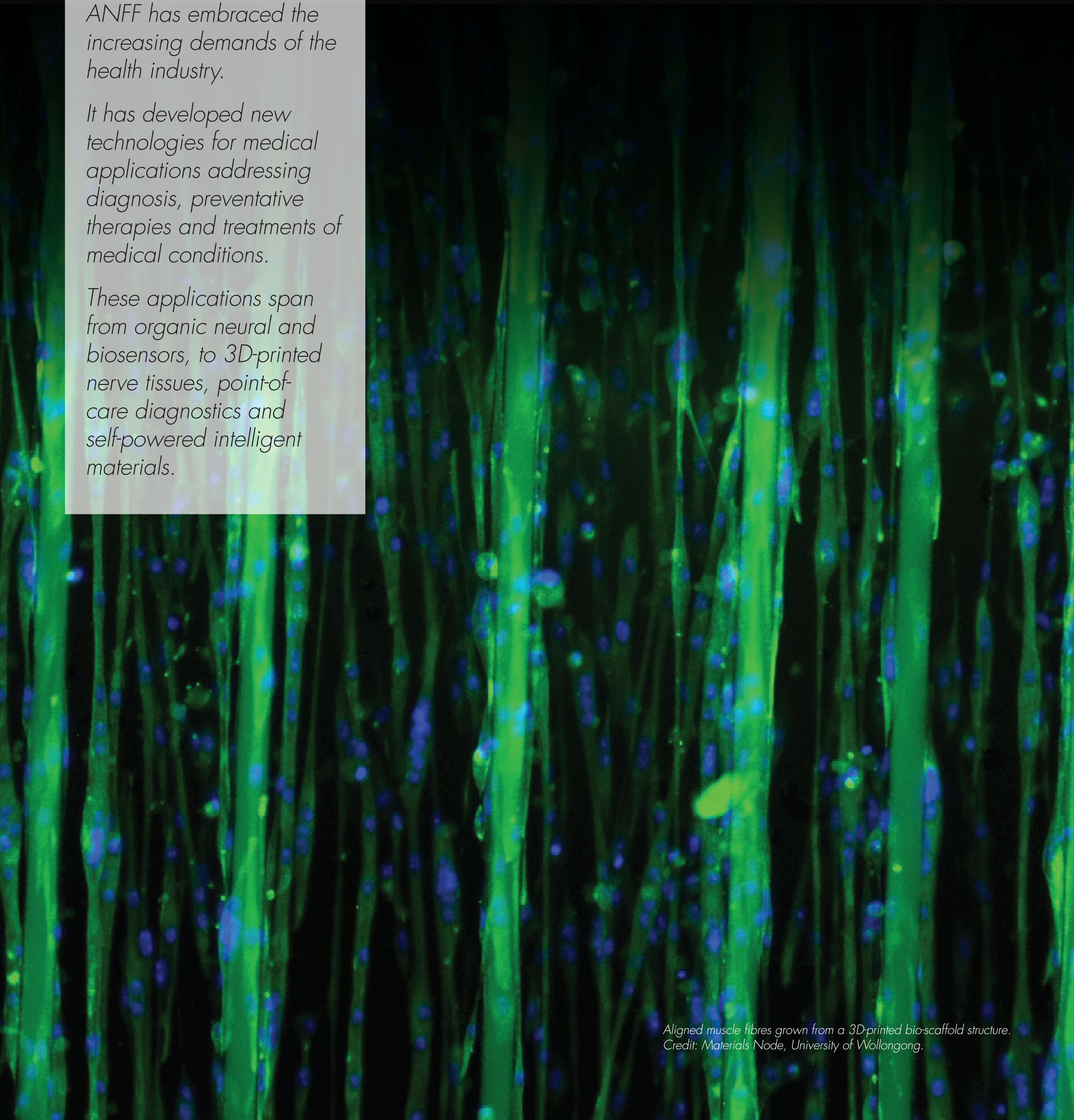
(a) Image of microscopic blood fractionation device, (b) Scanning electron micrograph (SEM) of device inlet, and (c,d) SEMs of post arrays.
Credit: Dr. David Inglis, Macquarie University.

A HEALTHY AUSTRALIA

ANFF has embraced the increasing demands of the health industry.

It has developed new technologies for medical applications addressing diagnosis, preventative therapies and treatments of medical conditions.

These applications span from organic neural and biosensors, to 3D-printed nerve tissues, point-of-care diagnostics and self-powered intelligent materials.



Aligned muscle fibres grown from a 3D-printed bio-scaffold structure. Credit: Materials Node, University of Wollongong.

3D PRINTING BIOMATERIALS, IMPLANTS AND ORGANS

Materials Node — University of Wollongong

3D printing of human nerve tissue is a step closer to being available in the operating theatre thanks to work by researchers from St Vincent's Hospital (SVH) in Melbourne, and the ARC Centre of Excellence for Electromaterials Science (ACES), part of the Materials Node of ANFF.

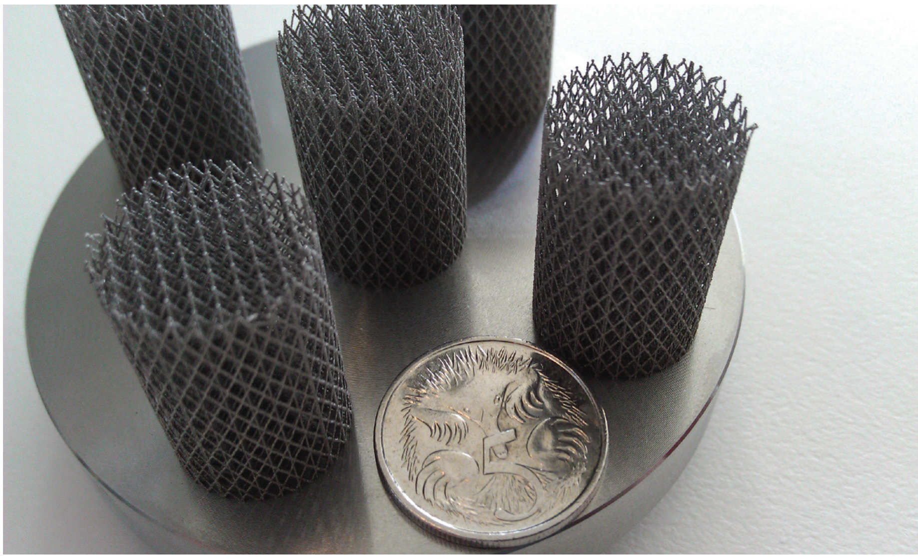
"It is already possible to print 3D biocompatible plastics and metals to manufacture patient-specific implants," ACES and ANFF Materials Node Director Professor Gordon Wallace said.

"Within a few years, we believe it will be possible to manufacture living tissues like skin, cartilage, arteries and heart valves using cells and biomaterials. Using a patient's own cells to create this tissue avoids issues of immune rejection. By 2025, it is feasible that we will be able to fabricate complete functional organs, tailored for an individual patient."

The Materials Node of ANFF provides facilities and expertise in 3D printing, or additive fabrication; a technique new to manufacturing that uses machines to build 3D objects layer-by-layer from digital data. In addition to manufacturing, the Node also supports research into the development of new materials that can be printed.

"While 3D printing is already being used in some medical applications, by bringing together the materials and scientists at ACES and the clinicians and researchers at SVH, we have been able to accelerate our progress so that we are now on the verge of a new wave of technology leveraging 3D printing/additive fabrication techniques to deliver solutions to a number of medical challenges. These include bionic devices, the regeneration of nerve, muscle and bone, as well as epilepsy detection and control," said Professor Wallace.

"In addition we have developed a custom-built, multi-head ink-jet printer that allows printing of multiple components to create new material structures during fabrication — via reactive printing to form biopolymer hydrogel structures that are ionically



3D-printed objects made from metal. Credit: Materials Node, University of Wollongong.

cross-linked during printing. With minimal modification, we have also found these print heads to be useful in allowing for the effective delivery of living cells during the printing process — delivering both nerve and muscle cells to create unique biofunctional structures."

While Australia is leading the charge in 3D bio-printing research globally, the group has made a strategic move to give Australian manufacturers a competitive advantage to hold this lead as the technology moves into the marketplace. In February 2013, ACES joined forces with Advanced Manufacturing CRC in an alliance that will leverage both ANFF's AdBioFab facility, and the CRC's connection to the advanced manufacturing industry in delivering potentially numerous disruptive innovations to global markets.

DELIVERY OF THERAPEUTICS TO THE LUNGS USING A MINIATURE INHALATION DEVICE

Dr Christina Cortez-Jugo, Victorian Node – MCN and Monash University, Ms Sarah Masoumi, Victorian Node – MCN and RMIT University, Professor Leslie Yeo, Victorian Node – MCN and RMIT University, Professor James Friend, Victorian Node – MCN and RMIT University

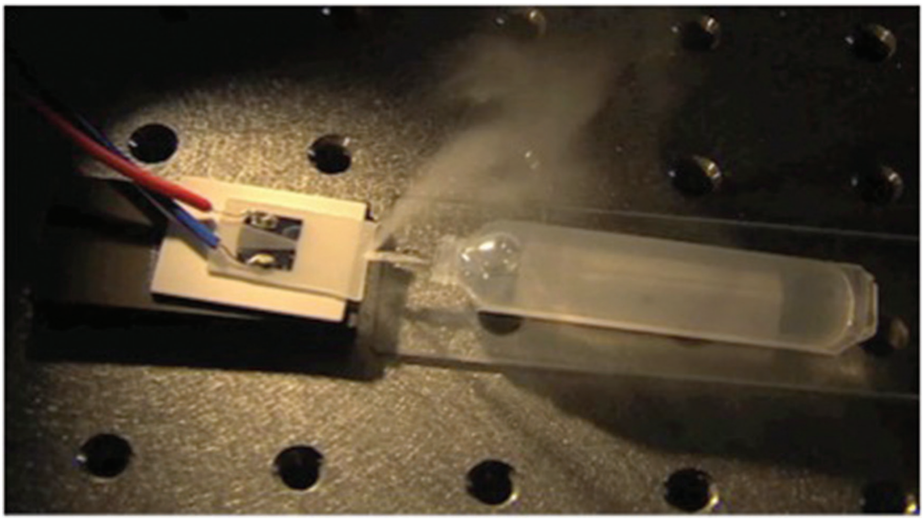
The lung presents an attractive target for the delivery of drugs particularly against lung diseases including lung cancer, tuberculosis, cystic fibrosis and asthma. This has led to significant research into devices that can deliver drugs to the lungs effectively and efficiently. A device under investigation for the generation and delivery of aerosolised drugs is the Respire® system.

At present, many large drugs directed at the lung, including antibodies, are injected intravenously because of the lack of inhalation devices that can do this effectively and efficiently. The Respire inhalation system would enable a portable way of delivering large macromolecular drugs straight to the lungs where the drug is needed, creating a high local concentration of active drug in the lung to improve patient outcomes.

The device, developed by Professor James Friend and Professor Leslie Yeo, was fabricated at the Melbourne Centre for Nanofabrication (MCN) using standard photolithography techniques. The technology is based on surface acoustic wave (SAW) atomisation. When power is supplied to the miniature device, waves akin to nano-earthquakes travel along the device causing the destabilisation and atomisation of liquid droplets in its path. A fine mist suitable for inhalation is formed.

MCN Tech Fellow, Christina Cortez Jugo from Monash University and colleagues from RMIT University are investigating the formation of inhalable droplets of clinically significant drugs including monoclonal antibodies for cancer therapy and asthma. Promising results show that these fragile drugs remain stable and active after atomisation, paving the way for further testing of their efficacy in treating disease.

The group atomised a solution of monoclonal antibodies targeted against the epidermal growth factor receptor (EGFR), which is over-expressed in lung cancer. The stability, immunoactivity and function of the atomised antibody were characterised using gel electrophoresis, confocal microscopy and flow cytometry. The results indicate that the Respire® system provides a feasible means of delivering active antibodies as a fine inhalable mist to the lung.



The Respire® device. Surface acoustic waves propagate along the surface of the nanofabricated device, leading to the atomisation of drug solutions into a fine mist suitable for inhalation. Credit: Melbourne Centre for Nanofabrication.

In collaboration with Dr Manuel Ferreira at the Queensland Institue for Medical Research QIMR, the group will be undertaking biodistribution and efficacy studies of inhaled antibody formulations in mice. In addition to monoclonal antibodies, the Respire® system is also being investigated for the inhalable delivery of nanomedicinal formulations and nucleic acid drugs, including small interfering RNA or siRNA for gene silencing applications. Access to the capabilities and expertise at MCN will continue to be important to facilitate the ongoing and future work in this project.

GENE THERAPY WITH A NANO PIN-PRICK

Professor Nico Voelcker, Dr Roey Elnathan, Dr Bahman Delalat, Dr Hashim Alhmoud (Mawson Institute), Dr Tobias Kraus (Institute for New Materials, Germany), South Australian Node — University of South Australia, A/Professor Simon Barry, Cell Therapy Manufacturers CRC — University of Adelaide

After her mother's death at the age of 56, Angelina Jolie undertook a gene scan that revealed she had an 87 percent chance of developing breast cancer. As a preventative measure, she famously went under the knife to have a double mastectomy.

This is a famous example of what will arguably be one of the most important advances in health care this century, largely thanks to the Human Genome Project. People can now scan their genes to predict diseases they may contract in the future so they can undertake preventative therapies.

Preventative therapies don't have to be as dramatic as what Angelina Jolie endured.

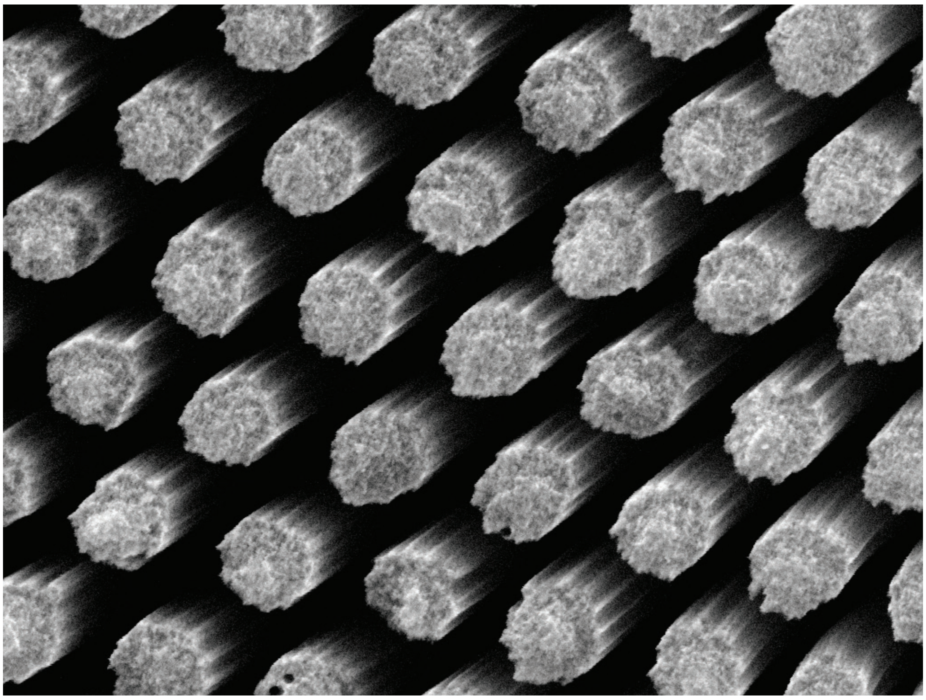
Professor Nico Voelcker and his team have developed a new approach to gene therapy using nanometer-scaled pins made from silicon, manufactured in ANFF laboratories.

Professor Voelcker describes the project: "The delivery of genes or agents that block gene expression to human cells is important for the therapy of difficult to treat diseases such as genetic disorders and autoimmune diseases. The current methods of gene delivery have drawbacks in terms of poor cell viability, poor efficiency of delivery or unwanted immune reactions."

Working with the South Australian Node of ANFF, the team has overcome these limitations by fabricating a gene delivery device made of silicon nanowires. The nanowires are able to penetrate the cell wall and deliver genes with high efficiency while maintaining cell health.

"The collaboration with the SA Node of ANFF helped us to develop the fabrication process and optimise the conditions to produce well-ordered nanowires from silicon with excellent control over the diameter and length, critical for the efficient delivery of genes," said Professor Voelcker.

The processes used to make the devices were common to semiconductor fabrication, a specialist area of ANFF–SA. They included spin coating, sputter deposition and chemical etching. The nanowire arrays were then loaded with DNA plasmids and incubated with target cells including adult and embryonic stem cells.



Silicon nanowires in the gene delivery device. Credit: University of South Australia.

"We observed gene delivery (transfection efficiencies) exceeding 90% at very high cell viability using our device," said Professor Voelcker.

"I am really excited by the prospect of applying our gene delivery approach for therapeutic cells in clinical applications such as treating graft-versus-host disease, autoimmune diseases such as diabetes mellitus type 1 and hopefully many others. Such a therapy will significantly reduce the whole-of-lifetime cost of healthcare provision when compared with lifelong, drug-based immune modulation."

MICROFLUIDIC DEVICES FOR MOLECULAR AND CELLULAR TARGETS

Dr Muhammad Shiddiky and Professor Matt Trau, Queensland Node — The University of Queensland

One leading cause of death in the modern world is the development of cancer. While treatment regimens have significantly advanced quality-of-life in the past 30 years, it is now widely recognised that an effective diagnostic technology that can detect cancer early and monitor and personalise its treatment can potentially provide one of the greatest social and economic benefits to society this century.

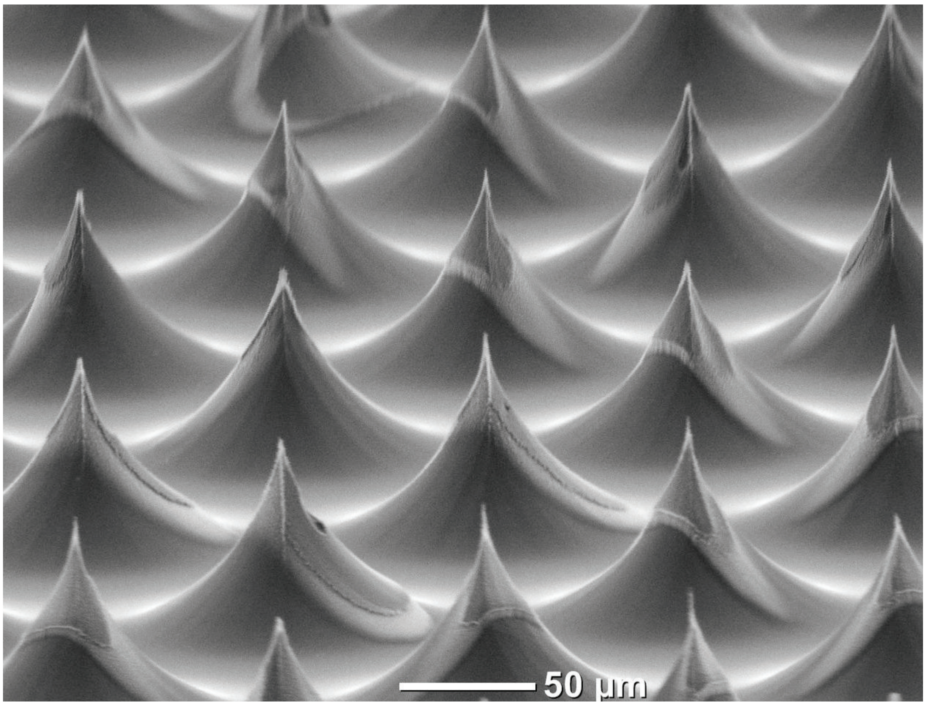
A team led by Dr Shiddiky and Professor Trau at the Australian Institute of Bioengineering and Nanotechnology (AIBN), The University of Queensland, have recently discovered a new physical phenomenon referred to as nano-shearing that could lead to a new generation of ultra sensitive point-of-care diagnostic devices.

"Fluid nano-shearing is a new capability of externally tuning and manipulating nanoscopic fluid flow around a biosensor surface that can enhance sensitivity and remove non-specific adsorption of molecules, cells, etc present in clinical samples. Therefore, this could have wide applications as an innovative approach to enhance the specific capture of rare molecules and cells in a microfluidic point-of-care diagnostic device — a very exciting prospect," said Dr Shiddiky.

By understanding and exploiting this phenomenon in a sensor, the group plans to develop a platform technology that can detect molecular and cellular targets, such as cancer cells, in ultra-low concentrations.

With support from the Queensland Node of ANFF (ANFF–Q), that has expertise in the design and fabrication of these microfluidic devices, the group has worked to understand the nano-shearing phenomenon in order to develop a functioning device.

Dr Shiddiky describes the project: "To investigate the nano-shearing phenomenon the team has constructed microfluidic devices which contain an array of asymmetric electrode pairs within a long serpentine channel. They also fabricated devices embracing electrodes pairs with a combination of planar and microtip spikes."



Surface of a microfluidic device that enhances nano-shearing in a fluid — a phenomenon that could lead to ultra-sensitive point-of-care diagnostic devices in the future. Credit: Trau Laboratory, AIBN, The University of Queensland.

To date this work has demonstrated two critical improvements for the capture of cellular targets:

- Sensitivity — they have enhanced the capture efficiency of target cells by enhancing sensor–target interactions.
- Specificity — they have tuned the fluid flow within the nanometers from the sensor surface to physically shear away unwanted species.

A new generation of ultra sensitive point-of-care diagnostic devices could have great significance to the global community. These devices could find a broad utility in diagnostic and research settings; in particular they could be installed in every doctor's surgery, 24 hour pharmacy or nursing home providing rapid diagnosis of conditions such as viral infections or cancer.

NEW APPROACHES TO MRI

Dr Hui Peng, Dr Elena Taran, and Polymer Chemistry Group, Queensland Node — The University of Queensland

A new class of magnetic resonance imaging (MRI) agent that has the potential to improve early diagnosis of various types of disease has been developed by a team at the Australian Institute of Bioengineering and Nanotechnology (AIBN) with ANFF–Q.

MRI is a medical imaging technique used in radiology to visualise internal structures of the body in detail and in 3 dimensions. It has proven to be revolutionary for medical diagnosis due to its rich information content, relatively high resolution and non-invasive nature. It also does not use harmful ionising radiation such as X-rays.

Before a patient receives an MRI scan, an imaging agent is often injected into the body to enhance the image quality and allow the precise delineation of diseased tissues to ensure more effective medical intervention. For the diagnostics of certain conditions, current imaging agents often suffer from poor sensitivity and image contrast.

MRI agents are highly engineered structures. In collaboration ANFF–Q, which specialises in functional organic materials, the AIBN team engineered a new class of imaging agents that promise to allow much clearer definition of diseased tissue and mapping of specific tissue types by enhancing image definition and reducing scan times. These materials are called diblock copolymers.

ANFF–Q's atomic force microscopy (AFM) facility was used to identify the microstructure of diblock copolymers deposited on a surface.

"Key to the engineering problem was the relationship between structure and how the materials behave in solution," said Dr Elena Taran, ANFF–Q's expert in AFM.

"These microstructures identified the size and shape of the polymer providing a critical insight into their functionality and performance as an MRI agent."

MRI agents are used to enhance the detail of an MRI image, such as in this brain scan.

UNRAVELLING THE MYSTERIES OF THE BRAIN

Dr Christopher Davey, Dr Sam Solomon, Dr Alex Argyros, Professor Simon Fleming, OptoFab Node — University of Sydney

A neural probe being developed at the OptoFab Node of ANFF may hold the key to many of the mysteries of the brain and provide critical insights into the cause of various neurological disorders.

Current electrode technology used to study neural signals in the brain provide very poor spatial resolution and therefore limited information about brain function. The new probes being developed at ANFF contain microscopic electrodes, providing better resolution, that can map multiple locations simultaneously.

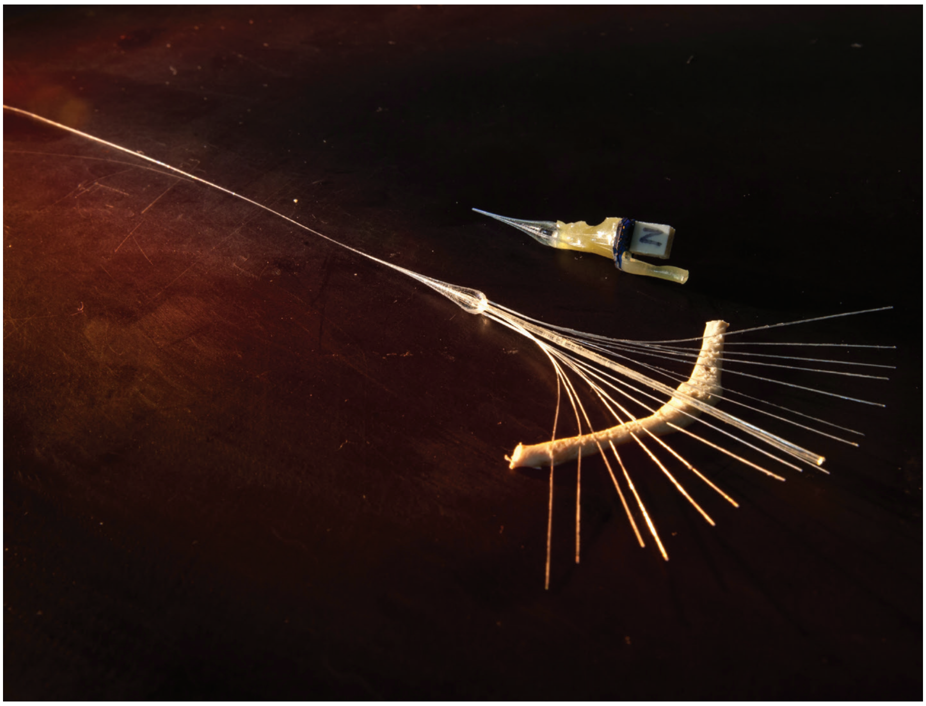
Christopher Davey from the University of Sydney and his team have worked with the OptoFab Node of ANFF who are experts in polymer fibre technology. They have borrowed fabrication processes developed for making metamaterials: materials that can bend light and make things invisible.

Professor Simon Fleming from OptoFab describes the process of making these fibres: "Simplistically this process involves filling the air holes in microstructured polymer optical fibre with a metal that could be co-drawn into a very fine microstructured fibre or, in the case of Christopher's project, an array of miniature closely spaced electrodes."

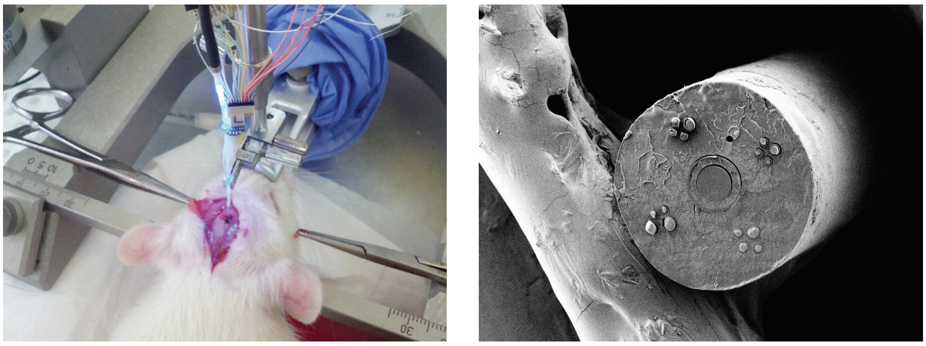
These electrodes have been purposefully adapted to neural probes and tapers have been drawn and connected to standard electrical interfaces. In vitro and in vivo testing has been performed in collaboration with neuroscientists at the Universities of Sydney and Queensland with positive results.

OptoFab has the only facilities in the world currently able to fabricate these fibres and devices. They can now be made easily and quickly using ANFF facilities.

The team's success to date has led the group to explore possibilities for further clinical applications including treating neural disease, degeneration and injury in the longer term.



The neural probe taper with and without circuit board connector interface. Credit: Richard Lwin, OptoFab Node.



Left: The neural probe connected to a mouse. Credit: Christopher Davey, Department of Physiology The University of Sydney. Right: Endface of the neural probe taper showing 16 metal wires used for the microscopic electrodes. Credit: Richard Lwin, OptoFab Node.

This process has been patented, and a preliminary business plan has been developed to commercialise this technology. It is hoped that one day they will bring new advances in neuroscience into our hospitals and provide treatment for neural disorders such as Alzheimer's and other costly diseases in the developed world.

AFFORDABLE POINT-OF-CARE DIAGNOSTICS: NEW MANUFACTURING TECHNOLOGY DEVELOPED AT ANFF

Professor Robert Short, Dr Endre Szili, South Australia Node — University of South Australia

A new manufacturing technology could enable the production of cheap disposable point-of-care (POC) devices carried in every GP's surgery, or even a home drug cabinet.

POC diagnostic devices are becoming more and more common place with the range of diseases they can detect ever expanding. A current example is a blood glucose monitor that a diabetic can use to take a painless blood sample to obtain a reading in a matter of seconds.

Next generation POC diagnostic devices use arrays of biomolecules that allow a large number of tests to be carried out with a single sample. A problem with their production is the precise positioning of biomolecules in an array in a microfluidic device. This is a particularly difficult task as the capacity to manufacture this new flavour of POC devices is limited.

Dr Endre Szili is working on a solution at the ANFF – SA Node who specialise in microfluidics and surface science.

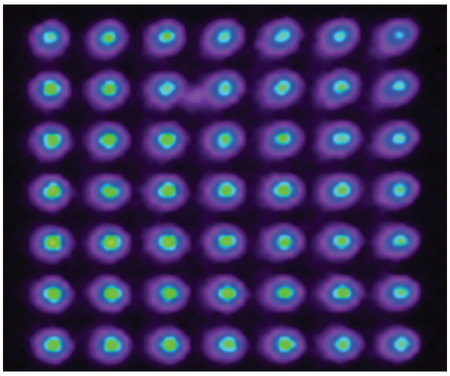
"We initially developed a new manufacturing method that uses micron-scale gas plasma sources to precisely pattern open 2D surfaces. This underpinned the development of technology to pattern microchannels of bonded microfluidic devices. The modified surface allows for the binding of biomolecules, such as proteins, at these exact locations by simply passing a fluid over the patterned surface.

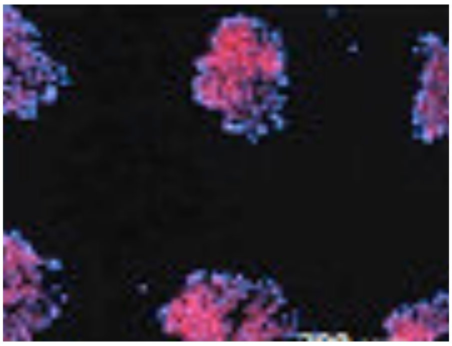
Most significantly, the technique does not require the use of physical masks, lithography or harmful solvents and the molecules retain their biological activity," says Szili.

"This is something that can't be achieved by existing patterning techniques. This method would underpin lower cost manufacturing of these devices."

The Australian project manager, Professor Rob Short, and his team at the University of South Australia have been collaborating with researchers from the United States and the United Kingdom to fabricate and characterise new microplasma devices for use in various biotechnology industries. One patent has been filed.

Endre Szili said; "the technology could underpin the next generation of affordable and accessible point-of-care therapeutic diagnostics devices. This is an exciting prospect for all Australians."





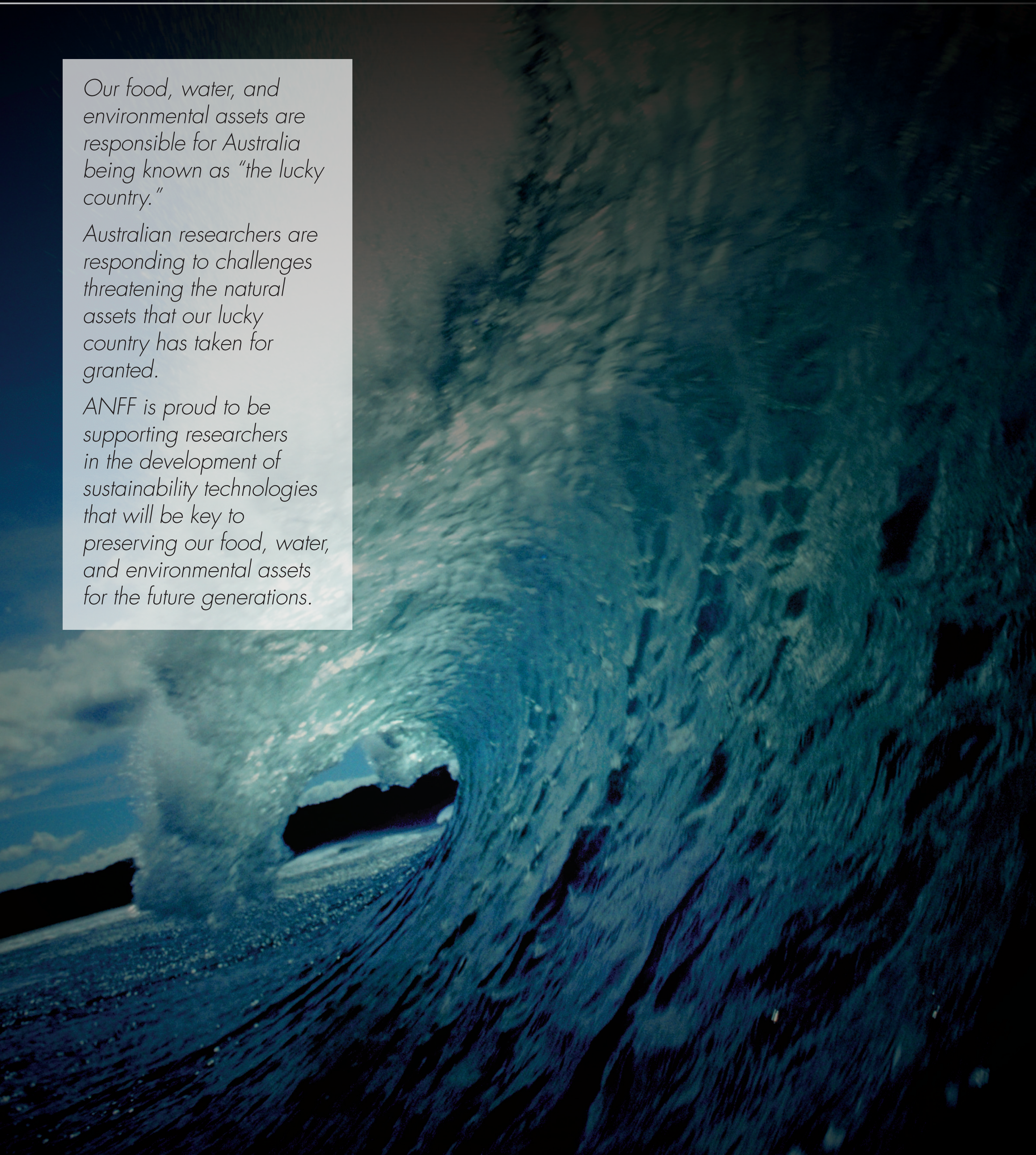
Top: The ignited microplasma array during operation in helium at atmospheric pressure. Bottom: Cell microarrays created using the microplasma device. Credit: University of South Australia.

FOOD, WATER, & THE ENVIRONMENT

Our food, water, and environmental assets are responsible for Australia being known as "the lucky country."

Australian researchers are responding to challenges threatening the natural assets that our lucky country has taken for granted.

ANFF is proud to be supporting researchers in the development of sustainability technologies that will be key to preserving our food, water, and environmental assets for the future generations.



ARTIFICIAL PHOTOSYNTHESIS

Professor Thomas Nann, SA Node — University of South Australia

Could the answer to the world's energy and carbon emission problems lie in nature's own process of photosynthesis?

"Most likely, yes," says ANFF–SA Node Director and University of South Australia Professor Thomas Nann.

Photosynthesis is a process used by plants and other organisms to convert carbon dioxide and light into stored chemical energy. This same energy and carbon is released when fossil fuels are burned thousands of years later. Artificial photosynthesis (AP) is an electrochemical process that mimics natural photosynthesis.

Professor Nann said, "Our projects aim to use AP to produce fuel from either water or carbon dioxide by using sunlight as the primary energy source."

"Our dream is to tile the outback with little devices that produce stored energy when the sun shines. Hydrogen, for instance, can be used as a fuel for cars, planes or converted to electrical energy."

A critical part of the electrochemical AP device is the fabrication of photoanodes and photocathodes. This is done by decorating high surface area substrates, such as the electrospun structure in figure 1, with quantum dots (figure 2).

The combination of a photoanode and a photocathode then allows for either the splitting of water to create hydrogen fuel, or reduction of carbon dioxide into formate fuel. Nann's team has been fabricating and characterising quantum dots and catalysts at the ANFF–SA laboratories in the University of South Australia. They have also fabricated microfluidic devices designed to distribute and position these nanoparticles on high surface area electrospun microstructures.

Devices made by Nann's team aim to maximise the efficiency of the sunlight-to-fuel conversion, which is currently similar to that of conventional solar cells.

According to Professor Nann, "This project could provide a very critical step towards establishing a future hydrogen fuel based economy — the most realistic and promising alternative to the current fossil fuel based economy we have today."

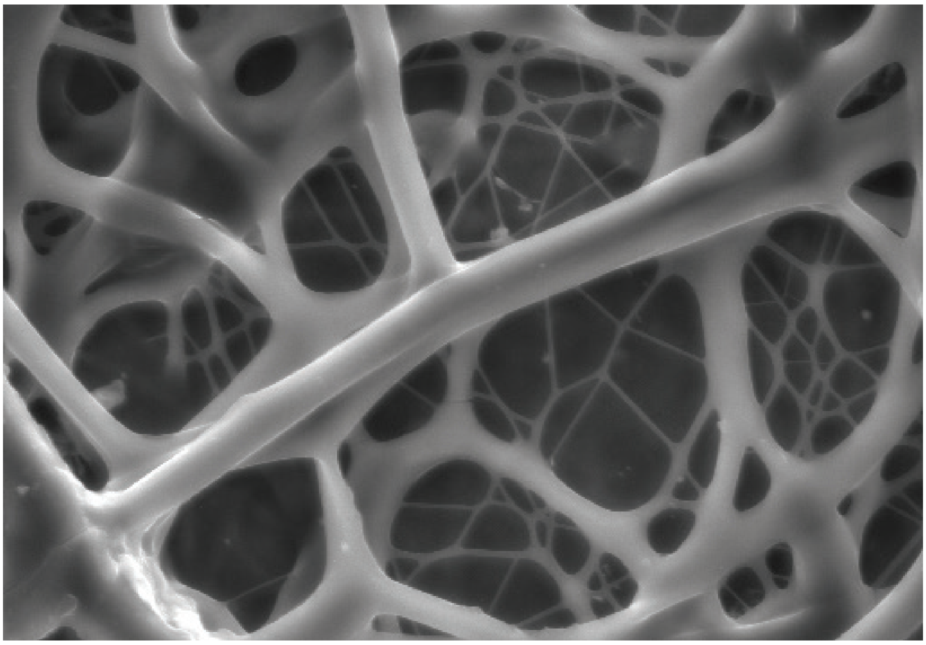


Figure 1: A high surface area microstructure that supports quantum dots. Credit: South Australian Node — University of South Australia

Figure 2: Quantum dots in solution. Credit: South Australian Node — University of South Australia

TINY SEMICONDUCTOR WIRES THAT CAN TRANSFORM SOLAR ENERGY

Mr Yu-Heng Lee, Mr Zhe Li, A/Professor Lan Fu, Professor Hoe Tan, and Professor Chennupati Jagadish, Department of Electronic Materials Engineering, Research School of Physics and Engineering, ACT Node — The Australian National University

Nanowire solar cells have the potential to make solar energy more efficient and affordable.

A problem that has plagued the solar industry for decades is the trade-off between light absorption and the efficiency with which a solar device can transform this absorbed light into electricity. Traditional solar cells are not good at both at the same time.

The ACT Node of ANFF with local researchers at the Australian National University (ANU) are working to develop a nanowire solar cell that potentially solves this problem, paving the way for high efficiency solar cells in the future.

ACT Node Director Professor Chennupati Jagadish, with PhD student Yu-Heng Lee, has been leading the development of the device at the ANU Research School of Physics.

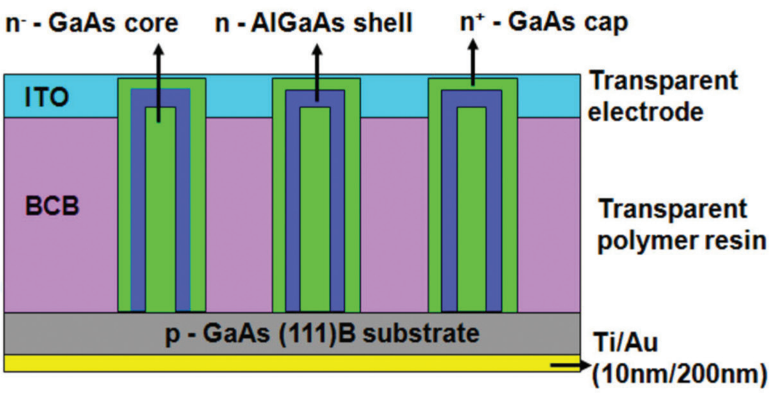
"Nanowires exhibit novel electrical and optical properties that give them the ability to both absorb more light and collect charge carriers (electricity) more efficiently. The light absorption and carrier collection efficiency trade-off can be eliminated by utilising a nanowire's unique geometry," said Professor Chennupati Jagadish.

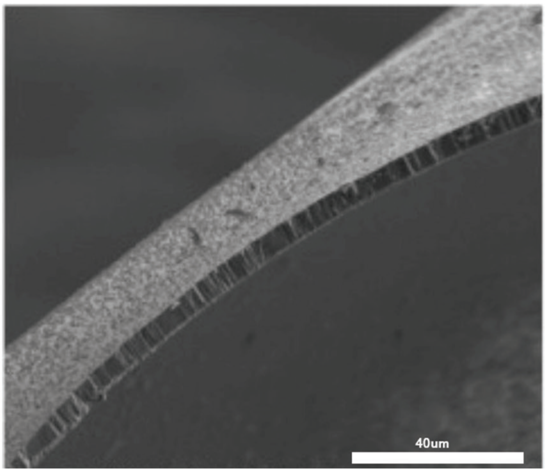
The group have fabricated an initial device that has a power conversion efficiency of about 4%. While this is much lower than today's silicon solar cells, the technology platform they have created will allow future developments that will produce cost effective cells with dramatically improved efficiency and surpass the capabilities of today's solar technology.

"With ANFF technical staff members, Dr Kaushal Vora and Dr Fouad Karouta, we have developed a fabrication procedure for devices made from multiple layers of III-V semiconductor materials. One of the improvements in efficiency is expected to come from the next stage of our work: fabricating multi-junction devices that can absorb a wider range of the solar spectrum and hence more light. This is one very unique aspect of our work," said Yu-Heng Lee.

"We have also come up with a technique to peel off polymer-embedded nanowires from the underlying wafer substrate. This finding opens up opportunities for creating flexible and lightweight solar cells that can be integrated into soft materials and fabrics.

In the future, we hope our technology will make solar energy a more financially viable option than current cells by both reducing the cost of manufacture through reduced material usage, and enhancing their overall performance."





Left: Schematic diagram of a nanowire solar cell. Right: Scanning electron microscope (SEM) image of the polymer-embedded nanowires peeled off from the substrate wafer. Credit: The Australian National University

WHITE GRAPHENE FOR CLEANING OIL SPILLS

Professor Ying Chen and Dr Weiwei Lei, Victorian Node — Institute for Frontier Materials, Deakin University

White graphene could provide a revolution in water purification and pollution management. It could protect our drinking water, or rapidly clean up oil slicks from water or spills on roads.

Oil spillage, organic solvents, and other industrial contaminants are primary pollutants of water sources and roads around the globe. Existing materials used to solve spillages often do not easily separate from water and carry their own environmental consequences.

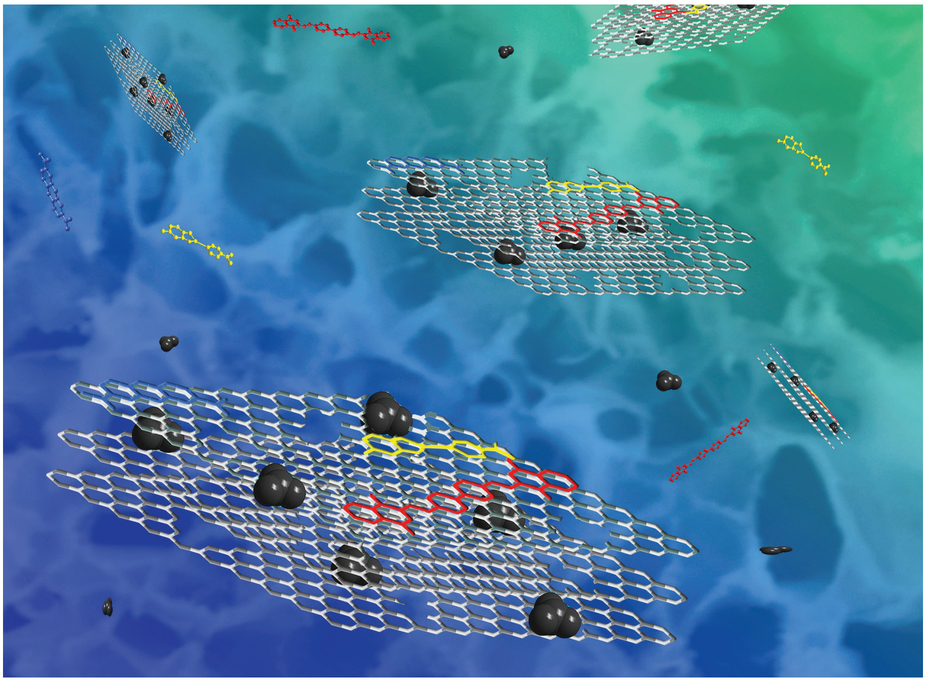
Researchers at Deakin University, in conjunction with the Victorian Node of ANFF, have developed a new sorption material for the effective removal of oils, organic solvents and dyes from water.

The new nanomaterial is known as white graphene. It is very similar to the better known carbon-based graphene, being a two dimensional nanostructure a few atomic layers thick, but made of boron nitride rather than carbon. These porous sheets have a very high surface area of 1427 m^2/g and highly selective absorbent capabilities that give the material its superior ability to collect pollutants. White graphene can absorb up to 29 times its own weight in engine oil.

Professor Ying Chen is a world leader in boron nitride nanomaterials research. He describes their discoveries: "We synthesized porous boron nitride nanosheets for the first time in the world and discovered their high selective absorbent properties on oil, dyes and solvents as common water contaminants. They are light weight, repel water and float, making it easy for the pollution logged nanosheets to be collected from the surface of water.

We also found a simple and effective recycling process of the pollution-saturated nanosheets. Simply burning the absorbed oil off in air leaves the white graphene behind ready to be used again."

The results published in *Nature Communications* have attracted strong attention from industries around the world interested in getting their foot in the door



Artists' impression of porous boron nitride nanosheets capturing oil and dye from water. Credit: Professor Chen and Dr Lei, Deakin University..

of this potentially revolutionary technology. The current focus of the project is up-scaling production; a task critical for large scale water purification or oil clean up projects to become financially viable.

Professor Chen expects that if the team can develop a means to mass-produce white graphene, their technology may be able to restore the water supply of many third world countries or save ecosystems from major oil spills.

BUILDING AN ARTIFICIAL NOSE

Mr Gino Putrino, Professor John Dell, Professor Lorenzo Faraone, Professor Adrian Keating, and Professor Mariusz Martyniuk, Western Australia Node — University of Western Australia

The air we breathe is packed full of invisible chemicals that carry a huge amount of useful information. A sensitive enough artificial nose could decipher this information, making it possible to tell if someone has lung cancer simply by sniffing their breath, detect explosives in an airport, or tell if vegetables in a supermarket are fresh.

Gino Putrino, PhD student at the University of Western Australia, with support from the WA Node of ANFF, is making an artificial nose using a new class of micro-electro-mechanical sensor (MEMS), which have been shown to be sensitive enough to detect ultra-low quantities of airborne chemicals.

Gino describes the MEMS sensor: "These sensors are made by fabricating a suspended mechanical beam that is clamped at one end. It is coated with a substance that sticks to a specific chemical you want to sense. If you hit this beam, it will start vibrating at its resonant frequency. If the chemicals you are trying to sense then stick to the beam, that frequency will change, and if you are able to detect that change, you have an incredibly sensitive device."

At the heart of Gino's project is the problem of detecting this change in frequency — giving the artificial nose a sense of smell.

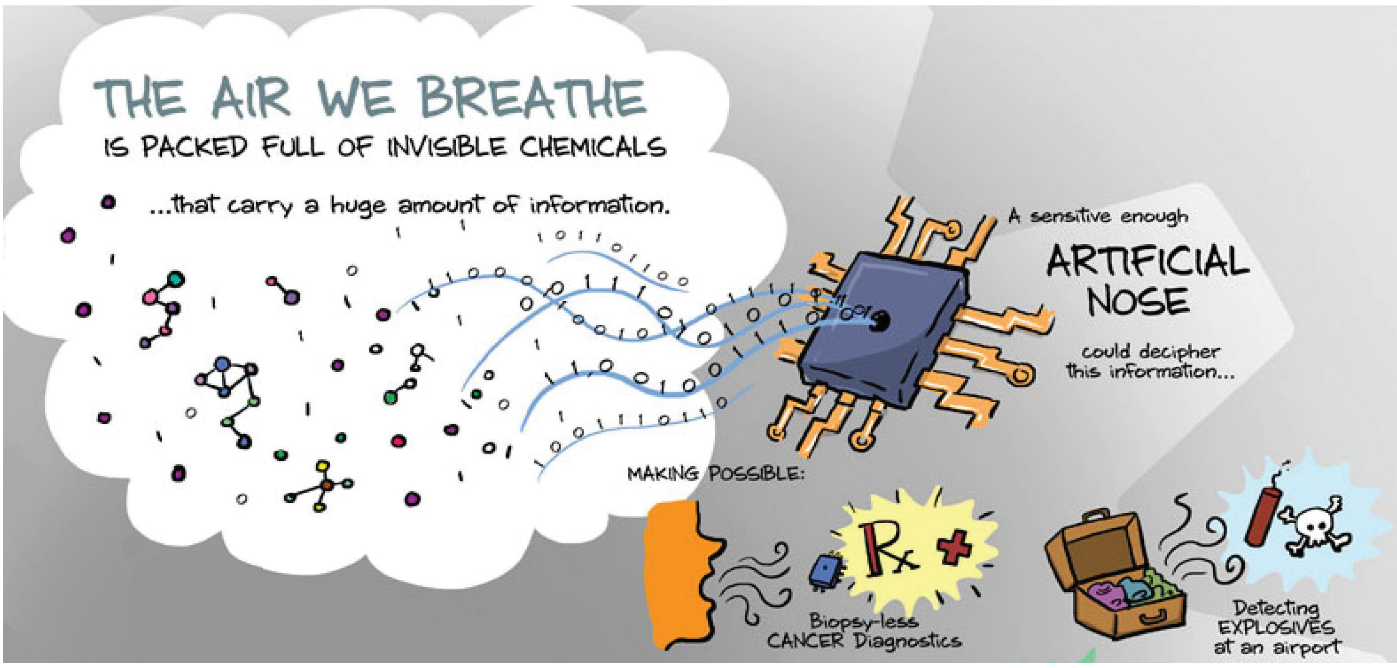
Gino describes how the design of his device has been inspired by the Green Hairstreak butterfly: "The shimmering colours of the butterflies wings are not created by pigments, but rather by nanostructured shapes which create an effect called diffraction, where different colours of light are bent in different directions."

"By fabricating a similar nano-structure underneath the beam, and aiming a laser through it, the amount of light that reaches the other side will depend on the height of the mechanical beam."

"By bringing all these things together — what mechanical engineers know about vibrating beams; what chemists and biochemists know about which chemicals stick to each other; what micro-electronic engineers know about making tiny things; and strangely, what physicists know about how butterfly wings bend light — then we can build such a device to check if groceries are fresh, to remotely pick up explosives in an airport, or to test for lung cancer without needing a biopsy."

Recently the optical measurement technique that is the subject of this research has been used to demonstrate sub-nanometre movements of MEMS mechanical beams, using low-power infra-red lasers. This result will translate into the ability to build chemical sensors which are sensitive enough to detect chemicals as dilute as a few parts per trillion (ppt). This is the equivalent of one drop of 100% alcohol into 20 Olympic-size swimming pools

Gino's work on this project has led to the publication of numerous journal articles and the submission of three patent applications, and has won Gino an international PhD TV 2 minute thesis competition.



Extract from Gino Putrino's winning presentation in the international "PhD TV 2 minute thesis" competition. Credit: WA Node, University of Western Australia.

A STEP TOWARDS MASS PRODUCTION OF GRAPHENE DEVICES

A/Professor Nunzio Motta, Queensland Node — Queensland University of Technology, & Dr Francesca Iacopi, Queensland Node — Griffith University

Graphene is an ideal material for electronic and micro-electro-mechanical devices such as extraordinarily sensitive chemical or mechanical sensors. Their range of applications is broad ranging from healthcare to environmental monitoring.

Most of the current graphene synthesis methods are not compatible with device production.

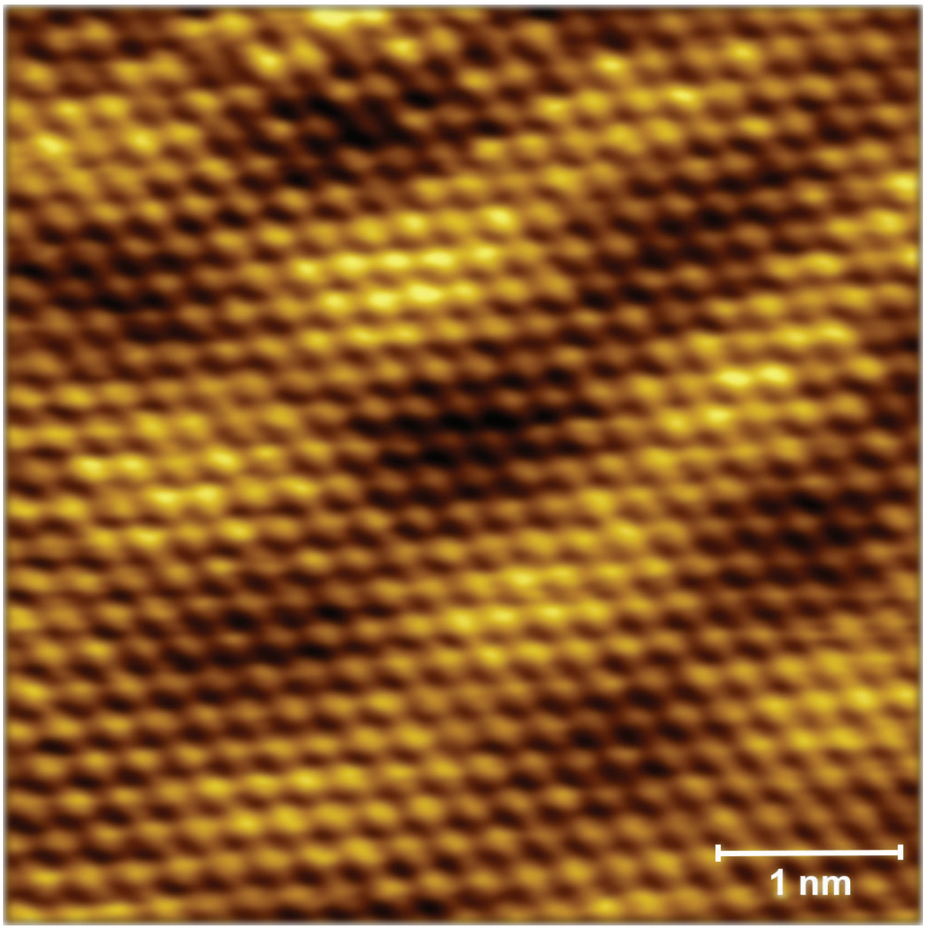
A team at Griffith University, in collaboration with the Queensland University of Technology (QUT), are developing a new method to fabricate graphene that is compatible with established semiconductor manufacturing processes.

"We are making device-quality graphene by heating an epitaxial silicon carbide (SiC) film in a vacuum until a few monolayers of silicon atoms sublime leaving behind the high quality graphene layer," said Dr Francesca Iacopi, ARC Future Fellow and project leader at Griffith University.

"The availability of high quality SiC-on-silicon films from the Griffith site of ANFF–Q is crucial."

ANFF–Q laboratories at Griffith University are world leaders in SiC epitaxial deposition. High quality SiC films were deposited at the ANFF–Q facilities with their flagship epitaxial reactor. The sublimation process was performed in-situ with the Scanning Tunnelling Electron Microscopy facilities with collaborators from QUT.

Having established a process that can be adapted to manufacturing, the potential impact is enormous. Graphene devices



An atomic resolution scanning tunnelling microscope image of a bilayer of graphene epitaxially grown on a SiC-on-silicon film. Credit: B. Gupta and N. Motta, QUT.

can only find real-life applications if they can be produced on a large scale."

In parallel with the development of graphene manufacturing, the team are looking to develop their own sensing technologies that they may be able to manufacture in-house. This platform would be able detect chemicals in fluids for applications in health and water monitoring.

ULTRA THIN OPTICAL SENSORS FOR THE DETECTION OF TOXIC CHEMICALS

A/Professor Wenlong Cheng, Mr Yi Chen, Mr Yue Tang, Mr Jye Si, Mr Shu Gong, Victorian Node — Melbourne Centre for Nanofabrication with the Department of Chemical Engineering, Monash University

Development of a new ultra-thin 2D optical material may enable the rapid, sensitive and inexpensive detection of toxic chemicals in air, water, and soil.

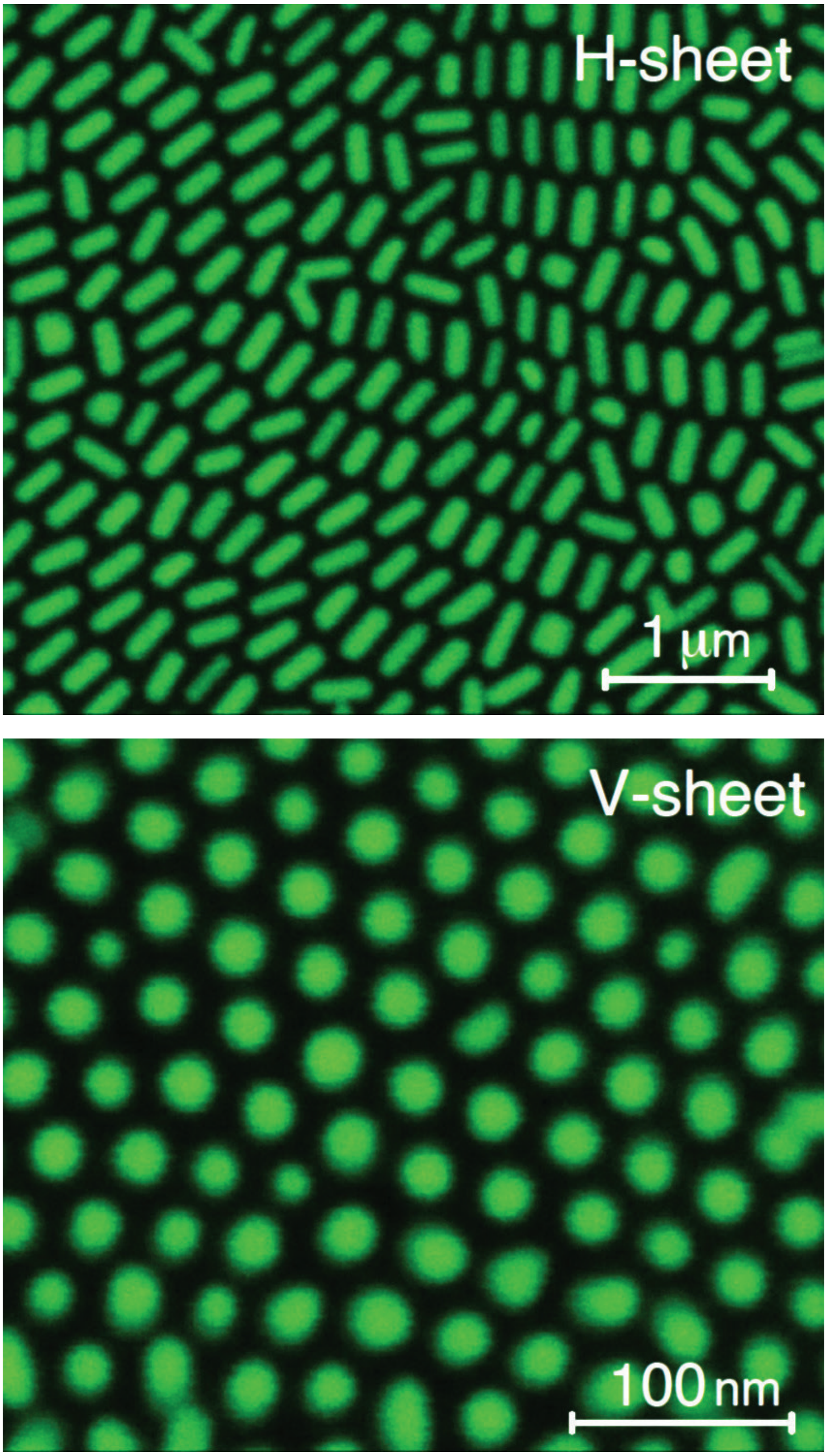
Surface Enhanced Raman Scattering (SERS) is an extremely powerful technique with the potential to identify chemicals in trace or even single molecule quantities. It requires the molecules to be adsorbed onto a SERS substrate that typically contains nanostructured "plasmonic" features.

However, the high cost, portability and reproducibility challenges currently prevent the practical application of SERS in many real-world situations. For instance, commercially available SERS substrates required for a measurement cost around $40 dollars, and are supported on rigid glass surfaces that limit where they can be used. This makes it difficult for trace chemical identification on topographically complex surfaces such as a door handle or a sheet of paper.

To combat these problems, A/Professor Wenlong Cheng has used nanofabrication facilities at the Melbourne Centre for Nanofabrication — ANFF's Victorian Node — to fabricate a cheap, thin and flexible SERS substrate for the rapid and sensitive detection of toxic species in air, water, and solids.

A/Professor Cheng said, "We developed a simple, yet efficient, wet chemical nanofabrication approach to obtain free-standing, monolayered, highly-ordered plasmonic nanosheets. The sheets could be as thin as 2.5 nm but could have macroscopic lateral dimensions. Such nanosheets are high-performance SERS substrates which achieve at least 10 times higher sensitivity than commercially available substrates."

The unique technology developed to fabricate the substrates has applications beyond detecting toxic chemicals. Applications may include smart diagnostics, better monitor displays, or more efficient solar energy systems. The project is currently expanding its scope and is looking to translate the technology into real-world products.



Plasmonic nanosheets from horizontally aligned gold nanorods (H Sheet, upper) and from vertically aligned gold nanorods (V Sheet, lower). Credit: Melbourne Centre for Nanofabrication.

A PRINTABLE CARBON MONOXIDE SENSOR COULD SAVE LIVES

Dr Timothy Sales, Dr Nathan Cooling, Dr Warwick Belcher and Professor Paul Dastoor, Materials Node — University of Newcastle

A cheap household solution for a silent household killer is being developed at the Materials Node of ANFF: the world's first all-printed organic carbon monoxide sensor.

Carbon monoxide (CO), often called the "silent killer", takes many thousands of lives every year. It is a colourless, odourless, tasteless, toxic gas produced as a by-product of combustion. It blocks oxygen from getting into the body, which can cause brain damage or death.

Researchers at the Priority Research Centre for Organic Electronics, part of the ANFF Materials Node, are using organic thin-film transistors embedded with sensing molecules to develop an all-printed organic CO sensor.

In designing the device, the team turned to nature for inspiration when seeking a suitable sensing molecule. They came up with haeme: the functional centre of haemoglobin in red blood cells responsible for shuttling oxygen around the human body. Haeme binds preferentially to CO; this prevents the transport of oxygen around the body and causes CO poisoning.

"It is well known that CO binds strongly to haeme," said researcher Timothy Sales.

"Haeme belongs to a class of molecules called porphyrins: a diverse group of compounds that are easily synthesised and have readily tuneable physical and chemical properties. By altering the structure of a porphyrin we can modify the way it interacts with gases such as CO."

The group has successfully incorporated their CO-sensing porphyrin molecules into a solution enabling them to be printed. The device — an all-printed organic thin-film transistor with embedded sensing molecules — will alter its electronic properties when exposed to CO gas. The team are aiming for CO detection limits as low as 10 ppm.

Deadly CO gas can be produced by any household appliance that burns fuel.

The group will soon be moving to pilot-scale production of the sensors with the Materials Node's recent installation of a roll-to-roll organic printer.

"As both the CO-sensing porphyrin molecule and the materials used to fabricate the transistor are solution processed, we are able to print all of the transistor components onto a flexible plastic substrate," said researcher Nathan Cooling.

"Being able to print CO sensors in large quantities could reduce the unit cost to about that of a chip packet. It would then become affordable to put the sensors on every gas mask, gas stove or oven, or combustion engine car or truck. It could revolutionise the safety industry and potentially save many thousands of lives."

The team is currently working with industry partners to further develop and commercialise this technology.

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