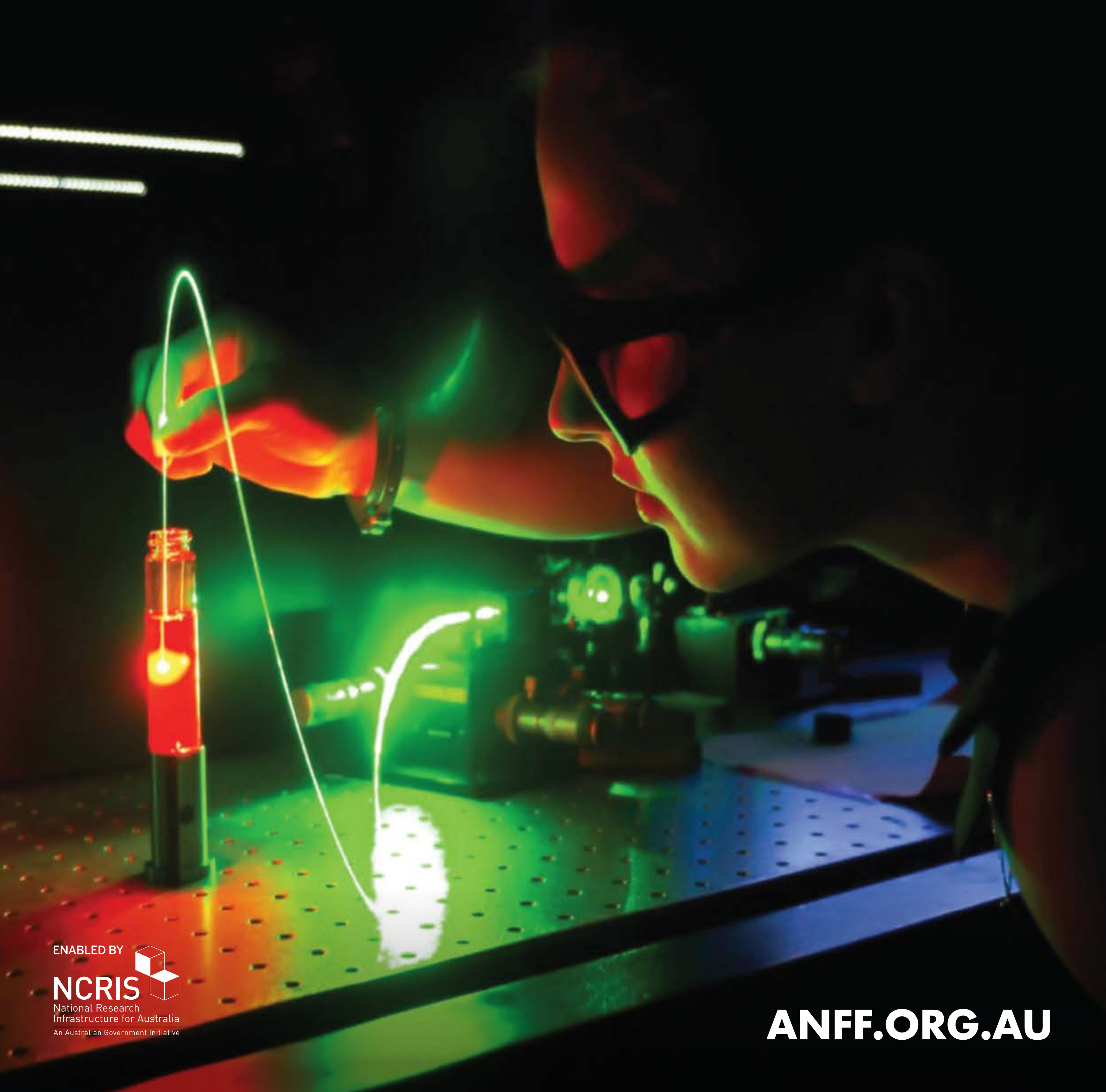
THE AUSTRALIAN NATIONAL FABRICATION FACILITY

ANFF

ANFF NEXT

CASEBOOK 2024



ENABLED BY NCRIS National Research Infrastructure for Australia An Australian Government Initiative

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Front cover credit: Integrated Photonics and Applications Centre (InPAC)

ANFF NEXT embodies the excitement and potential of forward-thinking endeavours, propelling us toward innovation and excellence. It represents the Australian National Fabrication Facility's (ANFF) strategic vision, emphasising growth and evolution from a high performing, stable foundation. This theme underscores our commitment to expanding capabilities, aligning with our strategic goals and serving the Australian research and development community's needs through partnerships and services that deeply support the advanced manufacturing sector's growth.

Seventeen years of stability and consistency at ANFF provides a platform from which we can continue to grow and evolve. With $55M secured this year from state and federal governments to support our plans, ANFF will continue to provide the critical, and excellent, service our community demands. Continual improvements will resonate with our strategic ambitions and be led by the community's requirements.

In 2024 and beyond, our ongoing investment in new equipment, processes and skills across our network of Nodes, informed by client insights, will ensure our capabilities remain relevant and transformative.

ANFF will also seize opportunities to expand our capabilities and services to meet the evolving needs of our users and partners. These 2 priorities will balance the core services of ANFF with the ability to provide even more value to our community.

Our strategic initiatives prioritise national research infrastructure excellence, capturing commercialisation benefits, broadening ANFF's offerings in line with government priorities and reinforcing ANFF's reputation and value as a trusted partner.

The stories in this 2024 ANFF Casebook showcase the successes of our network's clients. We celebrate their accomplishments and highlight their impacts across Australian society. These successes demonstrate how ANFF's expansive network of fabrication tools, facilities and expertise empowers research, development and commercialisation now and into the future.

ANFF NEXT stands as our beacon, ensuring that we are looking to the future and the changes that will keep us at the frontiers of innovation and excellence. It symbolises our relentless pursuit of progress, pushing boundaries, breaking new ground and elevating our collective potential.

ANFF » NEXT

RESEARCH THEMES

- HEALTH AND MEDTECH
- RECYCLING AND CLEAN ENERGY
- ENVIRONMENT AND CLIMATE
- AGTECH
- DEFENCE
- SENSORS
- FRONTIER TECHNOLOGIES AND MODERN MANUFACTURING
- QUANTUM

› ANFF 2023–2024

› As we delve into the 2024 ANFF Casebook, themed '**ANFF NEXT**', we embark on a journey that combines our rich 17-year history with a forward-looking vision. While we can't predict the future with absolute certainty, our experience in guiding and supporting research fuels our confidence in what lies ahead.

Within these pages, you'll discover a multitude of remarkable examples of research, development and commercialisation emerging from the ANFF network. As you read, I hope you'll share our excitement – the same enthusiasm that inspired the creation of this Casebook.

In this Casebook, you will explore cutting-edge innovations, breakthroughs, and collaborative efforts that define the future of fabrication and scientific discovery. Also, you can find reference to our refreshed ANFF Strategic Plan, providing insights into our direction.

'ANFF – Connected' – Our annual ANFF Showcase celebrated the exceptional talent within the ANFF client community. Held in February 2024 at the Melbourne Convention & Exhibition Centre, the event focused on 'Leveraging a connected ecosystem for success.' We delved into how ANFF's collaborations with various research and technology ecosystems contribute to research excellence, translation, commercialisation and industry innovation.

Advancing Nanoscience – In the same month, ICONN 2024 brought together nanoscience researchers, industry professionals and entrepreneurs from around the world. This conference provided a platform to discuss exciting advances in the field. Looking ahead, we eagerly anticipate hosting the ICONN 2026 conference.

Enabling Commercial Potential – The impact of our pre-seed fund ANFF-C continues to grow in the number of clients supported by the fund. Its mission is to unlock the commercial potential of technologies developed using ANFF infrastructure. Notable projects supported by ANFF-C include Ketowhistle, Heart-Dyno, Misti, Interromate, OOXii and Haemograph.

Strengthening the NCRIS Network – The NCRIS Concierge project, funded for 2 years from NCRIS 2023, aims to unite the NCRIS community and create a robust business model for Research Infrastructure Connected, a simple front door for the services available across NCRIS.

Empowering Nanofabrication Knowledge – ANFF Enlightened offers a collection of free nanofabrication courses, equipping you with essential knowledge to support your projects efficiently.

Please join us on this exhilarating journey and witness these brilliant innovations firsthand.

Andrew Brawley, ANFF Chair

› Where to next? That is the question that has been taking up our collective thoughts recently and has led to the theme of this year's case book, '**ANFF NEXT**.'

ANFF has been successful in the past year with state and federal governments investing over $55M into the network, with additional substantial investments confirmed from our institutional partners. This funding will ensure that the plans made in consultation with our community are realised and our capability continues to service the incredible breadth of science and innovation in Australia.

However, we can never stand still. ANFF has just refreshed its strategic plan so that we have a clear mental picture of where we want to have impact and how we plan to achieve it. These clear strategic initiatives will guide us as we look to grow beyond our initial mandate.

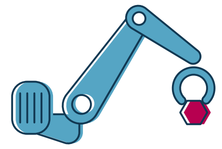
But what is **NEXT** for ANFF? Our support for all areas of research, development and translation is clear. However, there are still gaps. Where are the gaps that ANFF should fill now and where are the openings that ANFF could fill with new services and capabilities? We invite our community to help us identify the opportunities where bringing together ANFF's current experience with new funding and partnerships can accelerate innovation and help feed the array of translation support programs available.

Throughout this Casebook, you will see examples of incredible discovery and translation across many of Australia's critical areas of focus. Moving forward, we will explore with our stakeholders the idea that ANFF can do even more to support this development of new technologies, enable further innovation in existing industries and create a workforce capable of ensuring success in an advanced manufacturing economy. Our ultimate goal is to continue providing unique and valuable services that contribute to a thriving Australia.

Jane Fitzpatrick, CEO

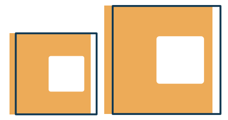
› ANFF IN NUMBERS

FINANCIAL YEAR 2023–2024 WAS YET ANOTHER STRONG YEAR, WITH THE ANFF NETWORK ACHIEVING THE FOLLOWING FANTASTIC OUTCOMES:

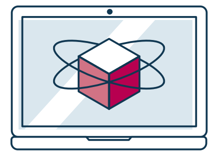


24+ yrs
217,154 hours of tool usage recorded

3,019
clients helped

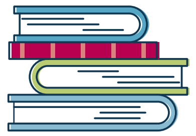


11,677
supplies manufactured



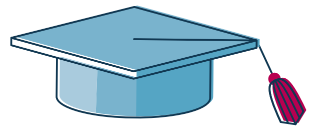
3,858
instances of process training

147
experts on hand to assist clients



602
publications that acknowledged ANFF in the calendar year 2023*

61%
published in the top 10% tier of journals



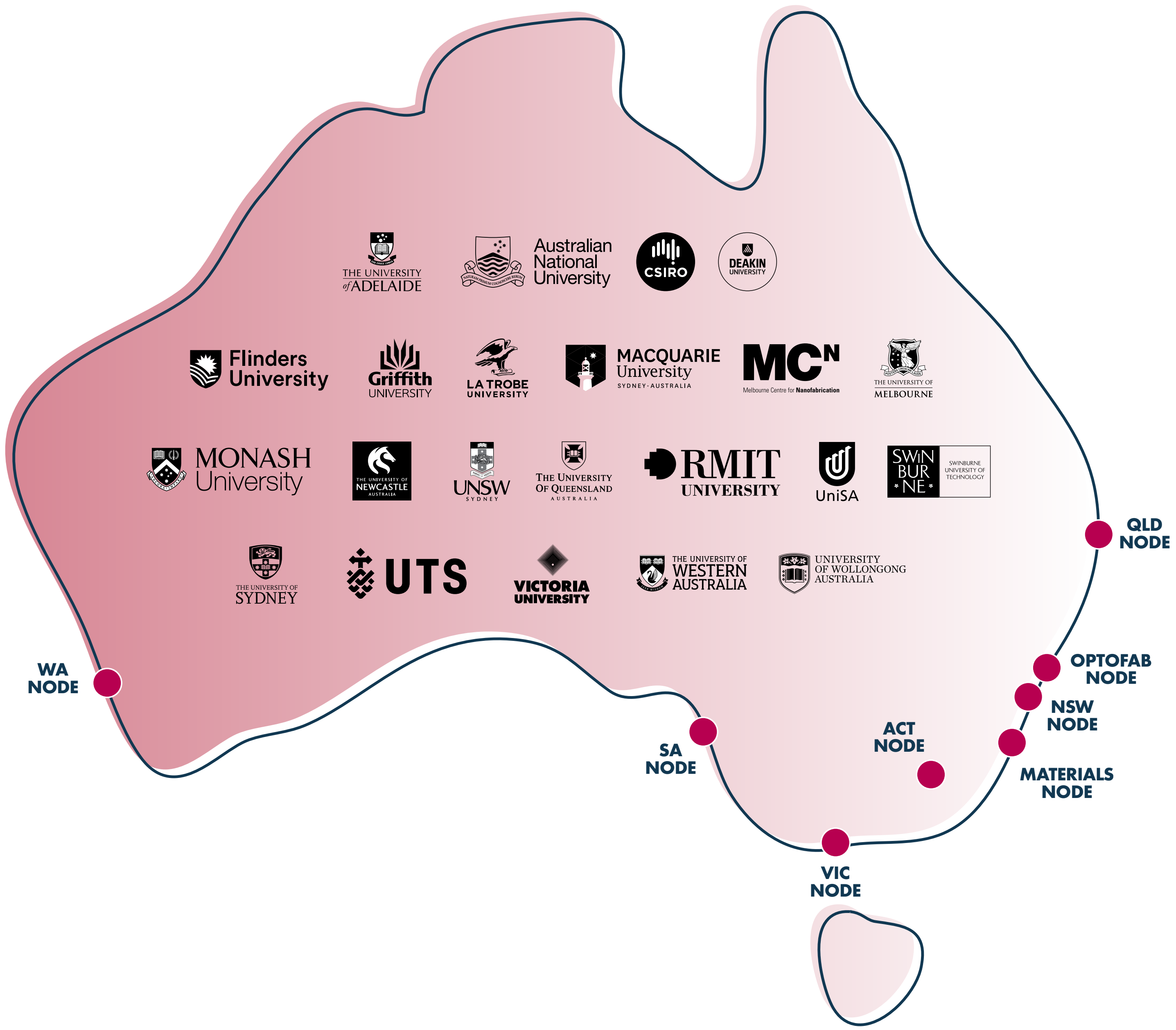
369
hours of training provided by our ANFF Enlightened

*final published publications indexed with Scopus for the year 2023 that acknowledged using ANFF facilities.

› ANFF SNAPSHOT

› ANFF offers affordable solutions to reduce barriers in undertaking R&D and commercialisation by providing open access to research infrastructure for micro- and nanofabrication. ANFF owns and provides access to capabilities that support innovative research, the development of new products, and improvements to current production methods. Distributed across 21 institutional Hubs organized into 8 Nodes, more than 500 tools are available across our network, with each Hub offering complementary, specialized manufacturing facilities supported by our exceptional staff.

Following extensive consultation with clients and other providers over many years, ANFF identified and integrated into its facilities the critical infrastructure required to work at the forefront of science and accelerate the commercialisation of novel technology. These capabilities, including tools for initial prototyping and complete, industry-relevant, process trains within the national research infrastructure landscape, provide extensive value across the innovation ecosystem. Infrastructure landscape, provide extensive value across the innovation ecosystem.



› ANFF STRATEGIC PLAN

OUR PURPOSE

The Australian National Fabrication Facility exists to empower and secure Australia's future by strategically investing in and shaping the research, development and commercialisation system supporting pioneering technologies.

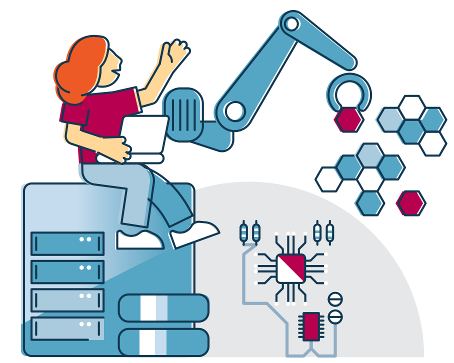
OUR VISION

We are a trusted partner and influential leader across Australia's advanced technologies, principally for micro- and nanofabricated solutions.

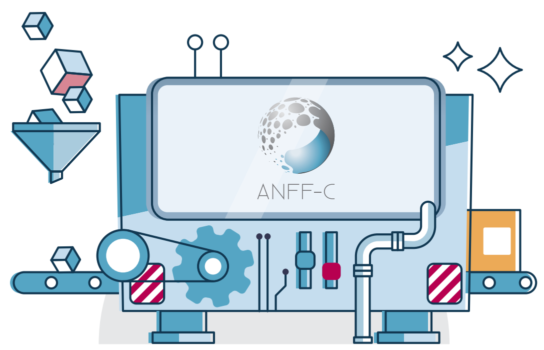
OUR FOUNDATIONS

Our organisation's culture reflects:

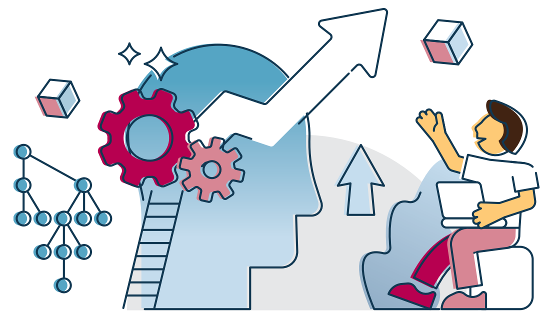
- respect and advocacy for our staff
- dedication to a diverse and inclusive workforce
- excellence in consultation and communication
- commitment to our responsibility towards sustainability
- fostering of a collaborative and productive network through positive engagement.



NATIONAL RESEARCH INFRASTRUCTURE EXCELLENCE



CAPTURING THE BENEFITS



EXTENDING ANFF'S OFFERING

COMMUNICATING ANFF'S VALUE

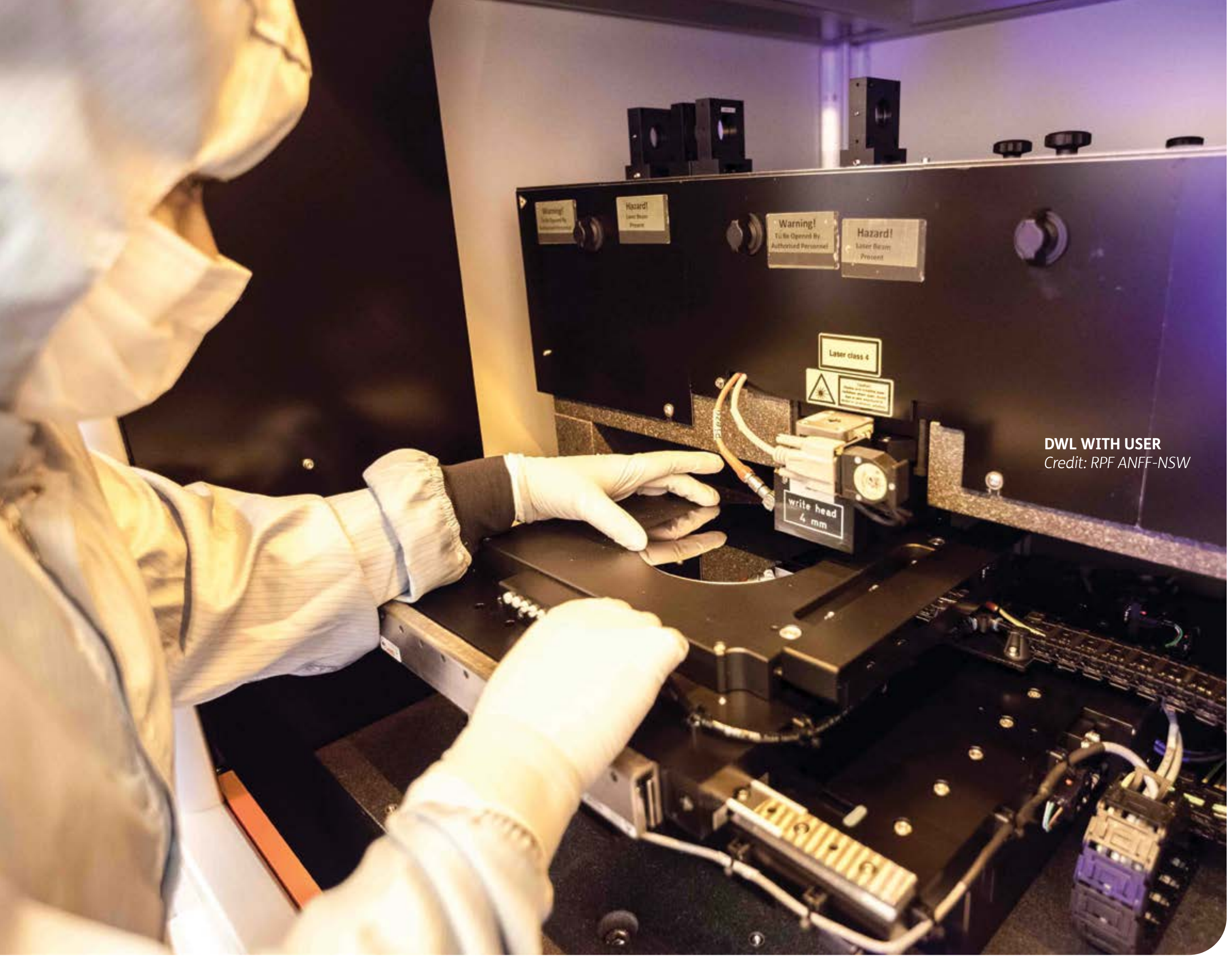
› ANFF, NCRIS AND RESEARCH INFRASTRUCTURE CONNECTED

Founded in 2007, ANFF was one of 9 projects established under the Commonwealth's National Collaborative Research Infrastructure Strategy (NCRIS).

NCRIS gives researchers and industry access to equipment, data, services and expertise to enable world-leading research and development for the benefit of all Australians.

At present, 28 interconnected NCRIS Providers encompass a wide range of scientific and research capabilities, including equipment, laboratories, data repositories and services across various disciplines. This network of Providers plays a pivotal role in advancing Australia's research landscape and driving innovation by enabling researchers and institutions to address complex questions in fields such as health, environmental science, technology and more.

Based on the success of the ANFF Client Engagement Facilitators in helping clients find the best way that ANFF can support their projects, ANFF has led the expansion of this concierge-style service across the entire NCRIS network. Research Infrastructure Connected (RIC) is your primary point of contact for navigating the NCRIS network. The breadth and variety of research infrastructure available through NCRIS can be overwhelming. The RIC website's (riconnected.org.au) advanced search allows you to use keywords and filters to find relevant NCRIS Providers, case studies and contact details. But of course, searching can only get you so far. RIC staff are available to discuss your project with you and help you to find the tools you need and the experts who can shorten the time it takes to get to a working solution. Additionally, RIC staff can provide additional coordinating support for projects that transcend a single NCRIS Provider. Now that Research Infrastructure Connected has been established, ANFF is handing over the reins to fellow NCRIS network member Pawsey Super Computing Centre while ANFF focuses on what comes **NEXT**.



DWL WITH USER
Credit: RPF ANFF-NSW

› PIONEERING SEMICONDUCTOR BREAKTHROUGHS DOWN UNDER

Australia's innovative semiconductor industry, driven by cutting-edge research and ANFF's advanced tools, is poised to transform technology and manufacturing.

Semiconductor devices underpin every aspect of the technologies, services and devices in our daily lives.

Australia has an emerging semiconductor industry built on innovative research and applications in high value niches. Historically strong in photovoltaics and radio-frequency devices with applications in defence, Wi-Fi and communications, Australia is now advancing newer developments in power electronics, LEDs and diode lasers. The country's semiconductor sector is also developing emerging cutting-edge technologies like quantum computers and quantum sensors, Internet of Things, next generation memory and AI devices.

And this is just the beginning. New types of computing architectures, neuromorphic and reservoir computing, 2-D materials and ultra-low energy computers will transform our future.

> The common thread through Australia's semiconductor sector is innovation enabled by access to key research and prototyping tools at ANFF.

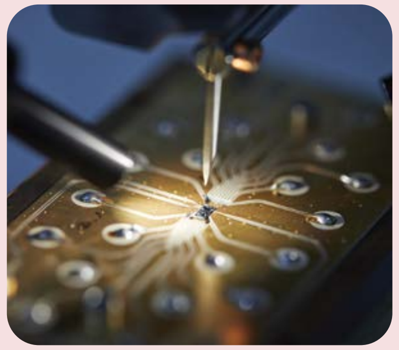
Australia is not a commodity manufacturer of semiconductor devices. Rather, our strengths are in world-first research and new technologies, enabled by access to ANFF's production-grade equipment, and novel semiconductor devices developed for cutting-edge applications.

Australia already has several compound semiconductor manufacturing businesses for products like LEDs, Schottky barrier diodes, FETs, laser diodes and imaging arrays. We also have some prominent quantum computing and quantum device businesses making novel devices using silicon CMOS technologies, including cryogenic applications and silicon photonics. ANFF facilities enable the early research and development required by these businesses, but all must then graduate to offshore fabrication facilities to scale up to commercial production.

> Our country has the opportunity now to build on the capacity and know-how at ANFF and in our universities to meet the scale up and low- and mid-volume manufacturing needs of our technology-led businesses in the semiconductor industry and to grow a local semiconductor manufacturing capability.

Australia boasts an innovative group of IP-based businesses and promising university research, which can support a multi-user compound semiconductor fab for development and low to mid volume production. While the country may not be positioned for a high-volume silicon CMOS fab due to a lack of established infrastructure in this area, the successful ANFF model demonstrates that Australia can thrive in the semiconductor sector through its unique strengths.

An open and shared, multi-user compound semiconductor fab would supercharge Australia's semiconductor industry, with complementary capabilities spread across the country. Aligning with local research and business as well as providing a drive for workforce training and development, a fab facility would extend the existing industry-relevant tools and infrastructure provided nationally by ANFF into onshore product manufacturing and exports.



DEVICE PACKAGING

Our device packaging capabilities include advanced wire bonding, which connects semiconductor chips to circuit boards using thin conductive metal wires. This crucial process enables electrical components to communicate with external systems, ensuring functionality in electronic devices. ANFF also offers comprehensive packaging, testing and validation services for micro- and nanodevice components.

^ QUANTUM SPIN QUBIT DEVICE BEING CONNECTED TO A CIRCUIT BOARD IN PREPARATION FOR QUALITY CONTROL ASSESSMENT.
Credit: Serwan Asaad

UWA MICROELECTRONICS RESEARCH GROUP

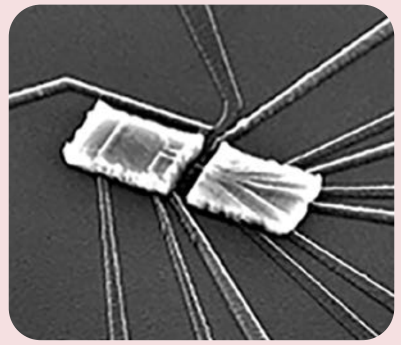
The MRG, led by ANFF-WA Node Director Prof Lorenzo Faraone, undertakes world-leading research in the areas of compound semiconductor device design, simulation, fabrication and characterisation. Their expertise spans high-performance infrared sensors, ultraviolet sensors, high-speed electronics and more. They also excel in developing innovative microelectromechanical systems (MEMS) and infrared sensors.

^ A RIBER 32P MOLECULAR BEAM EPITAXY SYSTEM USED TO CREATE II-VI MERCURY-BASED SEMICONDUCTORS.

SCHOTTKY DIODES

Diodes are semiconductor-based devices that allow current to flow in only one direction and act as one-way switches. Researchers at Griffith University and ANFF-QLD have patented new SiC Schottky diode technology that features improved diode performance and can be manufactured by standard silicon-processing equipment.

^ SiC SCHOTTKY DIODES SHOWN IN VARIOUS STAGES OF MANUFACTURE. EACH ALUMINIUM SQUARE ON THE SiC WAFER IS AN INDIVIDUAL DIODE.



LITHOGRAPHY

ANFF offers advanced lithography capabilities, including masked lithography (standard UV, projection) and maskless lithography (direct write, electron beam, focused ion beam and thermal scanning probe). These techniques enable precise patterning for micro- and nanofabrication, supporting diverse research and development projects.

^ SEM IMAGES OF A SILICON QUANTUM COMPUTING DEVICE AFTER COBALT DEPOSITION VIA MULTILAYERED METAL LIFT-OFF (LIGHT RECTANGLES: COBALT).
Credit: UNSW

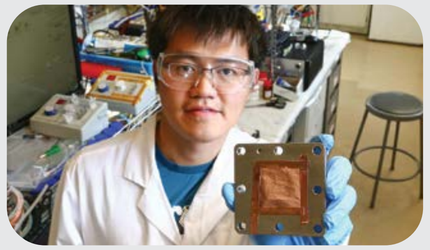
› EUREKA PRIZES

The Australian Museum's Eureka Prizes honour scientific excellence. The numerous ANFF-enabled Eureka Prize Winners and Finalists highlight fabrication's crucial role in innovation. We proudly celebrate our clients recognised by this esteemed platform.

WINNER

Macquarie University Eureka Price for Outstanding Early Career Researcher (2023) – Dr Fengwang Li

Dr Li (USYD) is creating an affordable, efficient process to convert waste carbon dioxide into ethylene, a basic component of plastics, using renewable energy. His method brings real-world carbon capture and utilisation a step closer, offering emissions-intensive industries a path towards net-zero.



Credit: Tyler Irving

FINALISTS

ANSTO Eureka Prize for Innovative Use of Technology (2024 Finalist) - UNSW Night Time Solar Team

Led by Prof Ned Ekins-Daukes, the UNSW Night Time Solar Team has developed groundbreaking technology to generate solar power at night. This innovation uses a semiconductor device to harness thermal infrared radiation from the Earth's cooling surface after sunset, producing electricity.

Macquarie University Eureka Prize for Outstanding Early Career Researcher (2024 Finalist) - Dr Ann-Na Cho

Using stem cell biology and tissue engineering, Dr Cho (USYD) has invented a lab-grown human brain model that enables more comprehensive neuroscientific research than traditional animal models. Read more about her innovative tissue-engineered models that mimic the human brain on page 26.

UNSW Eureka Prize for Scientific Research (2024 Finalist) - Prof Anita Ho-Baillie

Perovskite crystals are set to transform solar cell technology. Prof Ho-Baillie (USYD) has developed advanced solar cells that pair silicon with perovskite, enhancing their durability against heat and humidity. This innovation aligns with stringent international standards, propelling perovskite cells towards market readiness.

University of Sydney Eureka Prize for Sustainability Research (2024 Finalist) - Prof Xiwang Zhang and Dr Zhuyuan Wang

Tackling 2 pressing global issues – climate change and renewable energy – Prof Zhang and Dr Wang (UQ) have developed an electricity nanogenerator that simultaneously captures CO_2 and generates electricity, providing a clean and green method for energy generation.

Eureka Prize for Emerging Leader in Science (2024 Finalist) - Prof Julia Reisser

Prof Reisser (UWA), co-founder and co-CEO of ULUU, leads the charge against ocean plastic pollution. ULUU is a Perth startup that turns seaweed into biodegradable, climate-positive alternatives. Its prototype yarn is spun using ANFF-VIC Deakin's melt-spinning capability.

ANSTO Eureka Prize for Innovative Use of Technology – Perovskite Solar Window Team (2023 Finalist)

Cities will need to find new sources of renewable energy to reduce the impacts of climate change. The Perovskite Solar Window Team (Monash University and CSIRO) has developed a next-gen, perovskite-based, solar window technology. These materials have the potential to transform the windows of urban buildings into power generators.

Macquarie University Eureka Prize for Outstanding Early Career Researcher (2023 Finalist) - Dr Jiawen Li

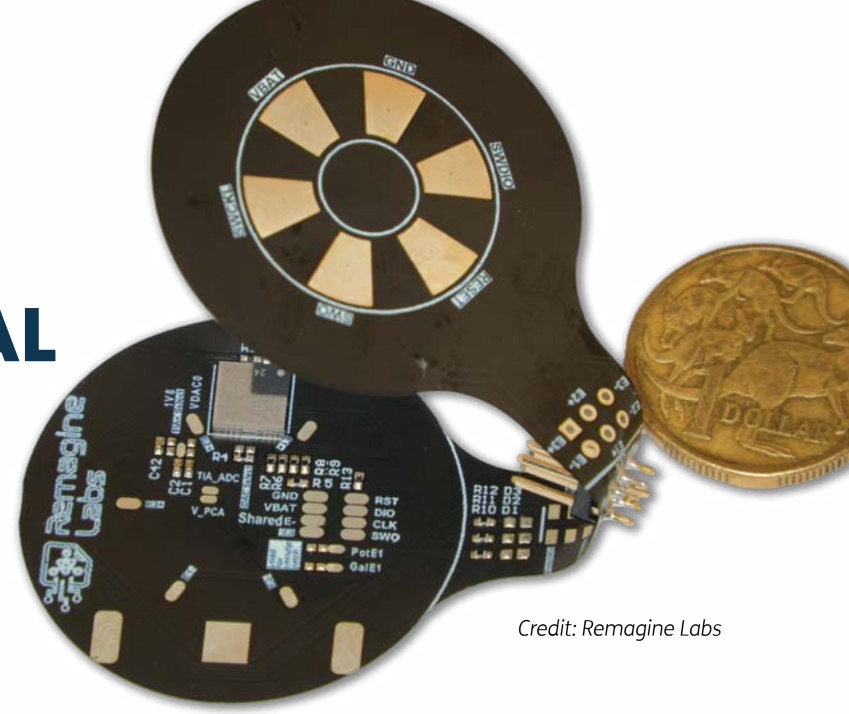
Dr Li (UoA) invented a microendoscope as thin as a strand of hair and powerful enough to accurately detect signs of heart disease. The highly sensitive 3D-printed imaging device has the potential to provide cardiologists with high-resolution and accurate molecular insights.

Eureka Prize for Emerging Leader in Science (2023 Finalist) - A/Prof Laura Bray

A/Prof Bray (QUT) is a rising leader addressing the significant need for new preclinical models in biomedical research. Applying state-of-the-art bioengineering techniques, she has developed sophisticated 3D human tissue models as innovative devices for drug and toxicity testing.

ANFF helps innovators turn ideas into reality. Our team will keep enhancing our services to support future Eureka Prize winners.

› WEARABLE ELECTRO-PHARMACEUTICAL TRANSFORMS EPILEPSY CARE



Credit: Remagine Labs

Remagine Labs has developed the world's first smart electro-pharmaceutical capable of transporting epilepsy drugs through the skin with personalised control of dosage.

Epilepsy is a disabling, long-term, neurological condition characterised by recurring, unprovoked seizures. Epilepsy is the fourth most common brain disorder in the world and impacts around 3 in every 100 Australians, with more than 10,000 cases per year. Seizure disorders can be caused genetically or by anything that damages the brain, including injury, stroke or brain diseases like dementia. While anyone can develop epilepsy, it is more commonly diagnosed in young children and older adults.

While epilepsy cannot be cured, seizures can be controlled. Medications are the first choice for epilepsy treatment. While common drugs used to treat epilepsy can be very effective when taken properly, 80% of patients don't take the right amount of medication. Successful management depends on consistent delivery of medications at the right dosage over time. Patients often have difficulty remembering to take their medication, which can lead to breakthrough seizures. Approximately one third of people living with epilepsy have uncontrolled seizures which can lead to hospitalisations, reduced quality-of-life and even death.

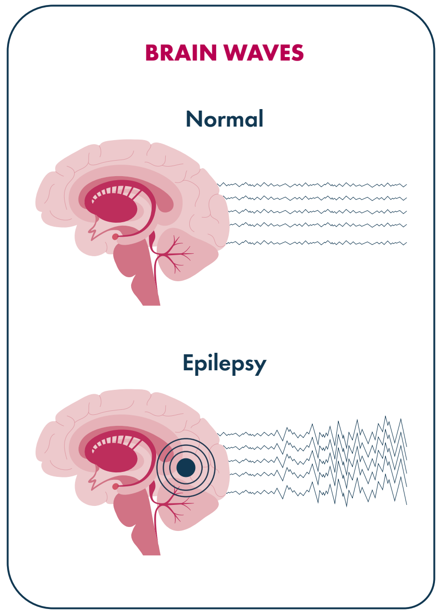
The brainchild of Prof Stan Skafidas at the University of Melbourne, Remagine Labs has combined expertise in printable electronics, drug formulation and transdermal drug delivery with proven commercialisation leadership to develop a smart, electro-pharmaceutical wearable, the world's first capable of administering epilepsy drugs through the skin for a week-long period.

Existing transdermal techniques, such as those found in nicotine patches, rely on passive diffusion that significantly limits which molecules can be delivered transdermally. What makes Remagine Labs' patch unique is that the release of medication can be actively controlled, allowing adjustment based on patient weight or other factors, offering a personalised approach to drug delivery.

Validated at the Monash Institute of Pharmaceutical Sciences using a porcine skin model, the company has demonstrated the ability to deliver the target drug at amounts greater than 10X that of passive patches, reaching the required therapeutic levels in the bloodstream more consistently than their oral counterparts.

Remagine Labs has worked closely with ANFF-VIC Node Director Prof Nico Voelcker and the Melbourne Centre for Nanofabrication to produce novel electrode designs for the transdermal electro-pharmaceutical, applying coatings of various materials to ensure long life and safety when used by patients on the skin. The team has also begun fabricating new micropillar designs suitable for larger molecules that cannot typically pass through the skin. A $3M grant from the Australian Government Cooperative Research Centres Project (CRC-P) scheme is enabling further development of the patch in preparation for clinical trials.

Remagine Labs' innovative wearable device significantly enhances patients' ability to adhere to their prescribed medication regimens, thereby reducing the incidence of breakthrough seizures and improving overall health outcomes. By integrating electronic control capabilities with advanced AI algorithms, this technology heralds a new era of personalised drug delivery, offering hope for more effective and tailored epilepsy management in the future.



PRINTED SOLAR PANELS BEING INSTALLED ON AN INDUSTRIAL BUILDING ROOFTOP.
Credit: Kardinia Energy

› ROLLING OUT SOLAR

Kardinia Energy's innovative printed solar technology will revolutionise solar installations, making them viable for previously unsuitable commercial and industrial spaces.

As of early 2023, over 3.4 million traditional silicon solar power systems have been installed on Australian homes and small businesses, continuing the technology's widespread adoption in this country.

However, some roofs simply aren't suitable for solar panel installation due to their orientation or structural integrity. Many industrial roof spaces can't take the weight of traditional solar panel arrays, which weigh 20 kilos per square metre, including 100 million square metres of low weight-bearing rooftops in Australia and 4 billion globally.

Kardinia Energy's next generation low-weight, flexible, printed solar will expand solar installation into previously unsuitable spaces. This technology has been developed for over 25 years at the University of Newcastle led by Prof Paul Dastoor and his team at the Centre for Organic Electronics.

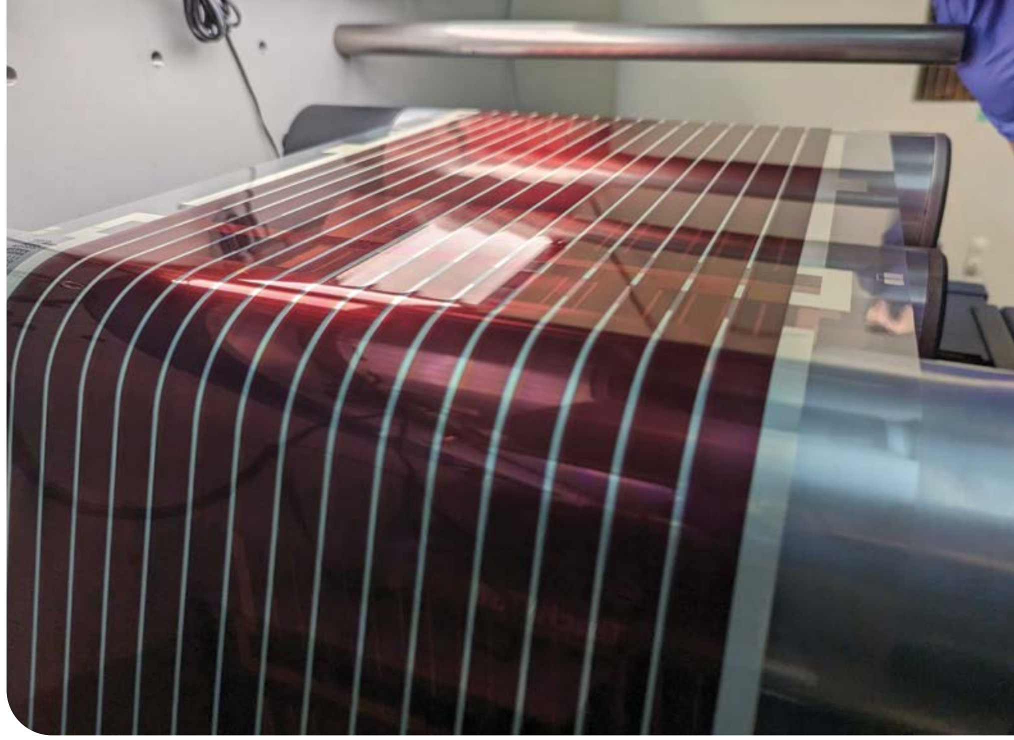
Kardinia Energy's solar panels use organic photovoltaic (OPV) materials, a fairly recent advancement. Unlike silicon-based panels, their printed solar panels consist of organic semi-conducting polymers on recyclable PET plastic. These materials are abundant and avoid the energy-intensive manufacturing of silicon panels.

Printed solar technology employs a special ink that converts light into electricity. The solar ink contains semiconductor materials and electrodes necessary for generating solar energy.

This solar ink is printed onto flexible surfaces such as plastic using commercial roll-to-roll (R2R) printers, like those for printing newspapers.

The resulting printed solar panels are as thin as a sheet of paper and weigh only 300 grams per square metre. The low cost of production is another significant advantage. Printed solar can be made at a cost of less than US$10 per square metre.

The biggest impact of this technology is expected in the commercial and industrial space. Kardinia Energy's printed solar is distinguished by its lightweight nature, making it ideal for structures that cannot support the weight of traditional solar panels, such as commercial and industrial rooftops. This innovation addresses the challenges of retrofitting buildings for solar energy and will make the adoption of solar more economical for industrial building owners.



UPPER: PRINTING PROCESS FOR R2R SOLAR PANELS
Credit: Kardinia Energy

We often think of solar installations as 'one and done,' but the true lifespan of silicon solar panels is more like 10 years. Older solar installations are aging out. Silicon-based solar technology is difficult to recycle, leading to impending environmental issues as these systems reach the end of their life. In complete contrast, Kardinia Energy's printed solar panels are 100% recyclable.

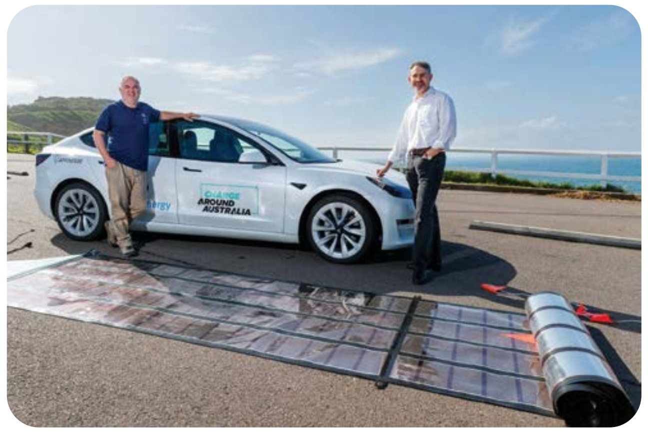
The technology can operate off-grid, which is particularly beneficial for remote communities and industrial operations that rely on higher-cost energy sources.

The printed solar panels are also compatible with existing solar infrastructure and can be used in both grid-connected and independent systems.

Kardinia Energy's panels are currently produced using the R2R print facility at the ANFF-Materials University of Newcastle Hub, but their success to date means they need more panels than the pilot manufacturing line can produce.

Kardinia Energy is partnering with the Trailblazer for Recycling and Clean Energy (TRaCE) to build Australia's first printed solar manufacturing facility in Newcastle – a proof-of-concept for scaled-up manufacturing production. ANFF-Materials will help with the transition and the transfer of knowledge from ANFF engineers to Kardinia Energy employees and will continue to support the development and innovation of the infrastructure required for ink synthesis and characterisation of solar harvesting materials.

The impact of the new Kardinia Energy R2R solar panel print facility in the Hunter Valley will be felt across the Australian manufacturing sector, leading to the creation of numerous skilled employment opportunities and opportunities for new companies. The facility will also foster innovation across the organic electronics sector and support translation of novel technologies to commercialisation.



UPPER: PRINTED SOLAR PANEL ARRAY
LOWER: POWERING A TESLA IN THE CHARGE AROUND AUSTRALIA TOUR
Credit: Kardinia Energy

› PROVIDING THE SPARK FOR RICHER SOIL

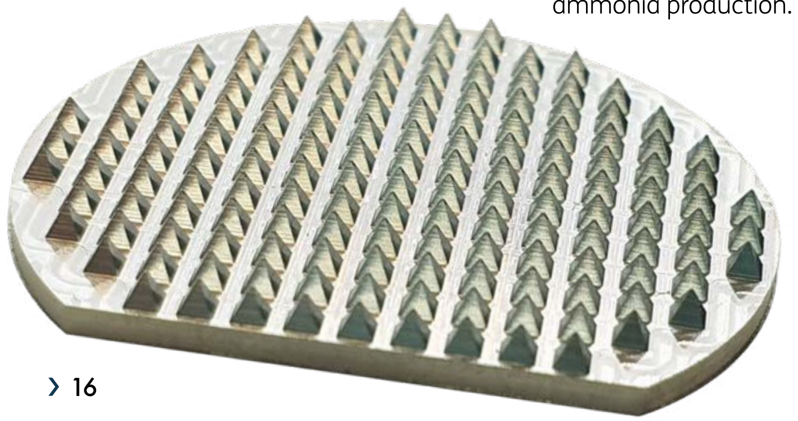
Pioneering engineers have redesigned plasma microreactors to transform hydrogen or air into customised fertilisers.

Fertilisers are essential for enhancing crop yields and ensuring food security, making their availability crucial for Australian agriculture. A large part of our fertiliser is imported, including all of Australia's granular urea supply for nitrogen-based fertilisers, over 110 million tonnes annually from the Middle East, Southeast Asia and China.

The fertiliser supply chain is vulnerable to world events. For example, in 2022, the Nord Stream pipelines that transport natural gas from Russia to Europe were sabotaged, and 20% of the global ammonia (NH_3) supply disappeared overnight.

Developing sovereign capability in fertiliser production is critical for Australian agriculture. Currently, ammonia is produced by the Haber-Bosch method from hydrogen extracted from natural gas and nitrogen from air. The process is centralised, highly energy-intensive and relies heavily on natural gas, producing carbon dioxide (CO_2) emissions that lead to approximately 3% of the world's carbon emissions.

PYRAMID-SHAPED ELECTRODES USED IN PLASMA-ASSISTED PRODUCTION OF AMMONIA.
Credit: Volker Hessel



Efforts are being made to develop more sustainable methods, such as using a plasma-assisted chemical reaction with renewable hydrogen, to reduce the environmental impact of ammonia production.

At the forefront of these innovations are Prof Volker Hessel and his team at the University of Adelaide and the University of Warwick. They have exploited uniquely designed micropyramid-disk plasma reactors to produce customised nitrogen-based fertilisers for Australian farmers.

A microplasma reactor is a device that generates tiny, highly energised gas plasmas confined to small spaces to drive chemical reactions efficiently. Conceptualised by Warwick's Prof Evgeny Rebrov and Dr Nima Pourali, their pyramid-shaped electrode design narrows the electrode gaps to less than one millimetre and focuses the plasma energy at the tiny tips.

These small, stable charge points allow energy to spread efficiently through intensified electric field zones, making the conversion of hydrogen and air into NH_3 more effective. This process significantly reduces energy consumption and emissions compared to traditional flat electrodes, offering a more economical solution for ammonia production.

The first fully functional prototype of this microreactor was crafted using the capabilities available at ANFF-SA. Having the microreactors machined locally by world-leading microfabrication experts saved the research team significant time and costs during their experimental work, while increasing project output and innovation. The pyramid-shaped electrodes were ideal for basic study of the chemical process and secured long-term funding for alternative plasma microreactor development.

Plasma microreactors can be scaled up to production scale for distributed manufacturing, like their flow chemistry counterparts in pharmaceutical industrial production, providing the means for locally or regionally produced ammonia that could free Australian agriculture from external global forces that affect availability and price.

Prof Hessel is partnering with Australian AgTech companies FarmN in Adelaide and Plasma-Leap in Sydney to commercialise the plasma-fertiliser technology. A field trial of an N-fertiliser-producing benchtop reactor has been installed in the Clare Valley in South Australia at a Seppeltsfield vineyard.

Plasma technology will revolutionise Australia's fertiliser industry by enabling on-site production, reducing reliance on traditional supply chains and aligning with sustainability goals. While cultural and technological shifts are necessary for adoption, Australian farmers are known for their openness to innovation, making this transition promising and impactful for the future of agriculture.

› UPCYCLING LOW-VALUE WOOL

Mud to Marle aims to turn waste fibres into wool and cotton blend products that are spun, knitted, woven and dyed in Australia.

Australia is renowned for its wool, supplying millions of kilograms of prized raw fibre globally each year. Wool fibre length plays a crucial role in determining its suitability for various applications. Long-staple wool is preferred for spinning into yarns used in textiles, while short-staple wool from the sheep's legs is considered low quality and sold at much lower prices.

The Mud to Marle project was inspired by a wool grower in NSW whose farm was flooded, resulting in mud-matted leg wool. 'Marle' refers to the colour effect in knitted fabrics created by blending 2 or more differently coloured yarns into a single thread.

Polyester marles pose significant environmental challenges. Polyester, used in knitted marle and stretch woven fabrics, makes up 60–70% of global textiles and has similar environmental impacts to plastic. The other marle component, cotton, is dyed to provide the thread's colour. The dyeing process for cotton uses toxic synthetic dyes, consumes vast amounts of fresh water and requires significant energy for heating and washing.

Additionally, most Australian wool and cotton processing occurs offshore due to the lack of commercial cotton spinning facilities in Australia. Cotton fibre is exported for yarn production and then re-imported for fabric manufacturing, adding to the environmental footprint.

Creating onshore sovereign capability to produce an environmentally friendly, natural fibre marle yarn is essential to enabling circularity in the textile industry.

Mud to Marle is developing a plastic-free, durable, comfort stretch woven textile using wool for stretch and cotton for durability. It introduces a new wool-only dyeing method to reduce the carbon footprint. By using lower-grade, shorter wool to create a yarn with the lowest impact milling footprint possible, Mud to Marle will create a premium fabric that capitalises on the natural properties of both fibres.

Funded by Country Road's Climate Fund, the Mud to Marle project is led by social enterprise Full Circle Fibres in collaboration with Deakin University's ANFF-supported Institute for Frontier Materials (IFM) and LoomTex, the Australian Textile Mill & Dyehouse.

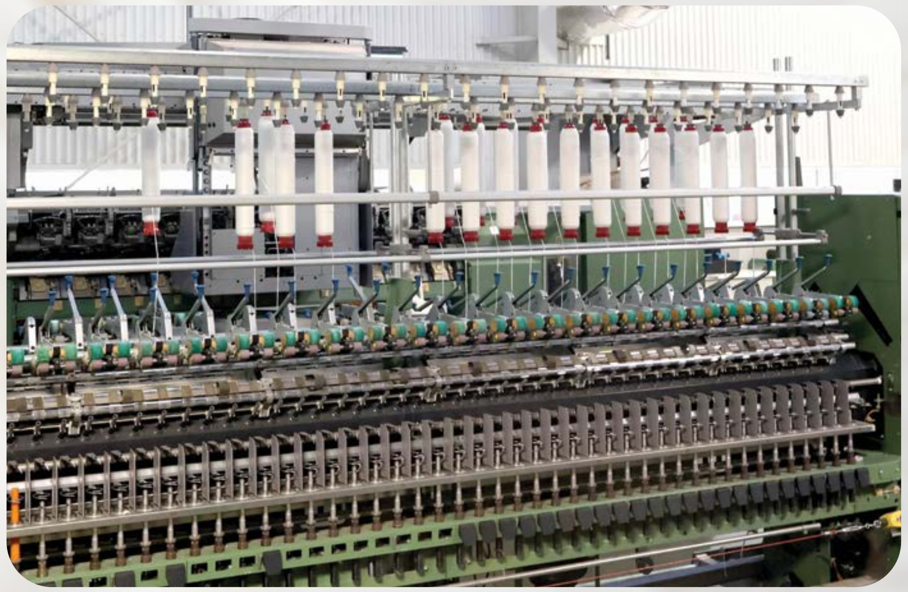
The project's goal is to trial an end-to-end marle yarn manufacturing process through sourcing Australian-grown wool and cotton with all production steps performed entirely onshore.

The wool used in their marle yarn is shorter, lower value fibre, blended with cotton for functionality and to prevent wool shrinkage. Wool provides close-to-skin comfort, while cotton adds strength. The dyeing process, in which only 30% of the wool is dyed, significantly reduces water and chemical use compared to traditional cotton dyeing methods.

Wool fibres are ethically sourced from Michell Wool in South Australia and then shipped to Geelong for yarn production. LoomTex dyes the wool fibres using more environmentally friendly methods. Although wool is not usually spun on cotton-spinning equipment, IFM's Future Fibres Institute operates the only cotton-spinning facility in Australia and has adapted it to also spin wool. The resulting marle yarn will enable production of unique woven and knitted natural-fibre fabrics that can be composted or recycled.

This innovative marle yarn demonstrates an advance in textile manufacturing, showcasing the ability to process underutilised wool on automated cotton-spinning equipment. By combining wool and cotton, the yarn gains the advantages of both. All manufacturing stages occur in Australia, proving that low-impact, circular textile production is viable for Australia's garment industry.

Onshore yarn manufacturing is crucial for developing resilient local supply chains amid global events. The Mud to Marle project demonstrates the potential for creating truly 'Made in Australia' fabrics.



› MODERN ALCHEMY: TURNING HYDROGEN INTO ECO-STEEL

Hysata's energy-efficient electrolyser for hydrogen production paves the way for eco-friendly iron and 'green' steel manufacturing.

When gazing at a city skyline or cruising across bridges and overpasses, we often overlook the critical role of steel in framing our way of life. From high-rise and residential buildings to industrial facilities, railways and our favourite footy stadiums, steel forms the scaffolding of where we live, travel, work and play.

Steelmaking begins with the smelting iron ore (Fe_2O_3) to produce pure iron. In this process, coal strips oxygen from iron ore in a reduction reaction, leaving behind metallic iron. An electric arc furnace then purifies iron into raw steel. Unfortunately, the use of coal generates carbon dioxide (CO_2). For every tonne of steel, 2 tonnes of CO_2 are produced. Steel production, in fact, accounts for 8% of global greenhouse gas emissions annually.

Every industry must reduce its carbon footprint to mitigate climate change. The decarbonisation of traditional steelmaking methods is crucial to significantly decrease CO_2 emissions.

> 'Green' iron is created when hydrogen (H_2) replaces coal in the reduction of iron ore.

Using H_2 to create metallic iron decarbonises steelmaking because water is produced instead of CO_2. The H_2 needed for this eco-friendlier iron manufacturing process is produced by electrolysis, in which an electric current splits water into hydrogen and oxygen.

An electrolyser cell has two electrodes (one for hydrogen, one for oxygen) surrounded by an electrolyte and separated by a membrane. As current flows, H_2 and O_2 gases are produced on the surface of the electrodes, forming as bubbles that waste electricity. This is like blowing bubbles as children, which took energy and made our cheeks sore. The membrane prevents these gases from mixing back together but has high electrical resistance, further wasting electricity. Current electrolysers are complex, costly and only 75% efficient, with 80–90% of the cost of H_2 production coming from the electricity bill.

To realise the goal of green iron, electrolysers that use less electricity and greatly lower H_2 production costs are needed.

> Hysata is a green energy company bringing down the cost of H_2 production with its revolutionary breakthrough in electrolyser technology that solves the root causes of inefficiency.

Its Capillary Fed Electrolyser (CFE) employs a low-resistance, thin membrane (only 2x the thickness of a human hair) that wicks the electrolyte between the electrodes, producing H_2 and O_2 gases without making bubbles.

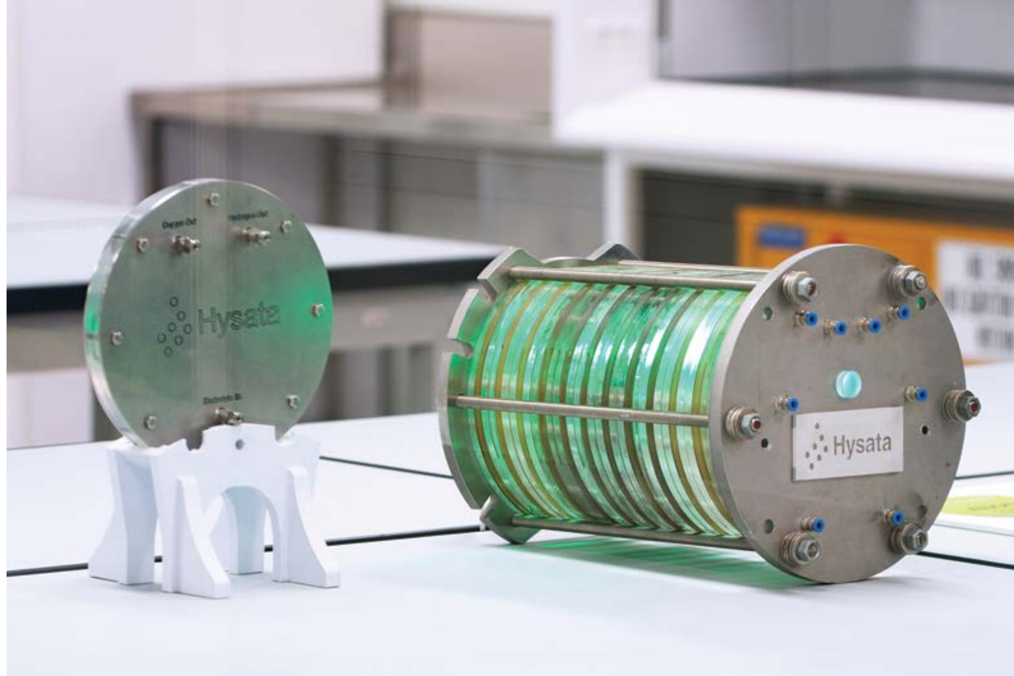
Hysata's invention is the world's most energy-efficient electrolyser. By combining a low-resistance membrane with bubble-free gas production, electrical resistance is significantly reduced. In CFE, 95% of the supplied electricity is converted to electrolysis. This efficiency gain pays off – Hysata's system requires 20% less power to make H_2.

The ANFF-Materials Node at the University of Wollongong has been an invaluable partner for Hysata in the development of the electrolyser cell, aiding in fabricating, testing and troubleshooting the electrolyser's design.

Hysata's H_2-production platform is based on a CFE the size of a dinner plate that contains the separation membrane and supporting framework. The cells can be stacked by the hundreds in arrays of steel pipes. This smart, modular design makes manufacturing easy to automate and scale up.

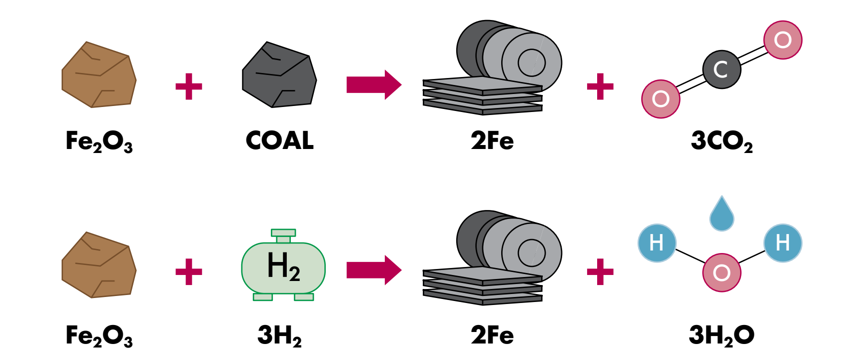
Growth in Australia's wind and solar energy infrastructure will increasingly power electrolysis systems, reducing fossil fuel dependence for H_2 production. Hysata has a clear path to deliver world-first electrolyser performance that produces the lowest cost green hydrogen. Expanding production at its beachside manufacturing facility in Wollongong, Hysata will provide valuable Australian job opportunities in a sector that will change the world.

Decarbonising the steel industry is a formidable challenge. But with green energy pioneers like Hysata, supported by policies such as the Future Made in Australia, we will emerge as a global leader in the green manufacturing transformation.

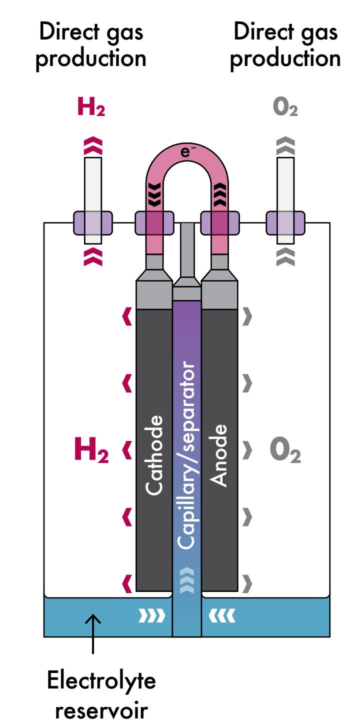


HYSATA DEVICE
Credit: Hysata

CHEMICAL EQUATIONS FOR IRON ORE REDUCTION



CAPILLARY-FED ELECTROLYSIS (CFE) CELL



THE FUTURE OF FARMING ON OCEAN WAVES

University of South Australia researchers' floating vertical sea farms harness the sun and sea to power self-sustainable greenhouses and combat growing global shortages of freshwater and suitable farmland.

Farmers tending an armada of greenhouses, floating along the coastline, with solar-powered desalination providing freshwater for self-irrigation. This futuristic vision is often connected with sci-fi movies and books.

As freshwater and suitable agricultural land diminish in quantity and quality, our planet becomes less capable of sustaining the world's growing population. Pioneering AgTech researchers Prof Haolan Xu and Dr Gary Owens from the University of South Australia are turning science fiction into real-world solutions for global water shortages and the growing scarcity of arable land.

By 2050, approximately 2.4 billion people are likely to experience water shortages (United Nations) as the global supply of water for agricultural irrigation is expected to decline by around 19%. While Australia is ranked 6th in the world for the most arable land, extreme weather, land and soil degradation, spreading of toxic substances and urbanisation are driving a decline in high-quality, arable land suitable for farming.

Prof Xu and Dr Owens' research harnesses the power of sun and sea in their vertical sea farm system. The farm consists of 2 chambers: an upper greenhouse and lower evaporator-based water harvest chamber.

Solar evaporators in the bottom chamber soak up the seawater, trap the salts and release clean water vapor into the air. This vapor then condenses on water belts and is transported to the soil in the upper greenhouse. Their elegant design takes into consideration varying solar light angles, ensuring that the evaporator, even under a double structure, receives sufficient sunlight throughout the day for effective operation.

The material used in the system is selective, allowing nutrients to traverse chambers while separating out potentially toxic salts, ensuring the safety and efficacy of the system for plant growth. Different materials could be deployed for various water sources, not just seawater, but also river water, salt lakes, borewater and even industrial wastewater, which opens possibilities for its application in different environments.

In successful field tests, 3 common vegetable crops – broccoli, lettuce and bok choi – were grown in their vertical sea farm system without maintenance or additional clean water irrigation.

While the design is only proof-of-concept at this stage, the vertical sea farm system has great potential for scalability due to its modular design. This scalability is crucial for adapting to various farming needs and environmental conditions, allowing farmers to start small with high-income crops and expand gradually, catering to their production desires.

With material characterisation support from ANFF-SA, the next stages of development will involve enlarging the prototype and creating larger modules that connect to form multi-unit systems, eventually leading to a network of floating domes across the water.

Combating the global decline of arable land due to salinity issues and contamination from industrial activities, the floating sea farm provides promise to utilise ocean spaces for farming. This innovative approach not only addresses the pressing challenges of water scarcity and diminishing agricultural land but also paints a vivid picture of a sustainable future, offering hope for a future where humanity can thrive despite the environmental challenges we face.

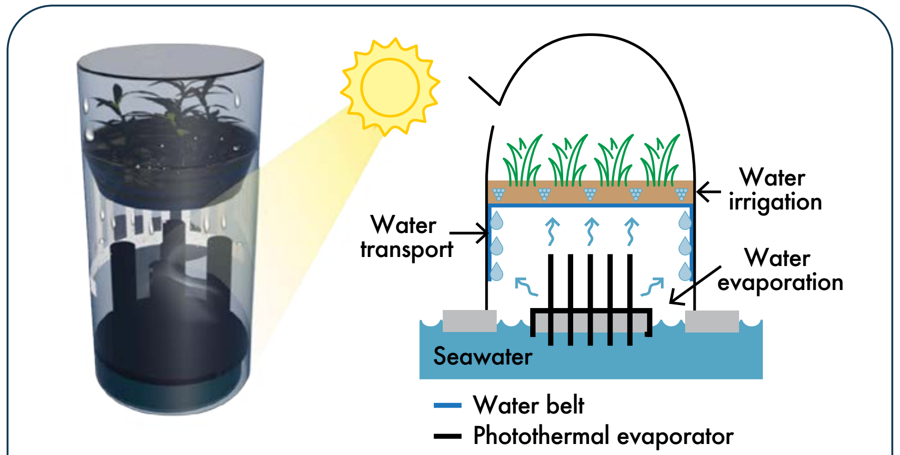


ILLUSTRATION OF THE DOUBLE-LAYERED VERTICAL SOLAR SEA FARM
Credit: Chem. Eng. J 2023 473:145452

MICROPAPER AND LASER PEN

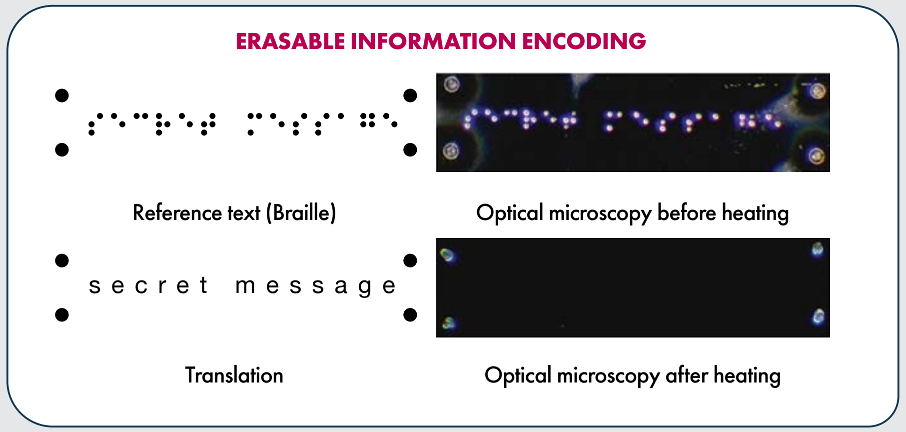
Flinders University researchers have discovered a light-responsive, inexpensive sulphur-based polymer that can be written upon by low-power, visible-light lasers – providing a new surface for erasable information storage.

Advances in data storage have been driven by evolution in printable and erasable materials.

Hard drives function by storing data on a disk's magnetic layer. When you save a file, the information is transformed from human-readable text into binary code (1s and 0s). The read-write heads then create a permanent magnetic field on the disk to store this data. Deleting a file doesn't erase the data; it merely removes the directory path to it. The binary data remains on the disk until it is overwritten by new data. The disk is printable, but not truly erasable.

Used widely in a variety of devices such as smartphones and USB drives, flash memory has recently emerged as a form of data storage that will eventually take us away from storage involving spinning disks and other moving parts. Rather than using a read/write head to write data to a magnetic layer of material, the data is written to an array of memory cells via electrical charges. The memory can be electrically erased and reprogrammed.

The next level in memory storage will come from the physical encoding of information in polymeric materials that can be modified by lasers. Many polymer films can be modified by direct laser lithography and laser surface ablation to make channels, lines, holes, spikes or other surface architectures with exquisite spatial control on the micro- and nanometre scales. However, these techniques usually require high power and high energy consumption, leading to higher costs to create modifications in these polymers. The challenge is to find a polymer film that is both writable with low-power systems and erasable.



THE BRAILLE NOTATION OF 'SECRET MESSAGE' ENCODED ONTO THE SULPHUR-BASED, ERASABLE FILM.
Credit: Angew. Chem. Int. Ed. 2024 63:e202404902

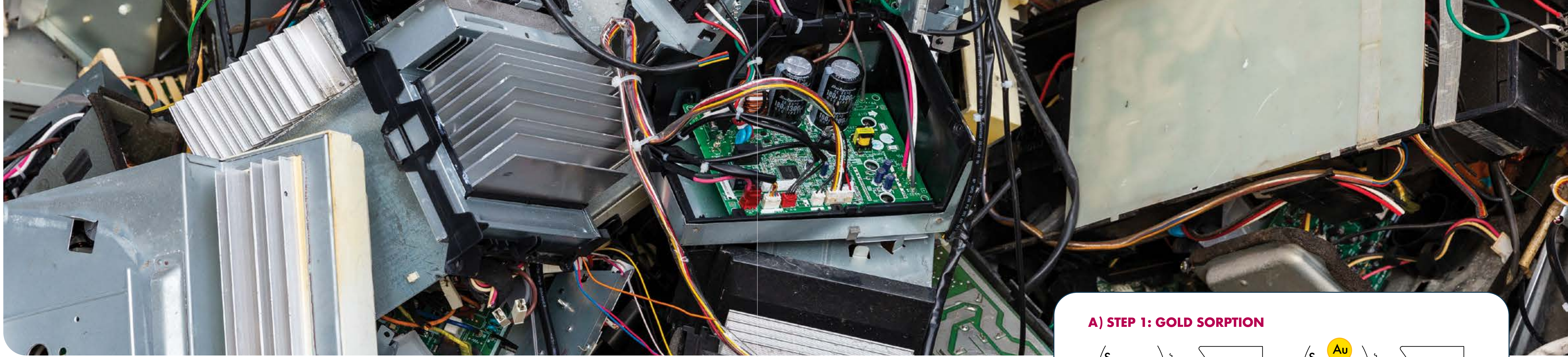
A team of researchers at Flinders University, led by Prof Justin Chalker, have met and overcome this challenge with their discovery of a low-cost, sulphur-based polymer that is unusually sensitive to laser light. As soon as a low-power laser touches the surface, it causes a local response in the polymer such as swelling or the etching of a pit.

The polymer's interaction with low-power light allows for the creation of surface microstructures. Spearheaded by PhD candidate Abigail Mann, with the support of ANFF-SA Flinders spectroscopist Dr Jason Gascooke, the Flinders team analysed how laser modifies the polymer and how to control the type and size of the modification. Ms Mann showed that the modifications were rapid, with exposure times on the millisecond to second timescales. Controlling the power, wavelength, beam diameter and writing speed enabled the installation of spikes, raised dots, pits, channels and holes on the polymer surface.

The outcome is a new technology for writing precise patterns on polymeric materials. Another important outcome is that information encoded on their writable polymer can be subsequently erased.

To illustrate the erasable information storage capability of their sulphur-based films, the team used laser to create a series of raised dots encoding the micro-scale Braille text 'secret message' on the polymer surface. The polymer film was then heated in a 160 °C oven until the raised dots were erased. This erasable information-encoding process constitutes a new direction in photoresponsive materials, with benefits in the simplicity of the material synthesis and use of low-power lasers.

The impact of this sulphur-based, direct write polymer extends far beyond erasable data storage, providing new possibilities for patterning surfaces on biomedical devices and new ways to make micro- and nanoscale devices for electronics, sensors and microfluidics.



› STRIKING GOLD IN OUR DISCARDED ELECTRONICS

Flinders University researchers have discovered a unique class of recyclable sulphur polymers that can recover precious metals and heavy metals from e-waste and gold mine tailings.

As technology evolves at a breakneck pace, the lifecycle of electronic devices has become alarmingly short. With 1 in 3 Australians upgrading their smartphones every 2 years or sooner, and the pandemic-driven surge in computer purchases, the volume of electronic waste (e-waste) has skyrocketed. Surprisingly, 7% of the world's gold is currently sitting in disused electronics, yet only about 20% of e-waste is effectively recycled. This presents both a significant environmental challenge and a golden opportunity.

E-waste is a rich source of precious metals, such as gold and copper, and heavy metals. In addition, the processing of gold ore in traditional gold mining creates waste material known as mine tailings that still contain trace amounts of gold. These piles of slag also harbour other valuable metals, presenting a dual opportunity for recovery and environmental remediation.

Prof Justin Chalker's team at the Institute for Nanoscale Science and Technology, in a project led by Dr Thomas Nicholls and PhD student Jasmine Pople, is pioneering a new class of tri-sulfide polymers to enhance recovery of metals from solutions. These polymers are synthesised using elemental sulphur (S_8), a byproduct of petroleum refining, so the sulphur is both cheap and abundant. The resulting polymers boast a high affinity for precious metals due to their high sulphur content and numerous S-S bonds.

The high affinity of S-S bonds for metal ions makes these polymers excellent ion sponges.

Gold ions adhere to the sulphur atoms in the polymer, allowing for selective recovery. The monomer can be modified to change selectivity; for example, a water-soluble poly(trisulfide) with a carboxylic acid modification can act as a copper sorbent. Additionally, these polymers can be tailored to bind to mercury, a common pollutant used to process gold ore.

Even the way these polymers are created is an improvement. They use electrochemically initiated polymerisation, which involves the electrons circulating in an electrochemical cell activating the monomer building blocks, triggering a polymerisation chain reaction in which the polymer precipitates from solution. By avoiding hazardous chemical initiators and high temperatures (this system works at room temperature), this method is much safer.

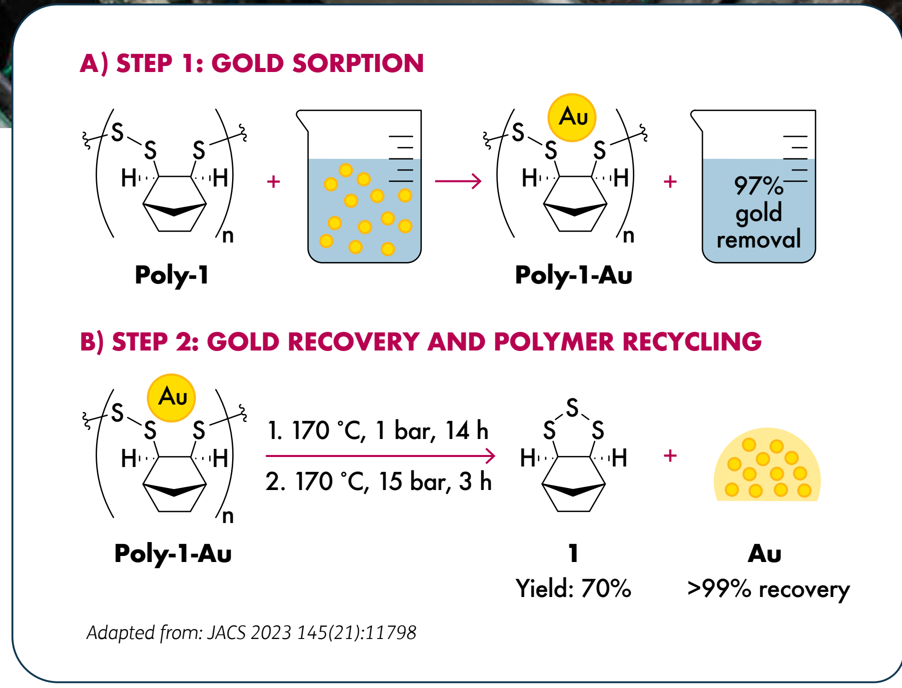
Access to ANFF-SA's electrochemical characterisation equipment has enabled the researchers to perform detailed analysis of the starting monomers, determine the optimal polymerisation conditions and monitor reactions in real-time. This support has been crucial in refining the polymerisation process.

Tri-sulphide polymers can be converted back to their original monomers through the process of thermal depolymerisation. The monomers can then be removed from the system, leaving behind purified gold.

This method not only recovers valuable metals but also allows the polymers to be recycled and reused, creating a sustainable, closed-loop system.

This innovative approach aligns with UN Goal 12 – Responsible Consumption and Production. Traditional polymer waste poses significant environmental and health risks, as mechanical recycling often leads to structural degradation and downcycling. The breakdown of traditional polymers like polyethylene creates particles that persist in the environment. In contrast, these sulphur polymers can be recycled without such degradation, reducing the environmental impact and promoting sustainable practices.

The strategy of converting excess elemental sulphur from the petroleum industry into useful monomers and polymers, coupled with the recovery of gold from e-waste, offers a promising solution to reduce the need for environmentally damaging open-pit gold mining. By embracing these advanced recovery methods, we can mitigate the environmental impacts of both e-waste and traditional mining, paving the way for a more sustainable future.



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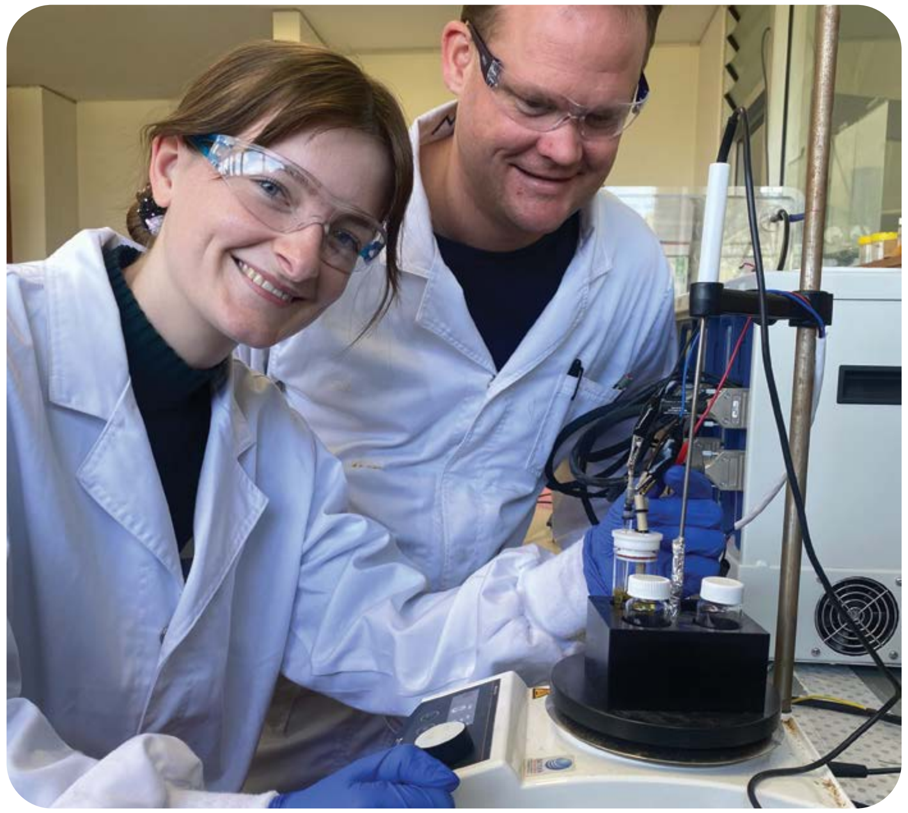


FLINDERS UNIVERSITY'S JASMINE POPLE AND DR THOMAS NICHOLLS

SILICON SPONGES FOR SENSITIVE SENSORS

Porous silicon's high surface area and versatility make it a game-changer for next-gen sensors and medical devices.

DIRECT LASER WRITING ON MESOPOROUS SILICON FILMS
Credit: Jesse Fletcher

Porous silicon (PS) is a unique form of silicon that features tiny nanopores within its structure, making it a highly versatile material with broad potential applications. Its compatibility with silicon-based microelectronics positions it as a promising candidate for a range of electrical and optical devices, such as sensors and solar cells.

The tiny holes in the structure increase the active surface area and allow for infiltration of analytes deeper into the film. This infiltration greatly enhances the sensitivity and efficiency of PS compared to conventional solid silicon, particularly in optical sensors where the analytes can interact with the sensor's guided light path. Furthermore, PS offers excellent mechanical and thermal properties while remaining cost-effective.

Despite its benefits, PS faces a major challenge: instability over time. After production, PS film surfaces are typically covered with hydrogen, maintaining stability only for a short time in non-reactive environments. Prolonged exposure to air initiates oxidation, leading to surface instability. Over time, PS films and devices made from them become less reliable. This instability is problematic for many uses, so various techniques are being developed to improve the long-term stability of PS films and devices.

One such promising approach is being explored by Jesse Fletcher, a PhD candidate at the University of Western Australia. Fletcher employs a combination of PS and direct laser writing (DLW) to create stable waveguiding regions in PS thin films, designed for photonic applications. Using DLW in a hydrocarbon atmosphere creates carbonised PS, which is a stabilising thin silicon carbide (SiC) layer on the pore surface.

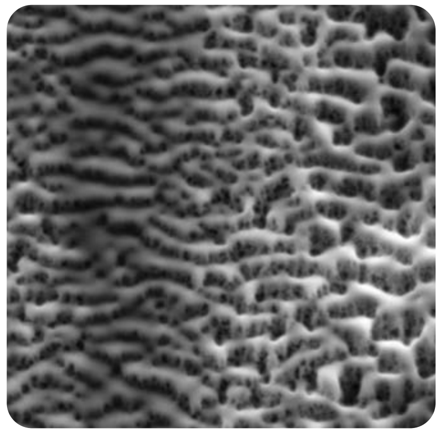
ANFF-WA supports this cutting-edge work by providing the space and equipment to fabricate PS films via electrochemical anodization of Si wafers in hydrofluoric acid, as well as the necessary post processing steps to develop viable devices.

Fletcher's fabrication method successfully transforms about one-third of the silicon wafer's thickness into PS. The carbonised regions, with their higher refractive index, form a waveguiding core in the PS film, directing and confining light along defined paths. By tuning the optical properties of the PS films, Fletcher produces low-loss materials where propagating light experiences minimal power reduction, especially when compared to solid Si. This low-loss PS enhances the interaction between the optical wave and the material being sensed, resulting in extremely high sensitivities.

Moreover, the ability to create large, on-chip waveguides simplifies the alignment of PS optical sensors with standard, off-the-shelf optical fibres, reducing implementation costs for this emerging technology. This feature makes PS a practical and cost-effective solution for a variety of applications.

The use of PS as a waveguiding platform opens exciting opportunities for highly sensitive sensors in biomedical and environmental monitoring. Its compatibility with biological systems allows organic molecules to stick to it easily. The high surface area also allows functionalisation of the surface, improving the selectivity of the platform for different biomolecules and biomarkers, such as proteins, DNA, metabolites and antibodies. Additionally, by adjusting its porosity, PS can be made bio-inert, bioactive or resorbable, enabling it to safely degrade within the body into orthosilicic acid, a harmless substance.

As stability challenges are overcome, porous silicon has the potential to transform optical and biosensing technologies. Jesse Fletcher's research on carbonising PS films points toward a future where these 'silicon sponges' serve as adaptable, reliable materials for next-generation sensors and devices across numerous industries.



SEM OF AN ANODISED PS FILM MILLED WITH AN ION BEAM
Credit: Jesse Fletcher

LOOKING ON THE BRIGHT SIDE FOR DEFENCE

Advances in optical fibre technology will enable high-power fibre lasers, positioning Australia as a leader in light-based defence systems.

Currently, 31 countries possess ballistic missiles, and counter-missile systems were developed as the primary means of defence. These systems are highly advanced, designed to detect, track, intercept and destroy incoming missiles. However, their cost remains a significant challenge. Each counter-missile costs millions, and even a single test of such a system can be a hundred times more expensive than the projectile it is designed to stop.

Beyond their traditional use against ballistic missiles, counter-missile systems are increasingly deployed to defend against a wider range of projectiles and weapons, such as rockets, mortars and drone swarms. These lower-cost, easily deployable threats are becoming mainstream and have the potential to overwhelm expensive missile defence systems. In particular, drone swarms can exhaust valuable counter-missiles, limiting the availability of these expensive assets for other, more critical engagements.

As a response to this emerging threat, directed energy weapons like high-powered lasers are being developed as a more cost-effective solution to neutralise drones and other small-scale aerial threats. Lasers work by generating photons using an energy source, typically electricity, and creating a focused beam output. The power of the beam can vary significantly – from low-energy lasers like pointers to high-powered military lasers capable of cutting through steel.

However, older generations of such lasers for military use required high power levels, extensive power generation and cooling infrastructure, necessitating large platforms like naval ships or permanent ground installations.

An alternative approach involves using optical fibres to channel light and generate a highly focused beam. The resulting laser is more precise because it produces a cleaner, more uniform circular beam that can be focused over long distances. Additionally, fibre laser systems offer a range of benefits such as a smaller physical footprint, higher electrical efficiency and lower overall operating costs. Despite these advantages, scaling up the power output of fibre lasers for military use has proven challenging due to technical limitations.

Optical fibres are great for interacting with light over long distances, but they can experience nonlinear effects like stimulated Brillouin scattering (SBS), which scatters light and limits power delivery.

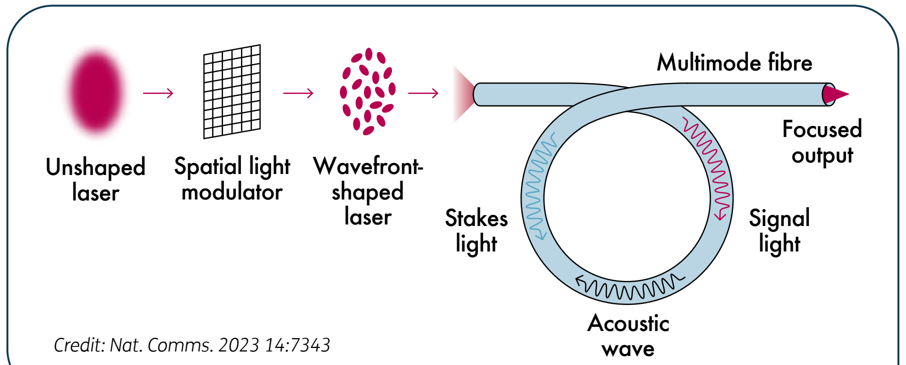
SBS occurs when light interacts with sound waves (acoustic phonons) in a medium, such as an optical fibre. A high-intensity light beam travelling through a fibre generates ultrasound waves, creating periodic density variations. The light interacts with these variations, causing some of it to scatter. If the scattered light travels in the opposite direction to the original beam, it can be amplified by the sound waves.

SBS becomes significant only above a certain threshold power. Below this threshold, the effect is minimal, but above it, SBS can reflect a substantial portion of the light back towards the source, limiting the laser's power output.

Minimising the impact of SBS is crucial in fibre optics and telecommunications because it can limit the performance of high-power fibre optic systems. Understanding and controlling SBS is crucial for improving the efficiency and reliability of these systems

Dr Linh Nguyen and Dr Ori Henderson-Sapir, along with colleagues from the University of South Australia, University of Adelaide and Yale University – with support from ANFF-OptoFab Adelaide – have scaled up fibre laser power by an order of magnitude without degrading beam quality. By shaping the input light's wavefront in a multimode fibre, they significantly mitigated the SBS power further. This method also allowed control over the output beam's shape, enhancing efficiency and robustness for applications like directed energy to neutralise drones.

Australia is now positioned to lead in developing next-generation, high-power fibre lasers, benefiting both defence and scientific research. The continued improvements in fibre optic laser technology will offer new possibilities in applications from defence to remote sensing.



Credit: Nat. Comms. 2023 14:7343

› LITTLE BRAINS TO HELP OUR KIDS

Dr Ann-Na Cho's huBMS system harnesses the power of microfluidics to create realistic brain organoids to unlock the secrets of childhood dementia.

Dementia doesn't just affect adults; children and teenagers can develop it too. Caused by 145 different genetic disorders, each child's experience of this debilitating condition is unique. Individually the genetic disorders are rare, but in Australia, over 100 babies are born with childhood dementia annually, and 91 children die from it each year, a number comparable to childhood cancer.

Sadly, without more research and medical breakthroughs, 70% of children with dementia will continue to lose their lives before they turn 18.

The human brain, with its complex mix of emotions, cognition and consciousness, remains one of the most intricate and poorly understood systems in science. Despite advances, scientists have struggled to fully unravel its mysteries. A significant challenge in translating research into clinical practice is the lack of laboratory models that accurately replicate the brain's physiological environment.

Brain organoids, miniature brains grown from human stem cells, are valuable for studying how the human brain develops and for researching brain diseases because they mimic actual brain microphysiology.

> Organoids can be used to understand brain mechanisms and diseases and test the effects of new therapeutics without the need for animal models.

However, current methods for growing these organoids need improvement to ensure consistent and high-quality results. Dr Ann-Na Cho from the University of Sydney is addressing these challenges by creating innovative human brain organoids using advanced biomedical engineering tools. Dr Cho's approach involves developing a comprehensive system that not only includes the cellular components of the brain but also incorporates surrounding systems such as blood vessels and immune responses, which are crucial for studying brain diseases.

Her 'Human Brain Microphysiological System' (huBMS) is a groundbreaking organoid model system built on 2 key components: a human brain extracellular matrix (BEM) to provide the specific signals needed for brain development and a microfluidic device that creates a periodic flow of nutrients to improve the survival and consistency of the organoids.

> In essence, Dr Cho's huBMS creates a more realistic biological environment for the organoids, guiding the development of brain cells more effectively than traditional methods.

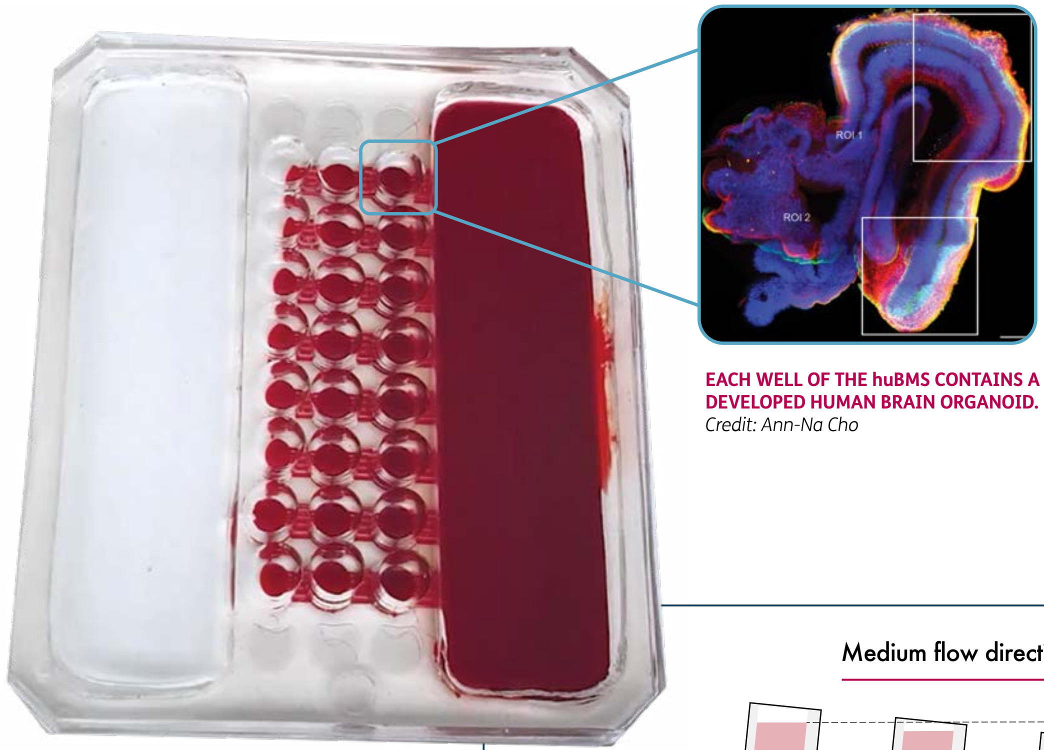
By providing brain-specific signals and improving nutrient and oxygen exchange, the system supports cell growth, neuronal differentiation and functional maturation and more accurately replicates actual human embryonic brain development.

In the huBMS, the microfluidic device plays a crucial role by creating a gravity-driven flow that mimics cerebrospinal and interstitial fluid dynamics. This flow optimises nutrient and oxygen exchange, significantly enhancing cell viability and functionality within the organoids.

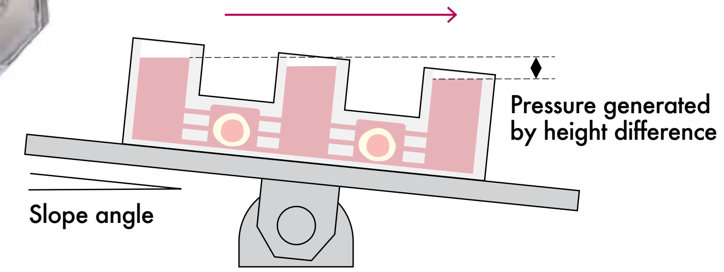
Dr Cho's team has collaborated with ANFF-NSW's Research and Prototype Foundry, including ANFF engineers Nelson Briones and Ethel Ilagan, to develop the microfluidic device. This device uses a common laboratory stirring device to generate fluid flow, improving organoid survival and differentiation capabilities.

The huBMS model closely mimics human brain physiology and pathology, facilitating the creation of a vascularised brain-on-a-chip. Initially, Dr Cho used the platform to investigate neuroinflammation in response to pathogens, and her research will inform new avenues for treating these potentially devastating infections.

Dr Cho's work is driven by a commitment to making a real impact on public health, particularly in addressing childhood brain diseases and psychiatric disorders that emerge early in life. The huBMS system has the potential to replace traditional animal models with a better and more relevant system and could transform our understanding of a range of brain diseases, including childhood dementia and developmental disorders such as autism.



EACH WELL OF THE huBMS CONTAINS A DEVELOPED HUMAN BRAIN ORGANOID.
Credit: Ann-Na Cho



PUMP-FREE MICROFLUDIC DEVICE FOR 3D DYNAMIC CULTURE.
Credit: Nat. Comms. 2021 12:4730

› COOL COMPUTING TO COMBAT GLOBAL WARMING

Hybrid light-matter particles developed by FLEET researchers solve the circuit heating problem that is driving up electricity consumption in computer devices.

Modern transistors on chips in computer devices are not energy efficient. As electrons move through these circuits, interaction with the materials in the circuit generates heat. All circuits currently in production have an intrinsic resistance and generate heat when current flows through them.

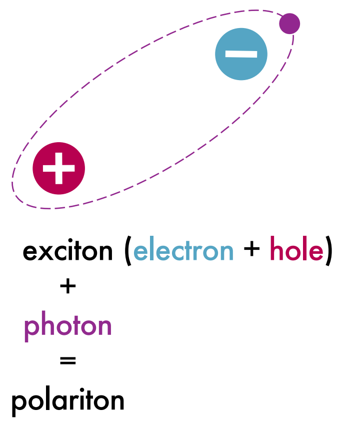
A substantial amount of the energy used by computers is wasted because the electricity used to power the circuits heats up the device as it performs its tasks. Not to mention the energy needed to combat this heating.

Although we barely notice the heating of our individual devices anymore, traditional data-server centres, cryptocurrency farms and AI data centres generate significant amounts of heat. These facilities produce enough heat that they can generate their own microclimates, contributing to global warming regardless of whether the power source is renewable.

To address this, we need to invent transistors that do not generate heat.

ARC CoE Future Low Energy Electronic Technologies (FLEET) researchers at Monash University and the Australian National University, led by Chief Investigator Elena Ostrovskaya, are investigating polariton superfluids, a phase of matter that allows current to flow without generating heat, as potential next gen transistors. Polaritons are hybrid particles formed of light and matter that are strong candidates for the realisation of near-zero resistance technology.

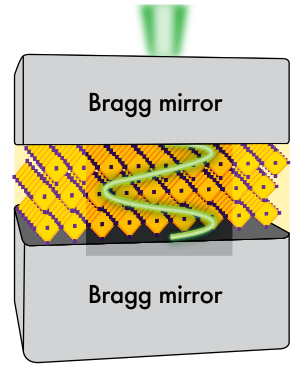
POLARITON



A polariton is formed when a photon is strongly coupled with an electric dipole that is free to move through a non-metallic material. In semiconductors, a dipole is created by the movement of electrons from the material into the electric circuit, leaving behind a positive 'hole'. The combination of the electron-hole pair is called an exciton. In essence, these photon–exciton hybrid particles possess properties of both light, in having little mass, and matter, with the ability to interact with other particles.

Superfluidity, most usually observed in helium cooled to temperatures near absolute zero (-273 °C), has been a property exhibited only at incredibly cold temperatures. Other materials can also exhibit superfluidity; however, cryogenic cooling is necessary to achieve near-zero resistance.

Incredibly, exciton-polaritons can form superfluids at room temperatures, which enables them to spread through a material with negligible resistance. As a result, polariton technology can be utilised in next-generation circuits to prevent circuit-based heating.



OPTICAL MICROCAVITY CONSISTING OF A THIN PEROVSKITE SEMICONDUCTOR BETWEEN 2 BRAGG REFLECTOR MIRRORS.
Credit: Mitko Oldfield

Polaritons could be a new class of information carriers that can transport data in computers.

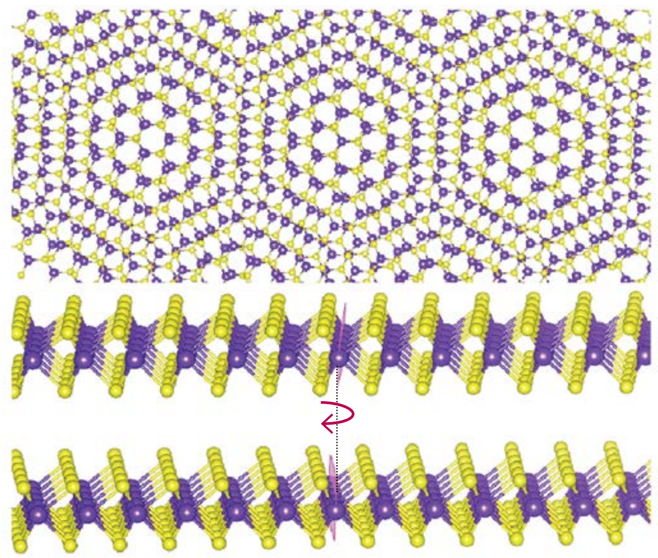
Previous attempts at forming polariton superfluids were complex and costly. However, Dr Mitko Oldfield's research at FLEET has focused on forming polaritons in perovskite semiconductor films that are easy-to-make, cost-effective and readily create excitons when the material is exposed to light. With assistance from our ANFF-ACT facility, Dr Oldfield successfully sandwiched the anatomically thin semiconductor between 2 Bragg reflector mirrors, creating an optical microcavity system with remarkable stability. Lasing of the microcavities resulted in strong exciton–photon coupling, achieving a superfluid state. This material shows great promise for both fundamental and applied room-temperature polaritonics.

Due to their semiconductor nature, polaritonic devices could be readily integrated into conventional electronic circuits. Future applications include using polaritons in anatomically thin semiconductors to enable near-zero resistance, ultra-low energy electronic devices.

Pushing the frontiers of transistor materials is part of the global effort to develop low-energy semiconductor technologies for computing and information processing.

› WITH A LITTLE TWIST

Twisting the layers in a semiconductor dramatically affects its electronic properties, creating the potential to simplify the structure of many common electronic components.



Moiré patterns occur when 2 regular patterns are overlaid at a slight angle, creating a large-scale interference pattern visible to the naked eye. A new picture emerges with a little twist.

Twistronics is an emerging field that examines what happens when you stack 2D atomic sheets on top of each other and then twist one layer out of alignment with the other. The twisting creates Moiré superlattices, giving rise to several emergent electronic properties, like ferroelectricity, that are not present in the individual layers of the materials themselves.

Ferroelectricity occurs in some materials in which they can have a built-in electric charge that can be flipped back and forth. Imagine a tiny magnet with a positive and negative side instead of north and south poles. These materials can switch the electric charge direction when you apply an electric field, similar to flipping a magnet's poles with a magnetic field. This ability to switch their charge direction makes ferroelectric materials useful in various applications like memory devices and sensors.

Conventional ferroelectric materials are typically bulk materials. In contrast, 2D ferroelectric materials are fabricated by stacking atomically thin layers, and the electrical behaviour of these stacked semiconductors can be changed with a mere twist.

Monash University's Dr Mark Edmonds and PhD student Thi Hai Yen (Emily) Vu explore the electrical properties of twisted transition metal dichalcogenide (TMD) semiconductors. While 2D ferroelectric materials are highly sought after, visualising and characterising these materials are challenging because they exhibit unique properties that are not easily observable, which requires sophisticated, high-resolution techniques to detect and measure.

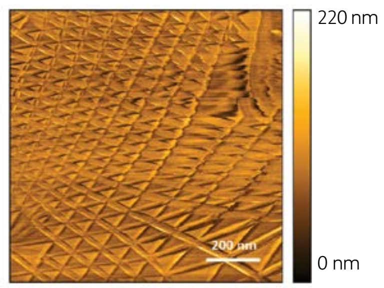
Dr Edmonds and Ms Vu teamed up with Dr Hemayet Uddin at ANFF's Melbourne Centre for Nanofabrication to adapt an atomic force scanning microscope to perform piezoresponse force microscopy (PFM) to visualise their twisted materials. PFM uses a tiny probe, not unlike a miniature pickaxe, to measure how materials change shape when an electric field is applied, helping visualise their surface structures at the nanoscale. The resulting PFM technique can operate in air and at room temperature, making the process simpler and applicable to a wider range of materials.

PFM is the ideal methodology to study the effects of changing the twist angle on ferroelectric properties and the size of the ferroelectric domains in Moiré superlattices, which could lead to significant advancement in the development of these novel 2D ferroelectric materials.

Electronic circuits typically consist of various components like metallic conductors, insulators, semiconductors and magnetic elements, requiring the integration of multiple materials, which poses significant engineering challenges. However, a single twistronic device, capable of being locally 'twisted' to realise each of these components, could revolutionise engineering by simplifying material requirements.

Beyond practical applications, Moiré superlattices and the innovative instruments created to measure their properties provide a straightforward platform for investigating complex scientific phenomena, offering new insights into superconductivity, ferroelectricity and magnetism, thereby deepening our understanding of fundamental physics.

PFM



PFM IMAGE OF TWISTED TMD SEMICONDUCTOR LAYERS
Credit: Mark Edmonds

› MOVING IN THE RIGHT DIRECTION

RMIT researchers have partnered with the Australian-based company Advanced Navigation to design and manufacture the world's most precise, compact and cost-effective gyroscope.

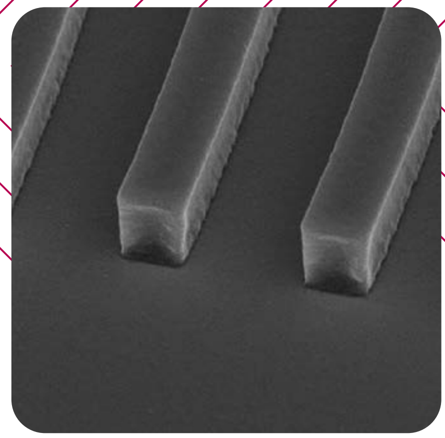
Drivers and pedestrians often need help getting from point A to point B. Paper maps have gone the way of the dinosaur, being replaced by GPS navigation. But relying on GPS systems to find your way is fraught with problems.

> How often have you walked or driven in the wrong direction because your system can't tell where you are or what direction you are facing?

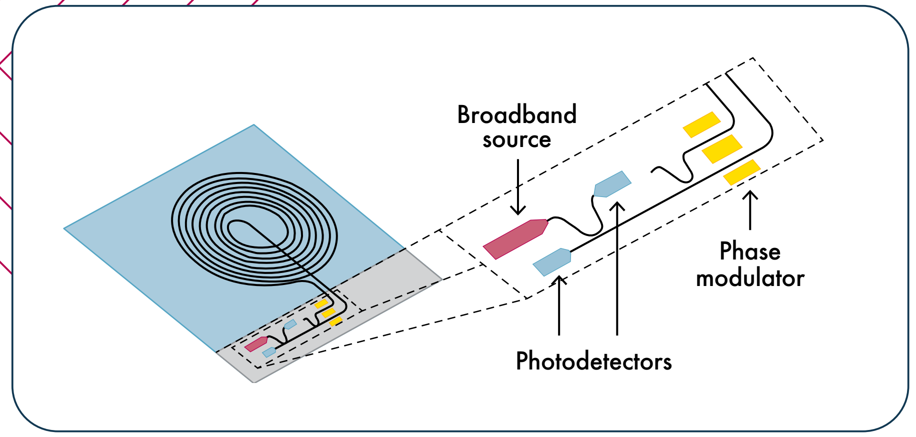
A more reliable navigation system does not rely on external signals like GPS. Inertial navigation systems (INS) are self-contained, electronic systems that calculate an object's position, velocity and orientation. An essential component of INS devices are 3-axis gyroscopes that measure rotation and angular velocity in 3 axes: x, y and z.

Micro-electromechanical systems (MEMS) are tiny devices that fit on a circuit board and have a myriad of uses. MEMS-based gyroscope sensors use high-speed, vibrating structures to measure rotation. When the gyro rotates, these structures shift and create small electrical signals that can be amplified and read by a control device. Found in phones, tablets and game controllers, MEMS gyroscopes are small, light and inexpensive. Unfortunately, they lack accuracy, as anyone using a map app can attest.

Precise navigation systems need very sensitive gyroscope sensors, like fibre optic gyroscopes (FOGs). FOGs use light wave interference to measure tiny distances and changes with high accuracy. In these gyroscopes, a laser beam is split into 2: one for reference and one for measurement. When these beams are combined, they create an interference pattern that a digital sensor captures. Gyroscopic rotation changes this pattern, and computer algorithms analyse it to make precise measurements. However, FOGs are usually large and costly, so they are mainly used in space or defence applications.



SILICON NITRIDE WAVEGUIDES
Credit: Jamie Low



SCHEMATIC OF A PHOTONIC INTEGRATED CIRCUIT GYROSCOPE
Credit: Opt. Express 2014 22(21):24988

> A gap exists where applications such as self-driving automotives or medical-grade exoskeletons require inertial movement sensors that are more precise than MEMS-based gyroscopes but producible at a fraction of the cost of a FOG.

RMIT's Integrated Photonics and Applications Centre (InPAC) has partnered with Advanced Navigation in a Cooperative Research Centre Project (CRC-P) grant to create such a gyroscope.

Advanced Navigation is an Australian innovator in AI-based robotics and navigation, developing transformative technologies from inertial and sonar navigation to photonic and quantum sensing. Advanced Navigation is already a leading INS manufacturer, with a range of MEMS- and FOG-based systems to provide position, velocity, acceleration and orientation under the most demanding conditions.

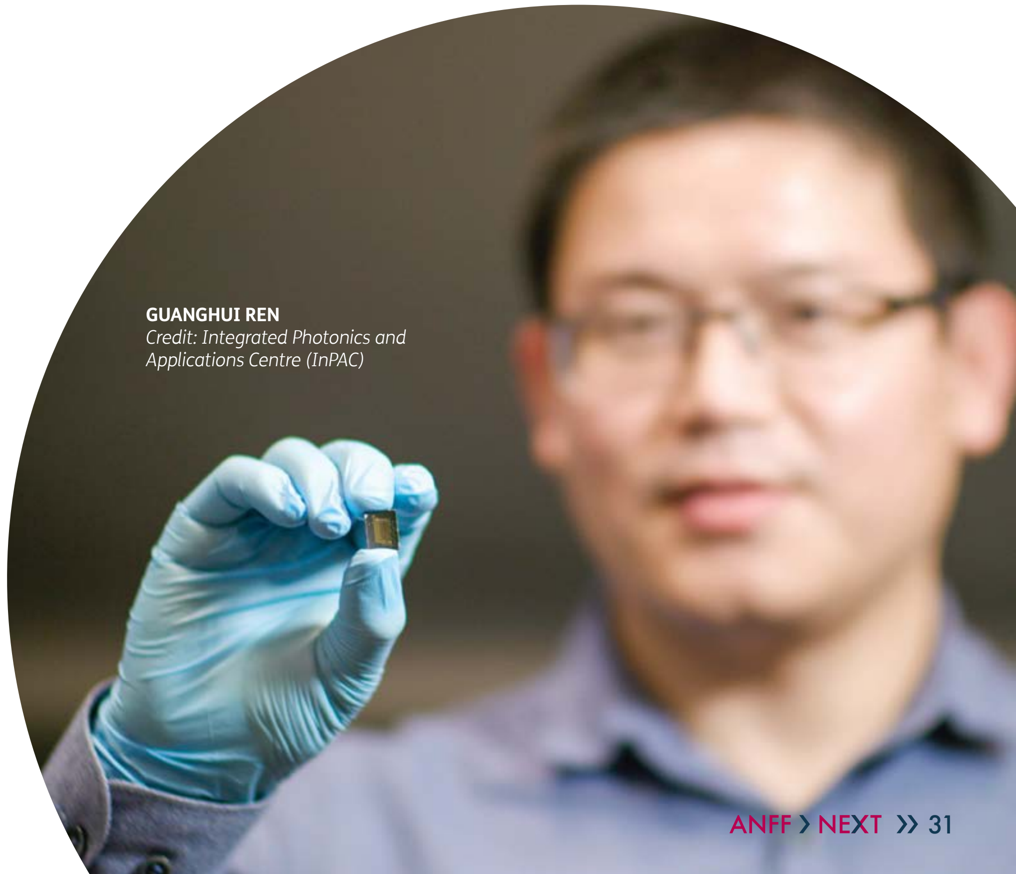
By integrating the controlling optical components of a FOG onto a single chip, the footprint and weight of the sensor can be reduced significantly, while still having a better performance than MEMS-based sensors.

> The core principle of the photonic gyroscope is to have active (lasers, modulators and detectors) and passive (resonators or waveguide loops) components integrated onto a single chip.

To date, researchers have successfully fabricated silicon nitride (SiN) optical waveguides on a lithium-niobate-on-insulator (LNOI) platform with integrated electro-optic modulators on the same chip.

The photonic chips will be developed by the InPAC team, with leading-edge facilities for designing and printing these photonic microchips provided by ANFF-VIC and ANFF-QLD, including RMIT's Micro Nano Research Facility, the Melbourne Centre for Nanofabrication and ANFF-QLD's facilities at the University of Queensland.

Their photonic gyroscope will squeeze space and military tech into navigation systems for daily life, with accurate sensing for self-driving cars, equipment control for autonomous farming and precision robotics such as exoskeletons for paraplegic patients. And with photonic devices integrated into our phones, we can finally trust our map apps to guide us accurately, ensuring we always head in the right direction.



GUANGHUI REN
Credit: Integrated Photonics and Applications Centre (InPAC)

SEEING THROUGH THE SMOKE

Innovative infrared drone sensor technology offers a promising solution for early bushfire detection and effective firefighting.

The end of winter and beginning of spring increasingly heralds a summer on fire.

The devastation caused by the 2019-20 Black Summer remains seared in Australia's collective memory. Yet, many Aussies have already forgotten how bad last summer was – 2023 was Australia's biggest bushfire season in more than a decade, with more land burned than during those Black Summer fires.

As climate change worsens, bushfires are likely to become more intense and frequent. Spotting and attacking blazes early are instrumental to reducing the risk of large-scale fires.

Bushfires are currently tracked by satellites and on the ground through fire towers, patrols, helicopters and aircraft. Drones offer clear advantages, delivering high-resolution images from closer range and providing real-time data. They're more cost-effective, access remote areas easily and eliminate safety risks for pilots flying in low-altitude, smoke-filled environments.

Infrared (IR) sensors can significantly enhance bushfire management by detecting fires early before they generate large amounts of heat. Even at night-time, they can identify hot spots and monitor vegetation moisture levels, helping predict fire-prone areas. This allows for quicker response times, better resource allocation and more effective containment strategies.

Credit: Wenwu Pan, image generated by ChatGPT

So, the sensible thing to do is to combine these 2 technologies into one awesome firefighting package. Equipped with specialised IR sensors, drones can conduct high-resolution, direct temperature measurements, significantly enhancing our ability to forecast and respond effectively to rapidly changing conditions on the ground.

The high cost of equipping drones with highly sensitive IR limits their widespread use, reducing data availability for firefighters and impacting the accuracy of trend forecasting.

The prohibitive price tag of cutting-edge IR technology is mainly due to the cost of its components. These systems rely on thin mercury cadmium telluride (MCT) films that absorb IR well, producing clear images. To create high-quality MCT films, they must be grown on a compatible semiconductor substrate like cadmium zinc telluride (CZT), as its lattice matches MCT's structure, reducing defects. However, CZT is expensive, fragile and only available in small sizes. These factors increase costs by limiting how many sensors can be made from each wafer and reducing production efficiency.

Unfortunately, cheaper, larger wafer size and more durable semiconductor alternatives like gallium arsenide (GaAs) or silicon (Si) don't match the atomic pattern in MCT well, leading to film defects that kill its pixel performance. The challenge is finding a semiconductor base layer that is compatible with the sensing layer to ensure high-quality, defect-free films.

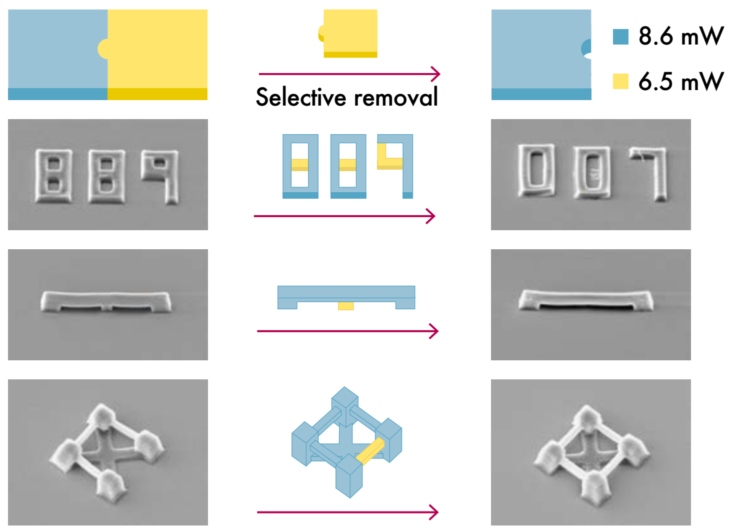
In partnership with ANFF-WA, Dr Wenwu Pan and his team from the University of Western Australia's Microelectronics Research Group have pioneered a new method for creating MCT-based IR sensors. They deposit a dual-compatible layer between the base and the film. With nanostructured lattice engineering, a cadmium telluride (CdTe) buffer layer mimics the CZT lattice structure and material quality, enabling MCT film deposition on GaAs and Si substrates. This innovation facilitates large-area and high-quality growth of MCT films at much lower cost.

The use of large, high-quality and more commercially available semiconductor substrates will make widespread, space-based IR imaging more practical. Their method will allow the production of numerous imaging sensors per wafer through multi-chip batch processing, like the high-yield production approach used in integrated circuit fabrication.

This breakthrough creates a more affordable, high-performance MCT IR sensor that will withstand tough environmental conditions, perfect for various applications in imaging, meteorology, and space awareness. This technology can be widely used in bushfire detection, enabling quicker response times and more effective firefighting strategies, ultimately helping to protect lives and property from devastating fires.

VANISHING INTO THE DARKNESS

A revolutionary photoresist for 3D printing allows precise removal of materials post-production, enabling customisable microstructures in a printed object.



Credit: Adv. Mater. 2023 35:2300151

In 3D printing, it may seem odd to print materials only to remove them later. However, making changes to a 3D structure after the polymer is cured, or hardened, is necessary for building more complex micro- and nanoscale designs. More intricate 3D objects may require temporary supports, or scaffolds, that are essential for forming certain structures but must be removed once their job is done.

Another reason for modifying a final product is to fix mistakes that occur during the manufacturing process, as even small defects can lead to wasted time and resources. The ability to precisely erase and reprint parts of a design ensures that the final product meets exact specifications, saving both time and materials.

Direct laser writing (DLW) is an additive manufacturing technique used to create customisable 3D micro- and nanoscale objects. In the two-photon polymerisation (2PP) process used in DLW, a pulsed, ultra-fast laser beam interacts with a photoresist material. Two photon absorption creates what's called a voxel, the smallest unit of material that can be manipulated or solidified by the laser. These voxels can be controlled at an incredibly small scale, allowing generation of highly detailed and complex 3D structures that are difficult to achieve with other manufacturing methods.

Conventional photoresists typically exhibit binary behaviour, meaning they either harden completely, or not at all, depending on the printing conditions. This irreversible cross-linking process renders the material photochemically inactive. However, there is a growing demand for incorporating dynamic functionalities into printed structures, ideally in a single printing process.

A major advancement in DLW is the ability to erase parts of 3D structures after they are printed. Traditionally, removing parts of a 3D structure has been achieved mechanically or through chemical processes, but these methods can be inefficient and imprecise. A more sophisticated approach involves using materials, called cleavable photoresists, that can break down in response to specific triggers. These materials can even be designed to degrade on their own, without the need for an external erasing tool.

Queensland University of Technology's Dr Steven Gauci, Prof Christopher Barner-Kowollik and their colleagues have developed a new type of photoresist that offers variable degradability. By adjusting the laser intensity during DLW 2PP printing, scientists can control which parts of the structure remain stable and which ones break down triggered by the mildest triggers of all – darkness.

This new photoresist is a major advancement in DLW technology, made possible with the help of ANFF-QLD and the use of its Nanoscribe 3D printer. Before, creating degradable structures required switching between different materials, making the process more complicated. Now, a single material can be used to print structures with both permanent and darkness-triggered degradable sections.

The potential applications are wide-ranging. In drug delivery, controlled degradation could be used to release medication in a targeted and precise manner. In tissue engineering, this resist could be utilised to create scaffolds for cell cultures that can be removed without damaging the surrounding cells. In regenerative medicine, scaffolds can be designed to break down naturally over time, aiding in tissue formation. These advancements open new possibilities in biomedical engineering.

This innovative research showcases how advancements in materials chemistry can overcome the limitations of traditional manufacturing. It demonstrates how curiosity-driven science can lead to new technologies with real-world applications that were previously unimaginable.

DR RUIRUI QIAO AND
DR LIWEN ZHANG

› CHANGE IS THE 4TH DIMENSION

The advent of light-responsive 4D-printed liquid metal/polymer nanocomposites is paving the way for a new generation of laser-controlled soft robots.

Robots are designed to perform tasks automatically in response to stimuli or other inputs. Engineers have long relied on rigid materials like metals and hard plastics to create 'hard' robotic systems. These conventional robots, while effective, lack the flexibility and adaptability required for more nuanced tasks.

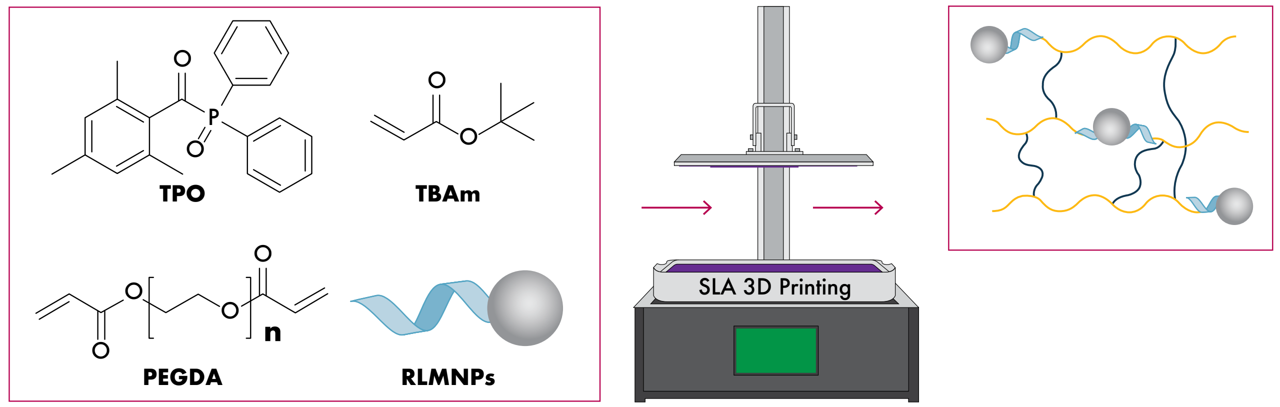
Enter soft robots that can bend, stretch and deform in ways hard robots cannot. This flexibility allows soft robots to interact more naturally with the human body, mimicking soft human tissues like joints and cartilage.

Innovative materials are key to the construction of soft robots and require a different approach to manufacturing. Conventional robot fabrication techniques, such as drilling and milling, are unsuitable for making soft robots. Instead, 3D printing is employed to create a soft robot layer by layer. This method offers advantages in customising the structure of materials and designing intricate structures while offering cost-effective and time-saving benefits.

However, conventional 3D-printed polymers are fixed in shape once printed, limiting their utility in applications that require adaptability. This is where 4D printing comes into play.

4D printing involves creating 3D-printed objects that can transform their shape over time – introducing a 'fourth dimension' – when exposed to certain stimuli.

Many printed polymers display limited responses to external stimuli such as light, electricity and magnetic fields, limiting their utility in 4D printing applications.



THE FABRICATION PROCESS OF 3D-PRINTED LIQUID METAL POLYMER COMPOSITES (LMPCS)
Credit: Nat. Comms. 2023 14:7815

The key to a successful 4D-printed device is the addition of specific ingredients to the printer ink that give the finished product new qualities and abilities capable of change when stimulated. The integration of functional nanomaterials into 3D-printed polymers presents several benefits for advancing 4D-printed soft robots. Nanoparticles with unique properties, such as photosensitivity and chemosensitivity, can enhance the stimuli responsiveness of printed objects, allowing for precise and efficient shape changes.

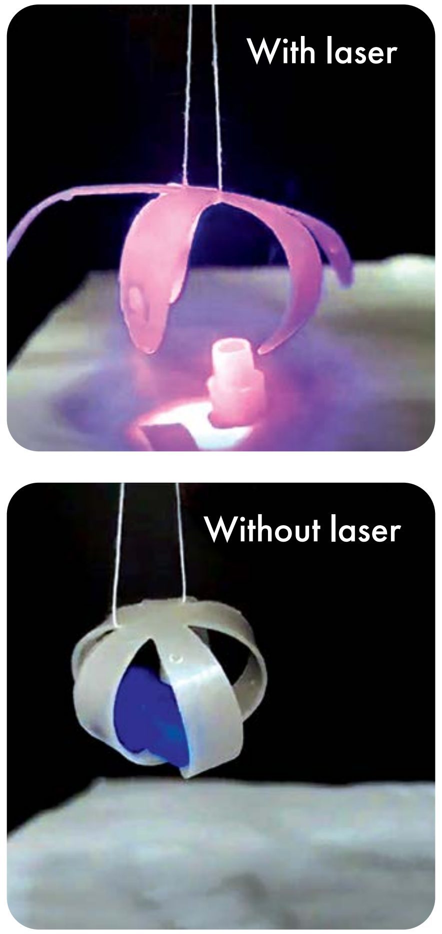
University of Queensland researchers Dr Liwen Zhang, Dr Ruirui Qiao and Prof Tom Davis from the Australian Institute for Bioengineering and Nanotechology have introduced a novel method for creating 4D-printed liquid metal polymer nanocomposites with shape memory capabilities. The team's nanocomposite materials can be coaxed into performing a range of mechanical tasks using near-infrared (NIR) lasers. Their unique soft robot combines gallium-indium (Ga-In) liquid metal nanoparticles (LMNPs), which absorb NIR and convert the energy to heat, with a biocompatible polymer that responds to heat by transitioning to a rubber-like state. Their LMNPs can be directly prepared in various 3D-printed resins, providing a simple and effective one-step printing approach for fabrication.

The sturdy 4D-printed soft robots are capable of bending, grasping, lifting and releasing objects weighing up to 5 times their own weight, while also being able to return to their resting shape.

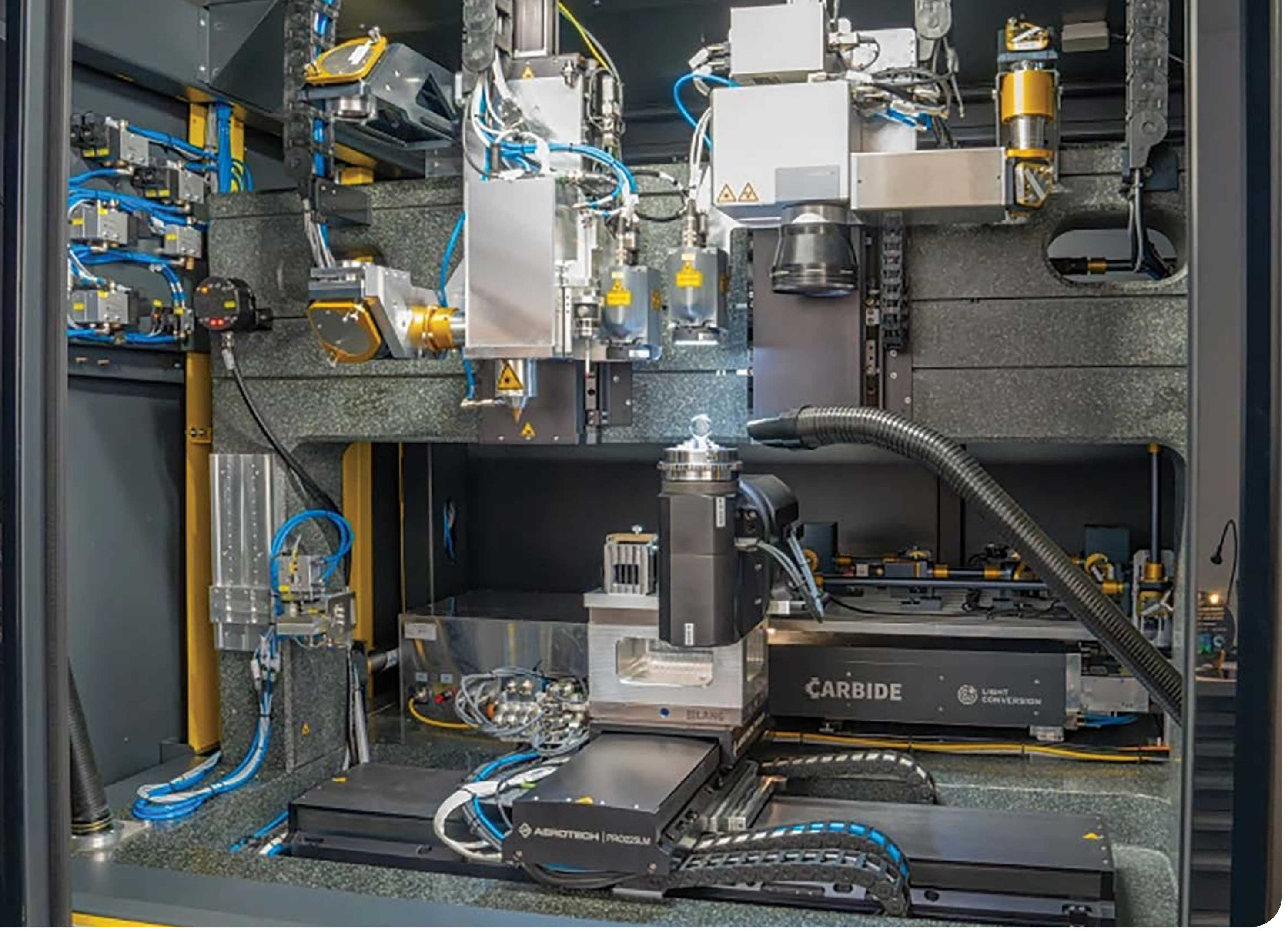
ANFF-QLD is partnering with these researchers to create truly tiny soft robots. ANFF's Nanoscribe 3D printer can print soft robots at sizes below 1 mm. The ability to customise and shape small-scaled, soft and intelligent materials through 4D printing will lead to wider manufacturing breakthroughs and innovations.

The possibilities for this kind of technology are only limited by our imaginations. Soft robots can serve as coronary stents, artificial muscles, tendons or ligaments, and adaptive prosthetics. This is possible because NIR lasers can penetrate body tissues, allowing a soft robot to be inserted in one shape and then triggered to change into its final functional form.

The future of robotics lies not just in artificial intelligence but in the innovative materials that make robotic advancements possible. Material science is a critical component in the development of soft robotics, and continued innovation in this field will expand the range of what future robots can achieve.



A 4D SOFT ROBOT CAPABLE OF GRASPING OBJECTS



THE ULTRAFAST LASER HOUSED IN THE ANFF-OPTOFAB MULTI-AXIS LASER MICROFABRICATION FACILITY AT MACQUARIE UNIVERSITY.

› PRECISION-DRIVEN FUTURE

ANFF's precision engineering facilities are driving transformative advancements in defence, space optics and medical devices, positioning Australia as a leader in micro- and nanofabrication.

ANFF is home to some of the most precise and unique machining capabilities in the country, enabling fabrication of novel components for defence, space optics and medical devices.

The ANFF-SA Precision Engineering Centre is our flagship micro- and nanomachining facility that is unique in Australia and brings exceptional strategic value to Australian industries. The Centre is a Sovereign Industrial Capability for defence and has attracted both co-investment and strategic partnership from Defence Science and Technology Group.

The ANFF-OptoFab ANU Precision Optics facility provides advanced optical coatings and custom optics. Currently, its Ion Beam Sputtering machine is one of only 2 in the world 'certified' for producing optics for the Laser Interferometer Gravitational-Wave Observatory (LIGO) project and was used to manufacture the coatings for the beamsplitters and power recycling optics currently in use.

Macquarie University houses one of Australia's most sophisticated laser microfabrication facilities, known as the ANFF-OptoFab Multi-axis Laser Microfabrication Facility. The state-of-the-art facility is capable of machining materials down to the size of a human hair. The 5-axis ultrafast laser allows for precise laser processing of parts with intricate topologies.

ANFF's cutting-edge machining and optical facilities provide a unique opportunity to bolster Australia's capabilities in defence, space and advanced manufacturing. These strategic assets ensure Australia remains a leader in micro- and nanofabrication and the new technologies they underpin.

CASE REPORT: **ANFF-SA PRECISION ENGINEERING CENTRE**

ANFF-SA's $10M Precision Engineering Centre is a state-of-the-art facility showcasing advanced optics capabilities that elevate Australia to the forefront of advanced manufacturing.

A testament to a decade-long collaboration between ANFF-SA and the Research Engineering (RE) team at DSTG, the Centre integrates world-class experts at ANFF-SA and DSTG with complementary cutting-edge micro- and nanomachining equipment, advanced sensing technologies and precision optics capabilities.

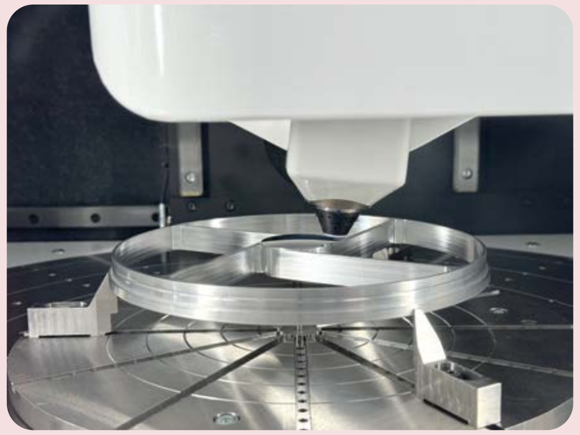
This collaborative hub unites Australia's academics, researchers and industry partners, fostering a dynamic environment where world-leading capabilities and diverse expertise are driving transformative advancements across sectors of strategic national importance, including defence, healthcare, mining, recycling, clean energy, water security, space and agriculture.

ANFF-SA's team of skilled engineers have achieved significant milestones, positioning Australia at the forefront of advanced manufacturing, precision optics and defence-related technologies.

Building on its success, the Centre is preparing for a further expansion, funded by additional investments from the South Australian and Federal Governments, to extend the Centre's research and engineering capabilities. The investment will enable the acquisition of next-generation equipment and recruitment of additional staff, to advance the development of optical communication technologies and complex rapid prototyping essential for modern defence strategies.

CASE REPORT: **HEO**

A long-term client of ANFF, HEO's cutting-edge space cameras are revolutionising satellite monitoring. Using precision-engineered mirrors crafted on ANFF-SA's Precitech's Nanoform, these cameras capture high-quality images of satellites moving at up to 15 km/s. By mounting their cameras on third-party spacecraft, HEO has created a flexible, scalable network for non-Earth imaging. Their groundbreaking approach allows for on-demand monitoring of satellites and space debris, representing a significant leap forward in space situational awareness. HEO's technology will enhance orbital security and sustainability while advancing Australia's strategic interests in defence and space.



Credit: HEO

CASE REPORT: **CHORUS**

ANFF-SA and DSTG have collaborated on a prototype mirror believed to be the largest diamond-turned mirror made in Australia. The advancement will play a central role in the upcoming phases of Australia's Compact Hybrid Optical/RF User Segment (CHORUS) project, poised to transform the landscape of defence communication technology. Led by Australia's leading space research centre, SmartSat Cooperative Research Centre, CHORUS aims to create more stable and secure military satellite communications. By seamlessly integrating optical and radio frequency satellite communications into a unified system, the project will deliver a new class of military satellite communications service for the Australian Defence Force and its allies.

FROM LAB TO LAUNCH

ANFF-C transforms groundbreaking research into successful commercial products, supporting early-stage ventures with funding and expert guidance to navigate the challenging path from lab to market.

ANFF technology platforms have been instrumental in supporting groundbreaking research that often has the potential to become commercial products. However, many of these innovations remain at the research stage, solving intriguing problems but not progressing further.

Turning bench-top research into real-world products is challenging, costly and often unsuccessful. Many promising ideas fall into the so-called translational 'Valley of Death.' Researchers excel at pushing the boundaries of knowledge but may lack expertise in the business side of translation, such as identifying target markets and communicating their business models to potential investors. Investing in proof-of-concept technology is risky for seed grant agencies, angel investors and venture capital firms.

ANFF-C aims to transform more of Australia's world-class basic research into successful commercial products and services. Our goal is to support early-stage ventures by reducing the commercial risk for potential investors. By providing pre-seed capital to help new ventures overcome development hurdles, we increase their chances of success. ANFF-C is open for business and actively investing in innovative ideas.

ANFF-C offers 2 stages of investment. Gate 1 supports very early-stage projects that have demonstrated product feasibility, with funding up to $20,000. This stage typically focuses on market validation ('who will pay for this?') and technical validation ('how can this be scaled?'). Gate 2

supports early-stage projects with funding up to $100,000. This funding is often used for developing regulatory strategies, manufacturing plans and studies to demonstrate the equivalency of new technology with existing solutions. And these 2 funding schemes can be combined.

Additionally, ANFF-C is open to leveraging its funds with other university or commercial funding. For instance, if a university has its own funding mechanism, ANFF-C is willing to share the costs of equivalency studies.

Australia is undergoing a transformation, aiming to become a key player in advanced manufacturing. However, startups face significant challenges in bringing their products to market. ANFF-C's Manufacturing for Startups Webinar Series addresses these hurdles and offers practical solutions by bringing in industry experts to discuss key considerations for early-stage projects looking to produce manufactured goods.

Previous seminars have covered topics like design for manufacturing and startup funding. You can catch videos of past speakers on our YouTube channel, The ANFF Network.

ANFF-C's most valuable support often comes from its networks and deep understanding of sector-specific ecosystems. We strive to provide seamless integration of financial support and advice to early-stage entities, accelerating their journey from concept to market. The fund also highlights the commercial options available to these entities, enabling them to attract professional investors or secure support from commercial funding schemes.

Looking ahead, ANFF-C is eager to identify more opportunities to fill its pipeline. We want to know about upcoming projects, even if they are a few years away from needing financial support. ANFF-C's wide range of capabilities ensures that clients' innovative R&D can be supported as they transition from the laboratory to the commercial world. ANFF-C is ready to help your great ideas reach the market.

ANFF-C IN NUMBERS

$1.4M
funding committed by ANFF-C

$8.4M
follow-on funding

28
technologies supported

4
university spinouts enabled

10
alumni companies

5.8
investment multiplier

ANFF-C ALUMNI COMPANIES

AdraCard, DRUGSENS, ecoJet Engineering, fullcirclefibres, Green Shield, Neogenix Biosciences, Praxis, ooxii, skindna, VividWhite

MS SHIYU WEI USING THE KETOWHISTLE
Credit: Tracey Nearmy ANU

› SIMPLY BREATHTAKING

Introducing the Ketowhistle: a non-invasive, breath-based sensor for easy, real-time ketone monitoring, revolutionising diabetes management.

A sharp jab to your fingertip brings a moment of pain. A drop of blood emerges, which can be a bit unsettling. You put the drop of blood on a strip and wait for the results. Finger prick tests are simple but could never be called pleasant.

> For over 1.3 million Australians living with diabetes, this invasive prick is repeated day after day, year after year, because monitoring ketone levels is crucial in managing the disease.

People with Type 1 diabetes and Type 2 diabetes treated with sodium glucose co-transporter 2 inhibitors risk diabetic ketoacidosis (DKA) due to excessive ketone production when the body, low on insulin, breaks down fats for energy. Rapid ketone buildup makes the blood acidic and toxic.

While the standard for blood ketone monitoring, the invasive nature of the finger prick test has created a barrier to routine testing, especially in children and older individuals. Additionally, the ketone test strips have a short shelf life, are single-use and are expensive.

The Australian National University (ANU) researchers Ms Shiyu Wei, Dr Buddini Karawdeniya, Prof Lan Fu and their collaborators are developing an innovative technology that will replace this invasive testing with a new method that is as simple as breathing.

Exhaled breath contains around 1,500 trace volatile organic compounds (VOCs). Our metabolism produces specific VOCs, including ketones, whose concentrations in breath change dynamically in response to metabolic shifts. Crucially, acetone concentrations in breath directly correlate with blood ketone levels, making it a good biomarker for DKA detection.

The breath-sensing method would be swift and non-invasive. However, current lifestyle monitors on the market are inaccurate, unreliable and unsuitable for diabetic monitoring.

> The Ketowhistle is a portable, self-administered, real-time acetone sensor that allows diabetics to monitor their health simply by blowing a whistle.

KETOWHISTLE.
Credit: Tracey Nearmy ANU

The device's core is an indium phosphide nanowire (InP NW) array-based sensing device exploiting chemiresistive technology, in which a material's change in electrical resistance in response to a specific chemical can be used to detect and quantify that substance.

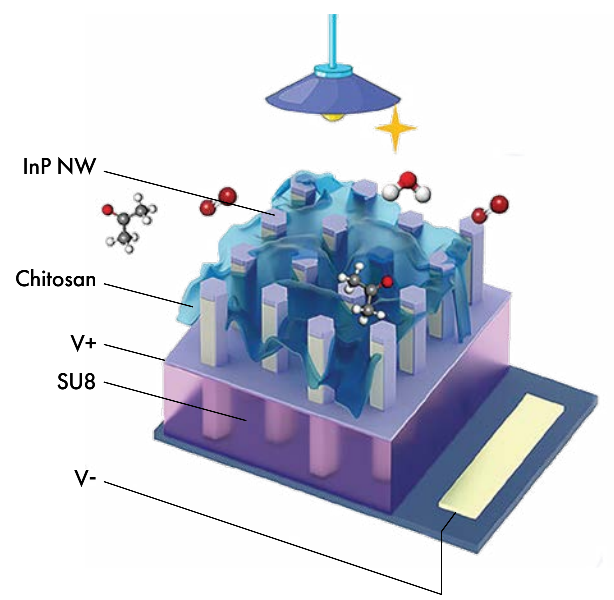
Incorporating chitosan, a polymer found in the exoskeletons of insects and shellfish, into the NW array achieves selectivity for acetone. The amine (–NH_2) groups in the polymer interact with the carbonyl (-C=O) group in acetone, enabling the nanowire sensor to attain high selectivity to acetone with no significant response to many common VOCs in exhaled breath, including other small ketones.

The Ketowhistle combines this InP/chitosan nanowire array-based sensor, a CO_2 sensor, signal-processing circuitry and an OLED screen display. Even better, the sensor is self-powered, so no fiddling with tiny batteries.

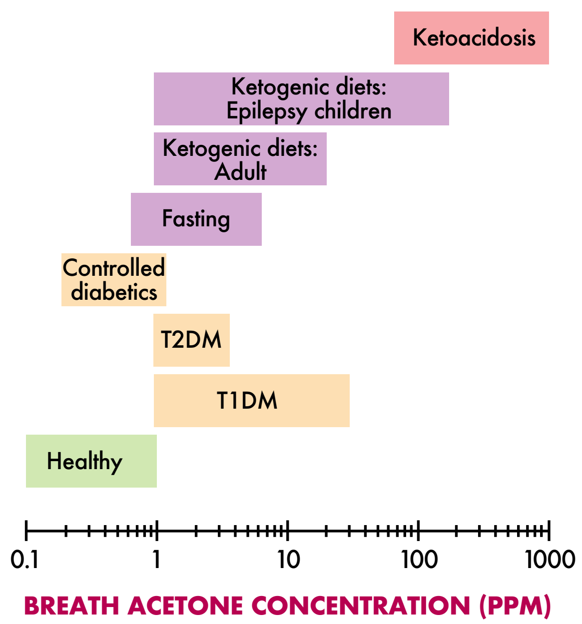
> The Ketowhistle provides a rapid result, high selectivity for acetone and an ultra-wide sensing dynamic range from 0.04 ppm up to >110,000 ppm, easily spanning the entire breath acetone spectrum.

Developed as part of the ANU interdisciplinary research initiative 'Our Health in Our Hands' (OHIOH) and the ARC Centre of Excellence for Transformative Meta-Optical Systems (TMOS), the nanowire array devices for this project were fabricated and optimised at the ANFF-ACT Node. The nanowire dimensions are crucial for the device's high sensitivity, and ANFF staff provided valuable insights for their optimisation. In addition, an ANFF-C Gate 1 grant has enabled a market study confirming the potential market for this device.

The Ketowhistle will prevent diabetic ketoacidosis by making it easier for patients to monitor their condition. Beyond diabetes management, it could also be used to monitor ketogenic diets in weight loss plans and nutrient status in athletes. This practical device has the potential to make a positive impact on many lives, becoming as routine in clinics and homes as thermometers.



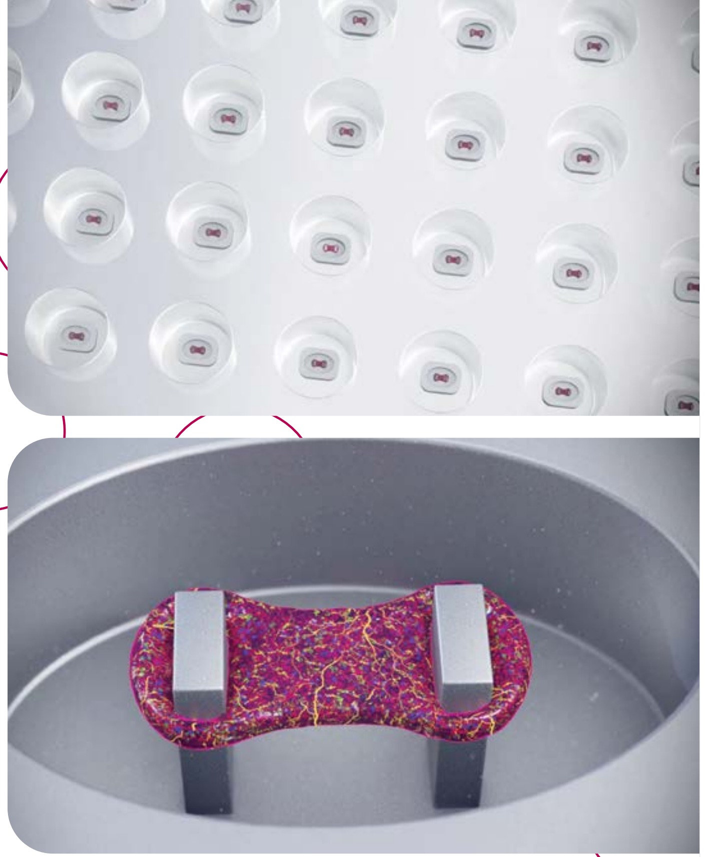
THE KETOWHISTLE'S CHEMIRESISTIVE SENSOR
(INP NW: INDIUM PHOSPHIDE PHOSPHATE NANOWIRES)
Credit: Adapted from Adv. Sci. 2024 11(19):2309481



BREATH ACETONE CONCENTRATION RANGES
FOR VARIOUS PHYSIOLOGICAL STATES
Credit: Adapted from Adv. Sci. 2024 11(19):2309481

› BREAKTHROUGHS WITH EVERY BEAT

Biotech startup Dynomics creates scalable, authentic cardiac organoids to unlock the root causes of heart failure.



TOP: 96-WELL PLATE; BOTTOM: HEART MUSCLE ORGANOID
Credit: Dynomics (www.dynomics.com)

Cardiovascular disease remains the leading cause of death worldwide. In Australia alone, each day 157 individuals experience an acute coronary event, and 112 suffer a stroke.

Current heart failure treatments focus on the aftermath, involving blood thinners, assistive devices and heart transplants, leading to a poor prognosis for many patients. Medical professionals need better ways to predict and prevent these catastrophic events. We need a better understanding of the heart.

Innovative non-animal models are helping scientific research come to grips with the world's number one killer. Researchers are using cardiac organoids to create more accurate mimics of the human heart. These devices reproduce the complex functions and conditions of the heart, helping scientists better understand heart diseases and develop more effective treatments.

Dynomics Co-Founder James Hudson and his team at the QIMR Berghofer Medical Research Institute have engineered human cardiac organoids that function similarly to adult human heart tissue. In their HeartDyno® system, human cardiac tissue, derived from pluripotent stem cells, is grown in a highly controlled environment in 96-well culture plates.

The HeartDyno® automates the formation of dense cardiac muscle bundles around a pair of elastic posts in each small well, from minimal cells and reagents. After the growth phase, each well contains an individual cardiac organoid that contracts. The platform facilitates culture maintenance and automated force of contraction analysis without any tissue handling.

Dynomics' system excels at managing metabolism in their culture system. By careful control of energy sources, the team can promote advanced maturation and function in their platform. This capability is crucial for developing sustainable, long-term cell culture systems that are a valuable addition to a researcher's toolbox.

The HeartDyno® platform is a world-first cardiac organoid system that will illuminate the complex functions and responses of the heart. The platform is easily scalable to provide organoids in large numbers that exhibit the behaviour and physiology of mature heart tissue. Organoid response to stimuli and culture conditions correlates with clinical observation of heart disease. Altogether, the HeartDyno® system shows great potential as a high-throughput screening platform to study genes and therapeutic drugs in a highly controlled and precise manner.

Dynomics' HeartDyno® platform is quite complex to produce, so they teamed up with ANFF-QLD and ANFF-SA to manufacture moulds for their 96-well plates. ANFF facilitated the transition from traditional materials to aluminium. ANFF-SA is now using precision engineering to carve Dynomics' mould designs out of aluminium blocks, polishing areas to ensure smooth surfaces for microscopy. This switch to aluminium greatly improves production efficiency, cutting down both time and costs, and enables scalability by enabling re-moulding hundreds of times from a single device.

To take the HeartDyno® platform to even greater heights, ANFF-C supported Dynomics to undertake an expert review to develop more advanced fabrication solutions. The company is currently progressing these and hopes to start producing their platforms via a large-scale manufacturing process.

The HeartDyno® system enables researchers to gain unprecedented insights into cardiac biology. Dynomics is poised to revolutionise heart disease treatment, addressing the root causes of heart failure and ultimately restoring heart function. The future of cardiac research looks brighter than ever with the HeartDyno® platform leading the way with every beat.

› SOUNDING BETTER ALREADY

Misti's acoustic nebuliser mask offers child-friendly, efficient respiratory relief, reducing hospital visits and waiting times.

When a child's sniffles turn into coughing, then hacking, their condition worsens. It could be minor, or something more. As their discomfort grows, so does their parents' stress, leading to a visit to the GP for relief and peace of mind.

Globally, 545 million people visit clinics annually with severe respiratory conditions. Among children, respiratory syncytial virus (RSV) is the leading cause, responsible for over 60% of acute respiratory illnesses, and can result in lower respiratory tract infections like pneumonia. RSV hospitalises 3.6 million children each year, with 1 in 5 infants visiting the GP for RSV by age 2.

DR ANUSHI RAJAPAKSA, FOUNDER & CEO
Credit: Misti

Children experience an average of 12 viral illnesses annually, leading to missed school days, doctor visits and parents taking time off work. Early respiratory care can reduce this cycle with treatments that are accessible, effective and effortless – and that can be administered at home.

Inhalation therapy offers fast relief for children with viral infections by delivering medication directly to the lungs, aiming to reduce symptoms, prevent complications and shorten illness duration. Current at-home solutions often fall short. Nasal sprays may irritate delicate nasal passages, inhaler outcomes can be inconsistent if not used correctly, snot suckers are uncomfortable and only temporarily effective, and steam vaporisers may fail to maintain safe humidity levels.

Medical-grade nebulisers that aerosolise medication can be especially beneficial for young children, as they are easier to use and provide better medication delivery. Most convert liquid medication into a mist using compressed air, ultrasonic vibrations or mesh to form the correct size of droplet. However, these nebulisers can be noisy and may deliver medication inefficiently, with only 50–75% of loaded medication converted to mist, leading to prolonged treatment times and wasted medication.

Melbourne-based MedTech pioneer Misti aims to shield children from respiratory illnesses with MyMisti™, a revolutionary nebuliser technology driven by acoustofluidics and packaged in an easy-to-use mask designed with children in mind. MyMisti™ breath-triggered, child-sized mask is easy to wear, non-invasive and runs on battery power.

Acoustic nebulisers use high-frequency sound waves to convert liquid medication into a fine mist of drug particles, which can be inhaled directly into the lungs. Unlike traditional nebulisers, they offer greater control over particle size and distribution. By adjusting the sound waves, the particle size changes, determining the therapy's delivery location in the lungs. Acoustic nebulisers can produce drug particles 1–3 microns in diameter, which can reach the lower airways and deep into the lungs. With 90–95% delivery efficiency, acoustic nebulisers deliver a large aerosol dose to the lung within a relatively short timeframe.

Additional respiratory applications for Misti's technology include the treatment of asthma and chronic obstructive pulmonary disease (COPD), with improved delivery of bronchodilators and corticosteroids for better management. Enhanced delivery of antibiotics and antiviral drugs directly to the site of infection in the lungs can aid in treating infectious diseases, and delivering genetic material to lung tissues can help treat genetic disorders affecting the respiratory system.

Misti's acoustic nebuliser technology will improve the treatment of childhood respiratory diseases. By providing a more child-friendly inhalation therapy easily administered at home, MyMisti™ has the potential to soothe the children in respiratory distress, reduce hospital visits and waiting times for parents, provide long-term savings on costly treatments and get kids back to being kids.

INTERROMATE IN REAL LIFE
Credit: Peter Dekker

› SEEING OUR CITIES IN A NEW LIGHT

> Interromate's robust optical fibre sensors provide the right 'eyes' to monitor the health of urban infrastructure threatened by harsh environments.

Urban life in Australia is a focus of public discussion, especially around sustainability and population distribution. With 67% of Australians living in capital cities, these areas often feel 'full' but continue to expand rapidly. Meanwhile, booming regional areas face mounting pressure on housing, services and infrastructure.

Skyrocketing urbanisation highlights the need for smart cities that use sensors, the internet and automation to enhance the quality of life across the country.

Sensor data helps manage a city's assets, resources and services efficiently, ultimately improving operations. Currently, electric sensors are common but have a short lifespan in hostile spaces such as the corrosive environment in wastewater treatment pipelines. Their reliance on electricity also prevents them being used in environments with explosion, fire or radiation risks.

> Light-based sensing offers a solution. Interromate, a commercial venture based at Macquarie University and a pioneer in advanced laser microfabrication, has developed photonic sensors that are uniquely capable of operating in harsh environments.

Their fibre optic sensors provide long-term, real-time data that traditional sensors cannot match. They use Bragg gratings, which act like a light filter, reflecting specific wavelengths of light while transmitting all others. Bragg gratings are created using ultrafast laser inscription that focuses a laser beam to permanently modify the internal structure of the glass at the heart of the fibre optic. These modifications only need to be made in a couple of millimetres of the fibre to have the desired effect.

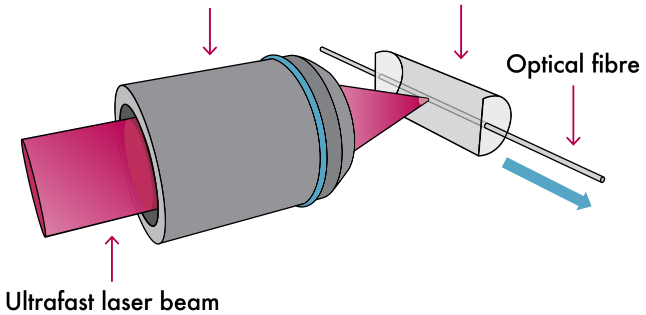
By filtering the light, Bragg gratings act as colour-specific mirrors inside the fibre. Interromate's system tracks the light reflected from these mirrors, providing information about conditions at specific locations along the fibre. Environmental factors affect the Bragg gratings, changing the frequency of the reflected light. For example, heating a glass fibre causes expansion, while cooling causes contraction, altering the light reflected by the sensor. Multiple Bragg gratings can be placed at different locations within the fibre to monitor various environmental changes, such as temperature, corrosion, humidity and strain.

FIBRE OPTIC SENSOR
Credit: Martin Ams

Interromate has removed one of the biggest challenges dooming electric sensors by minimising the impact of environmental conditions on the sensor components, significantly improving sensor readout accuracy and longevity. This is made possible by the inert nature of the sensors. Designed for use in a variety of hostile environments, including explosive, corrosive, high-voltage or hazardous areas, these fibre optic sensors can operate for several years, outperforming electronic analogues that fail after just a few days.

And it is not just the fibre that is on offer. Interromate pairs a commercially available optical fibre with either a custom-designed, user-friendly hardware package or an off-the-shelf interface, depending on the scale needed.

CREATING A BRAGG GRATING IN AN OPTICAL FIBRE



MULTIPLE SENSORS IN A SINGLE FIBRE

Credit: Martin Ams

> This technology is already making its presence felt. In the water utility sector, Interromate is partnering with Sydney Water and Melbourne Water to help them better manage and rehabilitate wastewater infrastructure.

Corrosion in deteriorated concrete gravity sewers can lead to premature pipe failure. Photonic sensing promises to improve sewer pipe management by providing in-situ monitoring capabilities, reducing the need to enter sewer pipes, and offering superior predictive corrosion strategies. This approach mitigates health risks to the public and leads to significant cost savings, allowing compromised pipes to be rehabilitated before corrosion goes too far.

Infrastructure sensors are the hidden foundation of smart green cities. They are essential for detecting developing problems, predicting when infrastructure components will reach the end of their life and extending the service life of city assets.

Interromate is at the forefront of smart city technology that will contribute to the sustainability and management of Australia's expanding urban environments.

› CLEAR VISION FOR THE GLOBE

OOXii has developed a Vision Kit containing everything a basic health worker needs to test vision and assemble affordable, customised glasses on the spot in remote and low-resource communities.

One billion people worldwide experience impaired vision simply because they lack access to affordable glasses. Described by the World Health Organization as a global health crisis, accessibility to eye care has been added as a resolution to Sustainable Development Goal #3: Good health and well-being.

To obtain glasses, one currently needs a prescription from an eye health professional determined through a series of tests. The refraction test is the key part of determining a prescription. The doctor uses a device called a phoropter, which contains different lenses. The patient looks through the phoropter and indicates which lenses make their vision clearer. These responses help determine the exact lens power needed to correct vision. Getting the correct prescription is just the first step of better vision, as the glasses must then be custom made.

Over half of avoidable vision impairment worldwide is simply due to lack of access to spectacles.

Accessing eye care in remote Australia and other similar locations presents several challenges. The vast distances between remote communities and urban centres make it difficult for residents to access eye care services. Even with FIFO (fly in, fly out) medical programs, many remote areas lack the facilities and equipment for refraction tests and glasses fabrication.

OOXii's (pronounced 'ook-see') mission is to make vision care accessible and affordable, especially in remote and low-resource settings by simplifying vision testing and short-cutting spectacle manufacturing. Their innovative Vision Testing Wheel makes it possible for people without prior knowledge of eyes or glasses to determine the correct lens powers to maximise vision. The Vision Kit comes with a full range of pre-cut optical lenses which can be easily inserted into durable, adjustable stainless-steel frames and dispensed on the spot. Combining stylish, durable glasses with pre-cut lenses that can be immediately dispensed, this innovative kit promises to transform the landscape of vision care.

OOXii's pilot studies conducted in Papua New Guinea funded by the Kokoda Track Foundation have yielded promising results, demonstrating the effectiveness and impact of their Vision Kits.

The joint assistance of ANFF-SA and the Medical Device Partnering Program (MDPP) has been pivotal in refining and developing key components of the OOXii Vision Kit, such as the design and functionality of the testing wheel prototype for manufacturing.

As well as accelerating OOXii's progress, the ANFF–MDPP collaboration also provided access to a funding pipeline through ANFF-C. ANFF-C's pre-seed funding has allowed OOXii to propel the design and development of the test wheel forward and incorporate innovations and enhancements that were on the wish list from field trials.

OOXii plans to distribute the OOXii Vision Kits to non-governmental organisations (NGOs) and others providing basic healthcare in remote and low-resource communities, so that functional vision can be obtained where eye health professionals are not accessible.

Ensuring that everyone has access to refractive care is not just about improving individual health; it has far-reaching implications for education, economic productivity and overall quality of life. Clear vision enables children to succeed in school, adults to be more productive at work, and communities to thrive. By addressing this fundamental need, significant strides can be made toward achieving broader development goals, reducing inequalities and fostering sustainable development worldwide.

THE VISION TESTING WHEEL IS A KEY COMPONENT OF OOXII'S VISION KIT. *Credit: OOXii*

› SURGERY'S HIGH-TECH BLOOD MONITOR

Haemograph's trailblazing rheometer transforms surgical safety by providing precise clotting data, helping clinicians balance clot prevention and bleeding control.

Imagine a world where surgery is safer and more efficient, thanks to advanced technology that ensures proper patient blood management before, during and after surgery.

When you're injured or have surgery, your blood naturally clots to prevent excessive blood loss. However, this life-saving process can also increase the risk of a clot forming inside a deep vein, most commonly in the leg, leading to deep-vein thrombosis (DVT).

To prevent blood clots, anticoagulant medications are often used during surgery and post-operative recovery. These medications thin the blood by disrupting normal clotting factors, making it more difficult for clots to form. However, blood thinners can also lead to excessive bleeding, so they may need to be tapered off and reversal agents given to prevent haemorrhaging.

A surgical team treads a fine line between a patient developing dangerous blood clots or bleeding excessively.

Anticoagulant therapy often involves trial and error when determining the right blood thinner, dosage and reversal agent for each patient. Since the best approach can vary from person to person, adjusting these factors in real-time during surgery and throughout recovery is crucial for the best patient outcomes.

Like many liquids, blood behaves differently depending on flow conditions. Circulating blood experiences different shear rates in arteries, veins and capillaries and vessels of different diameters.

Given the complexities from patient variation and shear rate dynamics, clinicians require a diagnostic device that provides real-time, accurate information during surgery and post-operative care.

Enter the rheometer, a device that measures liquid properties related to viscosity, i.e. measures of how 'thick' a liquid is. A blood coagulation rheometer assesses key clinical parameters such as the patient's wclot formation time, clot strength and clot structure.

Current blood clotting measurement methods are generalised, time consuming and static. An accurate, rapid and individualised system is needed to predict patient reactions to different drug combinations and monitor clotting during operations, helping healthcare providers make more informed decisions on the spot and improve patient outcomes.

This is where Haemograph comes in.

Haemograph is a Melbourne-based startup revolutionising surgical care with their innovative portable, point-of-care, blood coagulation rheometer. Requiring only a small blood sample, the rheometer delivers real-time results on clotting time, clot strength and other clot formation dynamics. The system can test a single blood sample against up to 6 medications at once, aiding in clinical decisions on drug selection and dosing by predicting adverse reactions to anticoagulants and identifying the most effective reversal agents.

Haemograph's rheometer can measure blood rheology at various diameters, which is crucial for understanding how blood clots form under the different shear rates found in arteries, veins and capillaries, elevating the device above other products on the market and providing a more comprehensive picture of clotting behaviour.

To achieve this, Haemograph needed to create microfluidic channels featuring multiple long, thin cylinders in series, with several ports connecting them. It was crucial for the rheometer's channel dimensions to be reproducible with minimal errors. The development of this advanced technology was made possible through collaboration with CSIRO and ANFF-VIC's Melbourne Centre for Nanofabrication, from prototype fabrication with precision 3D printers to essential support and training for the Haemograph team.

By providing fast, accurate information to clinicians, Haemograph's rheometer will guide medical professionals in administering the correct dosage of anticoagulants and reversal agents during surgeries and other medical procedures like dialysis, enabling them to successfully walk the tightrope between clotting and bleeding and ensuring better patient outcomes.

CO-DESIGNING THE FUTURE OF MEDTECH

ANFF's Designer in Residence program fosters human-centred design, empowering startups to create user-driven, impactful technological solutions.

Innovation alone does not guarantee a product's success. Even groundbreaking technologies can fail if they overlook everyday consumer needs. High-profile failures like Google Health Records, Segway PT and Evian's Water Bra illustrate how neglecting user preferences and real-world context can derail ambitious projects. For smaller tech startups, this challenge can be even more daunting – products may be finished before they truly begin if user needs are not addressed from the outset.

Design thinking places the user at the centre of the development process, helping technology developers create intuitive, user-friendly solutions.

To foster this mindset across the ANFF network, we enlisted Monash University's A/Prof Leah Heiss, the Eva and Marc Besen International Research Chair in Design, as our inaugural Designer in Residence.

Embedded within the Melbourne Centre for Nanofabrication, Dr Heiss shares her expertise in design thinking and human-centred design for health technologies, systems and services.

This initiative has already led to early successes, such as the 2022 ANFF National Staff Retreat and the 2023 ANFF-SA Microengineering School, where design thinking workshops deepened participants' understanding of user-centred product development.

The ANFF Design Acceleration Program (DAP) further formalises this approach by offering a structured design thinking experience to our ANFF-C clients. Through DAP, these entrepreneurs can address user experience challenges and explore how their products fit within users' lives and broader service systems. In late 2023, 2 Victorian MedTech startups, Haemograph and Symex, participated in a 3-day DAP workshop that infused design-oriented thinking into their product development processes.

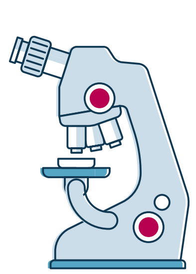
Co-design adds another layer to the process by actively involving multiple stakeholders in the design process. Dr Heiss demonstrated the power of co-design during ANFF's 2024 Sustainability Workshop, where her Interactive Co-Design session brought together participants to collaboratively envision a future for Australasian nanofacilities and nanolabs that aligns nanotechnology development with sustainable practices.

By embedding a design thinking mindset, ANFF ensures that innovations aren't just technically advanced but also aligned with real-world needs, driving both innovation and adoption as we move towards better technology futures.

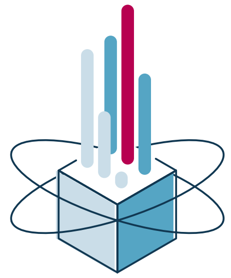
DR LEAH HEISS LEADING A DESIGN ACCELERATION PROGRAM WORKSHOP.
Credit: Melbourne Centre for Nanofabrication

ANFF EQUIPMENT

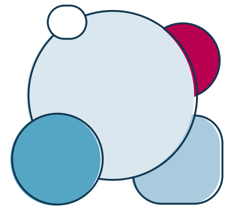
ANFF provides access to micro- and nanofabrication equipment and expertise. These capabilities are used to do anything from making new metamaterials to CNC milling of blood-carrying microchannels.



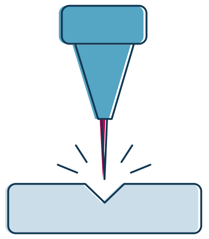
LABORATORY INFRASTRUCTURE



MODELLING & DEVICE DESIGN

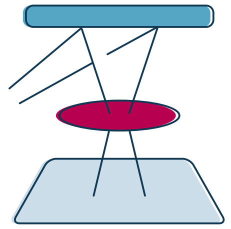


MATERIALS SYNTHESIS & MODIFICATION

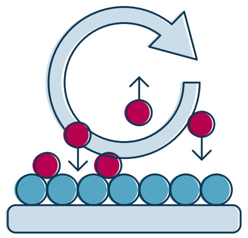


ETCHING

PACKAGING

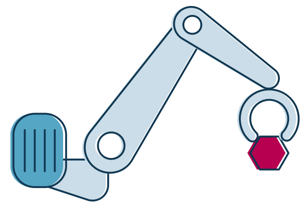


LITHOGRAPHY



DEPOSITION

TESTING & VALIDATION



MANUFACTURING & MACHINING

› FUELLING SUCCESS THROUGH CONNECTION

ANFF's Client Engagement Team unlocks opportunities for industry clients, linking them with the right ANFF tools and expertise to ignite innovation and boost success.

ANFF overcomes hurdles to science research and technological innovation by providing open access to Australia's world-class micro- and nanofabrication infrastructure, essential to this country's scientific and economic future.

However, finding a specific capability among our extensive network of 8 Nodes and 21 locations can be a challenge. We have so much to offer.

The ANFF network has improved its capacity to engage with industry by building a client-focused facilitator team, dedicated to spurring Australian innovation by simplifying the process of engaging with ANFF. Once the team develops an extensive understanding of a client's research and their development and commercialisation plans, it provides the client with a roadmap describing how ANFF's expertise and infrastructure would be of assistance to them.

The Client Engagement Facilitators (CEFs) are the primary contacts for any industry client whose needs transcend a single ANFF Node or for those that require assistance finding the best way that ANFF can support their project. CEFs provide concierge-level services, taking ownership of the client's problem and engaging the ANFF network to find the best possible solution.

Our CEFs truly have their clients' needs in mind. While they provide a gateway into ANFF, their goal isn't to bring work to ANFF but to find the best solution to help companies innovate, even if that solution lies with other NCRIS Providers or other support opportunities.

We are excited to announce that Dr Marta Sánchez Miranda has joined ANFF as the new Client Engagement Facilitator for Quantum Technologies, succeeding Dr Navin Chandrasekaran. Dr Sánchez Miranda brings a wealth of experience and expertise in quantum and photonics, and we are confident she will continue to drive innovation and support for our clients in this sector.

Our CEFs are increasingly recognised for their deepening expertise across Australia's diverse technology sectors. Their knowledge and insights are highly sought after, leading to invitations to participate in panels and workshops and deliver presentations for industry organisations such as MTPConnect, Quantum West, MedTech Actuator, InnovationAus, and the Victorian Medtech Skills and Devices Hub (VMH). Notably, Dr Chandrasekaran authored a white paper on 'Delivering the Quantum Promise: A Handbook for Businesses to Engage with the Australian Quantum Ecosystem.' This growing demand for our CEFs underscores their valuable role in shaping and supporting innovation in the Australian technology landscape.

130+

industry referrals to potential solutions provided in FY24.

Distributed nationwide, the focus areas of each CEF aligns with the national priorities that ANFF is best positioned to support:

- medical technologies (Mr Oded VanHam, based in Victoria)
- quantum and photonics (Dr Marta Sánchez Miranda, based in New South Wales)
- space and defence (Dr Matthew Chong, based in South Australia).

With our dedicated focus on industry engagement, ANFF invites organisations from all sectors to get in touch with the CEF team to assess your requirements with access to tools and facilities or to provide support in addressing an advanced manufacturing challenge.

DR MATTHEW CHONG, DR MARTA SÁNCHEZ MIRANDA AND MR ODED VAN HAM

› ACCESSING ANFF

ACCESS STEPS

ANFF is committed to exceeding the customer service expectations of our clients.

CONTACT US AT INFO@ANFF.ORG.AU → **DISCUSS PROJECT WITH ANFF AND ESTABLISH PATHWAY** → **ACHIEVE PROJECT OBJECTIVE**

RESEARCHERS

For researchers seeking to engage with ANFF, we invite you to contact your local Node who can have an initial discussion around how ANFF capabilities and expertise can align with your research needs.

INDUSTRY

The primary point of contact for industry is the ANFF Client Engagement Facilitator (CEF) team. They can help clients find the best way ANFF can support their projects or for those whose needs transcend a single Node. The CEF can then take ownership of the client's problem and engage the ANFF network to find the best possible solution.

ANFF-C

ANFF-C works with ANFF clients to identify and remove barriers on the translation pathway with dedicated funding for out-of-the-lab services.

Dr John Morrison, Director ANFF-C, would be delighted to discuss with you how the platform can be of assistance.

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The ANFF team at the 2023 National Staff Forum
at the Australian Synchrotron in Melbourne.

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