INSTITUTE FOR FRONTIER MATERIALS

Annual Report 2022

IFM
INSTITUTE FOR
FRONTIER MATERIALS

DEAKIN
UNIVERSITY

CHAIR'S REPORT

In 2022, as we enjoyed the first full year of research without pandemic lockdowns since 2020, IFM's researchers once again delivered excellent research with tangible outcomes for our industry partners and the communities we serve. Their work plays a significant role in allowing Deakin to realise its ambition to enable a sustainable world through the design of smarter technologies and a circular economy.

During the year, we welcomed biomanufacturing expert Professor Sally McArthur as IFM's new Director. Sally joins us from Swinburne University, where she was Director of the Manufacturing Futures Research Institute.

Many thanks to Alfred Deakin Professor Matthew Barnett who led IFM so ably through challenging times and who will now, finally, get to commence his highly prestigious ARC Laureate Fellowship!

Research-driven materials manufacturing

Contributing to a strong and vibrant sovereign manufacturing capability remains a priority for the Institute. I'm proud to announce that the IFM-led Battery Research and Innovation Hub, funded by the Victorian and federal governments and industry as part of the Victorian Higher Education Strategic Investment Fund (VHESIF), was completed in 2022. The $10.3 million hub is an advanced battery design, fabrication and testing facility to pilot production of next-generation and energy storage.

The VHESIF-funded $20 million ManuFutures2 at Waurn Ponds campus was also completed, doubling the size of ManuFutures to create a hub for IFM partners to further incubate and accelerate the ideas developed at IFM.

IFM researchers played a pivotal role in Deakin being awarded $50 million in funding from the Federal Government's inaugural Trailblazer Universities Program. With government funding more than matched by industry and university partners for a total value of more than $380 million, Deakin will spearhead the largest recycling and clean energy manufacturing ecosystem in Australia.

Through this Recycling and Renewable Energy Commercialisation Hub (REACH), we will work with governments, industry and education partners, to establish a multi-billion-dollar bioeconomy in Victoria, focused on clean energy, recycling and greener supply chains. The initiative will drive significant innovation in Geelong, Western Victoria and beyond, and is expected to generate 2,500 jobs and more than $1.4 billion in revenue in the next decade. This successful bid is an important recognition of Deakin's national leadership in sustainability innovation, research commercialisation and collaboration, our strong intellectual property pipeline and our enviable track record in successful industry engagement to create a positive impact.

The new ARC Research Hub for Functional and Sustainable Fibres, the successor to the ARC Research Hub for Future Fibres, commenced operations, using the world-class expertise and capabilities of IFM's Future Fibres research group, led by Professor Joselito Razal, to help accelerate circular innovations in textiles and fibres.

A big year for research excellence

IFM's research income increased by 14% to $21.2 million in 2022, a testament to the innovation and reputation of IFM's researchers. The number of papers published by IFM researchers in high-ranking journals continued to increase in line with the pleasing trend of recent years.

My congratulations to those who achieved success through grants, awards and professional recognition, among them Alfred Deakin Professor Maria Forsyth, who was elected a Fellow of the Australian Academy of Technological Sciences and Engineering for her decades at the forefront of global research and innovation in energy storage.

Congratulations also to Alfred Deakin Professor Ian Chen for his inclusion in the 2022 ClarivateTM Highly Cited Researchers list, which identifies researchers who have made the most significant contribution to global research in the past decade; ARC Discovery Early Career Researchers – Dr Qiran Cai, Dr Quanxiang (Sulley) Li and Dr Alban de Vaucorbeil; and our latest ARC Future Fellows – Associate Professor Weiwei Lei and Associate Professor Dan Liu.

I'm confident the future of research at IFM is in good hands!

Professor Julie Owens
Deputy Vice-Chancellor Research
Chair Institute for Frontier Materials

IFM INSTITUTE FOR FRONTIER MATERIALS
DEAKIN UNIVERSITY

CONTENTS

Institute for Frontier Materials acknowledges the Traditional Custodians of the land on which our Deakin University campuses reside. The Wadawurrung people of the Kulin Nation on whose land our Geelong campuses are located, the Wurundjeri people of the Kulin Nation on whose land our Burwood campus is located and the Gunditjmara people on whose land our Warrnambool facility is located.

Q&A

Professor Sally McArthur, Director, Institute for Frontier Materials

What inspired you to join IFM as director?

IFM has always been an exemplar of how research organisations can build and lead a culture of impact and industry collaboration within a university and a region.

I'm excited to bring my diverse range of experience and skills to Deakin and lead IFM into the future. I've joined a team of talented scientists who are transforming material design and creating novel, renewable materials and by-products.

Since you joined IFM in 2022, many things have happened, including the Battery Research and Innovation Hub launching and IFM joining Deakin's Recycling and Clean Energy Commercialisation Hub (REACH). How are you leading IFM through this growth?

It's an interesting balancing act – between the different opportunities that are coming up, building the best teams that we can put forward and bringing it all together so that people want to collaborate with us as a partner of choice.

We must be clear on what we're able to do and ensure that we build the ecosystem that can do it. But on the other side of that, we need to look at all our activities as a whole institute.

We know we can do a lot on an individual basis but what I can bring is the ability to look at the overall picture and ensure that the opportunities that come our way are not only shared across IFM but also with the wider Deakin environment and our external partners.

You are an expert in materials and manufacturing and in 2021 you became a Fellow of the Australian Academy of Technological Sciences and Engineering for your work in industry-academic research collaborations. What led to this focus in manufacturing?

Materials are great. They are the underpinning piece of what we do but materials don't occur in isolation. There's processing – making them into the object, but then there's the manufacturing – the integration of them into a product and that is crucial.

Making stuff is what I love, and you can't do that without thinking about the process. I'm a characterisation specialist – I measure things – and so one of the joys of coming to IFM is getting back to my materials roots and the diversity of the material capability. I also like that we can solve so many problems by effectively applying our materials knowledge. I love IFM's 'fumehood-to-factory' approach and our ability to bring innovation to scale through the work we can do with Carbon Nexus, the Battery Research and Innovation Hub and the advanced fibre recycling facility.

What do you think your skill set will bring to IFM?

My focus is on building communities. I want to ensure that what we do at IFM is visible and that we are underpinning a variety of different things and bringing them forward.

This is why I like to focus on collaborating with industry and working with start-ups – translating research and inspiring excitement from that is paramount.

It's a joy to watch people find the right area for them and help them discover their value.

I'm here to enable people.

One of my biggest goals is for IFM to be seen as the thought leaders in this space – in all the domains we are experts, whether it's materials for a circular economy or materials for processing and energy. I want to get to a place where nobody would even think about doing something without asking us to the table.

Reflecting on 2022, what are the most exciting achievements and why?

Getting the ARC Research Hub for Future Fibres, the ARC SafeREnergy Hub and the Battery Research and Innovation Hub up and running was momentous, but there were many smaller everyday achievements that were equally important.

Our IFM Annual Conference returned. We also had fantastic people supporting each other and working together to deliver business as usual, and three Discovery Early Career Researcher Awards (DECRA) – it all shows that our ecosystem is healthy.

It's also essential that we celebrate finishing things as well as starting things. The completion of the original hubs, plus completing many of our projects knowing that our industry partners are happy. We can't lose sight of those things.

What would you like to see IFM achieve in 2023?

Community is my main goal for 2023. To implement a clear strategic plan across the institute and help our groups develop their longer-term plans so that we have a strong foundation for the next big thing.

IFM has a role in the university to enable large-scale projects that bring all of the university's capabilities together to solve societal problems.

I am excited to see what we can achieve with this approach in 2023.

EXECUTIVE TEAM

Professor Sally McArthur
DIRECTOR

Professor Maria Forsyth
DEPUTY DIRECTOR

Professor Daniel Fabijanic
PROFESSOR, RESEARCH

Professor Russell Varley
PROFESSOR, CARBON FIBRE COMPOSITES THEME LEADER

Michelle Gait
GENERAL MANAGER

Professor Joselito Razal
PROFESSOR, FIBRES AND TEXTILES THEME LEADER

Professor Tiffany Walsh
PROFESSOR, BIONANOTECHNOLOGY

Professor Jenny Pringle
PROFESSOR, RESEARCH

2022 BOARD MEMBERS

Professor Julie Owens
CHAIR AND DEPUTY VICE-CHANCELLOR RESEARCH

Professor Iain Martin
VICE-CHANCELLOR

Professor Sally McArthur
DIRECTOR, IFM

Professor Maria Forsyth
DEPUTY DIRECTOR, IFM

Professor Nick Birbilis
EXECUTIVE DEAN, FACULTY SCIENCE ENGINEERING AND BUILT ENVIRONMENT

Professor Kon Mouzakis
CO-DIRECTOR, A2I2 INSTITUTE

Professor Gordon Wallace
EXTERNAL INDEPENDENT DIRECTOR

Professor Sybrand van der Zwaag
EXTERNAL INDEPENDENT DIRECTOR

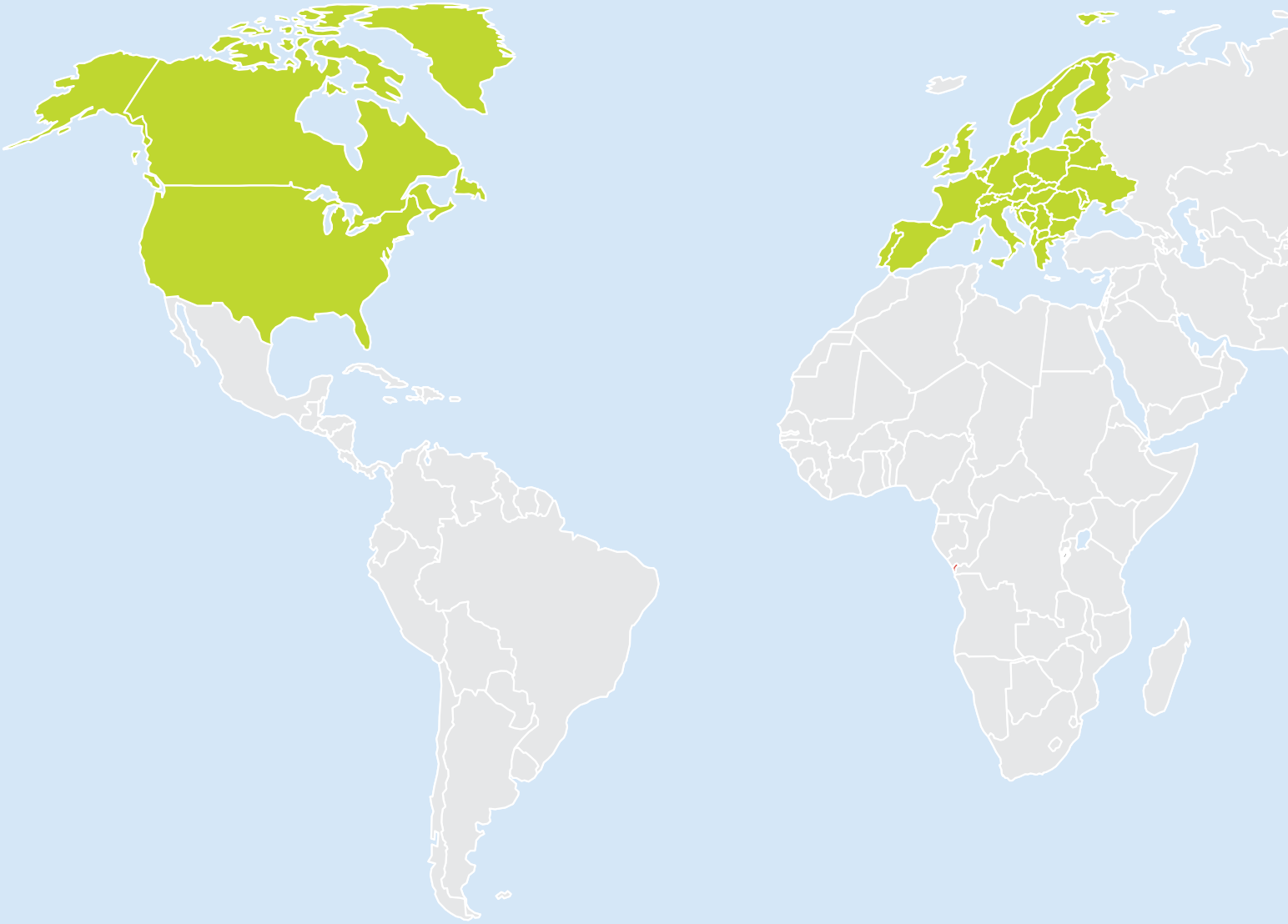
Michael Grogan
EXTERNAL, INDEPENDENT DIRECTOR

Dr Kathie McGregor
SENIOR REPRESENTATIVE, CSIRO

Genevieve Reid
DIRECTOR, DEAKIN SECTORIAL PARTNERSHIPS

Peter Hansford
LOCAL OR STATE GOVERNMENT REPRESENTATIVE

A WORLD OF COLLABORATORS



We're a trusted partner for 130 innovative organisations across the globe who want to access the best and brightest minds in material science. These partnerships are crucial to driving new discoveries and accelerating the research from idea to industry.

AUSTRALIA 95
BELGIUM 1
CANADA 2
CHINA 4
DENMARK 2
FRANCE 1
INDIA 1
JAPAN 1
MALAYSIA 1
NEW ZEALAND 2
SPAIN 1
SRI LANKA 1
SWITZERLAND 2
UNITED KINGDOM 4
UNITED STATES 12

OUR VISION

To lead and inspire innovations in materials science and engineering that have a transformational benefit to society.

IFM AT A GLANCE

$21.2m
Research income

Students from
39
countries

201
Higher degree research students

49
Student completions

505
Publications

51
Staff

119
Researchers

OUR MISSION

To create and translate knowledge at the frontier of materials science for globally raised standards of living by:

- redesigning materials for a circular economy
- imparting materials with extraordinary functionality through excellence in research quality, translation, training and research culture.

Materials for a Circular Economy

2022 snapshot

A circular economy requires superior materials that last multiple life cycles with minimal impact on the planet.

At the Institute for Frontier Materials, our researchers are pioneering material science innovations by redesigning materials that:

- have a clear pathway after their first life
- make use of waste
- are superior, fit for purpose and easily repaired to last a lifetime.

In 2022, IFM was part of Deakin University's bid for a share in the $380 million Federal Government Trailblazer Universities Program. Deakin was successful – receiving $50 million to kick-start the Deakin Recycling and Renewable Energy Commercialisation Hub (REACH), which will work with governments, industry, and education partners to establish a multibillion-dollar bioeconomy in Victoria focused on clean energy, recycling and greener supply chains.

REACH has a range of supported research-industry partnership projects already underway, three of which have come out of IFM.

One project aims to establish an Australian supply chain for the manufacture of advanced technology batteries with greater energy density and shorter charge times. Another major project aims to recycle soft plastic in a closed-loop system. The third is a carbon fibre recycling facility with Gen2Carbon.

REACH will build on Deakin's end-to-end manufacturing capabilities in renewable energy and recycling and its 'Future Economy' commercialisation ecosystem across its campuses, which includes IFM facilities, the Battery and Research Innovation Hub, Carbon Nexus and the Future Fibres Facility.

Meeting the need to go full circle

From recycled waste to world-first fibres, the Institute is at the vanguard of adaptation and innovation.

1 FUTURE FIBRES HUB LAUNCHED

In 2022, IFM researchers re-established the ARC Research Hub for Future Fibres after securing $5 million from the Australian Research Council (ARC) along with a cash contribution from Deakin University and $4.5 million pledge from 11 industry partners. IFM's Future Fibres, Australia's largest fibre and textile research group, and Carbon Fibre and Composites research groups will work out of the hub and use its world-class expertise and capabilities to improve the sustainability of the textile industry.

Led by Future Fibres theme leader Professor Joselito Razal, work at the Hub will help accelerate circular innovations in textiles and fibres. It will incorporate 10 chief investigators from IFM and 13 partner investigators – one from each industry partner and five from other academic and research institutions, four of which are international.

The group's recycling capabilities were further enhanced in 2022 when it acquired a fibre recycling facility within Deakin University's Waurn Ponds Campus.

2 INNOVATION IN SOLAR PANEL RECYCLING UNLOCKS VALUE

Dr Md Mokhlesur Rahman and his team successfully tested a new process that safely and effectively extracts silicon from old solar panels that can be converted into nano-silicon, which is worth more than $45,000 per kilogram.

When the nano-silicon is mixed with graphite, it can be used to make a new type of battery anode shown to increase lithium-ion battery capacity by a factor of 10 – a critical breakthrough in energy storage technology.

3 INNOVATION SEES VESTAS ON TRACK FOR ZERO WASTE

Working with the Danish wind turbine company Vestas, IFM researchers at Carbon Nexus in 2022 created new carbon fibre composites with improved compressive properties for longer-lasting and better-performing wind turbine blades. Poor ductility is considered the Achilles heel of carbon fibre – however researchers, led by Professor Russell Varley and Senior Research Fellow Dr Claudia Creighton, were able to overcome this by finely controlling the microstructure and chemistry of both the resin and fibre. The result allows for longer wind turbine blades, which increases energy harvesting rates and in turn lowers the cost of renewable energy. The project also developed a new approach to the recovery and reuse of carbon fibres from end-of-service-life (EOSL) blades that maintains the properties of the carbon fibre. This breakthrough technology supports the company's target to achieve zero waste by 2040.

4 MAJOR FUNDING BOOST FOR BRIGHT IDEAS

Two IFM projects to develop new uses for recycled waste have received close to $500,000 thanks to the Victorian Government's $4.9 million Circular Economy Markets Fund, which is being distributed by Sustainability Victoria.

The first project, led by Associate Professor Rangam Rajkhowa, received $284,553 to produce particles from textile waste and investigate a range of applications including pigments for printing/colouring textiles, vegan leather and art.

The second project will receive $202,000 to demonstrate how used polypropylene paint containers, a difficult-to-recycle waste stream, can be recycled into functional and economically viable products. The project will be led by Professor of Composite Materials Russell Varley and Dr Jane Zhang, who are both based at IFM's Carbon Nexus facility.

6 TEAMING UP FOR A WORLD FIRST

The Future Fibres group helped achieve a world first in 2022, producing a garment made from 100% tree-free and forest friendly lyocell fibre and designed by Australian fashion designer Lee Mathews.

The Nullarbor™ lyocell fibre was created by Nanollose, a bio-materials company focused on commercialising scalable technology to create fibres and fabrics with minimal environmental impact, in collaboration with leading cellulosic fibre manufacturer Birla Cellulose.

The 100 per cent Tree-Free Nullarbor fibre was made at its research and development facilities in India and spun into yarn by the Institute for Frontier Materials using standard industrial yarn making equipment, supported by Australian National Fabrication Facility (ANFF).

The resulting Nullarbor yarn spun by IFM was provided to Victorian knitwear developer, Knovus, who made two copies of the Lee Mathews designed garment and sample swatches using the latest zero-waste 3D knitting technology.

The process demonstrated that Nullarbor lyocell fibre integrates seamlessly with existing industrial equipment to produce high-quality garments.

7 FOOD WASTE KEY TO REUSABLE PPE

IFM researchers joined forces with the Faculty of Health, the Deakin Sustainable Health Network (SHN) and Barwon Health in 2022 to explore a new way to design reusable personal protective equipment (PPE) by combining plastic with food waste.

IFM's Dr Omid Zabihi and Professor Minoo Naebe were joined by Dr Rebecca Patrick (SHN) and Dr Mike Forrester (Barwon Health and SHN) in the research, which looked at upcycling PPE, made of polypropylene polymer, into functional composites – for applications in areas such as health, automotive and transport. In this project, funded by an Executive Dean – Health Strategic Fellowship, researchers processed waste single-use face masks to fabricate high-performance glass fibre-reinforced composites containing up to 70 wt% recycled contents. To rectify the brittleness of the recycled polypropylene, researchers modified the polymer with bio-sourced materials from food industry waste, which improved the strength of the polypropylene. Researchers hope their findings, expected to be published in 2023, will reduce waste, cut costs in waste disposal and PPE procurement, and contribute to the development of new technologies, materials and manufacturing processes across various industries beyond healthcare.

8 WASTE CARPET PRODUCT OFF TO A STRONG START

Around the world, millions of tonnes of carpets are being dumped and sent to landfill. However, researchers from the Institute for Frontier Materials (IFM) have helped develop an Australian first – a solution that reuses carpet fibre waste to create a product that strengthens concrete in a range of applications.

FibreCrete 100, a carpet fibre-reinforced concrete that can be applied to driveways, pedestrian and cycling paths, and industrial hardstand areas, was created in collaboration with Geelong-based GT Recycling and Godfrey Hirst. The product, which drew a Highly Commended Award from Carpet Recycling UK, was commercialised at the end of 2022.

IFM's Professor Lingxue Kong led the research alongside Dr Mary She.

8 HUB TO FOCUS ON GREENER ENERGY STORAGE

Recycled and natural materials will be key in the development of a new generation of safer and more reliable energy storage and conversion technologies at the Australian Research Council (ARC) Research Hub for Safe and Reliable Energy (SafeREnergy), which was officially launched in 2022 by Senator Jess Walsh, Senator for Victoria, and ARC CEO Judi Zielke.

SafeREnergy, led by IFM under the directorship of Alfred Deakin Professor Ying (Ian) Chen, is a collaboration between Deakin University, University of Queensland, University of Wollongong, University of Sydney, University of Adelaide, and University of Southern Queensland, and 10 industry partners.

The ARC is investing $5 million over five years to the Hub, under its Industrial Transformation Research Program. The hub also received $4.9 million in cash contributions, and $5.6 million of in-kind support from other participating organisations.

Ambitious goals drive innovation in alloys, scrap reclamation

Metals are remarkable materials – malleable, strong, durable and infinitely recyclable. But despite those circular properties, the production of metals faces multifaceted challenges that put pressure on the environment and the economy.

It's a problem that has been top of mind for the researchers who specialise in metals and advanced alloys at the Institute for Frontier Materials.

The group, led by Alfred Deakin Professor Matthew Barnett, wants to unlock the potential of metals to develop longer-lasting, energy-saving alloys. Prof. Barnett also wants his team to develop new approaches to reclaim the scrap metal that already exists – which has enormous potential for Australia's sovereign capabilities.

'End-of-life-recycling rates can approach 85%, however the global dollar losses of un-recycled metals amount to over $40 billion per year,' he says.

'In addition to our enormous exports of ore, last year Australia exported stainless-steel and aluminium scrap to the value of nearly $1 billion. This is a lost resource that represents significant opportunity to add value locally and shore up vulnerable supply chains.'

And Prof. Barnett says it's not only a lost economic opportunity.

'It's worse than that,' he says. 'The market value of a material scales almost linearly with the energy required to make it.

'So, this is also lost energy. Efforts to reclaim alloys lost to the economy can save on energy as well as landfill.'

Prof. Barnett is considered a world leader for his contributions to alloy development in sheet steel research, light metals development, alloy characterisation and alloy performance.

In 2021, he was awarded a highly competitive and prestigious Australian Research Council Laureate Fellowship, which provided almost $3 million in funding to explore his idea of 'Alloy alchemy: New paradigms in alloy science to promote a circular economy'. Ultimately, Prof. Barnett hopes to produce new ways to tap into the scrap metal market by developing alloys that better serve society across three measures: economic, environmental and social.

The Laureate Fellowship, which started in 2022, is only one part of his group's wider research focus.

"Our team is developing longer-lasting alloys – to keep value in the economy longer – and developing new approaches to reclaim lost scrap metal ..."

PROFESSOR MATTHEW BARNETT

'In 2022, the team delivered new coatings that extended life in the mining sector, developed aluminium compositions that promise to reduce the weight of overhead high-tension power cables and furthered concepts in mass-produced modular housing that is readily repurposed at end of life,' Prof. Barnett says.

'Our team is developing longer-lasting alloys – to keep value in the economy longer – and developing new approaches to reclaim lost scrap metal, while pushing down energy consumption during processing. The team is also creating solutions that make recycling easier.'

In one such project, the research team, led by Professor Daniel Fabijanic, worked with Callidus Welding Solutions to develop a novel coating system that improves the lifetime of seated ball valves used in the critical mineral industry. The valves play a key role in the hydrometallurgy production of critical minerals such as nickel, cobalt and gold, and are exposed to significant wear and tear because of the high-temperature, high-pressure, corrosive and erosive environment contained within. IFM's novel coating system fuses the coating onto the dominant surface alloy of the valve to improve its lifespan and efficiency.

IFM's Advanced Alloys research group is developing ways to make recycling metals easier, such as concepts for mass-produced modular housing that is readily repurposed at end of life.

The team has also partnered with FormFlow, a Geelong-based start-up that developed a unique corrugated steel bending process. IFM research, led by Dr Matthias Weiss, helped FormFlow create a 2D laser system that monitors the cross-sectional shape of corrugated sheets before and after bending for continuous quality control. They also designed an Industry 4.0 manufacturing cell capable of producing a corrugated corner bend from a flat sheet of steel.

The collaboration has contributed to FormFlow's expansion to FormFlow Living – a business that designs, develops and manufactures high-value, affordable modular housing using innovative building systems.

However, the team's work in metals manufacturing to date has only scratched the surface.

'The coming year will see the team combine efforts in a bid for a centre in "alloys of net zero", creating a synergy between efforts to prolong material life, increase recyclability and improve alloys for renewable energy applications,' Prof. Barnett says.

'The year will also see the group launch fastAlloy, an integrated rapid prototyping lab.'

2022 breakthroughs

Work hardening and the scratch resistance of Ni-Co alloys using a rapid prototyping approach

JOURNAL ***Wear***
AUTHORS **Sitarama Kada, Alban de Vaucorbeil, Daniel Fabijanic and Matthew Barnett**

The investigation revealed important implications for the prediction of scratch resistance using material properties and developed techniques to facilitate the rapid prototyping, from months to weeks, in the development of scratch-resistant alloys.

https://doi.org/10.1016/j.wear.2022.204493

Microstructure evolution of 316L stainless steel during solid-state additive friction stir deposition

JOURNAL ***Philosophical Magazine***
AUTHORS **Hossein Beladi, Ehsan Farabi, Peter Hodgson, Matthew Barnett, Gregory Rohrer, Daniel Fabijanic**

The paper revealed how one of the team's new additive manufacturing technologies can be used to create exceptional steel microstructures.

https://doi.org/10.1080/14786435.2021.2011980

Prototyping of straight section components using incremental shape rolling

JOURNAL ***The International Journal of Advanced Manufacturing Technology***
AUTHORS **Abdelrahman Essa, Buddhika Abeyrathna, Bernard Rolfe, Matthias Weiss**

This paper presents a new forming technology, incremental shape rolling, where a pre-cut blank is clamped between two dies, and then a single forming roll is used to incrementally form the material to the desired shape.

https://link.springer.com/article/10.1007/s00170-022-09600-7#auth-Abdelrahman-Essa

Enhanced precipitation kinetics in non-stretched Al-Cu-Li-Mg-Ag-(Sc)-(Zr) alloys

JOURNAL ***Scripta Materialia***
AUTHORS **Lu Jiang, Katrin Mester, Robert Knott, Kathleen Wood, Anna Sokolov, Timothy Langan, Matthew Barnett, Thomas Dorin**

This work investigates the impact of scandium and zirconium on the precipitation kinetics in an aluminium-copper-lithium alloy in the absence of pre-stretching.

https://www.sciencedirect.com/science/article/pii/S1359646223001185

Materials with Extraordinary Functionality

$500k boost for Xefco partnership

Future Fibres' Short Fibres Group and its long-standing partnership with advanced textile technology company Xefco received a $500,000 funding boost from the Innovative Manufacturing Cooperative Research Centre (IMCRC).

In this 10-month project, the Future Fibres group and Xefco aim to deliver longer-life antiviral face masks and other personal protective equipment (PPE) that safeguard against infectious pathogens such as COVID-19.

The project, now in its final stages, has improved the durability of already-developed antiviral and heat-reflective metallic coatings for textiles (pictured).

The new Battery Research and Innovation Hub.

2022 SNAPSHOT

The materials of the future must last longer, be flexible, transform function, and interact with people like natural materials do.

At IFM, researchers are uncovering materials with extraordinary functionality – making scientific discoveries and developing paths to bring those discoveries to large-scale commercialisation.

In imparting materials with extraordinary functionality, the institute aims to produce materials with extraordinary:

- paths to creation
- environmental durability
- performances in devices
- human interactability
- similarity to natural materials.

In 2022, IFM researchers made major breakthroughs in material science, from discovering how to safely store and transport gases, such as hydrogen, using ball milling, to developing a machine-learning model that can quickly and accurately identify whether a material is stable or unstable.

IFM also launched the new Battery Research and Innovation Hub, enabling its researchers to deliver next-generation solid-state lithium-ion cells, as well as alternative and upcoming technologies such as sodium batteries.

Invention, ingenuity to the fore

IFM's inventive teams are collaborating widely and across the globe on a range of breakthrough projects.

1 DISCOVERY UNLOCKS SAFER GAS STORAGE

The breakthrough process that offers a novel way to separate, store and transport huge amounts of gas, such as hydrogen, safely, with no waste, was first described by IFM nanotechnology researchers in the prestigious journal *Materials Today* in 2022. The IFM research, led by Alfred Deakin Professor Ying (Ian) Chen and Dr Srikanth Mateti outlines a completely different mechanochemical way of separating and storing gases, using boron nitride powder in a ball mill, which uses a tiny fraction of the energy and creates zero waste. The ball-milling gas absorption process consumes 76.8kJ/s to store and separate 1000L of gases. This is at least 90% lower than the amount of energy used in the petroleum industry's current separation process. The discovery could help create solid-state storage technologies for a range of gases, including hydrogen.

2 NEW PROCESS PREDICTS MATERIALS' STABILITY IN SECONDS

Understanding whether a material is vibrationally stable or not before an experiment requires quantum mechanical calculations that become very expensive as the system size increases.

Research led by IFM's Professor Tiffany Walsh, Dr Sherif Abdulkader Tawfik, and A2I2 co-director Alfred Deakin Professor Svetha Venkatesh, has resulted in the development of a machine-learning process that can obtain accurate classification of a material, including complex compounds, in a fraction of a second. The model can be employed as a 'plug-in' to online materials databases.

The research was published in *npj Computational Materials*.

3 MXENE INK FINDINGS IMPROVE ITS LONG-TERM STABILITY

IFM researchers described the impressive potential of MXene inks in the fabrication of conductive circuits and flexible devices in a paper published in the *Nanoscale* journal. The paper details how MXene inks prepared from solvent mixtures demonstrate long-term stability, which can be employed in commercial rollerball pens to write circuits on flexible substrates. One of the challenges preventing MXene from being used commercially is its rapid degradation under ambient conditions. The paper reported that mixed solvent systems consisting of varying amounts of water and either ethylene glycol or dimethyl sulfoxide can significantly improve the room temperature stability of MXene dispersions. These new findings were used to develop a Ti3C2Tx MXene ink composed of these solvent mixtures.

4 NEW COATING DELIVERS LONGER-LIFE SEATED BALL VALVES

As part of a collaboration between Callidus Welding Solutions and IFM, a research team led by Professor Daniel Fabijanic has developed a novel coating system that improves the lifetime of seated ball valves used in the critical mineral industry.

The valves, which are manufactured from high-performance alloys and can cost upwards of $250,000 each, play a key role in the hydrometallurgy production of critical minerals such as nickel, cobalt and gold, and are exposed to significant wear and tear as a result of the high-temperature, high-pressure, corrosive and erosive environment contained within. IFM's novel coating fuses onto the dominant surface alloy of the valve – in this instance, titanium – creating a longer-life product and increasing efficiency.

The project received $585,000 from the Innovative Manufacturing Cooperative Research Centre (IMCRC).

5 BOOST FOR CANCER TEST'S COMMERCIAL POTENTIAL

The interim results from a 2022 Peter Mac clinical study of cancer testing technology co-invented by IFM's Dr Wren Greene have shown great promise in moving the technology towards commercialisation.

Alongside Swinburne University of Technology's Professor Simon Moulton and Dr Saimon Moraes Silva, Dr Greene co-invented the Universal Biosensors (UBI) Tn Antigen cancer biosensor, which uses a finger-prick blood test to accurately measure changes to a cancer patient's tumour status when monitoring cancer remission and recurrence.

The results suggested the handheld Tn Antigen biosensor – which could be used by oncologists and cancer patients in specialist clinics, hospitals, GP clinics or at home – is potentially more sensitive and more specific than the existing FDA-approved Carcinoembryonic Antigen 'CEA' biomarker used for monitoring colorectal cancer (sensitivity 55.2% and specificity 83.6%).

6 NEXT-GEN TEXTILES INSPIRED BY AUSTRALIAN BEES

In 2022, the Future Fibres group partnered with a New Zealand-based biotechnology research company, Humble Bee Bio, to develop applications for a natural polymer that mimics the water-repellent and flame-resistant properties of the nest material of the Australian solitary bee. The aim is to use the nest material's unique properties and develop a textile coating that could replace the harmful plastic fibres – such as polyester – that are currently on the market.

With Humble Bee Bio providing the bio-synthetically produced protein building blocks of the nest material, the Future Fibres group will develop and engineer a fibre with the same natural qualities, without the need for the bee. The seven-month project received multiple grants, including $70,000 from the Innovative Manufacturing Cooperative Research Centre (IMCRC) and $149,650 from the Victorian Government's Recycling Victoria Innovation Fund, to engineer and sample coatings.

7 CARBON FIBRE FOCUS FOR US NAVY'S BATTERY RESEARCH

IFM researchers embarked on a project with the US Department of the Navy's Office of Naval Research in 2022 to determine what properties within carbon fibre can be controlled for the design of batteries.

The $500,000 project, led by Professor Luke Henderson, is in partnership with Chalmers University in Sweden and will run over three years. Several discoveries have been made so far, including a new coating that enhances the energy storage capabilities of carbon fibre and new energy technology based on multifunctional structural energy storage composites that increases energy storage when bent. This is the first time that the geometry of a composite has been shown to influence the electrochemical performance of a capacitor device. The next phase will be a follow-up study of carbon fibre as an electrode, which is currently under review.

8 NEXT-GEN BATTERIES TRIALLED IN SCOOTERS

New lithium-ion hybrid battery technology using cheap, safe and sustainable electrode materials made it to trials in 2022, further strengthening Australia's battery manufacturing capabilities.

The CRC-P for Advanced Hybrid Batteries is a collaborative project between IFM, Calix Ltd and Boron Molecular and is exploring materials that are cheap, safe and abundant in nature to develop next-generation battery technologies, such as lithium-ion hybrid batteries. The project seeks to demonstrate that these new 'Australian made' battery materials can be produced at scale and used in electric scooters.

In 2022, the team progressed small-scale battery research using a few grams of raw materials and coin cells, to large-scale production of materials at Calix and multilayer pouch cells produced at the Battery Research and Innovation Hub. The cathode (positive electrode) material, used within the technology and developed by Calix, has a multilayer structure and microporosity (nanoscale channels and pores) that allow for more reaction sites to improve performance. The unique structure enables flexibility during battery charge and discharge, protecting the particles from cracks and pulverisation, which is a key cause of performance decay. The multilayer pouch cells are now being tested in a customer trials program in collaboration with storEnergy industry partners, and a scooter battery pack using the technology has been developed by a UK partner.

Sustainable vision powers battery team's achievements

Over the past decade, the transition towards a world powered by sustainable energy has gained momentum.

In Australia, the renewable energy industry is growing, accounting for 32.5% of the country's total electricity generation in 2021 – up 5% from 2020, according to the Clean Energy Council.

But, as lithium-ion batteries, the most used batteries in the world, continue to demonstrate volatility in terms of both safety and sustainability, safer, cheaper and more sustainable battery storage technologies are needed to keep up with demand and support the energy transition.

Creating such technology requires taking a much closer look at the chemistry within a battery.

Electrochemistry is the examination of the chemical processes that involve movement of electrons between materials through an electronic conductor to create electricity.

It is essential in the development of battery technology – and is one area of materials science in which IFM researchers have been leading the way for more than a decade.

IFM Deputy Director and Alfred Deakin Professor Maria Forsyth is a world-leading materials scientist at the forefront of electrochemistry. Since 2010, Prof. Forsyth has led IFM's electrochemistry group, as Chair of Electromaterials and Corrosion Science.

From a team of six, the group has grown to comprise more than 70 researchers who are designing and making new electromaterials, including advanced safer electrolytes, new sustainable binders, cathode materials and sustainable anode materials. The team spans design, synthesis, modelling and advanced characterisation through to device prototyping. They are also using electrochemistry to explore the recycling and recovery of critical materials in used batteries and rare earth magnets used in every motor driving an EV or a wind turbine.

But it wasn't always so.

'When we first joined Deakin, we were doing more corrosion related research – with electrochemistry also at its core – to increase the life of infrastructure. A battery is essentially a corrosion cell. At the time, battery technologies for energy storage were not considered as important in the Australian landscape,' Prof. Forsyth says.

'I remember well that this changed in 2016. That year I was part of the ACOLA [Australian Council of Learned Academies] expert working group delivering a report for then chief scientist Alan Finkel on the role of energy storage in Australia's future energy supply.

'We were exploring opportunities for various energy storage technologies, including batteries, in Australia. That year, after South Australia had its blackout and the world's largest lithium-ion battery was supplied by Elon Musk and installed in Hornsdale to support the SA grid, was when I felt the beginning of a real shift in focus to electrochemical energy storage.'

Prof. Forsyth and her team have been at the forefront of battery research for over two decades and, with the surge of interest in battery technologies, they have continued to be leaders in the field, pushing the boundaries in energy storage research and developing new technologies for safer batteries such as zinc-ion and sodium-ion, as well as high energy density lithium metal batteries enabled by their novel ionic liquid electrolytes. Solid-state batteries based on solid polymer electrolytes developed through collaboration with CSIRO and with international research partners is another exciting development coming from the team.

Among their innovations in 2022 was the use of computational methods to design a new type of polymer electrolyte for polymer-based solid-state batteries and the development of a novel solid polymer electrolyte material that can replace the flammable liquid solvents currently used in sodium batteries.

The group also developed a new ionic liquid hybrid electrolyte that showed excellent performance in a high energy density lithium metal battery with improved stability and dendrite-free cycling; such batteries are applicable in aerospace, drones and long-range EVs.

In addition, researchers from the group, based at the ARC Training Centre for Future Energy Storage Technologies (StorEnergy) – of which Prof. Forsyth is Director – took steps towards a more efficient and cost-effective way to create sodium-ion batteries by developing optimisation protocols for their formation process.

But one of the group's biggest achievements in 2022 was the launch of the Battery Research and Innovation Hub – a $10.3 million world-class facility for battery design, fabrication

Deakin University's Vice-Chancellor, Professor Iain Martin, at the industry showcase of the new Battery Research and Innovation Hub based in Burwood alongside IFM's Professor Patrick Howlett and Alfred Deakin Professor Maria Forsyth.

and testing – an expansion of its previous iteration, BatTRI-Hub, which the group formed in 2016.

The bigger and better hub, situated a short walk from the Deakin Burwood campus, is enabling the team to demonstrate how fundamental science discoveries can be upscaled and made ready for the commercial market.

'Battery Hub is instrumental when we're talking about advanced manufacturing, but it is also instrumental in enabling start-ups and SMEs to enter the market, particularly to create new sustainable and ultimately more affordable systems,' Prof. Forsyth says.

'At Battery Hub, we're looking at current manufacturing technologies and the ways in which these could be changed to decrease the ultimate cost of a battery.

'We talk a lot about the fundamental science and new technologies, but there is also room for opportunities to improve processes – for example looking at AI for more modern manufacturing, using our new materials to make manufacturing more sustainable.'

With the Battery Hub up and running, Prof. Forsyth says they have a chance to regroup and refocus.

'One of my concerns is that everyone is looking to lithium-ion batteries as the "go to" for all applications, and it's a concern because not every application needs lithium-ion and we need to preserve our precious resources and the impact of mining these for where it makes sense to us to use them,' Prof. Forsyth says.

'I want to start looking at what's next, not only from the high-tech perspective but also in terms of safety and affordability.

'How do we make sure that everyone can afford energy storage in their homes or in remote and disadvantaged communities? I don't know what that will be yet but I do want to put some of our efforts into looking at energy justice both technically and also in the education and social context.'

Deputy Vice Chancellor of Research, Professor Julie Owens (centre) was joined by Nina Taylor MP, Member for Southern Metropolitan, Legislative Council, to celebrate the launch of the new Deakin Battery Research and Innovation Hub.

Deakin opens world-class Battery Research and Innovation Hub

IFM's new $10.3 million Battery Research and Innovation Hub was launched in 2022, providing expanded facilities to strengthen Victoria's role in the global supply chain for advanced batteries, and meet the specialised battery needs of industry partners.

The new purpose-built facility, featuring a pilot production line to manufacture advanced battery pouch cells, was officially opened by Nina Taylor MP, Member for Southern Metropolitan, Legislative Council, on behalf of Victoria's Minister for Training and Skills and Higher Education, Gayle Tierney.

The hub also includes a dedicated research innovation laboratory for new battery design and development, prototyping, and, crucially, the much in-demand cell and systems test facility for multiple battery types and sizes.

Initially, the hub will support 13 primary jobs in manufacturing (including battery production technicians and researchers in battery manufacturing), and an estimated 90 direct jobs will be created across the entire project lifetime (2021-2025).

The project includes co-funding from a partnership of the Victorian Government ($5.2 million) and Deakin University ($5.1 million), as part of the $350 million investment in local universities through the Victorian Higher Education State Investment Fund. The fund supports universities with capital works, applied research and research infrastructure to bolster job creation and the state's economic rebound from the COVID-19 crisis.

Taking research from the lab to large-scale production

The Institute for Frontier Materials links world-class materials science research with industry to bring innovative ideas into the commercial world.

IFM is home to Carbon Nexus, the world's largest open access carbon fibre and composite research facility; the Battery Research and Innovation Hub, a prototyping facility for new-generation batteries; and the Future Fibres Facility.

The institute is part of the 543-hectare Future Economy Precinct, where businesses can link with its high-level capabilities in technological innovation, specialised research equipment and industrial-scale infrastructure to drive commercial outcomes.

Here, IFM's work has made it a national leader in research commercialisation and collaboration, and helped Deakin to become Australia's number one university for equity held in start-up and spin-out companies (Survey of Commercialisation Outcomes from Public Research SCOPR).

In 2022, IFM joined Australia's largest recycling and clean energy advanced manufacturing ecosystem, REACH – the Recycling and Clean Energy Commercialisation Hub at Deakin University.

Alongside CSIRO, government, industry and education partners, REACH will establish a multibillion-dollar bioeconomy and drive the nation's transition to a cleaner, greener future.

IFM has the capabilities to work on products at any stage – from raw materials to finished product – using its collaborative framework.

In 2022, IFM researchers at Carbon Nexus embarked on a six-month partnership with leading defence contractor Thales Australia and the Innovative Manufacturing Cooperative Research Centre (IMCRC) to develop Australian-made carbon fibre for composite overwrapped gun barrels.

PROJECT SNAPSHOT
Development of Australian-made carbon fibre for composite overwrapped gun barrels for civil applications

PARTNER **Thales**

RESEARCH TEAM
Professor Russell Varley, Dr Claudia Creighton and Dr Maxime Maghe

TIMEFRAME **Six months**

1 PROJECT'S INITIAL RESEARCH

At IFM, researchers can explore a sustainable idea, improve products and processes, or solve a problem.

As Australia's only sovereign manufacturer with the capability to develop and produce bespoke carbon fibre, Carbon Nexus was the ideal fit for Thales Australia to develop a lightweight composite overwrap for civil gun barrels.

2 OPTIMISATION AND REFINEMENT

IFM provides unique development opportunities including new testing methods to determine the best optimisation for a product.

Using the Carbon Nexus Research Line, and through iterative parameter optimisation of the stabilisation and carbonisation process, researchers successfully developed a carbon fibre that delivered target properties to meet the design needs of Thales.

3 TESTING AND CHARACTERISATION

IFM's world-class analysis and characterisation facilities allow its groups to understand products better.

In-house carbon fibre testing and characterisation facilities at Carbon Nexus enabled in-situ and efficient production parameter optimisation.

As part of the materials characterisation program, single fibre properties and the translation of fibre properties into the composite were evaluated.

The generated materials properties then served as input data for Thales' Finite Elemental Analysis (FEA) model, used for the design and successful delivery of prototype filament-wound composite barrels.

4 SCALE-UP TRANSLATION

IFM can prepare a research idea for commercialisation through its custom-built pilot-scale facilities at Carbon Nexus, the Battery Research and Innovation Hub and Future Fibres facility. IFM researchers can produce larger-scale samples for testing or demonstration.

The carbon fibre production was subsequently upscaled to pilot-plant capacity to demonstrate future production capabilities.

As part of the scale-up translation, IFM researchers ran bespoke training in composites for Thales at Carbon Nexus. Using state-of-the-art equipment, Thales staff gained operator skills in composites manufacture, plus an introduction to quality assurance and composites characterisation.

Hub's overhaul a boost for industry partners

ManuFutures is a unique advanced manufacturing innovation hub located a short walk from IFM – all within Deakin's Future Economy Precinct at the Waurn Ponds campus. Here, IFM partners can accelerate their success after completing research and development.

In 2022, three IFM industry partners expanded production capabilities thanks to new arrangements at the recently remodelled ManuFutures hub.

The new-look $20 million ManuFutures building doubled in size during the year to deliver more tenancy opportunities, new manufacturing incubator programs, training and product engineering services.

Xefco, Paintback and Li-S Energy are among the IFM research partners to take up tenancy at the revamped hub.

The new arrangement enabled Li-S Energy to significantly boost its production capabilities.

IFM has played an important role in the genesis of Li-S Energy, which began as a joint venture between PPK Group Limited, BNNT Technology Limited and Deakin in 2019, before launching on the ASX in 2021 and becoming a multimillion-dollar company.

The new space will expand production capacity for lithium sulphur batteries to more than a thousand cells per week, which translates to more than two megawatt hours of production capacity each year. It also has several adjoining research labs to ensure close and ongoing cooperation between research and production teams.

Li-S Energy CEO Dr Lee Finniear, at the time, said the company was excited to establish its new facility as part of Deakin's advanced manufacturing precinct in Geelong.

"It continues to give us access to world-class researchers, cements our long-term partnership with Deakin, and will bring additional skilled jobs to regional Victoria," Dr Finniear said.

The Li-S Energy agreement was a cornerstone of the realisation of Deakin's Recycling and Renewable Energy Commercialisation Hub (REACH), which aims to drive a sustainable manufacturing revolution.

Li-S Energy is one of the specialised companies with which Deakin's Battery Research and Innovation Hub will partner at its new $10.3 million facility close to IFM in Burwood.

Recognising IFM research excellence

Excelling in our research is at the core of everything we do at IFM. In 2022, our researchers continued to focus on groundbreaking materials research.

Alfred Deakin Professor Maria Forsyth

Elected an **Australian Academy of Technological Sciences and Engineering (ATSE) Fellow** for her decades at the forefront of global research and collaboration in energy storage.

Dr Qiran Cai

ARC Discovery Early Career Researcher Award for his project that aims to investigate the thermal transport mechanism of strained two-dimensional materials for self-cooling thermal management ($459,592).

Alfred Deakin Professor Ying (Ian) Chen

Made the **2022 Clarivate™ Highly Cited Researchers** list, which identifies researchers who have made the most significant contributions to global research in the past decade and includes those who are ranked in the top 1% of research paper citations.

Dr Quanxiang (Sulley) Li

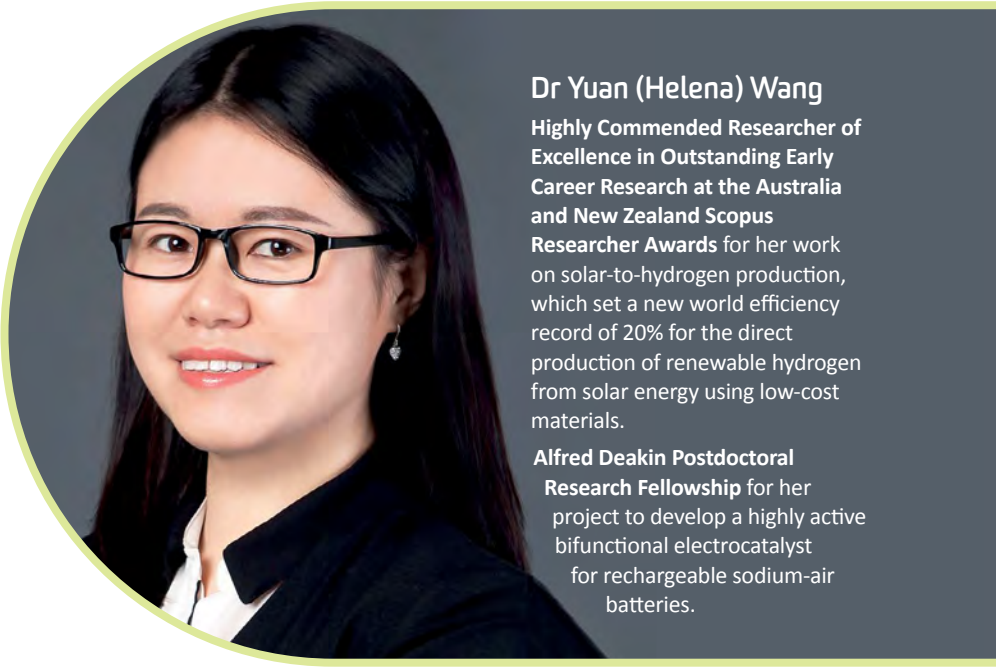
ARC Discovery Early Career Researcher Award for his project on developing innovative catalytic activation approaches for converting textiles waste to porous activated carbon fibre with potential application in energy storage and carbon capture ($454,054).

Dr Alban de Vaucorbeil

ARC Discovery Early Career Researcher Award for his project performing modelling to help develop an additive metal manufacturing process that makes use of scrap as input feed ($448,721).

Professor Liz de Rome

Inaugural Australasian College of Road Safety (ACRS) Women in Road Safety Award for her valuable contribution to reducing road trauma, through her career in road safety policy and research, including her contribution to the Australasian MotoCAP initiative.



Dr Yuan (Helena) Wang

Highly Commended Researcher of Excellence in Outstanding Early Career Research at the Australia and New Zealand Scopus Researcher Awards for her work on solar-to-hydrogen production, which set a new world efficiency record of 20% for the direct production of renewable hydrogen from solar energy using low-cost materials.

Alfred Deakin Postdoctoral Research Fellowship for her project to develop a highly active bifunctional electrocatalyst for rechargeable sodium-air batteries.

Dr Kamyar Shirvani Moghaddam

Most Outstanding Researcher in Materials award at the Venus International Awards for his work on composite materials, advanced nanostructures and carbon-based structures.

Dr Minkyung (Kaye) Kang

The Deakin University Vice-Chancellor's Early Career Researcher Award for Career Excellence for her contribution to Introducing a New Nanotechnology for our Sustainable Future and the advancement of the University's Strategic Plan, Deakin 2030: Ideas to Impact.

Dr Ali Balkis and Dr Hiroyuki Ueda

Made the **ClimateLaunchpad** finals for their start-up Sythlett Cells, which aims to sell slower-degrading, lightweight, non-flammable batteries for aviation.

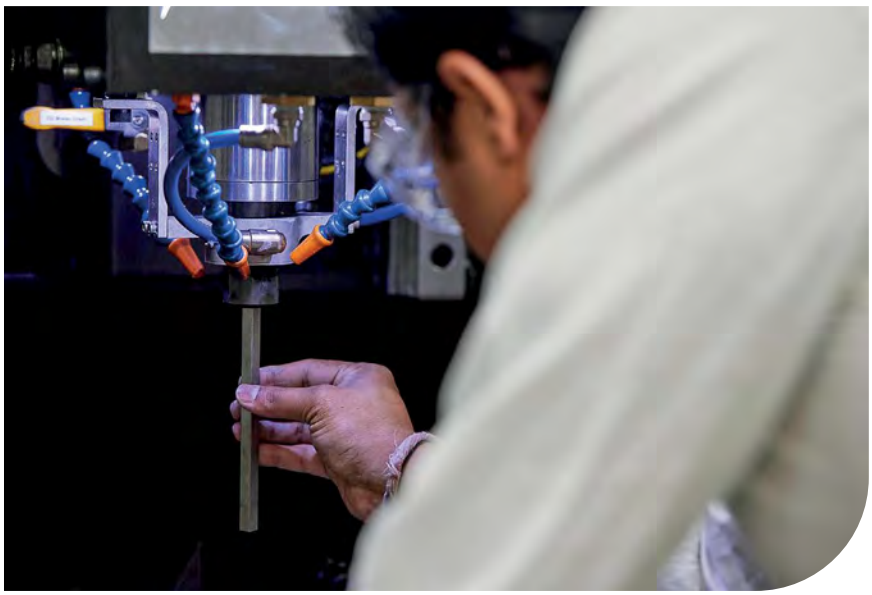
Bhagya Dharmasiri

The Rex Williamson Award – Deakin's highest prize for Science, Engineering and Built Environment and IFM students whose research has a significant chemistry focus.

Dr Sima Kashi

Alfred Deakin Postdoctoral Research Fellowship for her project to design and develop a structurally engineered multilayered hybrid nanocomposite for electromagnetic interference absorption using a combined experimental/simulation approach.

Leading the way in expert inquiry



Alfred Deakin Professor Matthew Barnett

ARC LAUREATE FELLOWSHIP

Alloy alchemy: New paradigms in alloy science to promote a circular economy

AWARDED: $2,982,000

PROJECT: Last year, Australia exported stainless steel and aluminium scrap to the value of almost $1 billion.

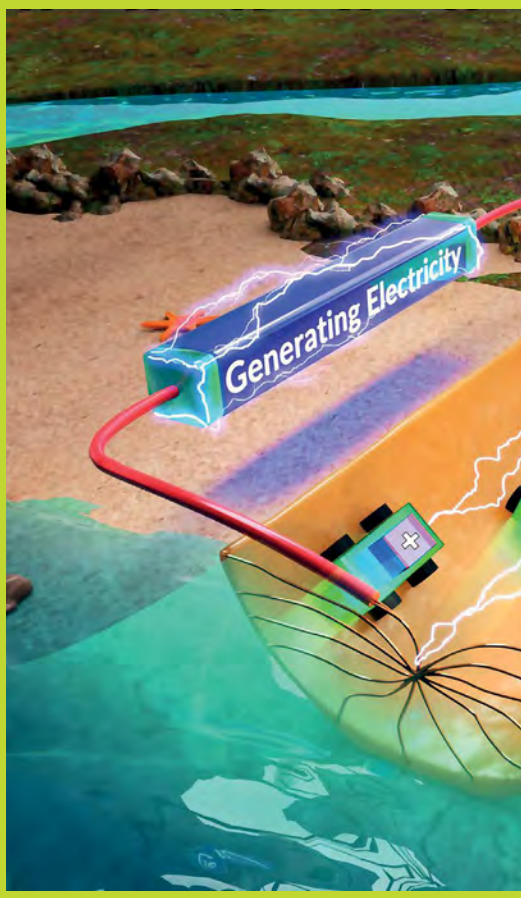
This lost resource has significant potential to add value onshore and strengthen vulnerable supply chains.

As part of Professor Matthew Barnett's Laureate Fellowship, he aims to find new paradigms in alloy science that make it easier to recycle and reuse high-performance metal alloys. He hopes to address alloy development that better serves society across three key measures: economic, environmental and social.

MILESTONES: In 2022, Prof. Barnett embarked on a worldwide recruitment drive and completed a study tour in Europe to understand the latest findings in the area of materials for the environment. The tour included a collaboration with Professor Stéphane Gorsse from the French National Centre for Scientific Research (CNRS), which resulted in a succinct collection of nine indicators that quantify the commercial, environmental

and social impacts of various alloy compositions.

KEY FINDINGS: In collaboration with colleagues at the CNRS in France, Prof. Barnett re-examined hundreds of recently proposed high-entropy alloy compositions and discovered a worrying number come with markedly increased impact across their chosen societal indicators. When compared with current superalloys used in high-temperature applications, such as jet engines, a subset of high-entropy alloys looked remarkably promising – findings that will be used to inform research directions for the Laureate.



Associate Professor Weiwei Lei

ARC FUTURE FELLOWSHIP

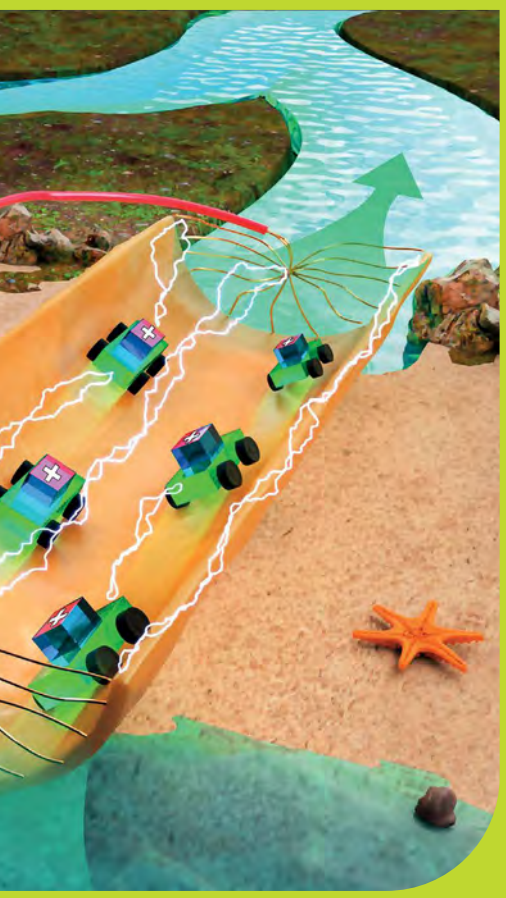
Two-dimensional transition metal nitrides for energy applications.

AWARDED: $887,746 (Round 1 – 2021)

Project: As the demand for sustainable energy generation and storage continues to grow, so too does the need for more flexible electronics and the miniaturised energy storage units required to power them. In such technology, two-dimensional (2D) nanomaterials have shown considerable promise in enabling new ways to harvest and store energy – specifically when it comes to freshwater energy generation. And heterostructures, the layered structured interfaces between materials, formed by a combination of 2D nanomaterials, offer even greater control over the structural and electronic properties.

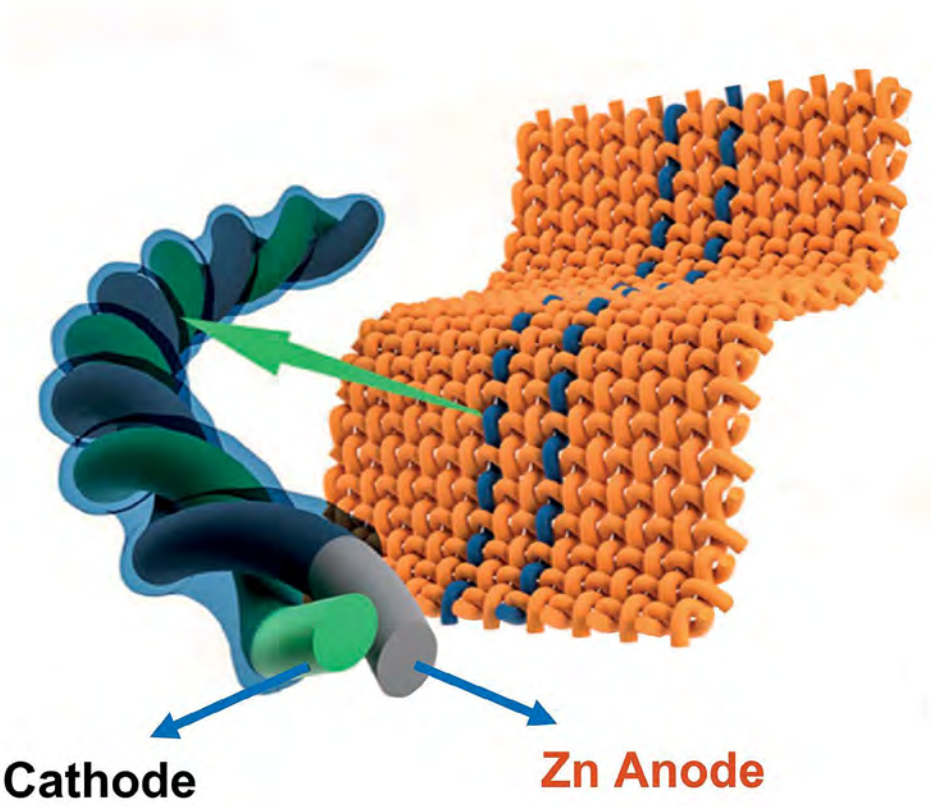
This project seeks to develop a versatile research platform for the fabrication of functional two-dimensional (2D) nanomaterials and their advanced heterostructures to be used for osmotic energy harvesting, storage, and freshwater generation.

APPLICATIONS: Technology for flexible sustainable energy and storage, freshwater generation, and miniaturised energy storage for electronic devices such as clear water units.



Associate Professor Weiwei Lei's research featured on the cover of ChemSusChem in 2022. Cover art: Y. Qian et al. Two-Dimensional Membranes with Highly Charged Nanochannels for Osmotic Energy Conversion.

MILESTONES: In 2022, Associate Professor Weiwei Lei and his team designed and developed a novel method for synthesising transition metal nitride nanosheets and their heterostructures for large specific surface areas with controlled layer thickness to realise the targeted functions. They also applied these novel nanostructures to energy and freshwater generation.



Associate Professor Dan Liu

ARC FUTURE FELLOWSHIP

Development of novel functionalised two-dimensional nanomaterials.

AWARDED: $791,428 (Round 1 – 2020)

PROJECT: Safe, environmentally friendly and wearable energy storage devices with high-energy density are in high demand, but it is very difficult for the current battery and supercapacitor technology to fulfil this purpose. Two-dimensional nanomaterials provide new opportunities to address these challenges. According to Associate Professor Dan Liu, the development of 2D nanomaterials has revolutionised the way we address current technological issues and design new products. In her project, her team is designing new wearable energy storage devices with enhanced safety and energy technology, such as a zinc (Zn) ion battery, with 2D nanomaterials.

APPLICATIONS: Reliable energy storage technology for wearable devices for purposes such as health monitoring and movement tracking.

MILESTONES: In 2022, the team purchased new facilities and employed new research staff and PhD students for this project. They designed several projects to study the mechanism and performance of these wearable devices resulting in breakthroughs for Zn battery chemistry and Zn battery-based wearable energy storage devices.

Associate Professor Dan Liu's project is designing new safe wearable energy devices for health monitoring and movement tracking. Pictured: A configuration of a zinc wearable battery.

KEY FINDINGS: Two-dimensional nanomaterials can effectively address the current safety and reliability issues in wearable energy storage devices. Conductive MXene nanosheets can be used to build highly conductive Zn deposition scaffolds, while insulating BN nanosheets have proved good materials for the construction of flexible Zn anode interfaces.

GRANTS AWARDED IN 2022

TEAM	PROJECT TITLE	YEAR	INDUSTRY PARTNER / FUNDING BODY	$AU TOTAL AWARDED
ARC Discovery				
Prof. David Cahill, Dr Shuaifei Zhao, Prof. Qilin Li, Prof. Bart Van der Bruggen	Smart foliage: imparting intelligence to synthetic leaves.	2023-2025	DP230100307	$250,000.00
ARC DECRA – Discovery Early Career Researcher Award				
Dr Sulley Li	Converting textiles waste to novel nanostructured porous carbon fibre.	2023-2025	DE230101472	$454,054.00
Dr Qiran Cai	Boron nitride nanosheets for low energy consumption self-cooling devices.	2023-2025	DE230101371	$459,592.00
Dr Alban de Vaucorbeil	Enabling solid state metal recycling with new numerical techniques.	2023-2026	DE230100338	$448,721.00
ARC Linkage Infrastructure Equipment & Facilities (total award)				
Assoc. Prof. Dan Liu, Prof. Ping Koy Lam, Assoc. Prof. Deepak Dubal, Dr Hidehiro Yonezawa, Assoc. Prof. Yan Jiao, Assoc. Prof. Jianzhen Ou, Prof. Liming Dai, Prof. Yuerui Lu, Prof. Brian Abbey, Prof. Elena Ostrovskaya, Prof. Ian Petersen, Dr James Bullock, Prof. Lan Fu, Prof. Dewei Chu	Cryogenic near-field imaging and spectroscopy facility at the 10-nm-scale.	2023	Led by University of Adelaide	$970,000.00
Prof. Zaiping Guo, Assoc. Prof. Ross Marceau, Prof. Shizhang Qiao, Prof. Heike Ebendorff-Heidepriem, Prof. Christopher Sumby, Dr Shilin Zhang, Prof. William Skinner, Assoc. Prof. Marta Krasowska, Assoc. Prof. Anton Blencowe, Prof. Ian Gentle, Prof. Jun Ma, Prof. Gunther Andersson, Dr Darryl Jones, Prof. Sean Li	A customised surface chemistry study system in realistic working condition.	2023	Led by University of South Australia	$2,206,421.00
Assoc. Prof. Alexey Glushenkov, Prof. Shujun Zhang, Dr Qiran Cai, Dr Srikanth Mateti, Prof. Ying (Ian) Chen, Prof. Yun Liu, Prof. Amanda Ellis, Dr Zi (Sophia) Gu, Prof. Deanna D'Alessandro, Prof. Andrey Sukhorukov, Dr Teng Lu, Assoc. Prof. Danyang Wang, Prof. Zhenxiang Cheng, Prof. Cameron Kepert, Prof. Baohua Jia	A cryogenic multifunctional multiscale material characterisation facility.	2023	Led by University of Wollongong	$909,754.00
Other government funding				
Assoc. Prof. Peter Lynch	Advanced microstructural characterisation of additively manufactured metallic alloys and in-situ testing using X-ray microcomputer tomography technique.	2022-2023	Department of Defence	$120,840.00
Assoc. Prof. Peter Lynch, Dr Sitarama Kada, Dr Pavel Cizek	Determine the Fatigue Life of Aerospace Materials. Part 5.	2022-2023	Department of Industry, Science, Energy and Resources & Formflow Pty Ltd	$240,000.00
Dr Lu Jiang, Assoc. Prof. Ross Marceau	Material characterisation of anodizing effects on small fatigue crack nucleation in AA7XXX alloys.	2023	Department of Industry, Science, Energy and Resources & Australian Mines Ltd	$91,295.00
Assoc. Prof. Nolene Byrne, Prof. Maria Forsyth, Dr Jenny Sun	Biochar to Batteries.	2022-2023	Barwon Region Water Corporation	$85,000.00
Prof. Joselito Razal, Dr Dylan Hegh	Biofibres for Sustainable Apparel Inspired by a Humble Bee.	2022-2023	Sustainability Victoria	$149,650.00
Prof. Joselito Razal, Dr Dylan Hegh	Biofibres for Sustainable Apparel Inspired by a Humble Bee.	2022-2023	Humble Bee Bio Pty Ltd	$150,000.00

TEAM	PROJECT TITLE	YEAR	INDUSTRY PARTNER / FUNDING BODY	$AU TOTAL AWARDED
Assoc. Prof. Rangam Rajkhowa, Dr Dylan Hegh, Dr Surya Subianto, Assoc. Prof. Alessandra Sutti, Dr Emma Prime, Dr Russell Kennedy	Particles derived from textile wastes for sustainable coloration of products.	2022-2025	Sustainability Victoria	$284,553.00
Prof. Lingxue Kong, Dr Shuaifei Zhao, Elham Tavassoli Kafrani	Sublingual self-emulsifying films containing cannabis.	2022	International Education Resilience Fund	$15,000.00
Prof. Daniel Fabijanic, Roshan Sasi	Design and fabrication of duplex matrix hardfacing alloys.	2022	International Education Resilience Fund	$9,000.00
Assoc. Prof. Matthias Weiss, Ms Keerthana John	Understanding concrete and joining effects on fire wall structural panel performance.	2022	International Education Resilience Fund	$12,000.00
Prof. Minoo Naebe, Parisa Zamani	Circular Economy focused model for materials assessment.	2022	International Education Resilience Fund	$15,000.00
Cooperative research centres				
Assoc. Prof. Alessandra Sutti, Prof. Colin Barrow, Dr Amol Patil, Dr Surya Subianto, Dr Nathan Thompson	Extraction and testing of marine fibres for textile applications.	2022-2024	Marine Bioproducts CRC – MBCRC	$400,000.00
Assoc. Prof. Nolene Byrne	Assessment of squeeze off reinforcement clamps.	2022-2023	Future Fuels CRC Ltd	$42,500.00
Assoc. Prof. Cristina Pozo-Gonzalo	Beneficiation and Chemical Processing of Lithium Minerals.	2022-2025	Future Battery Industries CRC	$136,100.00
Dr Dylan Hegh, Prof. Joselito Razal	Sustainable DWR Textile Coatings Inspired by Australian Bee Biopolymers.	2022	Innovative Manfacturing CRC Limited	$139,999.00
Prof. Russell Varley, Dr Maxime Maghe, Dr Masihullah Jabarulla Khan	Non-Combustible Fabric Development.	2022	Innovative Manfacturing CRC Limited	$140,089.00
Prof. Russell Varley, Maxime Maghe, Dr Claudia Creighton	Development of Lightweight Australian Composite Overwrapped Gun Barrels.	2022	Innovative Manfacturing CRC Limited	$103,133.00
Industry and other funding				
Dr Julie Sharp	Evaluation, Validation and Design of SPF Vaccine against Oncology Targets – Phase 2.	2022	Cytomatrix Grant- Research	$54,527.00
Dr Julie Sharp, Dr Ashalyn Watt	Evaluation and comparison of in-vivo effects of short polymer fibres (SPF) loaded with a combination of peptides, DNA and proteins versus controls.	2022	Cytomatrix Grant- Research	$167,907.00
Prof. Luke Henderson, Dr David Hayne, Dr Filip Stojcevski	'Green Steel' electrode development.	2022	MIH2 Pty Ltd	$57,692.00
Assoc. Prof. Alessandra Sutti	1: Textile dyeing via atmospheric plasma coating 2: Atmospheric plasma coatings for textile treatments & material functionalisation.	2022-2023	Xefco Pty Ltd	$54,699.00
Dr Timothy Khoo, Prof. Patrick Howlett, Prof. Maria Forsyth	Safe and high performance Li-S Electrolytes.	2022-2023	Li-S Energy Pty Ltd	$1,670,785.00
Assoc. Prof. Luhua Li, Prof. Mike Yongjun Tan, Dr Xing Jin	Anti-corrosion/erosion Coatings by White Graphene Composites.	2022	White Graphene Limited	$50,500.00
Assoc. Prof. Luhua Li, Prof. Mike Yongjun Tan, Dr Xing Jin	White Graphene/Polymer Composites for Hydrogen Pipeline Coating.	2022	White Graphene Limited	$277,012.00
Prof. Daniel Fabijanic, Dr Jithin Joseph, Prof. Matthew Barnett	Improving the Abrasive Wear Resistance of Ground Engaging Tools – Phase II.	2022-2023	Sandvik Mining & Construction Australia (Production/Supply) Pty Ltd	$56,572.00
Prof. Daniel Fabijanic, Dr Jithin Joseph, Prof. Matthew Barnett	Improving the Abrasive Wear Resistance of Ground Engaging Tools – Phase II.	2022-2023	Innovation Connections	$50,000.00

TEAM	PROJECT TITLE	YEAR	INDUSTRY PARTNER / FUNDING BODY	$AU TOTAL AWARDED
Prof. Matthew Barnett, Prof. Daniel Fabijanic	Liquidus temperature determination.	2022	Bradken Resources Pty Ltd	$10,500.00
Dr Timothy Khoo	Li-S lithium nanomesh electrolyte studies.	2022-2023	Li-S Energy Pty Ltd	$242,601.10
Assoc. Prof. Matthias Weiss, Dr Michael Pereira, Dr Peng Neo Zhang	A Forming technology to produce bipolar plates for Alkaline Electrolyser cells.	2022-2023	Hysata Pty Ltd	$147,517.00
Prof. Russell Varley, Dr Masihullah Jabarulla Khan, Sam Swan	Manufacture of Lightweight Carbon Fibre Wheels: New adhesives and UV Resistant Structures.	2022-2023	Innovation Connections	$49,885.00
Prof. Russell Varley, Dr Masihullah Jabarulla Khan, Sam Swan	Manufacture of Lightweight Carbon Fibre Wheels: New adhesives and UV Resistant Structures.	2022-2023	Partington.cc Pty Ltd	$49,885.00
Prof. Russell Varley	Light-weighting Metallic Structures for Dump truck tray for EV applications.	2022-2023	Nexus Mine Pty Ltd	$50,265.00
Prof. Russell Varley, Dr Jane Zhang	Rubber Recycling Literature Survey.	2022-2023	Bradken Resources Pty Ltd	$19,831.00
Prof. Russell Varley, Dr Jane Zhang	Enhancing the performance of polymers and rubbers in wear liner applications for the mining industry.	2022-2023	Bradken Resources Pty Ltd	$25,077.00
Prof. Russell Varley	Validation of the use of polyamide as a novel low cost precursor towards high performance carbon fibre.	2022-2023	CO2 Tech Pty Ltd	$39,000.00
Dr Lu Jiang, Dr Thomas Dorin	Effect of solution treatment temperature and duration on dispersoids in Al-Cu-Sc-Zr alloys	2022	SRL Holding Company	$39,500.00
Prof. Peter Hodgson, Prof. Bernard Rolfe, Baoqi Dong	Student application – Measurement of concurrent interphase precipitation and phase transformation in Ti-Mo steels by Small Angle Neutron Scattering (SANS).	2022-2024	AINSE Grant- Postgraduate Research Award	$29,750.00
Prof. Russell Varley	Fabrication of sheets and slabs from recycled plastic packaging and water-based paint solids.	2022	Paintback	$25,684.00
Dr Ashalyn Watt	The therapeutic potential of umbilical cord blood endothelial colony forming cells in vascular dementia.	2023	Inner Wheel Australia Foundation Trust	$65,000.00
Prof. Daniel Fabijanic, Prof. Matthew Barnett	High stress abrasion of prospective Molycop grinding media alloys.	2022	Moly-Cop USA LLC	$33,900.00
Dr Timothy Khoo	Failure Analysis Trials of Battery Pack.	2022-2023	Contemporary Amperex Technology Co Ltd (CATL)	$26,000.00
Prof. Minoo Naebe	Novel Modification and Spin-Processing of Asphaltene to Produce Low-Cost High Performance Carbon Fibers.	2022-2023	Alberta Innovates	236269.76 (CAD)
Prof. Russell Varley	12K Carbon Fibre development.	2022	Inventa Projects Switzerland	$17,948.00
Dr Hiroyuki Ueda, Dr Timothy Khoo	Next-generation solid-state batteries to drive an automotive revolution.	2022-2023	Toyota Motor Corporation	$92,784.20
Dr Mega Kar, Prof. Maria Forsyth, Prof. Jenny Pringle, Prof. Patrick Howlett, Dr Fangfang Chen	Novel Ionic Liquid based Solid-State Electrolytes for Solid-State Lithium Metal Batteries (SSLMBs).	2022-2024	Petronas Research SDN BHD	$852,047.79
Assoc. Prof. Maryam Naebe, Dr Abu Naser Md Ahsanul Haque, Dr Zengxiao Cai	Biodegradable plastic mulch from cotton gin trash.	2023	Cotton Incorporated, USA	$111,211.94
Prof. Russell Varley	Production of 2km of 0.5k tow Carbon Fibre from PAN precursor fibre.	2022	University of Bristol	$9,953.00
Prof. Luke Henderson, Dr Claudia Creighton	Manufacturing Carbon Fibers as Battery Electrodes	2022-2025	ONR USA Grant- Research-Office of Naval Research USA	$192,621.00
Assoc. Prof. Nolene Byrne	Regenerated Cotton for Electronic Textiles.		European Commission – Marie Sklodowska-Curie Actions – Staff Exchanges	

COLLABORATIONS

25 YEARS OF PARTNERSHIP

Ford Australia

15+ YEARS OF PARTNERSHIP

AINSE Ltd
Australian Research Council
Bluescope Steel Ltd
Defence Science and Technology Organisation
CSIRO
Ford USA
Godfrey Hirst Australia
La Trobe University
Monash University
Queensland University of Technology
Swinburne University of Technology

10+ YEARS OF PARTNERSHIP

Carbon Revolution Operations Pty Ltd
Ear Science Institute Australia Incorporated
GT Recycling
RMIT University
The University of Queensland
The University of Wollongong
The University of New South Wales
VESKI

5+ YEARS OF PARTNERSHIP

Australian National University
Australian Nuclear Science and Technology Organisation
Barwon Region Water Corporation
Bradken Resources Pty Ltd
Callidus Welding Solutions
Conveyor Products and Solutions Pty Ltd
Cotton Incorporated, USA
CSL Limited
Cytec Engineered Materials Inc
Department of Jobs, Precincts and Regions
Department of Industry, Science, Energy and Resources
Department of Transport
ELG Carbon Fibre Ltd
Gale Pacific Ltd
HeiQ Pty Ltd
Office of Naval Research USA (ONR)
Polymat
Swiss Federal Laboratories for Materials Science and Technology
The Boeing Company
The United States Army Research Office (USAR)
Toyota Motor Corporation
Transport For NSW
Wuhan Iron & Steel (Group) Corp
Xefco Pty Ltd

LESS THAN 5 YEARS OF PARTNERSHIP

Alberta Innovates
Australian Mines Limited
BNNT Precious Metals Limited
Bradken Resources Pty Ltd
Calix Limited
CrossLink Composites
Department of Defence
DTU Chemical Engineering
Enviroflex Pty Ltd
Flinders University
Formflow Pty Ltd
Future Battery Industries CRC Limited
Future Fuels CRC Ltd
Gelion Technologies Pty Ltd
Innovative Manfacturing CRC Limited
Iondrive Technologies Pty Ltd
Ionic Industries Ltd
John Keells Holdings PLC
LD Electric Vehicles Pty Ltd
Li-S Energy Pty Ltd
Macquarie University
McGill University
MIH2 Pty Ltd
Nanollose Limited
New Zealand Woolscouring Limited
Petronas Research SDN BHD
Renex Op Co Pty Ltd
Rockwool International A/S (Inactive)
Sandvik Mining & Construction Australia (Production/Supply) Pty Ltd
Sentek Pty Ltd
Shoalhaven City Council
Sicona Battery Technologies Pty Ltd
Simba Textile Mills Pty Ltd
South East Water Limited
Speedpanel Systems Pty Ltd
SRL Holding Company Pty Ltd
State Key Laboratory of Superhard Materials, Jilin University
Sustainability Victoria
TDA Golden Field IP Pty Ltd
The Remediation Group Pty Ltd
The University of Adelaide
The University of Hong Kong
The University of Melbourne
The University of Newcastle
The University of Sydney
The University of Tennessee
University of California
University of South Australia
University of Technology, Sydney
University of Western Sydney
Victoria University
University of Bristol
White Graphene Limited

NEW PARTNERS IN 2022

AML3D Limited
C Sea Solutions P/L (trading as ULUU)
CASS Grant – Research – The CASS Foundation Limited
CO2 Tech Pty Ltd
Contemporary Amperex Technology Co Ltd (CATL)
GHD Pty Ltd
HB11 Energy Holdings Pty. Ltd.
Humble Bee Bio Pty Ltd
Hysata Pty Ltd
International Education Resilience Fund
Inventa Projects Switzerland
Marine Bioproducts CRC – MBCRC
Medigrowth Australia Pty Ltd
Moly-Cop USA LLC
Nexus Mine Pty Ltd
Paintback Limited
Partington.cc Pty Ltd
Transport Accident Commission

FINANCIAL SUMMARY

FOR PERIOD ENDED 31 DECEMBER 2022	2021 ACTUAL $	2022 ACTUAL $
INCOME		
Research Income	18,385,210	21,246,446
Other Income	497,494	793,127
Research Allocation/ University Contribution	16,809,138	11,955,243
Total Income	**35,691,843**	**33,994,815**
EMPLOYMENT COSTS		
Academic Salaries	18,142,629	18,023,759
General Salaries	8,175,932	6,886,972
Contractors	283,267	120,439
Total Employment costs	**26,601,829**	**25,031,170**
NON SALARY EXPENSES		
Buildings & Grounds Infrastructure Costs	233,687	227,388
Communication/Advertising, Marketing & Promotions	154,332	219,205
Consumables	2,227,927	2,275,865
Depreciation & Amortisation	1,923,363	1,832,090
Equipment – Repairs, Maintenance & Other Costs	1,134,575	1,429,790
Other Costs	2,040,442	1,285,524
Professional, Legal and Consultants	17,399	73,565
Staff Recruiting, Training & Other/Library Information Resource Expenses	104,943	256,664
Student Expenses	1,163,223	857,731
Travel, Catering & Entertainment	90,126	505,821
Total Non Salary Expenses	**9,090,014**	**8,963,645**
Surplus/(Deficit)	-	-

PERFORMANCE

HDR Student Load 2017-2022 (Equivalent full time)

2017	2018	2019	2020	2021	2022
139.3	**150.1**	**158.7**	**156.9**	**168.8**	**160.5**

HDR Student Completions 2017-2022 (Equivalent full time)

2017	2018	2019	2020	2021	2022
33.0	**29.0**	**38.0**	**26.0**	**40.0**	**54.0**

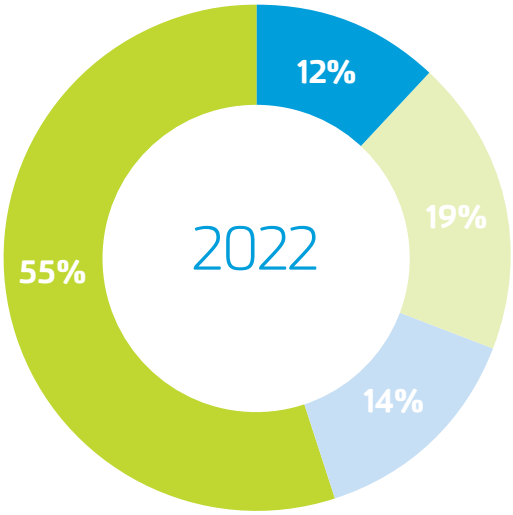
Publications 2017-2020 (Number of journal araticles)

2017	2018	2019	2020	2021	2022
212.5	**251.5**	**302.8**	**316.7**	**266.5**	**248.4**

Funded grant applications in 2022

GRANTS	APPLIED	SUCCESSFUL	% SUCCESS	AMOUNT AWARDED
Reportable – Category 1	46	5	11%	$1,612,367
Reportable – Category 2-4	50	44	88%	$6,464,000
Non-Reportable – Other	13	3	23%	$-

The amount awarded represents the amount awarded over the total life of the project as initially communicated by the funding agency



New grants awarded in 2022

Category 1 (ACG) **19%** $1,612,637

ACG (Australian Competitive Grants) is the term used to describe a group of some 70 research grant schemes to which all universities can apply and where awards are based on merit of the application and the research team. The ARC and NHMRC are two of the major funding bodies included in this list.

Category 2 (Other public) **14%** $1,172,338

Other public (Other Public Sector Research funding) is government funding, federal or state, from schemes not included in the ACG group and not necessarily determined through a competitive process; it includes contract research and research-related consultancies.

Category 3 (Industry) **55%** $4,570,655.03

Industry (Industry and Other Funding) includes all research funding from industry, international sources, donations, bequests and foundations, and Higher Degree by Research fee income for domestic and international students.

Category 4 (CRC) **12%** $961,821

CRC is a university's research income from Cooperative Research Centres excluding their own contribution. Note: CRC income is based on financial year results.

WORK WITH US
If you are interested in working with IFM, we're keen to hear from you.

GET IN TOUCH TODAY
W: ifm.deakin.edu.au
E: ifm-enquiries@deakin.edu.au
P: +61 3 5227 8804
A: Deakin University
75 Pigdons Road,
Waurn Ponds, VIC, 3216, Australia

Search IFM Deakin

IFM
INSTITUTE FOR FRONTIER MATERIALS

DEAKIN UNIVERSITY