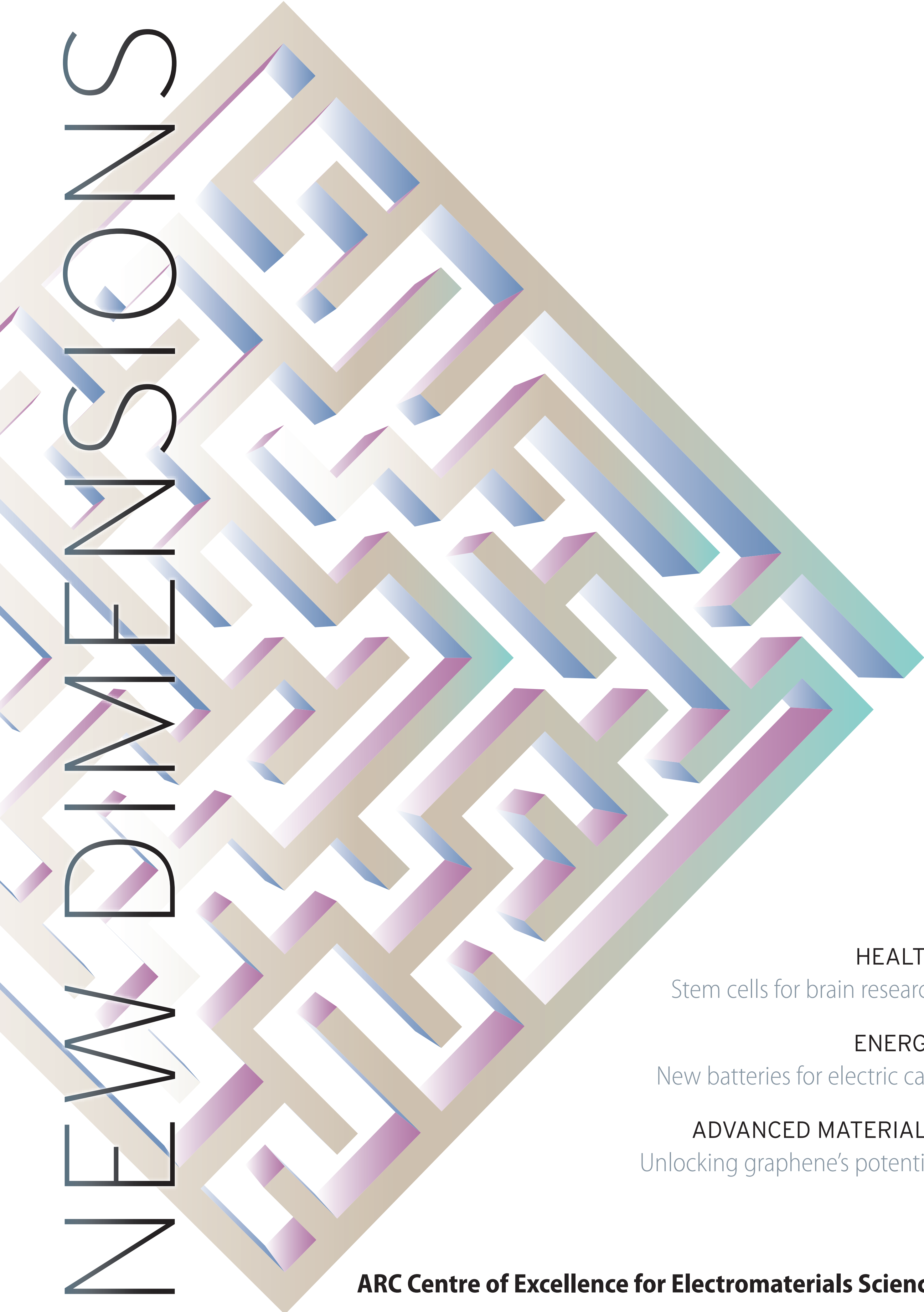
NEW DIMENSIONS



HEALTH
Stem cells for brain research

ENERGY
New batteries for electric cars

ADVANCED MATERIALS
Unlocking graphene's potential

ARC Centre of Excellence for Electromaterials Science

CONTENTS

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FOREWORD

I am delighted to support the ARC Centre of Excellence for Electromaterials Science as you launch into a further seven years of exploring electromaterials and how they can improve our lives and wellbeing.

This is a field with huge potential and we are lucky to have some of the world's leading researchers and professionals to undertake the work.

With extensive international collaboration underway on cross-disciplinary projects, the centre is not only pushing back the frontiers of knowledge, but is also an inspiration to young people who may be considering a career in science.

A robust and thriving research sector drives the future development of our industries and the value of this is well-recognised within the Coalition Government.

We have committed to building a world-class education and research sector as one of the five pillars of a stronger, more productive and prosperous Australia.

Within my portfolio of Education alone, this year we announced $11 billion for future research, as a major investment in the long-term sustainability of Australia's science and research capacity.

This includes nearly $140 million to renew the ARC Future Fellowships scheme. The Coalition Government has committed to 100 outstanding mid-career research fellowships each year, with each researcher receiving funding for four years to undertake vital research.

This support for research builds on a proud legacy of many great Australians whose work has substantially improved our wellbeing.

It is vital for our future that we continue to support research excellence. The ARC Centre of Excellence for Electromaterials Science has produced outstanding research outcomes in the past and I know it will continue to do so with this renewed funding. I look forward to your continued success and wish all involved in the centre well for the future.

The Hon Christopher Pyne MP
Minister for Education

The Australian Research Council (ARC) Centre of Excellence for Electromaterials Science (ACES) plays an important role in the research landscape both nationally and internationally.

Since its establishment in 2005, under the guidance and leadership of Professor Gordon Wallace, the Centre has produced outstanding outcomes, including: the development of nanotube yarn to power implantable biomedical devices; the manipulation of fishing line to produce artificial muscles with super human strength; and the acceleration of 3D printing to deliver solutions to a number of medical challenges.

I am pleased the Centre submitted such a strong bid in the most recent ARC Centres of Excellence round and will move forward for a further seven years.

ACES has built an internationally recognised research program in materials science, and looking forward it will translate this knowledge into devices that will have an impact on the Australian community. Benefits for the community include the development of new industries and manufacturing opportunities around the next generation of batteries, solar cells and medical implants.

The ARC *Centres of Excellence* scheme, which supports ACES, is an important research investment model. This scheme allows research groups to tackle large-scale challenges and it provides them with funding surety to undertake that work.

The ARC is extremely proud of this scheme and its ability to foster and build highly innovative and potentially transformational research, as well as training our future generation of researchers in this environment. One of the most rewarding aspects of the scheme is its capacity to bring different discipline perspectives together to solve big problems.

What is equally important is the right people to forge ahead. ACES has a strong leader in Professor Wallace and he has built a dedicated team that is committed to accelerating research discoveries for the benefit of the nation.

I wish Professor Wallace and the entire ACES team all the very best in their endeavours in the next seven years.

Professor Aidan Byrne
Chief Executive Officer
Australian Research Council

Research is the key to unlocking New South Wales' intellectual capital, as well as bolstering its competitiveness, productivity and innovative capacity.

Since its establishment in 2005, the ARC Centre of Excellence for Electromaterials Science (ACES), headquartered at the University of Wollongong, has built on its internationally-recognised research program in materials science.

The researchers at ACES, led by Professor Gordon Wallace, have received a significant boost this year. The Centre has been refunded for a further seven years from 2014 – including a $500,000 investment from the NSW Government's Research Attraction and Acceleration Program (RAAP).

ACES is a great example of the Centre of Excellence concept – a prestigious hub of expertise through which high-quality researchers maintain and develop Australia's international standing in areas of research strength.

Professor Wallace and his team continue their efforts to translate their knowledge into devices that will have an impact on the Australian community, including the development of new industries and manufacturing opportunities around the next generation of batteries, solar cells and medical implants. Implantable biomedical devices powered by glucose in our blood rather than a battery could soon become a reality after a recent breakthrough by an international team comprising ACES researchers.

I congratulate ACES on its achievements to date and wish the Centre, including its university partners across Australia, in Asia, Europe and the UK, continued success into the future.

Professor Mary O'Kane
NSW Chief Scientist & Engineer

ACES: THE NEW DIMENSIONS

Based on previous success within ACES, we have developed an ambitious program that will take our research, training, commercialisation and engagement programs into new dimensions from now through to 2020.

We enter this new era with a confidence that comes from having established a world-class body of knowledge through our previously funded ARC Centre of Excellence. Having revealed the amazing properties of electromaterials encountered in the nanodomain, we are now challenged to take these properties into structures, with nano-micron sized features suitably distributed throughout macroscopic devices.

This will require chemistries and materials amenable to processing and fabrication, using new tools and protocols. We expect this will result in advances not only in electromaterials but also in the complete systems containing them that mimic the performance of naturally occurring structures. Our holistic approach will ensure that fundamental discoveries can be translated into practical devices. Our integrated program will ensure that we see advances in medical diagnostics and soft robotics. The platforms created to achieve this will serve as a launch pad to create new dimensions in synthetic energy and synthetic biosystems.

Together with our colleagues in other research institutions, Cooperative Research Centres and the Australian National Fabrication Facility, as well as medical practitioners and clinicians and the commercial sector, we will provide real solutions to real world challenges.

Our vibrant ethics, policy and social engagement program will address the non-technical issues that arise along the research and development path. As an integral part of our research program, innovative approaches to the social challenges that inevitably arise from game-changing technologies will be developed through interaction with all sectors of the Australian community.

This cauldron of research activity will provide an excellent training ground. It will challenge the most gifted researchers attracted from around the globe to create new dimensions in their skills portfolio. Excelling in technical capabilities, they will be challenged to excel in research management, commercialisation and or science communication. Our PhD candidates will be given every opportunity to take these talents to the global stage.

We will also develop new facets to our public engagement programs. Building on our successful partnership with the Wollongong Science Centre we will expand to include other centres around the country including the national provider, Questacon.

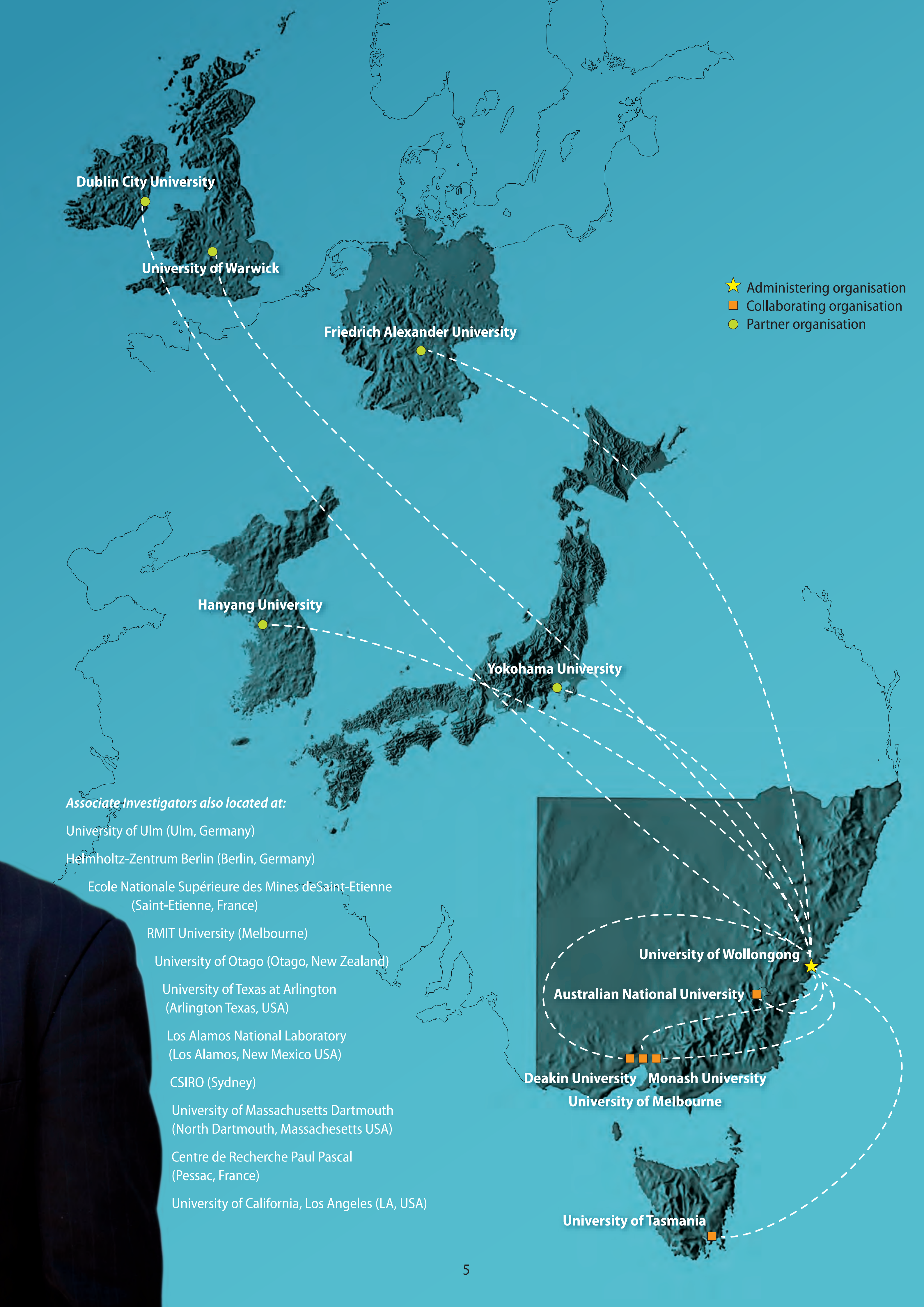
Our commercialisation focus will be on creating new industries, and equipping our graduates to lead them. We already see opportunities in nanostructured carbon synthesis and processing, energy storage and wearable diagnostics. Other opportunities, including 3D bioprinting, will undoubtedly emerge.

All of this can only be achieved with amazing people, and we have some of the best!

We're a balanced team of youth and experience, with diverse skills, and a commitment to success. We have established a global network of partners that will be integral to our success in research, training, commercialisation and engagement.

With a commitment from all the ACES team to explore new dimensions in all aspects of our work, we are confident of beginning a new Centre of Excellence with an extraordinary future.

Professor Gordon Wallace
ACES Executive Research Director



Associate Investigators also located at:

University of Ulm (Ulm, Germany)

Helmholtz-Zentrum Berlin (Berlin, Germany)

Ecole Nationale Supérieure des Mines deSaint-Etienne (Saint-Etienne, France)

RMIT University (Melbourne)

University of Otago (Otago, New Zealand)

University of Texas at Arlington (Arlington Texas, USA)

Los Alamos National Laboratory (Los Alamos, New Mexico USA)

CSIRO (Sydney)

University of Massachusetts Dartmouth (North Dartmouth, Massachesetts USA)

Centre de Recherche Paul Pascal (Pessac, France)

University of California, Los Angeles (LA, USA)

HIGHLIGHTS

2006

February ACES is officially launched with $12million in Federal Government funding for three partners – The University of Wollongong, Monash University and the Bionic Ear Institute. The NSW Department of State & Regional Development also provided support funding.

July St Vincent's Hospital Melbourne signs on to ACES.

2007

July ACES lead node becomes host to the Australian National Fabrication Facility (ANFF) – Materials Node. ANFF offers extensive capabilities in the design, development and fabrication of nano-structured electronic materials and devices.

November ACES welcomes Dame Bridget Ogilvie as the new Chair of the International Advisory Board.

November A consortium including ACES is awarded $6 million from the Victorian Government to develop printable solar cell technologies.

2008

January Researchers discover a cheap, simple and scalable way to make graphene dispersions that could be used to develop the next generation solar cells and batteries.

August A new cathode for fuel cells is developed with a conducting polymer at Monash University, offering an alternative to expensive platinum nanoparticle cathodes.

August In an Australian-first, ACES installs and adapts a Bio-Atomic Force Microscope allowing a new focus on nanobionic research.

October ACES headquarters move into state-of-the-art facilities in the Australian Institute for Innovative Materials (AIIM) on Innovation Campus in Wollongong.

December Researchers develop a smart stent made from magnesium oxide that releases drugs into the bloodstream and breaks down in the body after use.

2011

ACES CI Professor Susan Dodds serves on the Federal Government's National Enabling Technology Strategy Stakeholder Advisory Council.

May Monash University leads ACES in the discovery of new highly efficient manganese-based catalysts for water oxidation.

August ACES Director Professor Gordon Wallace and Associate Director Professor Maria Forsyth are awarded Australian Laureate Fellowships.

October ACES and its collaborators develop powerful new twisting artificial muscles from very tough and highly flexible yarns of carbon nanotubes.

November The National Breast Cancer Foundation funds ACES researchers to develop a lymph sleeve based on 'intelligent fabric' to help patients with lymphodema.

2012

February A new composite material made with graphene is revealed that can produce the toughest fibres to date.

July ACES Chief Investigator Professor Doug MacFarlane receives an Australian Laureate Fellowship, a third for ACES.

July ACES CI Professor Susan Dodds is appointed as a Member of the Australian Health Ethics Committee by the Minister for Health.

September The ACES Ethics Program holds its first public engagement event.

October ACES lead node expands into the new $43.8million AIIM processing and devices Facility at the University of Wollongong.

November ACES researchers work with the University of Texas at Dallas to develop hybrid yarn muscles, based on carbon nanotubes.

December AquaHydrex Pty Ltd is launched, based on ACES' new electrochemical systems for splitting water, with capital investment secured from True North Venture Partners.

February ACES receives a further $7.7million in Federal Government funding from 1 July 2010 until December 2013, plus support funding from the NSW State Government, acknowledging the strong profile ACES has developed in Australia and internationally.

May A robotic fish, propelled by an active flexible joint tail fin made of conducting polymer artificial muscles developed by ACES and its collaborators, is revealed.

July Research organisations in ACES now number five: the University of Tasmania and La Trobe University sign onto ACES, with CIs Professor Susan Dodds and Professor Graeme Clark respectively at these new organisations.

November Monash University leads ACES in the development of a tandem dye-sensitised solar cell with a three-fold increase in energy conversion efficiency on previous versions.

2009

February Researchers patent novel hydrogen production that, packaged with complementary IP, could develop efficient water splitting technology.

June ACES PI Professor Mark Cook leads a world first surgery at St Vincent's Hospital Melbourne, implanting a seizure prediction device in an epileptic patient.

July ACES expands with Deakin University becoming the sixth node. Professor Maria Forsyth later opens a new $1.294m Nuclear Magnetic Resonance (NMR) imaging facility at Deakin.

December Chief Investigator Professor Spiccia from Monash University joins an elite group of researchers when he receives a Humboldt Research Award.

2010

May An Additive Biofabrication Facility is opened at St Vincent's Hospital, Melbourne.

May ACES led by Associate Professor Jun Chen develops a novel catalyst that opens up a whole new water splitting dimension: the ability to split sea water.

June ACES and collaborators demonstrate yarns that function as high performance electrodes of supercapacitors.

December The Australian Research Council announces that ACES will be funded for another seven years (2014–2020) as a new Centre of Excellence, with $25million awarded by the Federal Government. The NSW State Government granted funding for strategic business development.

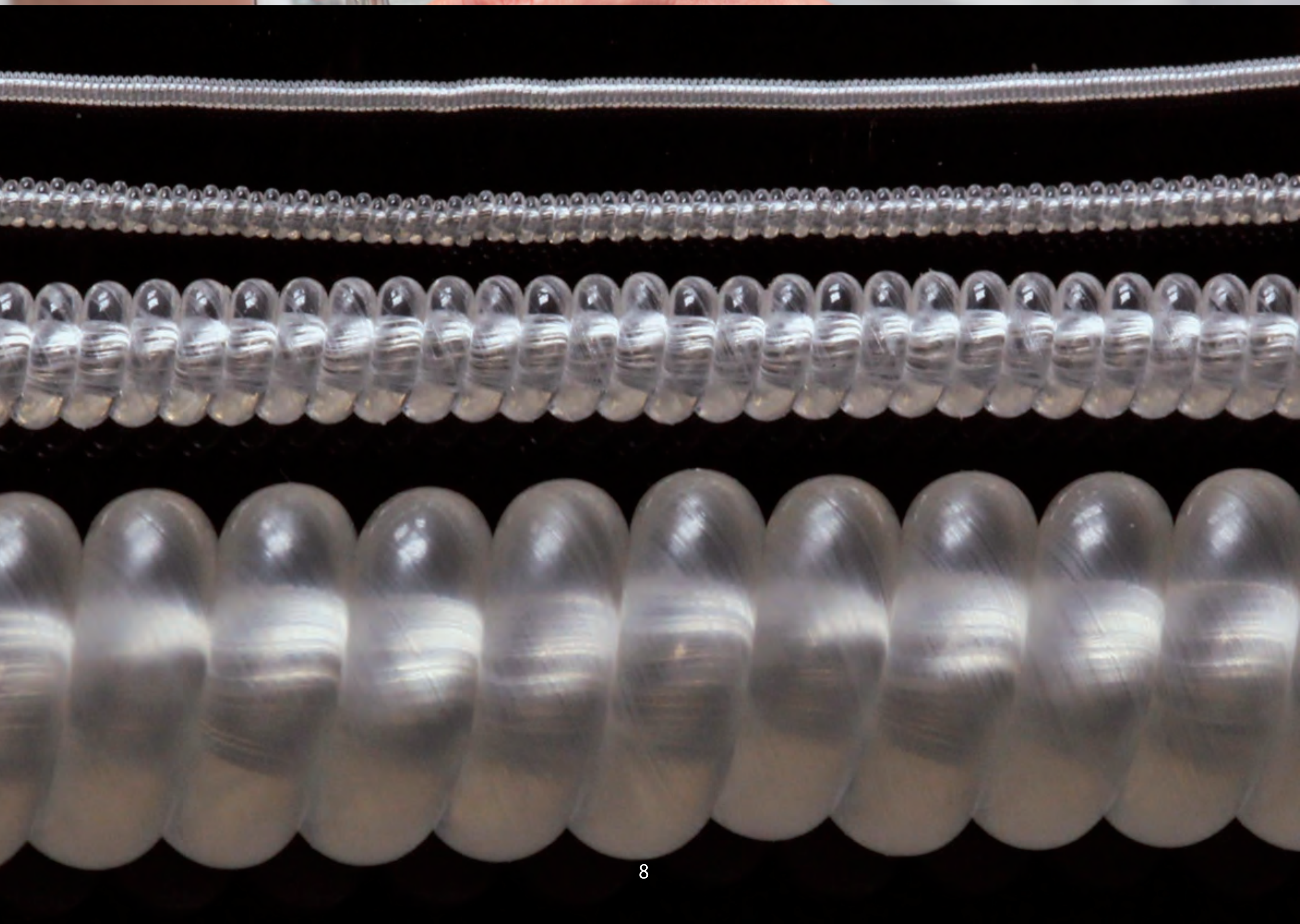
2013

February ACES researchers and collaborators discover they can make artificial muscles with super human strength from polymer material as found commonly in fishing line.

May ACES lead node partners with three other universities to launch the world's first dual Masters Degree in BioFabrication.

July The newly funded ARC Centre of Excellence for Electromaterials Science kicks off with six Australian and five international partner organisations.

2014



HOOKING

THE BIG ONE

SIMPLY, TAKES TIME

ACES' material synthesis and characterisation expertise underpinned a major step forward in the development of 'artificial muscles'.

Dr Javad Foroughi discovered the twisting action of the fibre that underpins the ACES artificial muscle work during his PhD.

Comparing 'muscles' made by coiling nylon fibres.

Sometimes in research, it takes many twists, turns and time to uncover a simple answer.

ACES researcher Professor Geoff Spinks and his collaborators spent nearly two decades developing exotic materials as artificial muscles – with positive results – only to find that the best performing systems could be made from ordinary, everyday fishing line.

Think about it: developing a process on a small scale that will mimic one of the most powerful 'motors' in nature is a huge challenge.

"Muscles are amazing machines that produce much more mechanical power than any similar-sized motor or engine," Spinks said. "They are compact and silent, can generate large and fast movements and can operate for billions of cycles. Matching all these performances in a synthetic system has been beyond the reach of scientists to date."

To arrive at a simple answer, the collaborators, including ACES in Australia, the University of Texas in Dallas (UTD), Hanyang University in Korea and the University of British Columbia (UBC) in Vancouver, first had to understand what kind of materials would respond to stimuli like a human muscle and why they responded that way.

The one that almost got away

Professor Spinks remembers well the email he received from his then PhD student Javad Foroughi with the subject line *'black snake'.*

"We had sent Javad on an exchange to work with our partners at the University of Texas in Dallas. They are experts in making carbon nanotube fibres and when combined with our expertise in characterisation, we had developed a way to make artificial muscles from the carbon nanotubes.

"Javad was meant to be taking this work a step further using techniques developed by our Texas partners to create a yarn from both their carbon nanotubes and our conducting polymer materials. Our calculations predicted that we should get a better performance by combining the two materials."

But as is the case sometimes in research, Foroughi was put to work on something else – the routine task of testing the properties of the new carbon nanotube yarn on its own.

"I had the carbon nanotube yarn in a beaker of liquid and I put in an electrode, rather like rigging up a battery, and applied a charge," Foroughi said. "The fibre started writhing around like a black snake. I had never seen this before and I thought this was very interesting, perhaps even significant."

He took a short video and sent it back to Professor Spinks in Australia.

"I didn't think it was all that significant," admits Spinks, "but the emails from Javad kept coming. He sent another one with the subject line *'kangaroo'* showing a piece of the carbon nanotube fibre lifting a small piece of blue tack, up and down, jumping if you will, like its namesake.

"To his credit, Javad's persistence and the evidence he collated convinced me that he was indeed onto something worth investigating."

Back in Australia, Professor Spinks set about trying to understand the source of the rotation and test the performance limits. After a while, he and Javad were able to generate very large and very fast rotations. The new artificial muscle, made from carbon nanotube threads ten times smaller than a human hair, produced a rotating action 1,000 times larger than previously known systems. When immersed in a liquid electrolyte and with a voltage applied, the thread absorbed some of the surrounding liquid. As it swelled, the untethered end of the twisted yarn started to turn. The amount of rotation was about 2,500 degrees for each centimetre of thread length. On a per weight basis, the thread generated nearly as much power and torque as a conventional electric motor.

Meanwhile, research partners at the University of British Columbia in Vancouver, Canada, had discovered the carbon nanothreads also shortened in length when a voltage was applied. When everyone next met up they put two and two together and realised the

Professor Spinks led the ACES research team through three significant artificial muscle discoveries.

shortening and the rotation were a property of the way the thread was structured.

It was *twisted.*

Twisted line hooks catch of the day

The discovery that twisting the fibre resulted in a twisting muscle-like action led to a paper published in *Science,* but perhaps more significantly, it allowed the team to improve the performance of the artificial muscle and explore other materials. UTD went on to find that a similar torsional actuation response could be produced by filling the yarn with candle wax to make a hybrid yarn. Heating the wax generated the torsional or twisting movement. They also observed that overtwisting these yarns generated coils, that when heated, contracted by up to 10 percent.

"We were very excited by this development," Spinks said. "It meant we had taken our muscle out of the beaker which opened it up for more applications, particularly in our speciality area of wearable bionic devices."

At this stage the team did not know why the coiling amplified the length-wise tensile actuation. Further research revealed more, and finally they discovered that similar effects occur in highly oriented polymer fibres when they are twisted into coils.

"The pathway to this discovery was by no means obvious," Spinks said.

"If we here in ACES had not been developing nanostructured electromaterials like carbon nanotubes we would not have observed their very large torsional actuation. That work led us to investigate further the effect of the twist and the discovery of overtwist-induced coiling. From there we produced high performing contractile muscles from both overtwisted carbon nanotube yarns, and more recently, ordinary polymer fibres like fishing line," he said.

The fishing line muscles work by heat activation and early demonstrations used an ordinary hair dryer for heating. However, for more convenience and better temperature control, it was recognised that electrical heating would be better. To this end, the team wrapped electromaterials such as carbon nanotubes around the fishing line to make it conductive and operable by electric heating.

Reeling it in

Ultimately, the international collaboration developed an artificial muscle from fishing line capable of generating a contraction and force that compares favourably with our own muscle. Depending on how the fishing line muscles are made, the contractions can be as high as 50 percent with response times in a fraction of a second. The fishing line muscles can also produce forces up to 100 times higher than similar-sized natural muscle.

The discovery relied on the material synthesis and characterisation expertise within ACES to develop a better understanding of how the material structure affected the performance of the artificial muscles. As ACES researchers introduced new generations of electromaterials, such as conducting polymers and carbon nanotubes, the performance of the artificial muscles improved.

Research continues to further improve the efficiency of the artificial muscle as well as explore stimuli, other than heat, to generate movement. Professor Spinks and his team at the University of Wollongong have also begun to use the technology in wearable devices (see opposite).

They've landed a big one, and it will simply be a matter of time before we see this innovation in health devices, 'intelligent clothing' and industrial applications.

STARGAZING

Professor Michelle Coote
ACES Chief Investigator
ACES @ Australian National University

Professor Michelle Coote believes being part of ACES gives her the best shot at translating her research into practical applications.

It could have been a voyager mission cereal box card or the passing of Halley's comet that sparked Michelle Coote's interest in science as a teenager. She remembers wanting to study the stars, and had the marks, the offer and a resume listing extra-curricular activities such as *'work experience in astrophysics at the University of New South Wales'.*

At the last minute she changed her mind and went for industrial chemistry.

It was a practical decision, but at its heart, still an exploratory mission as Michelle made her way through an undergraduate degree, industrial experience in a leading paint laboratory, honours, a PhD on radical polymerisation kinetics and a post doctoral fellowship in polymer physics.

"At that point I decided that I was really interested in fundamental chemistry and went on to complete another postdoc, this time at the Australian National University, in theoretical chemistry, before going on to develop it and use it for solving problems in polymer science," Michelle said.

"It's an exciting time to be working in this field. Thanks to increasing supercomputer power and developments in chemical theory, we have now reached the point where it is possible to use theory to really understand the underlying chemistry of quite complicated chemical processes – it's almost as good as having the ultimate electron microscope for watching atoms and bonds rearrange in real time. This insight is teaching us how to design reagents and catalysts for manipulating chemical reactions, new materials with better properties, and solve other practical problems."

In a way, Michelle has almost come full circle. She has since established a polymer chemistry laboratory at the Australian National University (ANU) and is even collaborating with industry to improve paint, using the theory she has mastered along the way to guide her team's experiments. And then there are the stars. She won't tell you, or make much of it, but she *is* one. Michelle was this year elected by her peers *("I still can't believe it")* as a Fellow of the Australian Academy of Science for her work in developing and applying accurate computational chemistry for modelling radical polymerisation processes.

Michelle's expertise is now a vital part of ACES, after ANU recently signed on as a seven year partner.

"I'm excited to be joining ACES," Michelle said. "We have recently made some exciting discoveries at ANU about the effects of electric fields on chemical reactions, and ACES has the world-class experts and resources we need to test some of these findings and use them in practical applications. My dream is to catalyse reactions by applying fields, maybe even triggering reversible debonding in self-healing polymers, which could have applications in 3D printing, recyclable materials and even artificial muscles. Being part of ACES will give us the best shot at achieving this," she said.

A global leader in green energy research, Doug leads a formidable team of researchers at Monash University.

Setting his bedroom on fire with his new chemistry set at age eight only strengthened young Doug MacFarlane's fascination with science, and chemistry in particular.

"In those days, that was a serious bit of chemistry kit! My bedroom became my laboratory and the scene of frequent fires and floods," Doug said.

The lack of consequence dealt suggests Doug's parents foresaw the impressive career that lay ahead for their inquisitive son.

These days, Professor Doug MacFarlane is a global leader in green energy research and heads a formidable team of research fellows and PhD students at Monash University in Melbourne. He is also an International Fellow of the Queen's University Belfast, a Visiting Professor at the Chinese Academy of Sciences and an Adjunct Professor of the University of Alabama.

Fiercely motivated by finding solutions for serious worldwide energy challenges, Doug has extensive experience in leadership roles having served as Deputy Dean, Deputy Head and then Head of School at Monash University.

It was his collaborations with Maria Forsyth and Gordon Wallace from the ACES team that he thanks for enabling his research to build, resulting in significant published papers in journals such as Science and Nature.

Professor Doug MacFarlane
Synthetic Energy Systems Theme Leader
ACES @ Monash University

Doug's contribution to research was recognised in 2007 when he received a prestigious Australian Federation Fellowship which allowed him to focus full time on his beloved research, and through it, deliver solutions for serious worldwide energy challenges. In 2013 his Fellowship was extended for a further five years in the form of an Australian Laureate Fellowship. His contributions to pure science was further recognised by his election to the Australian Academy of Science in 2007, while his work in technological applications of this prompted his election also to the Australian Academy of Technological Sciences and Engineering. Doug is therefore one of the relatively small number of Australians who are fellows of two of the Learned Academies.

"Climate change is the most important problem faced by the world today," Doug said. "There is no question about the science behind our predictions of the impacts of Carbon Dioxide in the atmosphere and the ocean, and action on this is urgent."

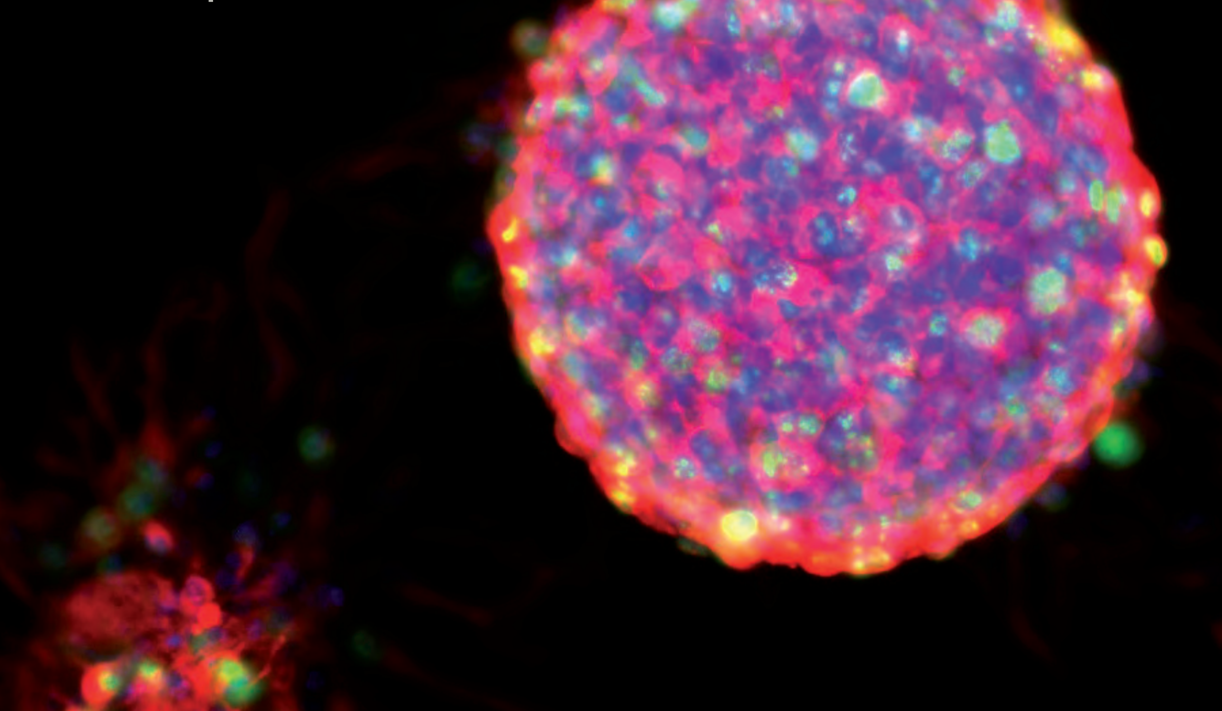
With a genuine passion for delivering green energy solutions, coupled with an outstanding research track record, Doug is the ideal candidate to lead the new ACE Synthetic Energy Systems program.

"Our current reliance on fossil fuels is a huge problem for the word," Doug said. "The ACES Solar Fuels project will pave the way for the production of fuels from sunlight."

GREEN SOLUTIONS FOR GLOBAL CHALLENGES

BRAIN BUILDING

Human stem cells are being used to build life-like brain tissue so researchers can better understand, and ultimately treat, neural psychiatric disorders like schizophrenia.



You've heard it before. The human brain is an amazingly complex organ, containing around 86 billion neurons (nerve cells).

Impressive, but that is probably not the reason that the human brain differs distinctly from that of an animal. What is the reason? We're not sure. What we do know is: what works in animal brains, doesn't necessarily work in humans.

Pharmaceutical companies spend millions of dollars testing therapeutic drugs on animals (with positive results), only to discover in human trials that the drug has an altogether different level of effectiveness.

At the ACES labs at St Vincent's Hospital Melbourne and the University of Wollongong, researchers are building brain tissue with living human stem cells in order to better understand neural diseases, and ultimately to treat them.

It's called disease modelling. Using stem cells to develop tissue constructs in the lab that accurately reflect actual brain tissue.

Conventionally, animal models of disease are used, but in an effort to produce more relevant results in the lab, ACES researchers are using the real deal. It makes sense. After all, brain disorders like schizophrenia are actually unique to humans.

Associate Professor Jeremy Crook, at the A*Star Institute of Medical Biology in Singapore, was the first to use human stem cells to model psychiatric disease in the lab.

"This disease modelling represented a new biologically relevant approach to understanding the cellular and molecular mechanisms underlying complex brain disorders like schizophrenia and bipolar disorder," Crook said.

Imagine the possibilities, having various living human neural tissue models on hand to test the effectiveness of drugs or devices, and to learn more about how diseased tissue functions.

Crook joined ACES as a Chief Investigator in 2014, working alongside bionics expert Associate Professor Robert Kapsa and Synthetic BioSystems theme leader Professor Mark Cook, and brought with him his bag full of human stem cells derived from diseased brain tissue.

"Our priority goal for the next seven years in the Centre of Excellence is to use the human stem cells to fabricate useable 3D neural tissue constructs that reasonably reflect the tissue sub-types you find in different regions of the brain including neurons and supporting cells," Crook said.

It's not only disease models that researchers are interested in. As part of these studies, engineered biosynthetic brain tissue constructs are also being developed that will enable better understanding of normal neural function and will potentially provide implants to manage brain dysfunction conditions including brain injury sustained as a result of trauma and possibly even to connect the brain with robotic devices.

In the future, it is feasible that the ACES work on understanding stem cells' interactions with specific materials and structures, will develop to the point that implants and bio-synthetic neural micro-tissue constructs could be fabricated using the patient's own stem cells derived from blood or skin, cultured in the lab and 3D printed into customised environment-controlled therapeutic neural implants. For now, the big challenge for researchers is to increase the level of control they have in fabricating the complicated tissue constructs.

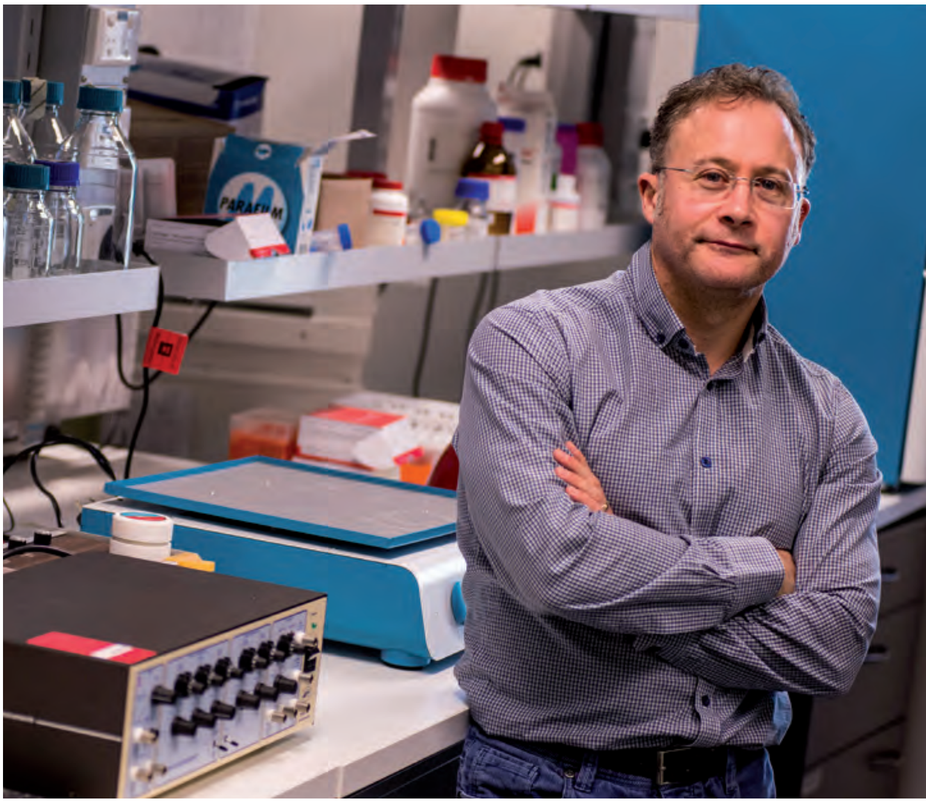
"The brain is mind bogglingly complex!" Crook said. "It's undoubtedly the most complex thing known to mankind. We are using additive biofabrication technologies such as 3D bio-printing to carefully control our tissue constructs from the nano, through to micro and right up to macro dimensions, deliberately organising cells within the construct to closely mimic functional brain tissue sub-regions."

This ambitious challenge is being addressed at the ACES additive bio-fabrication facility based at St Vincent's Hospital in Melbourne, where Kapsa and his team have developed an animal cell-based prototype tissue construct, and biofabrication protocols by which to make them.

"We expect to have recorded neural signals induced from neural networks in 3D biosynthetic tissue constructs by October 2014," Kapsa said.

"These initial prototypes will then be refined and applied to human stem cells from people with neurological conditions such as epilepsy, complementing ACES activities in Wollongong.

"In time, we envision that our microtissue systems may even be able to be used as biosynthetic processing units for Synthetic Biosystem constructs that control and restore the function of tissues or organs rendered dysfunctional by injury, disease or even normal ageing."



Renowned stem cell expert Professor Jeremy Crook joined ACES as a Chief Investigator in 2014.

"The brain is mind bogglingly complex! It's undoubtedly the most complex thing known to mankind. We are using additive biofabrication technologies such as 3D bio-printing to carefully control our tissue constructs from the nano, through to micro and right up to macro dimensions, deliberately organising cells within the construct to closely mimic functional brain tissue sub-regions."

TALKING IT OVER

Professor Susan Dodds
ACES Ethics, Policy and Public Engagement Theme Leader
ACES @ the University of Tasmania

Susan believes that managing the risks and benefits of emerging technologies should start with a community discussion.

Susan Dodds isn't afraid to ask people to consider difficult questions. At a recent community forum, she asked the audience to consider whether banning 3D printing technology for its potential to create homemade weapons was reasonable, when it could come at the expense of developing new medical devices and food production methods for the benefit of millions of people.

Rather than reacting, Sue thinks we should first understand how the new technology is being used and then discuss our response as a community.

Susan is a philosopher, and her work is in ethics and political philosophy, with a recent focus on science applications through her affiliation with ACES.

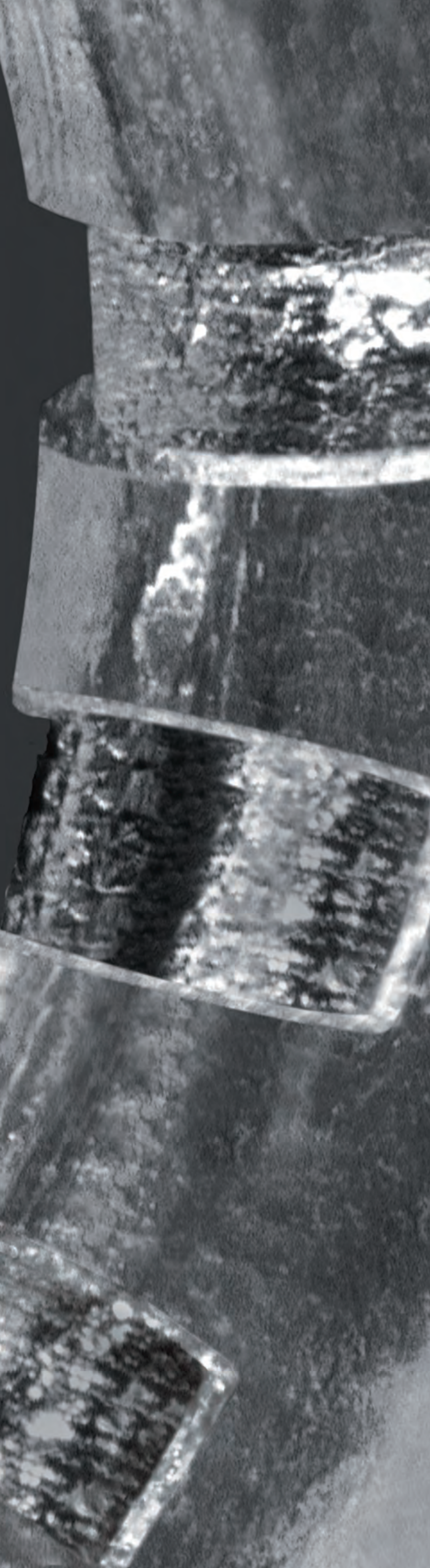
"My interest in ethics and public policy led me to a greater interest in science," Susan said. "My growing interest in science has paralleled my interest in figuring out how contemporary democracies, which seek to respect diverse ethical commitments and religious perspectives, can make policy in areas of science or medicine that are ethically contentious."

Susan seeks to engage the community in discussions around how to manage emerging technologies in her role as the ACES Ethics, Policy and Public Engagement Theme Leader. It's all about figuring out whether and how people with diverse values and backgrounds can come to agree on shared concerns about emerging technologies and how they impact on human vulnerability and resilience.

During the next phase of ACES, Susan will extend her work on deliberative democratic approaches to policy making relating to synthetic biosystems. She is also interested in working on the ethical issues emerging from 3D printing and its medical applications. Finally, the new centre provides her with an opportunity to support the use of distributed energy systems for addressing global inequalities in access to resources, energy and health care.

"I think the key to developing new technologies in a way that doesn't ignore risks or outstrip community understanding and support for the potential benefits is to bring researchers, regulators, different community members and those who may be affected by the technology together in discussion," she said. "When people with different views really listen to each others' concerns, and try to understand one another in finding a solution that each can accept, then it is possible to design policy or regulation that addresses the most significant concerns held in those communities without creating a culture of excessive or inappropriate regulation."

PRINTING SOLUTIONS FOR PATIENTS



ACES PhD candidate Binbin Zhang developed a built-in drug delivery system for the cochlear implant.

Fundamental materials research at ACES has enabled the development of a built-in drug delivery system for cochlear implant electrodes that could further improve an implantee's quality of life and hearing abilities.

Linkages:

ACES @ the University of Wollongong, the HEARing Cooperative Research Centre (CRC) and the Materials Node of the Australian National Fabrication Facility (ANFF).

The challenge:

The cochlear implant has helped nearly one million people worldwide regain their hearing. Surgical implantation of the device can often result in an inflammatory response. This response, while important for ensuring that the cochlea is effectively sealed off from bacteria which might infiltrate into the middle ear, can significantly affect the performance of the cochlear implant if it is too vigorous.

Project innovation:

ACES researchers have devised a polymer drug delivery system that complements the design of a cochlear implant electrode to better control post-implantation inflammation. To meet the specific requirements of the task, ACES researchers have used state of the art 3D printing technology to fabricate a polymer scaffold (sheath) containing the anti-inflammatory medication that fits around the electrode. The scaffold, which allows the medication to diffuse into the surrounding tissue, can be implanted with the electrode to treat the initial swelling. It would then break down harmlessly in the body much like dissolvable stitches.

Our engagement:

The HEARing CRC provided a three year PhD scholarship for Binbin Zhang who worked with Associate Professor Simon Moulton and Professor Gordon Wallace in the ACES labs at the University of Wollongong, alongside fabrication expert Dr Stephen Beirne within the ANFF Materials Node.

The potential impact:

Integrated drug delivery systems promise a hassle-free treatment for many thousands of cochlear implant patients who experience inflammation following surgery.

ACES CI Professor Mark Cook, pictured, implanted a seizure prediction device in 15 patients in a world-first study.

TREATING THE UNTREATABLE

ACES researchers are working on a new electromaterial based brain implant that can release anti-epileptic drugs when, and only when, a seizure is about to occur.

"It's really hard for me to run and play with my mates," nine year old Lizzy (pictured above) said, dressed head to toe in purple, the colour of support for epilepsy. "It's hard to remember things and it makes my learning hard. Sometimes I miss out on things because of my seizures."

If you are one of 60 million people like Lizzy who live with epilepsy, you may only experience seizures for a small amount of time but it dictates every move you make. It's easy to imagine how catastrophic the consequences of having a seizure at the wrong time could be, resulting in traffic accidents, burns and drowning.

Epilepsy, in its many forms, is more common than you think. One in 100 people have chronic epilepsy and up to ten percent of people will have some kind of seizure during their lives. Sadly, it usually affects young people, and right throughout their entire lives.

Lizzy's mum Zoe Gow says they received a diagnosis for Lizzy when she was three years old, after an initial incorrect diagnosis of gastro.

"It was not long after this that I walked into her room one night just after she fell asleep and I found her sitting up, non verbal, head deviated to the side," Zoe said. "I picked her up I thought she was dying. I rang the ambulance and they found her laying on our bed, the ambulance driver took one look at her and turned to me and said she was in postictal (post-epileptic seizure). That was when it clicked that what we had been seeing was seizures."

"There is still so much stigma out there and it worries me that we will always be fighting for help and inclusion, and like all families with a child with uncontrolled epilepsy, we fear the unknown of how her seizures will change and her risk of Sudden Unexpected Death in Epilepsy."

Medications and surgical procedures can be very helpful, however a huge 30 percent of people with epilepsy are not sufficiently well controlled with currently available treatments. Many suffer unpleasant and often serious side effects; including nausea, dizziness and increased risk of osteoporosis. Most are ineligible for surgery, usually due to the exact location of the seizures in inaccessible parts of the brain.

Typical for people with epilepsy, Lizzy has tried multiple drugs with minimal improvement.

"It kept on happening," Zoe said. "We would get excited thinking we had found something to control her seizures and then BAM they were back. It is soul destroying watching your daughter change with the side effects and not benefiting by having seizure control."

"The side effects she has had include personality changes, aggressive behaviour, respiratory acidosis, rash, reduced quality of sleep, cognitive impact on her learning, decreased ability to sweat, lowered immune system the list goes on and on."

ACES researchers are working to create a brain implant to help Lizzy and the 18 million others like her who are currently untreatable. The treatment concept is a two pronged approach, resulting in a device that will firstly detect the imminent onset of a seizure and then secondly trigger the release of an anti seizure drug to the exact point of the brain at which it is needed.

Technology for the first step, detecting the seizure, is already established. In 2010, ACES Chief Investigator Professor Mark Cook, from the University of

Melbourne, implanted for the first time in people the Seizure Advisory System, developed by US company NeuroVista, into the brains of 15 patients at St Vincent's Hospital in Melbourne.

"It was a great opportunity to lead this world-first study," Professor Cook said.

The detection system constantly monitors electrical activity in the brain and calculates the risk of a seizure, then transmits that information to a personal device similar to a pager. Patients are able to make lifestyle decisions based on this warning information, ensuring that they are safe, notify others or take a fast-acting drug when a seizure appears imminent.

"Incredibly, it was possible to predict seizure in the great majority of patients."

Associate Professor Simon Moulton (pictured below) said the development of advanced fabrication approaches "has led to significant improvements in the long-term release of anti-epilepsy drugs".

The second element of the treatment is the release of anti-seizure drugs, directly and only to the part of the brain where they are required. Such a targeted delivery would eliminate the debilitating side effects of the drugs, which are usually given in large doses orally, just so a small amount will cross the blood brain barrier and reach the seizure location in the brain. An ARC Discovery Grant in 2009 allowed an expert team of researchers to focus on the drug delivery project, developing an implantable biodegradable polymer system, and the results to date are more than encouraging.

A small implantable 'mat' is created from a polymer material into which the anti-seizure drug is integrated. As the polymer interacts with and breaksdown in the body, the drug is released.

What happens when the polymer has entirely biodegraded? The drug release is over. So you can understand that key factors in this drug delivery method include maximising the amount of drug the polymer can hold as a reservoir waiting to be used; monitoring the amount of drug that is released at the various timepoints during the degradation process and optimising the time over which the drug can be released in the brain.

In the early days of 2009, researchers were achieving a drug release lasting two days. In 2014, the release is sustained over four months in the lab and three months in animals.

Associate Professor Simon Moulton leads the drug delivery program at ACES at the University of Wollongong and says that the improvements he has seen over the last five years are thanks to the way in which his team have improved the way they fabricate the actual polymer mat.

What started as simple casting of a drug and polymer mix into a mould, developed to combining various forms of electrospinning with casting, and now the next stage offering much promise is 3D printing. This technology is able to provide researchers with many more ways to produce the final polymer shape; significantly better control over the drug placement within that shape and an improved reservoir for holding more drug as polymer layers are printed one by one into a 3D format. 3D printing can also allow more than one type of drug to be printed in separate reservoirs within the polymer shape (many epilepsy sufferers need multiple drugs).

It is not only people with epilepsy who suffer from seizures. Head trauma patients, such as car accident victims, often tackle this same problem up to a year following injury.

It is no coincidence then that the aim is to initially work towards achieving sustained drug release over at least a 12 month period, making it of interest to clinicians treating those short-term seizure sufferers.

"Thanks to the development and implementation of advanced fabrication approaches we have achieved significant improvements in the long-term release of anti-epilepsy drugs," Moulton said.

"We now plan to explore the use of 3D printing to further advance these delivery time scales. We believe we can reach our goal of 12 month drug release with the next two years."

The sustained, slow release of medication through the polymer drug delivery system targeted to the site of seizures would no doubt benefit people with epilepsy by eliminating the need to take such large amounts of anti-seizure drugs as required when administered orally, preventing dosing the whole body as the drug release is direct to the brain and thus reducing the instances of those unwanted and unpleasant drug side effects. Not stopping here, ACES researchers want to then go one step further, and combine the detection system with an electromaterial based drug delivery system to create one system that delivers the drugs directly to the brain only when the detection systems indicates a seizure is imminent.

This time, the drug delivery system will be fabricated using a conducting polymer material, capable of responding to electrical stimuli supplied from the detection system. Using this smart drug delivery material produced in the ACES labs, the on-demand system could release a pre-determined quantity of drug directly to the seizure site in the brain, only when a seizure is predicted to occur.

"This is a very ambitious undertaking, with profound potential benefits to people with epilepsy. For the first time someone who is currently untreatable can live their life without the constant restraints imposed upon them by this debilitating condition," Moulton said.

As Lizzy's family continues to search for their own answer, it's clear that their journey has inspired them to strive for positive change for all epilepsy sufferers. They have established a lobby group, *Epilepsy Let's Talk About It!*, pushing for improvements in epilepsy support services.

"You get kicked down a lot on this epilepsy journey," Zoe said. "It is stressful and all-consuming but you keep looking and hoping to find a treatment that will give your child some relief from their seizures. Giving Lizzy the best chance at a good quality of life is what drives us."

TWO minute taxi

with:

PhD candidate Joseph Giorgio

Project:

Light weight and flexible dye-sensitised solar cells

ACES @ the University of Wollongong

Where are you going?

I will be finishing my PhD in six months so I am currently looking for long-term employment. I would like to build a career carrying out research in an industrial setting. I enjoy prototyping and making real devices so I would like to gain experience working in both small start-up and large multinational companies. I want to be part of a team bringing research from the lab bench to market.

Why did you choose the ACES cab to get you there?

At ACES, I found the three key ingredients for a good PhD:

1) an interesting project;
2) helpful and friendly supervisors and colleagues; and
3) amazing facilities and equipment to use.

What is your research about?

I am working on a new type of solar cell made from environmentally friendly and inexpensive materials. I research a specific design which allows for light-weight and flexible devices to be made. Imagine a solar panel that is paper-thin, light and flexible so you can roll up and take with you. The panels also work indoors – it's just that they produce less electricity than in direct sunlight.

Best case scenario, what would the outcome of your project be and why is this important?

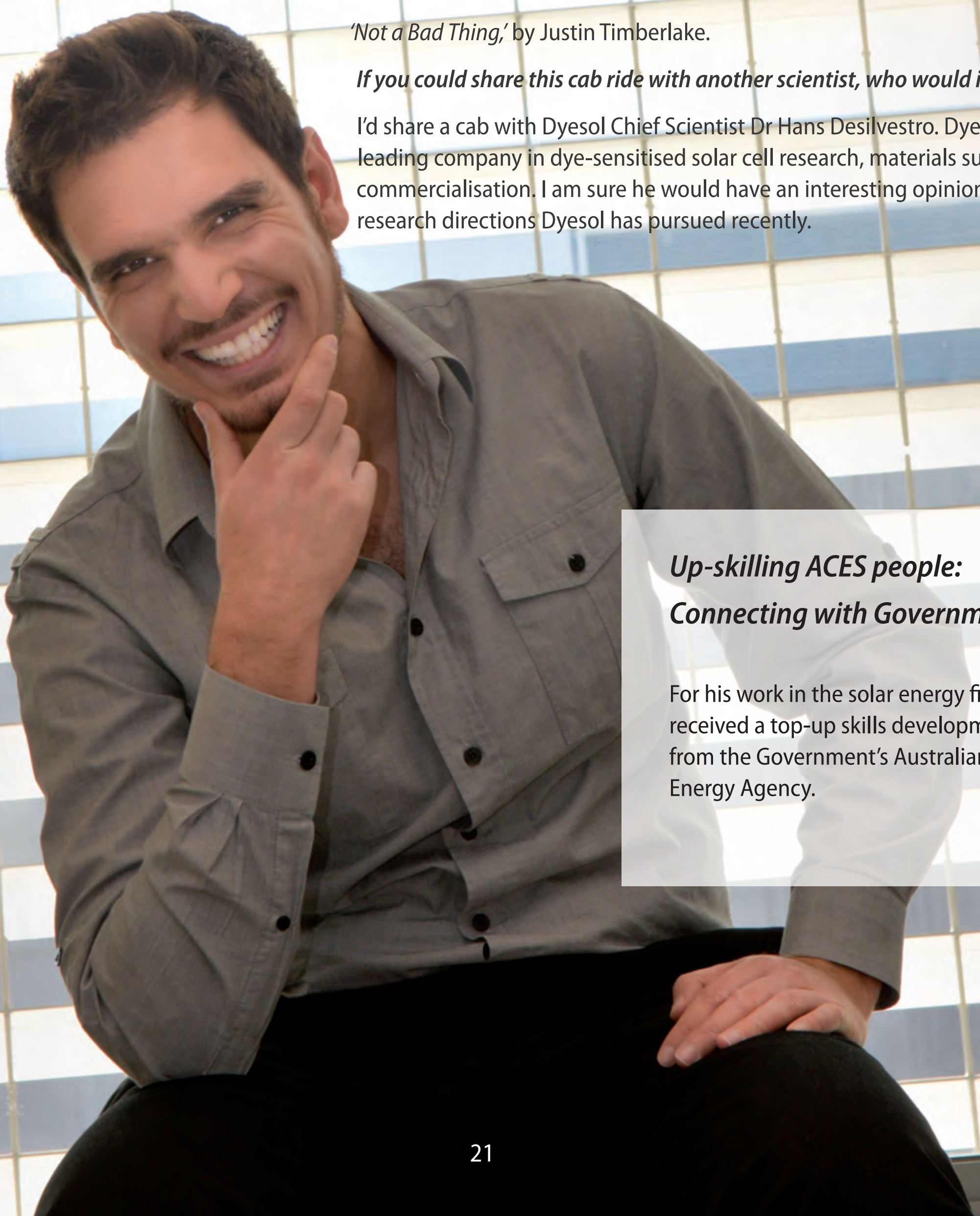
The outcome of my project, best case, would be that I develop a cheap and portable source of electricity. Imagine going to your local hardware store and buying a $50 solar panel that you can take with you hiking and camping or buying a roll of the stuff for the roof of your house.

What's playing on the radio right now?

'Not a Bad Thing,' by Justin Timberlake.

If you could share this cab ride with another scientist, who would it be and why?

I'd share a cab with Dyesol Chief Scientist Dr Hans Desilvestro. Dyesol is a leading company in dye-sensitised solar cell research, materials supply and commercialisation. I am sure he would have an interesting opinion on the new research directions Dyesol has pursued recently.



Up-skilling ACES people: Connecting with Government

For his work in the solar energy field, Joseph received a top-up skills development scholarship from the Government's Australian Renewable Energy Agency.

BETTER BATTERIES TO IGNITE THE ELECTRIC CAR INDUSTRY

ACES researchers are working on new battery technology to turn our nation of car lovers, into electric car lovers.

It's not looking good for electric cars in Australia.

To say that Australians have been slow to embrace electric vehicles would be a huge understatement. According to the Federal Chamber of Automotive Industries, of the half a million vehicles sold in Australia in the first quarter of 2014, only 42 were electric.

The first electric car model to go on sale in Australia, the Mitsubishi iMiev, was withdrawn from showrooms after slow sales. The second, the Nissan Leaf, is offered at a discount of around 30 percent.

So what is putting Australians off electric vehicles?

Range anxiety

It's a long weekend, you're on a road trip and the freeway stretches out for miles ahead. Hopefully you don't have a long trip planned, because if you took off in the Sydney CBD, some electric cars may only make it 160km north to Newcastle. And what if the battery power is draining faster this particular day (maybe you have the air conditioning cranked)? Will you be anywhere near a recharging station? This is range anxiety; the panic that electric car drivers feel when they are in fear of running out of charge nowhere near a willing power point.

The limited range offered by a fully charged electric vehicle on the Australian market is one likely factor negatively influencing sales (in addition to a lack of recharging facilities and no financial incentives).

Tesla has announced plans to release a model new to the Australian market, offering ranges of up to 600km, however at an estimated price point of $100,000 (some estimates are up to $150,000), it's not a viable alternative for the mainstream market.

At the ACES labs at Deakin University in Victoria, Dr Patrick Howlett leads a team working to develop a new metal-air battery that he hopes could one day result in electric cars that deliver high performance, but are significantly cheaper.

Limitations of Lithium

Most electric vehicles currently store energy using batteries made with lithium compounds, which are relatively expensive materials with potential supply issues in the future.

With a significant world-wide effort in lithium based battery technology, advances have been made and performance has greatly improved but, aside from the expense, lithium has other limitations. The ability of a lithium battery to maintain its original capacity over long periods of use, particularly in harsh climates such as those in Australia, is unproven.

The metal-air batteries being developed at ACES use energy dense metal negative electrodes, such as zinc or magnesium, with an ionic liquid electrolyte, but the magic happens at the other end of the battery cell, where oxygen from the air is used for the positive electrode reaction.

"It comes down to volume," Howlett said. "The metal-air battery takes in oxygen from the atmosphere, reducing the need to allow for oxygen within the battery cell itself."

With less volume comes less weight and an opportunity for a better energy to weight ratio, hence, performance.

Howlett's team, led by Australian Laureate Fellow Professor Maria Forsyth, is mainly working with magnesium and zinc metal electrodes.

"We really don't care what the metal is, so long as it works," Howlett said.

"We've had success with magnesium-air batteries, producing up to two volts, however it's a difficult material to make rechargeable."

Zinc, on the other hand, has proven easier to make rechargeable, is readily available and cheap, with resources totally almost two billion tonnes world-wide.

Commercial zinc-air batteries exist already and are used in applications such as hearing aids. The trouble is, the current technology is not rechargeable.

Deakin University PhD candidate Tristan Simon devoted his study to developing a rechargeable zinc-air battery.

"One of the main reasons the zinc-air battery can't be recharged is that when the battery is used, zinc gets dissolves away from the smooth metal surface back into the electrolyte," Simon said. "When it gets recharged, we need to put the zinc back in place again. The trick is, it needs to go back on as a smooth surface, otherwise the battery short circuits."

Simon developed new electrolytes using ionic liquids, and found that the zinc could be efficiently deposited back from the electrolyte when recharged, with variations in the electrolyte causing variations in the way in which the zinc deposited.

"This is the technology most likely to deliver electric vehicles with the performance that motorists demand."

Conquering Corrosion

"The simple problem with this sort of battery is that you need a high energy negative electrode, a reactive metal, and they react with just about everything," Howlett said. "You can just imagine the problems when you open the battery cell up to air and moisture for the positive electrode."

ACES researchers have met the challenge of creating a corrosion-resistant metal electrode, thanks to ionic liquid electrolytes. For starters, ionic liquids are salt in liquid state, so they don't evaporate.

Secondly, researchers have demonstrated that with the right additives, the ionic liquid solution can form a protective layer on the electrode, shielding it from the oxygen and moisture invasion.

In the newly refunded Centre, researchers are turning their focus to improving the performance of the positive electrode.

"Presently, it is difficult to make the electrode work well during recharge," Howlett said. "There are also limitations in the amount of current that the electrode can support, ultimately limiting the charge and discharge rates."

Howlett's team will work to develop new catalyst materials and use 3D printing technology to build nano-structured electrodes to improve performance.

With collaborative agreements in place with major automotive manufacturers, Howlett and his team know that the work they're doing in their Burwood labs has the potential to be a significant game changer in the electric car industry.

"I'm motivated by the importance of the research that we do. To make a high performance rechargeable device based on this chemistry, that's the big goal, and in the long-term, this is the technology most likely to deliver electric vehicles with the performance that motorists demand."

TWO minute taxi

with:

PhD candidate Yajing (Jenny) Yan

Project:

A new air-battery powered by magnesium (Mg)

ACES @ Deakin University

Where are you going?

I'm on my way to being one of those researchers working for companies like Toyota, BMW or Apple who make people's lives easier by improving their daily use devices.

Why did you choose the ACES cab to get you there?

For starters, I knew I had to become a good researcher to achieve my goal and ACES is full of intelligent researchers who not only do brilliant work, but are good at supervising. Secondly, ACES has lots of connections with industry and many industry projects.

What is your research about?

I'm basically trying to make a lighter, safer, cheaper and higher energy battery using pure Mg as a negative electrode instead of lithium. Other features include that the Mg electrode is coupled with a safer electrolyte called ionic liquid, and uses oxygen from the air as a reactant on the positive electrode side. This type of battery is called an Mg-Air battery. My work aims to design a better ionic liquid electrolyte to improve the discharge behaviour of Mg-Air batteries.

Best case scenario, what would the outcome of your project be and why is this important?

The best case scenario in my three year PhD is that we assemble a primary Mg-Air cell which can be put into low energy devices such as TV remotes. But in the future, we expect more scientists will work on the Mg-Air rechargeable batteries and someday you might be able to drive a rechargeable electric car with these safe, green batteries without worrying about the petrol price.

What's playing on the radio right now?

'Wake me up,' by Avicii on mix 101.1, my favourite!

If you could share this cab ride with another scientist, who would it be and why?

I'd pay for a cab ride with Professor Michel Armand from the National Center for Scientific Research, France. He's been working in this field for decades and accomplished lots of great achievements. It would be a great honour to work with him and learn from him.

A pep talk from her head of school pushed Jenny Pringle to work for a first class honours and another nudge by a leading chemistry professor set her science career in motion with a PhD in ionic liquids. Jenny hasn't forgotten the difference a bit of encouragement can make to students.

Jenny Pringle takes people with her. She recently received an invitation to one of those formal affairs involving senators, government officials and science legends. Jenny was one of the first to reply in the affirmative. Yes, she would be there, as would her colleagues, director and, swept into the same sentence, a number of her *uninvited,* but very welcome PhD students.

If you're looking to build a career in materials science, this is someone you want to work with.

Jenny's focus on supporting students stems from the fact that she's had some fantastic mentors of her own, from her parents, both of whom fostered her interest in environmental science, to her encouraging university lecturers and supervisors.

"One of the turning points for me was near the end of my honours year in chemistry when I was called into the head of school's office for a pep talk. He said that if I worked that extra bit harder I could get a first, which I took on board," she said.

"The lesson I've taken from this situation is that it's important to remember how big a difference a bit of encouragement can make to students."

Jenny had not intended to stay on to complete a PhD but was convinced after one of her chemistry lecturers told her about a then emerging field of research in ionic liquids (ILs), and the potential for her to make new formulations for use as solvents for different reactions. She went on to complete a post doctoral fellowship at Monash University, and subsequently started working in ACES, using ILs as electrolytes for different kinds of energy devices.

Jenny last year moved to ACES at Deakin University where she has more of an opportunity to group her team and expand her energy research. She credits her *"fortunate research journey"* thus far to the people she has met and learnt from along the way, and says her eight years in the ACES environment has fostered an incredible support network.

"One of the aspects that I most value about ACES is that being part of it allows access to research leaders and our many international collaborators who are so available for exchanging ideas. Having that degree of support and encouragement as a young researcher is rare but incredibly valuable."

And that's why Jenny sent a bold RSVP off on behalf of her students. She's paying it forward.

Dr Jenny Pringle
Chief Investigator
ACES @ Deakin University

PAYING IT FORWARD

THERE'S SOMETHING ABOUT GRAPHENE

ACES researchers are using their chemical expertise and production know-how to help industry turn the super material graphene into practical devices.

The scientific community had long suspected that graphite, that cold, grey element, could yield more for society than pencils and basic conducting materials for electronics.

They could see that it was made up of layer upon layer of one atom thick sheets, but despite the many brilliant minds working on it, the question of how to separate them remained unanswered.

The answer in the end was simple.

Two English physicists used scotch tape to peel away layers from a graphite block revealing a single layer of honeycombed graphene – a million times thinner than a human hair; light, flexible, strong and able to confer strength to other materials; and more conductive than copper.

The collective imagination went wild. Headlines hailed graphene as a 'supermaterial' or 'black gold' for its amazing properties. Some said that we could look forward to transparent, super-thin computer and TV display screens that could be rolled up and put away or faster, slimmer phones. Others were interested in its potential biomedical uses – imagine a better performing cochlear implant or bionic eye.

The possibilities, according to some scientists were just beyond comprehension.

One barrier remained. The isolation and characterisation of graphene in 2004, which later earned the two physicists the Nobel Prize, started a new race: developing a cheap, scalable method of producing high quality graphene that would allow us to use it in the next generation of devices.

When graphene got sexy

About the time graphene got sexy, ACES was well in the race, having amassed knowledge on characterising formulations and potential processes for producing large quantities of dispersions.

They had also, through the Materials Node of the Australian National Fabrication Facility (ANFF) at the University of Wollongong, built up the in-house processing expertise and equipment needed to make graphene dispersions.

"Our focus was and still is on developing graphene chemistries that can be used to tune physical properties while enabling device fabrication," ACES Director Professor Wallace said. "You need this dual focus to fully exploit the potential of this amazing material."

In 2008 Professor Wallace's team had a significant breakthrough when then ACES Fellow Dr Dan Li, in collaboration with Professor Ric Kaner of University of California, Los Angeles, discovered a low-cost process for the large-scale production of a stable graphene dispersion.

"The key challenge of working with graphene is that individual sheets want to clump together," Wallace said. "This makes it hard to produce formulations for use in industrial applications."

"Dan took it back to basics by putting a charge on the particles so that they would repel each other. He added a touch of ammonia to increase the pH of the solution which raised the electrostatic charge of the sheets, thus preventing them from sticking together."

"Our focus is developing graphene chemistries that could be used to tune its physical properties while enabling it to be processed and used for device fabrication. You need this dual focus to fully exploit the potential of this amazing material."

At the end of the experiment, Li, now a professor and research program leader at Monash University, remembers seeing a stable black solution, and thinking, *this must be a breakthrough.*

"The fact that we had just made graphene particles disperse in water without any added surfactant was just amazing and very exciting to me," Li said. "It opened up numerous opportunities to process graphene into useful structures for real-world applications."

The discovery created a graphene dispersion that could be used to make devices using fabrication methods such as such as ink-jet printing, spray coating and 3D printing.

"It had an immediate impact on our ability to create practical devices from graphene," Wallace said.

Work it, graphene

Discovering a process for scalable, high volume production of graphene was just the beginning for ACES. Since 2008 the team has refined the process and indeed used the original finding to make tailored graphene dispersions, particularly in partnership with industry.

The team also has its own vision for graphene, using it to create an implantable device that detects the onset of an epileptic seizure, and in other projects, to stimulate nerve and muscle repair.

"Biocomposites wherein the graphene is effectively dispersed throughout a biomaterial host using clever chemistries remains an area of great interest to us," Wallace said.

As part of an international collaboration the team has also developed a way to make nano-fibres out of graphene that could be used to give super-strength to materials used in bullet-proof vests and aircraft fuselages.

Professor Wallace predicts that 3D printing technologies will significantly improve his team's ability to develop the next generation of graphene-based devices, and this will be a key focus of ACES for the next seven years.

"Our ability to spatially arrange graphene within 3D structures will enable the more effective translation of nanoworld properties to the 'real' world," he said. "In particular for us this will impact on areas including synthetic energy conversion and storage systems, as well as synthetic biosystems."

"The question is whether we, as scientists, technologists and engineers, can take its amazing properties from the nanomaterial world to the level of macroscopic devices," he said.

NEW HYDROGEN TECHNOLOGIES TO PRODUCE CLEAN ENERGY AND STORAGE SOLUTIONS

"ACES has and continues to be an outstanding partner for AquaHydrex. They are well positioned to be a world-class commercial research partner. The quality of their facilities and equipment, coupled with the ability of their people to adopt new commercial methodologies has helped to accelerate our progress."

AquaHydrex Pty Ltd General Manager Paul Barrett.

Linkages:

ACES @ the University of Wollongong (UOW) and Monash University, and UOW spin-off company AquaHydrex Pty Ltd.

ACES is tackling Australia's energy challenge at a fundamental research level and collaborating with commercial partners to ensure the widespread adoption of new hydrogen technologies.

The challenge:

Clean energy derived from hydrogen has long promised a revolution in transport fuels, industrial energy storage applications and the way we generate and store energy at a household level. In fact, hydrogen is already fuelling electric cars and industry uses hydrogen technologies to store energy – however as a general rule it is cost prohibitive. Existing methods of producing hydrogen – which involve splitting hydrogen from oxygen by passing an electrical current through water – rely on expensive materials like platinum and other rare earth elements, and use energy derived from fossil fuel to 'split the water'. Put simply, it is more expensive to produce than conventional energy and this has prevented its widespread adoption. ACES researchers are working with technology company Aquahydrex to commercialise an innovative, cheaper way of producing hydrogen.

Project innovation:

The team has developed an innovative new process for creating hydrogen, which results in a cost-competitive, cleaner fuel source or energy storage device for many applications.

The features of the new process include:

- The hydrogen is created using light from the sun, rather than conventional sources;
- It relies on a cheap abundant material to split the water; and
- It uses seawater as the base material, saving fresh water for other purposes, with no harmful by-products created as a result.

The team has already proven the science behind the new process, and efforts to scale-up and prototype devices for use across a range of applications are in progress.

Our engagement:

Developing the new process began within the University of Wollongong (UOW) and Monash University nodes of ACES as well other Australian Research Council (ARC) supported projects at Monash University. The results of the research were so promising that spin-off company Aquahydrex Pty Ltd was formed, and investment secured from True North Venture Capital. ACES continues to lead Aquahydrex's fundamental research program that will ensure the venture remains at the forefront of hydrogen technology development, and is commercially successful in the long-term.

The potential impact:

The new process could be used across a range of applications, from fuelling electric cars and powering homes, to helping industry and power plants store energy for future use.

I am delighted to be part of the ACES team that continues to build an outstanding international reputation in fundamental electromaterials science and its application in areas critical to society. The strength of the Centre – past, present and future – is its vibrant, clever and collaborative researchers and the unique research training experience that it therefore provides. Our research team includes fundamental chemists, materials scientists, biologists, engineers and clinicians. We also have a strong team in ethics and public engagement working alongside our scientists and engineers, as well as helping to convey the link between our research and its impact on the community.

In ACES our researchers design, synthesise and investigate the properties of materials that will have important applications in key areas, namely energy and bionics. We can then use purpose designed fabrication techniques such as 3D printing and electro-spinning to create assemblies of these materials in just the right way to provide optimum conductivity, catalytic activity and interfacial stability. Our state-of-the-art fabrication tools coupled with our knowledge of how to create these architectures, allow us to make progress beyond the lab and into potential manufacturing opportunities.

Going forward, we foresee many other opportunities to take discoveries made by our young researchers in the Centre of Excellence into manufacturing start-ups in areas such as new materials, biomedical engineering and energy storage. Our innovative research training programs will give our young scientists and engineers greatly sort after communication, entrepreneurial and commercialisation skills alongside their excellent research. Over the next seven years, ACES will make important contributions to new scientific knowledge, train the next generation of electromaterials scientists and engineers as well as create several manufacturing opportunities which will benefit Australia.

Professor Maria Forsyth
ACES Associate Director
ACES @ Deakin University

ARC Centre of Excellence for Electromaterials Science

Australian Government
Australian Research Council

NSW GOVERNMENT Trade & Investment

University of Wollongong

Deakin University

Monash University

University of Tasmania

Australian National University

University of Melbourne

Dublin City University

University of Warwick

Friedrich Alexander University

Hanyang University

Yokohama University

ANFF

Lab to Industry Partnerships

Industry partnerships are critical in translating our cutting edge materials research to useful devices for health and energy applications. ACES seeks alliances with industry partners who share our commitment to innovation.

Study Opportunities

Work with some of the most dynamic and highly regarded researchers in the world. With 11 partners worldwide, state-of-the-art facilities and options to include industry or communications experience in your study, ACES provides a head start to your career.

Research Collaborations

From chemists to clinicians, ACES is a multidisciplinary organisation with strong links to industry. Connect with the ACES team to develop solutions for the clean energy, human health and next generation manufacturing industries.

electromaterials.edu.au