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Director’s report

Great things start with a great vision. The MacDiarmid Institute for Advanced Materials and Nanotechnology is part of Sir Paul Callaghan’s vision for a vibrant and prosperous New Zealand transformed through science and technology.

His recipe was simple: bring together New Zealand’s best and brightest in science and give them the means and mission to undertake excellent research, train New Zealand’s future leaders and translate the research outputs into economic benefits. When Sir Paul founded the MacDiarmid Institute in 2002, this idea was revolutionary; more than a decade later, it has proven its value and has been copied many times within the New Zealand research sphere. Sir Paul saw the value in bringing together not just the scientists but the scientists and the businesses, the scientists and communities, New Zealand with the world. In setting up the MacDiarmid Institute and inspiring all that followed, he has made a huge impact on New Zealand’s culture, science and economy.

2015 was a transition year for the MacDiarmid Institute. Director Professor Kate McGrath was appointed Vice-Provost (Research) at the Victoria University of Wellington after securing a further six years of funding for the Institute in 2014. Kate left a legacy of collaboration and excellent research outputs across a wide breadth of materials sciences. Around the same time, our new Centre Manager Jacqui FitzGerald, and a new chair of the board Dr Ray Thomson, commenced their roles. About mid-2015, two new Deputy Directors were appointed: Associate Professor Nicola Gaston (Stakeholder Engagement) and Dr Justin Hodgkiss (Commercialisation and Industry Engagement). I arrived mid-August and found the Institute in excellent shape. I would like to thank all of these wonderful people, who helped me in settling in and making this transition as smooth as possible. Throughout the transition, the Institute continued to achieve at the highest academic level.

Chair’s report

Great things start with a great vision.

2015 has been a year of much change at the MacDiarmid Institute. I came in as a fresh board appointment to the Chair role on 1 January 2015 and Kate McGrath stepped down as Director on 30 June 2015.

As a result we have appointed a new and energetic leadership team. The new Director is Thomas Nann, who was chosen in a keen contest. Thomas brings international experience to the role and in addition to his strong academic background, has the necessary personal skills to help reshape the Institute over the next few years. In addition we have appointed two new Deputy Directors, Justin Hodgkiss (Commercialisation and Industry Engagement) and Nicola Gaston (Stakeholder Engagement).

In the commercialisation area I have been actively involved with several projects being worked on by our investigators. At least five projects involved with MacDiarmid Investigators have entered or are in discussion to enter the recently established Tech Incubators.

Finally I extend my thanks to Kate McGrath, our immediate past Director, for her considerable contribution to the Institute over her four years as Director and I wish her well in her new role as Vice-Provost (Research) at Victoria University of Wellington.
About us

The MacDiarmid Institute for Advanced Materials and Nanotechnology is a national network of top New Zealand scientists.

The Institute leverages strengths across the country and internationally, working collaboratively utilising a programme-based approach to undertake harder, higher level research that drives innovation and economic growth in and for relevant New Zealand industries.
Out of the lab
The MacDiarmid Institute is an interdisciplinary network of leading scientists in physics, chemistry and biology in New Zealand. Each MacDiarmid Investigator is based at a university or research institute, where they teach and research. Yet each Investigator connects tangibly with colleagues in their field and across disciplines through their engagement with the Institute.

The MacDiarmid takes us beyond our institutions,” says Professor Thomas Nann, who has led the Institute since August 2015. “It gives the best researchers in nano and materials science in New Zealand the opportunity to share and learn and research together and make a real difference to New Zealand. Our science stories (pages 6–27) show ‘the MacDiarmid difference’: stories of collaboration and discoveries that may never have happened without the MacDiarmid connections. These certainly would not have happened in the timeframes they have, and possibly not in New Zealand.”

Over recent decades, science has become increasingly segregated. While necessary to some degree, the segregation creates artificial boundaries between the disciplines of physics, chemistry and biology. These boundaries do not represent the world around us; all science is part of a whole – learning from exploring the world around us – albeit – in our case – in the tiny dimensions of nanoparticles and materials science.

The MacDiarmid Institute dissolves these boundaries and enables researchers in one area of science to shine the light of their own research and singular approach onto the area of their MacDiarmid colleagues from other disciplines. It is this collaboration that allows researchers to get below the surface in materials science.

This is the ‘MacDiarmid difference’.

Overview

Materials science areas

1 MacDiarmid researchers are teaming up to develop smart materials inspired by the natural world.

2 With MacDiarmid-led research, New Zealand has the potential to be a world-leader in the transition to a 100% renewable energy economy. MacDiarmid research on clean energy materials spans from new, highly efficient photovoltaic cells, and materials for greenhouse gas absorption and energy storage (for example batteries), to high temperature superconductors for wind turbines.

3 New materials enable new functions. MacDiarmid researchers develop new advanced nanomaterials for devices such as touchscreen displays and medical imaging technologies.
Most of us carefully keep milk away from light. But three teams of scientists at the MacDiarmid Institute are instead shifting milk into the light, so that it yields a wealth of useful information with the potential to add value to our dairy industry, and more.

Studying how matter interacts with electromagnetic waves – which include visible light – is called spectroscopy. Every atom, molecule, or more complex substance has its own ‘absorption spectrum’. This can be graphed, and shows how a substance absorbs each frequency of electromagnetic wave. In theory, if you had the technology and knew what to look for, you could discover what was in almost anything by using spectroscopy. Of course, in practice, it’s nowhere near that simple.

**Absorbing projects**

MacDiarmid Principal Investigator Associate Professor Cather Simpson, at the University of Auckland, has invented Milk-on-a-Disc. A transparent disc is spun inside a device like a robust CD-player.

As milk flows down the disc’s specially designed channels, light shines onto it, and an attached spectrometer charts which frequencies of light are absorbed, and which are scattered. The rapidly obtained results reveal detailed data about the milk’s composition – providing a vital, no-fuss tool for dairy farmers.

Another team at the MacDiarmid Institute are also innovating in spectroscopy, with potentially exciting applications in dairying. Non-transparent, cloudy liquids often cause headaches for spectroscopists, but a possible solution recently emerged from fundamental research by a team comprising Professor Eric Le Ru, along with PhD student Brendan Darby and postdoctoral researcher Dr Baptiste Auguié.

Their invention, dubbed ‘CloudSpec’ is little bigger than a microwave, and has a unique design that they hope will enable new information to be unlocked from cloudy liquids - milk and more.
**Laser sharp**

Principal Investigator Professor Bill Williams, meanwhile, is experimenting with ‘optical tweezers’ - an instrument based on the discovery, around 30 years ago, that tightly focused beams of laser light can be used to grasp and then manipulate microscopic objects, in order to learn more about their physical properties.

Because this technique is so new, applications are waiting to be discovered, and Williams and his team are among the first in the world exploring the possibilities. As shown in a recent collaborative project with Professor Kate McGrath and Riddet Institute PhD student Marjorie Griffith, these include studying how milk fat globules can be manipulated.

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**Quick and convenient**

Cather Simpson’s work has attracted wide interest from dairy farmers, as Milk-on-a-Disc is designed to fit into their busy lives. Imagine a milking shed with one device set up at each milking station. The farmer loads the discs before milking, and chooses what needs to be tested for.

The rest of the process is automated. During milking, a small sample of each cow’s milk is tested, and the data is collected and stored, allowing the farmer to analyse their milk production in multiple ways over time. The device is likely to also include a ‘trigger’ that identifies problems such as mastitis on the spot. Simpson and her team are planning for a commercial prototype in 2017.

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**Seizing the opportunity**

CloudSpec is currently at the research stage. It began life as a customised lab instrument that the team developed for another project – studying the optical properties of molecules on metallic nanoparticles – which was recently published in Nature Photonics. Only recently did they begin to explore their invention’s exciting range of commercial possibilities, thanks to Victoria University’s tech-transfer office and additional support from a KidNet Emerging Innovator award received by MacDiarmid PhD student Brendan Darby.

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**Solving sticky issues**

While Milk-on-a-Disc and CloudSpec have applications on the farm, research using optical tweezers could well benefit the factory.

Optical tweezers can be used to study emulsions – microscopic droplets of one fluid immersed in another. Professor Williams and his team want to see how fat drops interact with other particles in various environmental conditions, including under different temperatures and pressures.

Making yoghurt and cheese relies on the destabilisation of these fat particles, so that they start sticking together. Using optical tweezers, postdoctoral researcher Dr Rob Ward and PhD student Sapna Ravindran, supported by a Primary Growth Partnership project and Fonterra, aim to measure how this stickiness develops. And understanding that in greater detail would allow makers of milk products to control these processes more tightly.

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**Different angles**

When it comes to milk, the diversity of work undertaken by MacDiarmid scientists is one of our strengths. Our people are illuminating the way forward for New Zealand’s world-class dairy industry.
New Zealand’s love of the great outdoors may be world-famous, but it is our use of renewable energy that really makes us stand out internationally. As of the end of 2015, 86% of our electricity was generated by renewable sources (largely geothermal and hydroelectric), leaving us second only to Iceland across all OECD countries. And we’re not done yet – at the United Nations Conference of Parties (COP21) held in Paris in 2015, we committed to increasing that proportion to 90% by the year 2025.

Achieving this ambitious target will be a challenge, but the cutting-edge research from scientists at the MacDiarmid Institute will have a role to play, and could transform the way we harvest energy.

Maan Alkaisi and Jeff Tallon
Super-stuff

Passing electricity through a wire can produce a lot of heat. While this can be useful in some applications (e.g. electric ovens), in others, it causes considerable energy losses. There are a class of materials called superconductors that can conduct electricity without losing heat energy. They used to operate only at -269°C, but 28 years ago work from Professor Jeff Tallon and colleagues from Victoria University’s Robinson Research Institute shifted their operating temperature to -163°C. While still undoubtedly cold, this big temperature jump helped to completely revolutionise the field of superconductivity and has major implications for the energy sector. Professor Tallon is still a leader in the field today. In a recent paper in Nature Communications, he and fellow researcher Dr Evgeny Talantsev uncovered a single underlying principle common to all superconductors, and proved that their fundamental behaviour could be described by a single measurement of electrical current density. This ground-breaking result will make it easier to identify materials with advantageous superconducting properties.

Full of energy

Cables made from superconductors are being used in the world’s best particle accelerators, and in precision hospital MRI scanners, but it’s their role in the energy sector that is causing a lot of excitement. Speaking about the efforts of his wider team, Professor Tallon said, “We have high-temperature superconductor programmes in energy generation, storage and conversion. All of which are hugely challenging projects. In wind turbines, replacing the bulky copper cabling of the generator with resistance-free superconductors would greatly reduce the weight, and boost its efficiency. In large transformers, these materials remove the need to use oil as a coolant, hugely reducing the risk of accidental ignition. The key to their success is the vast amount of electrical current superconductors can carry. “Take a conductor with the same cross-section as my thumb, (1 cm²),” said Professor Tallon. “One made from copper could carry about 10 Amps but for high-temperature superconductors, it’s more like 30 million Amps!”

A shining example

Arguably, it’s the sun that is our most vital source of energy. Not only does sunlight help plants and crops to flourish, but by using photovoltaic solar panels, it can also be converted into electricity. When sunlight hits these panels (which are mainly made from layers of silicon), it knocks electrons out of position, causing them to flow and contribute to conduction. Because only certain wavelengths of sunlight have this effect, while others are either reflected off the surface or transmitted out of the material, solar panels are far from 100% efficient.

But Professor Maan Alkaisi at the University of Canterbury is using nanotechnology to change that. By printing a pattern of inverted pyramids just 300nm tall (that’s 20 times smaller than a red blood cell) on the surface of a solar panel, and coating them in silicon nanoparticles, he has been able to drastically improve the efficiency of the panel. “For all energy conversion devices, the challenge is always to increase the efficiency while keeping the cost down,” Professor Alkaisi said. “What we’re doing doesn’t require expensive equipment, and it can be scaled up.”

Glass ceiling

The coating has two features – the nanopyramids trap sunlight, reducing reflections from the surface, and the nanoparticles tune the range of wavelengths that the panel can capture. Together they provide a thin, permanent structure that improves the efficiency of commercial solar panels at a very low cost. Professor Alkaisi has also shown that by making a master ‘mould’ of his pyramid structure, this coating can be applied to other materials, such as polymers and glass. “My vision is to use this to make transparent, building-integrated photovoltaics,” he said. “Imagine a greenhouse that lets sunlight reach the plants, while absorbing some of it to produce electricity for use in irrigation, lighting and ventilation. For both the future of food production and energy generation, the possibilities are endless!”

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A clear way forward

The substances that coat our touchscreens and make them work need two key qualities: conductivity, so that they’re sensitive to the position of our fingers; and transparency, so that we can see what’s on the screen. They also need to be able to be mass produced economically and robust enough to facilitate long-term everyday use.

Race for replacement

Currently, most touchscreens in the world owe their functionality to a very thin layer of indium tin oxide. But there is global worry about the continued supply of this transparent conductive oxide. Supply of the mined ingredient that it’s based on, indium, is finite, and prices for it are going up. The search is on to develop other transparent conductors that can be used in its place. This is where the MacDiarmid Institute scientists come in.

Something old, something new

Principal Investigators Associate Professor Martin Allen, Professor Alison Downard, and Professor Roger Reeves at the University of Canterbury, along with Principal Investigator Dr Natalie Plank, from Victoria University of Wellington’s School of Chemical and Physical Sciences, are working with a tried and true material - zinc oxide. This is similar to indium tin oxide, but it’s cheaper, and the ingredients needed to make it are much more readily available.

Meanwhile, Principal Investigator Professor Uli Züelicke, also at the Victoria University of Wellington School of Chemical and Physical Sciences, is working on understanding the new and exciting properties of graphene, a material made up of a microscopically thin sheet of carbon atoms arranged in a honeycomb lattice. Touchscreen manufacturers have already begun to use zinc oxide-based materials, but the field is wide open for further development. And the possibilities for zinc oxide - and other transparent conductors like graphene - don’t stop there.

Wonder material

Graphene was isolated and studied electronically in 2004, and a Nobel Prize was awarded in 2010 in relation to its potential use in electronic devices. Scientists around the world have found increasingly effective ways to produce it, and have been experimenting with its exciting and unusual physical properties. Graphene is mechanically strong, and conducts electric current and heat better than almost anything else. This makes it an almost ideal candidate for use as a durable touchscreen material. Professor Züelicke is researching new ways to manipulate graphene’s properties using mathematical models and simulations. In particular, he is investigating how graphene reacts to electric and magnetic fields as well as mechanical stress, which are crucial features for touchscreen development.

Safe, but not boring

While graphene is a young, unconventional material, zinc oxide has been used for years in sunscreens and other skin products, and as a nutritional food additive. It’s inexpensive to produce, recyclable, and is known to be non-toxic and biocompatible. Plank, Allen, Downward and Reeves are excited by the numerous possibilities that such a safe and abundant substance offers. To make the best use of zinc oxide, and produce stable, viable devices, they and their teams are working on understanding and controlling its very unusual surface properties in detail. Other oxides are on their radar too: tin oxide, gallium oxide, and combinations of these.

A window to the future

Graphene, oxides, and other transparent conductors could form the basis for a new range of transparent devices for smart windows. Think invisible solar panels. Or thin-film transistors - where the finest of transparent coatings can be activated to become a video screen.

There are various ways of coating screens with transparent conductors, but nano-technology offers particularly exciting possibilities. Nanowires, so fine they can’t be seen by the naked eye, can be made from an oxide, or a conductive metal, and placed across screens as a mesh.

Increasing flexibility

Dr Plank has developed a method to cheaply ‘grow’ nanowires. She says that while zinc oxide nanowires are usually around 150nm wide, she can now make wires that are only 10 to 20nm. “This gives them a vastly improved electronic response.” Dr Plank says nanowires have the advantage of flexibility. “If you pull, press or bend them, they won’t break. They can be used on flexible substrates like plastic, and could have all sorts of exciting and innovative uses on clothing and in medical diagnostic tools.”
Making molecular magnets

These days, magnetic memory is everywhere. Hidden inside your smartphone, your laptop and even your credit card, billions of tiny magnetic stripes store information in the form of 1’s and 0’s; the language of our digital age. But recent research from Professor Sally Brooker’s team at the University of Otago is looking at magnets in a new way. They have developed and immobilised magnets each made from a single molecule that could open up a world of high-density data storage, and futuristic computers.

Short on storage

Typically, magnets are made up of regions called domains, which, in reality, are clustered groups of atoms or molecules that are aligned with one another. Because these regions are separated by domain walls, each one can store a single ‘bit’ of information; so to store lots of data, we need lots of domains. But in this era of miniaturisation, size is everything, and the only way to squeeze more data in, is by making the domains themselves smaller. This is exactly where the Otago team’s work comes in - instead of relying on groups of molecules, their single molecule magnets, or SMMs for short, could store information on just one.

So, what do they look like? “Our SMMs are nanocylinders - large rings of organic stuff - that surround three transition metal ions and one lanthanide ion,” said Professor Brooker, “and it’s this structure that allows us to control their chemistry.” Large is very much a relative term here – the ring measures just 1.3nm across, equivalent to one-millionth of a millimetre. The big ring structure developed by Professor Brooker and her co-worker, Dr Humphrey Feltham, makes these SMMs very robust. Unlike many other molecular magnets in development, theirs retains its structure when dissolved – vital for processing into practical, scalable SMM devices.

Collaboration is key

Professor Brooker and Dr Feltham have worked on SMMs for a number of years, collaborating with Professor Annie Powell (Germany), Professor Rodolphe Clérac (France) and Professor Chibotaru (Belgium). Their first paper was featured on the cover of the Chemistry a European Journal, and has been highly cited (111 times since 2011). But it was during Dr Feltham’s first post-doc, funded by the MacDiarmid Institute, that they had their latest breakthrough. Working with Professor Brooker’s colleague Dr Carla Meleandri, they successfully attached their magnetic molecules to the surface of gold nanoparticles. The design of the connection between them ensured each nanoparticle was covered by a single layer of SMM. Then, using the Institute’s SQUID magnetometer in Lower Hutt, they demonstrated that their molecule retained its unique magnetic behaviour once immobilised on the nanoparticle. A very exciting day at the lab! Professor Brooker visited the world’s leading SMM researcher, Professor Roberta Sessoli (Florence), and this result really caught the Italian team’s attention. “This is the team that discovered the very first single molecule magnets in 1993,” recalls Professor Brooker. “They can choose to work with any group they want, so we are very excited to be now collaborating with them in order to characterise our new material in more depth.”

Cool customers

For most practical applications, magnetic storage materials need to retain their magnetisation for 10 years – right now, single molecule magnets are some way from that. Even at the incredibly low temperature of 1.5K (-271.65°C), the best lifetimes are only a couple of years, so they are not economically viable at present.

“It’s important to remember that back in the day, it thought computers could never be smaller than a room, or weigh less than several tonnes,” Professor Brooker said. “Due to the low temperatures required, superconductors weren’t considered practical at first, and now they’re vital to countless technologies… so don’t write these magnets off!”

Data-mine

There is plenty of reason for her optimism - the payoff of the success of this technology could be huge. Because every molecule behaves like a separate magnetic domain, SMMs have the potential to store unimagined quantities of data in fantastically small volumes. In fact, one paper suggests that while every cm² of today’s best memory devices can store 200GB (enough to store more than 80,000 books), single molecule magnets could manage more than 3TB per cm² - that’s at least 150 times more information stored in the same space.

Looking even further ahead, SMMs could also have a role to play in the next generation of quantum computers. Because of their small size, these molecules can make use of a weird effect called ‘quantum tunneling of magnetisation’, whereby, instead of each domain storing either a 1 or a 0, it could store both at the same time. This seemingly small change could have massive implications - it would be as if, using the same 26 letters of the alphabet, we could suddenly spell billions of words instead of a few hundred thousand. To put it simply, this could change the world.

Sally Brooker and her research group
**Borrowing from biology**

**What nature already knows**
We seldom stop to think about how our bodies grow, develop and repair themselves. Or wonder how, from the time we are a tiny fertilised egg, our cells construct everything we need.

If humans were a mechanical device, made in a factory, each little part of us (protein, carbohydrate, hormone etc) would have to be laboriously assembled – like Lego. Unfortunately, this would not be quick enough or accurate enough to sustain life. We – and all life as we know it – would not be possible. But nature has a cunning mechanism - self-assembly. The biological lego assembles itself; proteins form naturally when a newly formed sequence of amino acids curves and twists itself into the finished structure.

Nature does this with ease and great accuracy. And it’s this ability to self-assemble that MacDiarmid scientists are harnessing to collaborate on new and exciting nanomaterials.

**Tiny and tricky to handle**
You’ve found a new semi-conductor. It has great potential in the flexible and wearable electronics industry, potentially enabling computers to be printed on fabric or walls. But the material is tiny (as you’d expect) and making it is time-consuming and tedious. You need to find an efficient way to manufacture it. What do you do? You turn to nature, of course.

This is what happened when a team of MacDiarmid scientists at Victoria University led by Dr Justin Hodgkiss needed to find an efficient way to manufacture a new printable electronic material – an electronic ink called perylene diimide (PDI). PDI can be printed and offers new environmentally friendly and low cost ways of making existing electronic gadgets, plus the potential to enable computers, sensors, displays, or smart ID tags to be printed on walls, packaging, fabrics, or skin. But in order to conduct electricity, PDI needs to assemble in a very precise way. If left to assemble randomly, the material does not work as a semiconductor. Dr Hodgkiss and his team had been experimenting with peptides to get PDI to assemble properly but it just wasn’t working. So they turned to their MacDiarmid colleague at Auckland University, Professor Juliet Gerrard.

**Clicking two technologies together**
Professor Gerrard’s team had been experimenting with little pieces of protein – called peptides – to try to enhance protein assembly. They studied the peptides that influenced how a protein assembled different units into the correct size and shape and figured out how to modify the peptides but still retain the ability to self-assemble. By doing this they could control and enhance the way the peptide assembled.

This was just what Dr Hodgkiss’ team needed to take their development forward. Working closely under the MacDiarmid umbrella, the two teams found they could improve the coupling between the peptides and the electronic material (PDI). By adding linker units between the peptide and the PDI they engineered a new material that could self-assemble. They managed to get hybrid (part chemical, part biological) materials to self-assemble from a water-based ink.

Professor Gerrard says her team had to design a peptide that would do the job the Wellington team needed. “Often in science we struggle to make something and then realise that biological systems have already worked out how to do it.”

**Knitting nature with nanoscience**
Dr Hodgkiss’ team then worked closely with a third MacDiarmid team led by Victoria University physicist Dr Plank. She had been looking at how hybrid materials could be used to form the active part of a transistor device – the building block of modern electronics. Her team used the new hybrid material to make a functioning device that worked as an electronic switch – a highlight result in the team’s publication in Advanced Functional Materials.

Dr Plank says that compared to regular semiconductors (made of silicon) these new materials are “soft” and that it was initially hard to think of a way to make a device from something so different. “By mimicking biology we could get the material to grow from the ‘bottom-up’ rather than the usual and slow ‘top-down’ approach. It is exciting to take a biological assembly method and apply it to a material that can have a function electronically.”

We talk about ‘the MacDiarmid difference’, and this project highlights that difference; the combination of chemistry, biology, and physics really allowed us to realise an ambitious idea and convey it to a broad audience.

Our team was fiddling around with how to use our knowledge of proteins to assemble nanomaterials and the Victoria University team was trying to build field effect transistors. It was just a matter of clicking these two technologies together.

We can take a biological assembly method and apply it to a material that can have a function electronically.

**Natalie Plank**

**Justin Hodgkiss**

**Juliet Gerrard**
A MOF could remove CO₂ from polluting smoke stacks.

Molecular sponges

Another MacDiarmid team led by Massey University Professor Shane Telfer has developed self-assembling nanomaterials – in this case three dimensional metal-organic frameworks (or MOFs). MOFs are ‘molecular sponges’ with pores about the size of molecules. This means a MOF could deliver a drug to a specific site within the body, or store gases, such as hydrogen (for fuel) or carbon dioxide (to remove it from polluting smoke stacks). MOFs are mostly free space, like an open porous net, with a metal at the corners and an organic component as the rods or linkers.

As with the two-dimensional electronic inks, the three-dimensional metal-organic framework materials that Professor Telfer’s team are working on also self-assemble. His team has developed a way to get materials to self-assemble from the two-dimensional plane to the third dimension. They are added separately into a reaction mixture, which is then heated to crystallise (assemble) the framework. The metal and organic components come together and arrange themselves into an ordered lattice by self-assembly.

Professor Telfer says there are many applications for MOFs including drug delivery.

“With MOF sponges small enough to be taken up by cells to deliver a payload, such as a drug or an imaging agent. Other applications include gas storage – for example for methane or hydrogen powered vehicles. Instead of an empty fuel tank which would have to be at very high pressure, we can pre-fill the tank with these materials and the gas can be held safely within them.”

He says MOFs can also be used for separation/purification – for example as breathing filters in gas masks for chemical weapon or pesticide detoxification. “We can use them in membranes on a larger scale for industry in the smokestacks of coal-fired power-plants where MOFs could filter CO₂ and other toxins before they get into the atmosphere.”
Systematic ligand modulation enhances the moisture stability and gas sorption characteristics of quaternary metal-organic frameworks.

Complex metal-organic frameworks (MOFs) that maintain high structural order promise sophisticated and tunable properties. Here, we build on our strategy of using combinations of structurally distinct ligands to generate a new isoreticular series of ordered quaternary Zn4O-carboxylate MOFs. Rational design of the framework components steers the system toward multicomponent MOFs and away from competing phases during synthesis. Systematic ligand modulation led to the identification of a set of frameworks with unusually high stability toward water vapour. These frameworks lose no porosity after 100 days’ exposure to ambient air or 20 adsorption–desorption cycles up to 70% relative humidity. Across this series of frameworks, a counterintuitive relationship between the length of pendant alkyl groups and framework stability toward water vapour emerges. This phenomenon was probed via a series of gas and vapour adsorption experiments together with Grand Canonical Monte Carlo (GCMC) simulations, and could be rationalized on the basis of the propensity of the frameworks to adsorb water vapour and the proximity of the adsorbed water molecules to the water-sensitive metal clusters. Systematic variation of the pore volume and topography also tunes the CO2 and CH4 gas adsorption behaviour. Certain of these materials display increases in their adsorption capacities of 237% (CO2) and 172% (CH4) compared to the parent framework.

Abstract 1
Advanced Functional Materials, 2015, 25, 5640-5649

Functional Organic Semiconductors Assembled via Natural Aggregating Peptides

Natural proteins have evolved peptide sequences that adhere to each other with exceptional strength and specificity. In this work, we explore the concept of using such peptide sequences as tectons for encoding the self-assembly of synthetic functional materials. We first identified aggregating peptide sequences by inspection of protein-protein interfaces in the peroxiredoxin family. We then created hybrid bioelectronic materials by tethering these 8-mer peptide sequences to organic semiconducting molecules, along with an additional sequence to act as a trigger for aggregation. We show the hybrid materials self-assemble into nanofibres, whereby the semiconducting units are brought into electronic communication with each other in a way that strongly depends on the peptide interactions. A bioorganic field-effect transistor is fabricated from this class of materials, highlighting the possibilities of exploiting natural peptide tectons to encode self-assembly in other functional materials and devices.

Abstract 2

Systematic ligand modulation optimises water vapour stability & gas adsorption capacity

Quaternary Zn4O-carboxylate MOFs
Stable to water vapour & tunable gas adsorption

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Quaternary Zn4O-carboxylate MOFs

Abstract 1
Advanced Functional Materials, 2015, 25, 5640-5649

Functional Organic Semiconductors Assembled via Natural Aggregating Peptides

Natural proteins have evolved peptide sequences that adhere to each other with exceptional strength and specificity. In this work, we explore the concept of using such peptide sequences as tectons for encoding the self-assembly of synthetic functional materials. We first identified aggregating peptide sequences by inspection of protein-protein interfaces in the peroxiredoxin family. We then created hybrid bioelectronic materials by tethering these 8-mer peptide sequences to organic semiconducting molecules, along with an additional sequence to act as a trigger for aggregation. We show the hybrid materials self-assemble into nanofibres, whereby the semiconducting units are brought into electronic communication with each other in a way that strongly depends on the peptide interactions. A bioorganic field-effect transistor is fabricated from this class of materials, highlighting the possibilities of exploiting natural peptide tectons to encode self-assembly in other functional materials and devices.

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Into the marketplace
A central piece of the MacDiarmid Institute's original vision was that our science would lead to spin-out companies—甚至 new industries—that would make a real and positive impact on our economy and make New Zealand a place where talent wants to live. This original vision is now being realised—with two new spin-out companies formed in 2015. Many other MacDiarmid researchers are in close discussions with investors and expected to form companies in 2015.

Hi-Aspect Ltd and AuramerBio Ltd, our spin-out companies from 2015, are profiled on the following pages. Both companies were formed with investment from PowerHouse Ventures Ltd in the Tech Incubator scheme. This relatively new investment vehicle seems well suited to advancing our early stage technologies out of the lab and we expect to see more projects moving down this path in the future.

A highlight of 2015 was the "Pitch on a Peak" event that was part of the Asian Business Angels forum in Queenstown. Tech investment conferences have not traditionally featured in our calendar, but this event highlighted the rewards at stake and showed how with MacDiarmid Institute coaching and support, our scientists can foot it with tech transfer specialists and wow international angel investors.

We create partnerships between research institutions, researchers and investors.
Scientists need to know more about financing and marketing before they can tell whether their idea is robust enough for somebody to make and sell it. If you don’t go to events like this, you won’t understand that.

MacDiarmid Institute materials science is making its way from the laboratory into the wider economic sphere. It’s always been the goal of MacDiarmid scientists to influence New Zealand’s prosperity through research, and 2015 was an outstanding year.

This year for the first time MacDiarmid scientists took their ideas to the world - literally - meeting with 150 investors from around the world at a technology showcase in Queenstown. The showcase saw MacDiarmid scientists giving three minute ‘pitches’ to angel investors at the Asian Business Angel Forum hosted by New Zealand in October.

The Asian Business Angel Forum is Asia’s largest premier angel investor gathering for emerging and growing businesses. “Pitch on a Peak” was one of the key components of the event, a showcase of New Zealand technology investment opportunities, ranging from early-stage technologies, to companies seeking first round angel funding, to internationalising companies.

The MacDiarmid Institute was strongly represented with five of the projects showcased on the day, including four of the five early-stage technologies. These were AuramerBio, Milk-on-a-Disc, BioActive Silver, Medical Dosimeters and Engender Technologies.

Readying the researchers

The MacDiarmid Institute science teams received extensive input from Dr Ray Thomson, Chair of the MacDiarmid Institute’s board, Richard Pinfold, the Institute’s commercialisation developer, and (NZTE) officials. These people helped the scientists review their business growth plans, become investment-ready and deliver compelling pitches. “It was an opportunity to put some of our scientists in front of international and local investors, to get them out of the lab and into the commercial arena,” says Dr Thomson, who has had extensive involvement with angel investment, including time as Chair of the NZ Angel Association. “And hopefully a chance for them to develop some connections, get advice from the investors who were there, and maybe get them interested in investing in them.” As Mr Pinfold notes, the event attracted around 150 angel investors, some of them with billion dollar exit packages from their own companies behind them. “Obviously fairly switched on types, who had made good business decisions in the past. There were far bigger hitters than we were anticipating, which really bought some gravitas to the entire event.”

“Ther responses were overwhelmingly positive,” says Quentin Quin, NZTE’s General Manager, Capital, who helped coach the scientists and also surveyed the attendees to get their feedback on the event. “Over 90% of attendees said that the investment opportunities presented met their expectations. 98% thought that all or most of the companies were well prepared and articulated their proposition clearly. Here’s an example – ‘Great coaching – it was hard to differentiate the researchers/academics from the tech-transfer specialists, something I have not seen before,’ said one attendee.”

Taking diagnostics to the farm

Milk-on-a-Disc was presented by Associate Professor Cather Simpson, who developed the novel technology with Professor David Williams; both researchers are from the School of Chemical Sciences at the University of Auckland and both are Principal Investigators with the MacDiarmid Institute. Milk-on-a-Disc could also be described as a laboratory on a disc, designed to measure the composition of the milk. This can be done on every cow, in the cow-shed and at milking time, before the cow leaves the bail.
Milk-on-a-Disc provides farmers with information such as the protein content and fat content, but also has the potential to help farmers assess the health of the animal, such as whether the cow is pregnant, has mastitis, or her nutritional status. The technology draws on the tools used in the human medical diagnostic sector; Associate Professor Simpson describes it as taking “point of care to point of cow”. “It allows farmers to find out things that they don’t know they want to know, but which will allow them to make better decisions and therefore enhance their productivity.”

**Learning to pitch**

Associate Professor Simpson had only three minutes to present Milk-on-a-Disc at Pitch on a Peak, a considerably tighter timeframe than scientists are used to. It was challenging, she says, but one that focused the mind. “Pitch on a Peak allowed us to hone our story,” she says. “Milk-on-a-Disc is a project that we may not have done at all if there wasn’t a commercial outcome for it. The science is fascinating, but trying to analyse a complex fluid like milk is a really big ask, and there’s no point in developing a technology like this if nobody is going to buy it. Pitch on a Peak gave us a better sense of what kind of investor pool there might be, to bring this through to completion.”

Several investors who attended the conference have since visited Associate Professor Simpson and her team at the Photon Factory at the University or Auckland, or followed up to express interest not just about Milk-on-a-Disc but other projects the team is and could be working on. “The event helped build a buzz around our technology. That was happening before, but with a lower case ‘b’. Now we have a Buzz with a capital ‘B’ and gold flashes around it.” The spin-out company Orbis Diagnostics has since been established and registered to develop the technology. “So we now have a company, rather than an idea for a company,” says Associate Professor Simpson. “I think the catalyst for that was Pitch on a Peak.”

Both Associate Professor Simpson and Professor Williams say university scientists hoping to commercialise their research can only benefit from such events. “It was a high voltage high energy session,” says Professor Williams. “Your ideas are challenged, you meet people who know more than you do about the domain that you’re working in, you get new ideas, on how to get stuff out of the lab and into the marketplace, and you get a whole different perspective on research. It’s very challenging and it’s fun. “If you have any kind of expectation that what you’re doing might lead to something that can be made and sold, you have to appreciate the other end of the business. Scientists need to know more about financing and marketing before they can tell whether their idea is robust enough for somebody to make and sell it. If you don’t go to events like this, you won’t understand that.”

**Aptamers – the new antibodies**

Another MacDiarmid Institute project presented at Pitch on a Peak was from AuramerBio, a new medical diagnostics start-up combining aptamers with nanomaterials to create new diagnostic tools. Aptamers are like a tiny antibody; they’re made of DNA, and can be designed to bind to very specific targets. But it gets better. They can be made in a lab (rather than extracted from animals), and can be produced quickly and at a fraction of the cost. AuramerBio have managed to develop an aptamer that can target much smaller molecules than antibodies normally can, and with a much greater level of sensitivity to the targeted molecule. “Hormones are a good example,” says AuramerBio’s CEO, Jeremy Jones. “Relative to a protein, these molecules can be thousands of times smaller. Targeting these small molecules is where we shine and blow competitors in aptamer science out of the water.”

Cather Simpson
The event helped build a buzz around our technology.

As Jones highlighted at Pitch on a Peak, there are many benefits that aptamers have over antibodies. “Antibodies can take 12 to 18 months to develop. For us to get to an equivalent point, it takes less than a month. This is going to revolutionise the way medical professionals diagnose and monitor the health of their patients,” he adds. “Aptamers are poised to disrupt the 40 billion dollar market that antibodies currently have.”

MacDiarmid collaboration

AuramerBio has emerged out of cross-discipline MacDiarmid collaboration between Professor Ken McNatty and Dr Shalen Kumar at Victoria University of Wellington’s (VUW) School of Biological Sciences, Dr Justin Hodgkiss’ team at VUW’s School of Chemical Physical Sciences and Professor Jadranka Travas-Sejdic’s team at the University of Auckland’s School of Chemical Sciences. “So it was a combination of the biology, the development of synthetic antibodies, with engineering and surface chemistry, the development of the electrochemical device,” says Jones. “It was in the two disciplines coming together that the magic happened.”

Until recently aptamers compared unfavourably to antibody technology, as the binding capacity was still weak. “But the work that Ken and Shalen have been doing in developing their aptamers, is allowing us to achieve a strength of binding that is far in excess of what people have seen before.”

Already attracting investor interest

At the time of Pitch on a Peak, the company had already secured seed funding, with a 24-month runway to execute its business plan. “But for a start-up, capital raising is an ongoing cycle,” says Jones. “so it’s important to get on the radar of new investors. And when it comes time for us to raise that next round of funding, they’ll know who we are, those guys they saw at that Queenstown event, and be able to see how far we’ve come since then. It’s about raising the profile among that community who could potentially invest in that next round. “There were a number of people who were in that room who were extremely experienced, international investors who had done what we’re trying to do now with other products and companies. So I was hoping to tap into that experience.”

One of the highlights of the event was the chance to discuss the technology with Allan May, a life sciences investor who has worked with over 50 biotech and med-tech start-up companies. “His advice was invaluable helping to inform our strategies around our target markets.” The contacts made and conversations that emerged at the event has also led to new opportuniies. “One of the conversations was around drug testing, for illicit drugs. We’ve established our technology in relation to hormones, but it’s a very small leap to go from that to illicit drugs, such as methamphetamine, or cocaine, or THC. They are in the same class of compounds that we’ve already been working with, and involves the same area of expertise. So that has led to us doing a bit of digging, sitting down with ESR [the Institute of Environmental Science and Research] to build a project, and we’re now seeking funding to develop a product in that area.”

Pitch on a Peak was held by New Zealand Trade and Enterprise (NZTE) in partnership with the Angel Association New Zealand and Callaghan Innovation.

Other MacDiarmid scientists who presented at the forum also sparked considerable interest among angel investors. Dr Carla Meledandri (BioActive Silver), and Dr Grant Williams (Medical Dosimeters) and their teams are in ongoing talks with investors about new MacDiarmid spin-out companies. Watch this space.
Moving research into the commercial world is not without its challenges, but it has been an exciting step for the University of Auckland’s Professor Juliet Gerrard and her team. Her company, Hi-Aspect, was formed in order to commercialise a protein-based nanomaterial for use in skincare products and wound dressings.

**The early days**

It was a blue-sky research project, which led Professor Gerrard to her discovery of this material. While working at the University of Canterbury, and collaborating with Plant and Food Research, she began to explore how proteins assemble in the body - a fundamental biochemistry question. But the research team soon took their work further. “Rather than just understanding the structure that biology had given us, we wanted to change it, and see what we could do with it,” Professor Gerrard said.

The structure they came up with is visually very similar to another superstar material - carbon nanotubes. But unlike carbon, these protein nanofibrils were found to form a soft, stable gel in water, which proved to be stronger than collagen. They’re also stretchy, incredibly hard to break, and form a scaffold for other molecules, such as vitamins or healing ingredients, to stick to.

**Healing skin with biomaterials**

**Spinning-out**

Through the Institute, Professor Gerrard began to meet MacDiarmid researchers from other disciplines who were developing various nanotech devices. “Before that I was a biochemist working just on biological problems. Now I was looking at it from a new viewpoint.” The big step, then, came with the realisation that their material could be produced not just from ultrapure lab ingredients, but with low-cost ingredients. They were ready to emerge from the lab.

Fundamental science may have driven the research, but Professor Gerrard was already aware of the potential impact that their results could have on the wider world. “New Zealand is very much a biological economy, and we felt confident that our work could add real value to that sector”, she said. Others agreed, and with the support of Callaghan Innovation and Powerhouse Ventures Ltd, she set up Hi-Aspect in 2015.

**Commercial future**

The protein nanofibrils form the foundation of Hi-Aspect’s work, and they are being made into gels, films and patches for use in wound dressings and skincare formulations. “The scale up has gone so well, we have kilograms of the stuff!” said Professor Gerrard, so it’s perhaps unsurprising that they’re now in discussion with organisations all over the world to develop the materials further.

Fundamentally, what Professor Gerrard and her team are doing is using otherwise wasted or low-value biological materials to produce high-value goods for export. But for the everyday consumer, Hi-Aspect’s nanofibrils could find their way into their daily lives - from a new generation of dressings that help wounds heal faster, to a moisturiser that actually delivers what it says on the label. All made using New Zealand science.

From a new generation of dressings that help wounds heal faster, to a moisturiser that actually delivers what it says on the label. All made using New Zealand science.
Into the community
Sir Paul Callaghan, the founding director of the MacDiarmid Institute, used to talk about culture change in New Zealand science being the central mission of the institute. He led by example in taking science out of the labs and into the lives of all New Zealanders, and challenged us as scientists to take an entrepreneurial approach to our research and its broader possibilities.

We celebrate Sir Paul’s vision of New Zealand as ‘a place where talent wants to live’ by continuing to take the MacDiarmid Institute’s research out to teachers and students and communities under our ‘inspire’ strategic goal, which seeks to ‘engender passion for science and innovation across society’.

We have continued to inspire educators to teach science with ease and enthusiasm with our highly popular Kōrero workshops for early childhood and primary school teachers (see page 44), and a new programme for high school physics teachers (page 46).

We ran our week-long NanoCamp to inspire secondary school pupils (page 48) and brought Māori and Pacific Island secondary school students into MacDiarmid labs for a week working with MacDiarmid scientists.

We took science to the regions with our new Lecture Series. In July and August MacDiarmid researchers gave lectures in Napier, Nelson, Tauranga and Whanganui, talking to packed halls about how we meet the world’s future energy needs. The talks covered MacDiarmid research into CO₂ capture, and new printable photovoltaic cells which make solar power cheaper and more efficient. Justin Hodgkiss, Jeff Talton (both Victoria University), Shane Teller, Mark Waterland and Luke Liu (from Massey) and Keith Gordon (Otago) presented these popular talks.

The price of ‘talent lives here’ is the eternal sharing of our science with New Zealand communities. This is both a privilege and an enormous pleasure.
A group sits around a table playing with green slime. They giggle as the slime oozes through fingers and droops towards the table.

This isn’t children’s laughter. These are teachers, playing with science alongside MacDiarmid Institute scientists. They are pondering – what is slime? Is it a solid or a liquid? Or something else?

The primary and early childhood teachers are at a MacDiarmid Kōrero with Scientists workshop. In two-hour interactive workshops, they explore basic concepts like magnets, light, and acids and bases. In its third year, the Kōrero programme is already hugely popular, oversubscribed and with waiting lists of primary and early childhood teachers wishing to attend.

For MacDiarmid Institute Principal Investigator Dr Duncan McGillivray, who ran the Auckland workshops, the best thing was seeing the teachers become passionate about science. "When teachers are excited about science, their excitement flows through to the kids."

Gabrielle from Chisnallwood Intermediate School in Christchurch was fresh out of teachers’ college when she attended her first Kōrero workshop run by MacDiarmid Institute Principal Investigator Professor Paul Kruger in 2014 and then again in 2015. “I learnt how to relate science to kids.” She says the experiments they were taught could be run anywhere – schools do not need a lab to replicate the Kōrero science.

“I popped into a couple of shops to buy what we needed then headed straight back to the school and had the kids making pH indicators out of red cabbage and extracting DNA from strawberries. I set up science stations and the kids came around and explored. The kids loved everything we showed them, especially the bubbles. The kids from her classroom then tried the experiments out with their families at home. "We could see from the photos they uploaded into Google Classroom that they’d done the red cabbage experiment at home. And made bubbles and talked with their families about surface tension."

The Kōrero programme was revamped in 2015, with returning teachers asked to give a presentation on how they had taken the Kōrero science into the classroom.

Dr Natalie Plank, Principal Investigator with the MacDiarmid Institute, ran the Wellington workshop. She said the teacher’s videos showed the children’s keen interest in science. “We could see how children are inherently little scientists, asking how and why.”

Just three weeks after attending Kōrero 2015 in Auckland, early childhood teacher James set up a Facebook page ‘Science ECE – experiments for young children’. The page now has over 2700 members.

James says people seem to be hearing of the Facebook page by word of mouth. “After going on the Kōrero course, I thought I’d start the page and just pin up experiments. Lots of the members are kiwi parents but there’s also a group of 50 or so science teachers from Mumbai who have joined.”

Dr McGillivray says the key was getting away from the idea that science was about knowing stuff, and helping teachers realise that science is about finding stuff out. “Science is about noticing and asking questions - I observe, I wonder, I think.”

Dr Plank says that scientists do not know everything but are comfortable with not knowing. “For us the not-knowing is an essential part of science.” Gabrielle said she felt she could pass this on to the kids. “I didn’t feel stupid asking any question at all. Paul Kruger and his team put things into ‘teacher speak’ so even teachers with no science training, people who had themselves disliked science at school, were able to come up with scientific language and made to feel more comfortable with the ‘scientific method’.”

The Kōrero programme will run again in 2015 with the development of more online forums for teachers wishing to keep in touch with each other and with the MacDiarmid scientists they met. “One of the things we hear is that the teachers want to keep in touch with us so we plan to make it very easy for them to do that throughout the year,” says Dr McGillivray.

And is slime a solid or a liquid? It turns out it is neither. It’s a gel.
Taking physics out of the classroom

Most days you will find Dr Kerry Parker, physics and science teacher at Wellington High School, in front of a class of NCEA students. But 9 October 2015 found her up a ladder having a good look at Victoria University’s NMR machine.

Dr Parker was one of 12 physics teachers from around the country getting a crash course in current physics thinking at the MacDiarmid Institute physics teachers workshop.

Dr Parker says it helped remind her that physics doesn’t stop with NCEA. “I’ve been able to draw on Professor Züelicke’s discussion about relativity in my Year 13 physics classes and also make students aware of the maths and physics they will experience at university. And if a student wants to pursue particular questions, I can point them up the hill to Victoria University to speak with one of the MacDiarmid scientists we met at the workshop.”

Many of the teachers found the physics and maths hard going. “It was a pretty tough day.”

David Housden, Chairperson of the New Zealand Institute of Physics Education Section (NZIPES) and science teacher at St Bernard’s College in Lower Hutt, says the workshop was outstanding.

Gisborne Boys’ High Deputy Principal and science teacher Peter Ray agrees. “It could take the workshop learning straight back into the classroom. The modern physics and relativity topics we did were right in line with the (NCEA) curriculum but extended it for us. When I returned I showed the students a web-link of what you would see if you were travelling at the speed of light. The students are fascinated by that stuff and it takes them a little bit further, gives them a glimpse of what’s coming up for them if they take physics at university. They love astrophysics - black holes, bending of light - and I can use these to teach physics concepts.”

Wellington High School’s Dr Parker says it helped extend their minds. “I can point them up the hill to Victoria University to speak with one of the MacDiarmid scientists we met at the workshop. It gave me inspiration I could pass onto the students - really extend their minds.”

Associate Professors Governale and Ruck say developing sufficient graduates skilled in physics is a key aspect of ensuring a workforce capable of driving wealth creation via high value manufacturing.

“Being in Gisborne I can feel professionally isolated, so it was a real opportunity for me to attend the workshop. It gave me inspiration I could pass onto the students - really extend their minds.”

This was not being met within the wider New Zealand science community.”

“Much of our professional development is generic and not subject specific. But this was professional development we could actually use. It was meaty and tough and academically challenging. It got us thinking about how we prepare students to actually succeed at university.”

It was unlike any professional development I’d ever done – I felt as though I’d had a deep massage of my brain in places that hadn’t been used for a long time.”

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Students go behind the scenes to explore science at the MacDiarmid NanoCamp and Discovery programmes.

**NanoCamp**

Fifteen of New Zealand’s brightest high school science pupils traveled from all over the country to Wellington to get an introduction to nanoscience and advanced materials during NanoCamp 2015 (held in January 2016). The annual MacDiarmid camp, held for the sixth year, introduces Year 12 and 13 pupils to materials science with a hands-on programme. The aim is to encourage pupils to pursue science when they leave school by providing them with an overview of the excellent science being done in New Zealand. The 2015 camp included courses in spintronics, microscopy, nanoelectronics, chemistry, superconductors, and optics at Victoria University of Wellington, Callaghan Innovation and GNS Science.

**Discovery Awards**

Two groups of talented Māori and Pasifika pupils from around the country descended on Auckland and Victoria universities in January to get a taste of tertiary-level science. In Wellington the students joined the NanoCamp programme and in Auckland students spent time in the photon factory, played with ultra-fast cameras and nanofluidics and saw a high tech materials science company in action.

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**Summer of Discovery**

There is so much to science that I never knew about – whole branches of fascinating things that are waiting to be discovered.

The experience was really indescribable and has reawoken to me why I love science so much.

**Overall this week was very fascinating and broadened my views on the jobs scientists can actually obtain**

Alex

**There is so much to science that I never knew about – whole branches of fascinating things that are waiting to be discovered.**

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Shania
Optical bootcamp
The MacDiarmid Emerging Scientists Association (MESA) ran its 4th annual three-day ‘bootcamp’ – an ‘adventurous academic experience in a remote location’ – during the International Year of Light.
Themed ‘Shining Light,’ the 2015 camp explored new frontiers in optical research at the Kaikoura Field Station. MacDiarmid Principal Investigators Associate Professor Cather Simpson and Professor Bill Williams, along with Dr Baptiste Auguié, joined the students and post-docs in a long weekend of intensive research.

Integrating science with Māori culture
The 2015 Student and Postdoc Symposium was held in Te Upoko o te Ika a Māui in November on the theme of “Mātauranga Māori, Nanotechnology and Advanced Materials”.
Postdoc Bart Ludbrook said the aim was to stimulate discussion around the role of the MacDiarmid Institute with respect to the development of Mātauranga Māori and that a highlight was a crash course in Te Reo Māori. MESA past president and PhD student Harry Warring said he really enjoyed the fresh approach to the Symposium. “It was great to explore how we can better integrate science with Māori culture.”

Higher Learning

Gender imbalance within science
MacDiarmid Institute Deputy Director and Principal Investigator Associate Professor Nicola Gaston published a book (Why Science is Sexist, BWB Texts, 2015) that looks at the gender imbalance within science, and asks why this is.
Associate Professor Gaston notes that of the 297 Nobel Prizes awarded in physics, only two have ever gone to women. “I wanted to figure out what is actually happening - why are women so poorly represented in science, especially physical science, at senior levels in particular? There is an unconscious bias that women don’t belong in science, because of historical differences in the contribution that women and men have been able to make. It’s important we take on board that these biases are in all of us. And by getting this conversation started, we hopefully reframe things so that it is clear that academic success is about hard work and not about some mysterious talent.”
Associate Professor Gaston has had positive feedback, with the President of the Royal Society of New Zealand Richard Bedford calling the book useful and noting that the Society would be recommending the book to all RSNZ Fellowship Evaluation Panel conveners this year.
“Even more important to me has been the many personal emails I’ve received from other women – many of whom I don’t know well - expressing a general sense of relief that it’s possible to talk about the topic. To be able to start a conversation.
“One thing we learned in the MacDiarmid Institute from Paul Callaghan, was that we can all contribute to the public space, beyond just doing our science.”
In 2015 the MacDiarmid Institute’s biennial Advanced Materials and Nanoscience conference (AMN7) featured a stunning line up of local and international presenters, whose specialty areas covered the whole spectrum of research in advanced materials and nanotechnology. The whole programme was of exceptional quality.

The conference is designed to provide delegates with a platform to exchange ideas, broaden their knowledge, kick-start collaborations, reacquaint with colleagues, and meet new friends. AMN7 was no exception with plenty of opportunities to connect over morning and afternoon tea breaks and poster sessions and a conference dinner designed to allow delegates to mingle as much as possible.

Delegates also had a chance to view nanoscience in a new light at the exhibition ‘Small Matters, Nanoart’ held alongside the conference. An astonishing range of novel images from the world of nanotechnology at the Nelson Provincial Museum were shown in an exhibition mounted by the Institute in association with the AMN7 conference. In a city famous for its artists, and as the home of the great Lord Rutherford, this combination of art and science seemed particularly apt.

Bringing international nanoscience to Nelson

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Awards
Ian Brown
Shortland Medal 2015
2015 Hector Medal
Richard Blaikie
2015 Thomson Medal – Science leadership for nanotechnology and research collaboration
Elected to Fellowship of Optical Society of America
Sally Brooker
Awarded the University of Otago Distinguished Research Medal
Invited to present the inaugural triennial Curtis Lecture, Victoria University of Wellington
Justin Hodgkinson
Easterfield Medal from the New Zealand Institute of Chemistry
Keith Gordon
University of Otago Division of Sciences Senior Researcher of the Year 2015
Shane Tolfer
NZIC prize for Excellence in Chemical Research (2015)
David Williams
Awarded the 2015 Castner Medal

Accolades

David Williams, Juliet Gerrard, Jadranka Trasv-Sejdic and coworkers
Nanoscale
Protein nanorings organised by poly (styrene-block-ethylene oxide) self-assembled thin films, 2015

Sally Brooker, Jeff Tallon and coworkers
Dalton Transactions
Pressure induced separation of phase-transition-triggered-abrupt vs gradual components of spin crossover, Dalton Transactions, 2015

Sally Brooker and coworkers
Chem Soc Rev

Sally Brooker
Inorganic Chemistry Frontiers
Spin crossover with thermal hysteresis: practicalities and lessons learnt, invited review, 2015

Paul Kruger and coworkers
Super Molecular Chemistry
Metallosupramolecular architectures based upon new 2-(1-pyrazolyl)benzimidazole chelating ligands, 2015

Thomas Nann and coworkers
ChemSusChem
A TiO₂ nanofiber-carbon nanotube-composite photoanode for improved efficiency in dye-sensitized solar cells, 2015

Michelle Dickinson, also known as Nanogirl
New Zealand Order of Merit (MNZM)
The Blake Leadership Award
The Callaghan Medal
Governance & financials
## Financials 2015

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<th>CATEGORY</th>
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<td>Core Funding</td>
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<tr>
<td>Other Funding (Mainly Interest Income)</td>
<td>227,002.66</td>
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<tr>
<td><strong>Total Revenue</strong></td>
<td>3,147,056.84</td>
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<td>Director and Principal Investigators</td>
<td>659,156.83</td>
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<td>Associate Investigators</td>
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<tr>
<td>Post Doctoral fellows</td>
<td>125,151.28</td>
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<tr>
<td>Research/Technical assistants</td>
<td>116,819.08</td>
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<td>Others</td>
<td>221,231.00</td>
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<td><strong>Total Salaries &amp; Salary-related costs</strong></td>
<td>1,122,358.19</td>
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<tr>
<td>Overheads</td>
<td>981,563.42</td>
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<tr>
<td>Project Costs</td>
<td>377,957.82</td>
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<td>Travel</td>
<td>256,841.29</td>
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<td>Postgraduate students</td>
<td>408,336.12</td>
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<td>Equipment depreciation/rental</td>
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<td>Subcontractor(s) specified</td>
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<td><strong>Total Other Costs</strong></td>
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<td><strong>Total Expenditure</strong></td>
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<tr>
<td><strong>Net Surplus / (Deficit)</strong></td>
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### Category Total:
- Core Funding: 2,920,054.18
- Other Funding: 227,002.66
- Total Revenue: 3,147,056.84
- Director and Principal Investigators: 659,156.83
- Associate Investigators: 0.00
- Post Doctoral fellows: 125,151.28
- Research/Technical assistants: 116,819.08
- Others: 221,231.00
- Total Salaries & Salary-related costs: 1,122,358.19
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- Total Expenditure: 3,147,056.84
- Net Surplus / (Deficit): 0.00

## At a Glance 2015

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<th>BROAD CATEGORY</th>
<th>DETAILLED CATEGORY</th>
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<td>Number of students completing qualifications by level</td>
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<td>Doctoral degree</td>
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<td>Other</td>
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<td><strong>Total</strong></td>
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Principal Investigators
Professor Alkaisi, Maaen, University of Canterbury
Professor Allen, Martin, University of Canterbury
Professor Blakie, Richard, University of Otago
Professor Broker, Sally, University of Otago
Professor Brown, Simon, University of Canterbury
Professor Doward, Alison, University of Canterbury
Associate Professor Gaston, Nicola, Victoria University of Wellington
Professor Gerrard, Julett, University of Canterbury
Professor Gordon, Keith, University of Otago
Associate Professor Gournale, Michele, Victoria University of Wellington
Dr Hodgkiss, Justin, Victoria University of Wellington
Dr Kennedy, John, GNS Science
Associate Professor Kruger, Paul, University of Canterbury
Professor Le Ru, Eric, Victoria University of Wellington
Dr Markant, Andreas, GNS Science
Dr McGillivray, Duncan, The University of Auckland
Professor Nairn, Thomas, Victoria University of Wellington
Professor Pank, Natalie, Victoria University of Wellington
Professor Reeves, Roger, University of Canterbury
Professor Rehm, Bob, Victoria University of Wellington
Associate Professor Simpson, Cather, The University of Auckland
Professor Smith, Kevin, The University of Auckland
Professor Tallon, Jeff, Victoria University of Wellington
Professor Telfer, Shane, Massey University
Professor Travers-Seyd, Jadranka, The University of Auckland
Professor Trodahl, Joe, Victoria University of Wellington
Professor Williams, BJ, Massey University
Professor Williams, David, The University of Auckland
Dr Williams, Grant, Victoria University of Wellington
Dr Willmot, Geoff, Callaghan Innovation
Professor Zaekisha, Ulrich, Victoria University of Wellington

Associate Investigators
Dr Arnold, Mike, Callaghan Innovation
Professor Bimbble, Margaret, The University of Auckland
Professor Brothers, Penny, The University of Auckland
Dr Brown, Ian, Callaghan Innovation
Dr Buckley, Bob, Callaghan Innovation
Dr Bumby, Chris, Callaghan Innovation
Dr Carrier, Damien, Callaghan Innovation
Dr Chong, Shen, Robinson Research Institute
Professor Dawnent, Sally, Victoria University of Wellington
Dr Dickinson, Michelle, The University of Auckland
Dr Downs, James, Massey University
Professor Evans, John, Christchurch School of Medicine & Health Sciences, University of Otago
Dr Gallosio, Petrik, Victoria University of Wellington
Dr Golinski, Vladimirt, University of Canterbury
Dr Granville, Simon, Callaghan Innovation
Dr Halperton, Jen, Victoria University of Wellington
Professor Harston, Jyll, University of Otago
Dr Ingham, Bridget, Callaghan Innovation
Dr Jameson, Guy, University of Otago
Professor Jameson, Geoff, Massey University
Dr Jin, Janyong, The University of Auckland
Dr Kemmott, Tim, Callaghan Innovation
Dr Knibbe, Ruth, Callaghan Innovation
Dr Laventure, Jerome, GNS Science
Dr Lucas, Nigel, University of Otago
Dr Marshall, Aaron, University of Canterbury
Dr Meledandri, Carla, University of Otago
Associate Professor Moratti, Steve, Victoria University of Wellington
Dr Narayanswamy, Suresh, Callaghan Innovation
Dr Nataf, Franck, Victoria University of Wellington
Dr Nock, Volker, University of Canterbury
Dr Prabakar, Srijiey, LASPA
Dr Reid, Mike, University of Auckland
Professor Spencer, John, Victoria University of Wellington
Dr Steiger, Mark, University of Canterbury
Dr Wang, Wenhu, Tsinghua University
Associate Professor Waterland, Mark, Massey University
Dr Waterhouse, Geoff, The University of Auckland
Dr Whitty, Catherine, Massey University
Dr Wimbush, Stuart, Callaghan Innovation
Dr Woodfield, Tim, University of Otago
Dr Zujiwick, Zoran, The University of Auckland

Emeritus Investigators
Professor Hall, Simon, Massey University
Professor Hendy, Shaun, The University of Auckland
Professor Johnston, Jim, Victoria University of Wellington
Professor Kaiser, Alan, Victoria University of Wellington
Professor Mackenzie, Ken, Victoria University of Wellington
Professor McGrath, Kate, Victoria University of Wellington
Professor Metson, Jim, The University of Auckland
Professor Tallon, Jeff, Victoria University of Wellington

Postdoctoral Fellows
Postdoctoral Fellow, Hammenschmidt, Lukas, Victoria University of Wellington
Postdoctoral Fellow, Dubuis, Guy, Victoria University of Wellington
Postdoctoral Fellow, Bradley, Szebhan, Victoria University of Wellington
Postdoctoral Fellow, Medini, Kania, University of Auckland
Postdoctoral Fellow, Ludbrook, Bart, Victoria University of Wellington
Postdoctoral Fellow, Chen, Kai, Victoria University of Wellington
Postdoctoral Fellow, Bove, Saurabh, University of Canterbury
Postdoctoral Fellow, Kuehn, Brian, University of Auckland
Postdoctoral Fellow, Akai-Shobabtai, Maryam, University of Auckland
Postdoctoral Fellow, Domigan, Laura, University of Auckland
Postdoctoral Fellow, Hilder, Tamyn, Victoria University of Wellington
Postdoctoral Fellow, Auguié, Baptiste, Victoria University of Wellington

Administration Team
Centre Manager, FitzGerald, Jacquie, Victoria University of Wellington
Senior Administrator, Dadley, Sarah, Victoria University of Wellington
Administrator, Hunt, Rebekah, Canterbury University
Communications and Marketing Officer, Doherty, Kylee, Victoria University of Wellington
Research Technician, Flynn, David, Victoria University of Wellington
Technical Assistant, Turner, Gary, Canterbury University

Students
Jayawardena, Gihan, MSc, University of Auckland
Alkaisi, Adel, PhD, Massey University
Chan, Andrew, PhD, University of Auckland
Dosado, Audrey, PhD, University of Auckland
McNeill, Alexandra, PhD, University of Canterbury
Baranov, Anton, PhD, University of Canterbury
Meffan, Claude, PhD, University of Canterbury
Ullstad, Felicia, PhD, Victoria University of Wellington
Xu, Guangyuan, PhD, University of Auckland
Hong, Fan, PhD, University of Otago
McFahon, Jamie, PhD, Victoria University of Wellington
Zaklitkova, Diagnara, PhD, University of Otago
Browning, Leo, PhD, Victoria University of Wellington
Liu, Ye, PhD, Victoria University of Wellington
Broom, Mathew, PhD, University of Auckland
Zhang, Peike, PhD, University of Auckland
Wilkes, Ryan, PhD, University of Canterbury
Manogu, Sesh, PhD, University of Auckland
Gangotra, Ankhi, PhD, University of Auckland
Cotton, Gamma, PhD, University of Otago
Lauferisky, Geoffrey, PhD, Victoria University of Wellington
Le Ster, Maxime, PhD, University of Canterbury
Schreuder, Katherine, PhD, Victoria University of Wellington
Kotulik, Markis, PhD, Victoria University of Wellington
Gallaher, Joseph, PhD, Victoria University of Wellington
Prasad, Shyamal, PhD, Victoria University of Wellington
Butkus, Justinas, PhD, Victoria University of Wellington
Hosking, Peter, PhD, University of Auckland
Chen, Linda, PhD, University of Canterbury
Martinez Gazoz, Rodrigo, PhD, University of Canterbury
Emery, Christine, PhD, University of Canterbury
Hyndman, Adam, PhD, University of Canterbury
Neisam, Alex, PhD, University of Canterbury
Hernandez, Pablo, PhD, Massey University
Irani, Arif, PhD, Massey University
Owen, Jesse, PhD, Massey University
Ravindran, Sapna, PhD, Massey University
Alagari, Omar, PhD, Victoria University of Wellington
Eakin, Galen, PhD, Victoria University of Wellington
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<tr>
<td>10.1088/2015-1991/1/4/046112</td>
<td>2-r2-D-8493326192</td>
<td>Sambale, S., Williams, G.V.M., Stephen, J., Chung, S.V.</td>
<td>Materials Research Express</td>
<td>Spin-glass and variable range hopping quantum interference magnetoresistance in Fe2Ge2.5Si0.5Ga0.5Se0.5.</td>
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<td>10.1039/c4an02270j</td>
<td>2-r2-D-84928750346</td>
<td>Weatherall, E., Willmott, G.R.</td>
<td>Analyst</td>
<td>Applications of Tunable Resistive Pulse Sensing</td>
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<td>10.1021/acscb500544</td>
<td>2-r2-D-84928710751</td>
<td>Weatherall, E., Willmott, G.R.</td>
<td>Journal of Physical Chemistry B</td>
<td>Conductive and Biphasic Pulses in Tunable Resistive Pulse Sensing</td>
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<td>10.1017</td>
<td>51446181115000115</td>
<td>Winkler, R., Zülicke, U.</td>
<td>ANZIAM Journal</td>
<td>Discrete symmetries of low-dimensional Disc models: A selective review with a focus on condensed-matter realizations</td>
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