Qubit’s arrow
Andrew Dzurak and his team take a quantum leap forward

The latest on the bionic eye

Plus
Award-winning chemist Cyrille Boyer
Opening of the Ainsworth Building
New Industry Research Fellowships
Bringing innovation to life

So, what is engineering? In a nutshell, it’s bringing innovation to life. And – I’m delighted to say – we’ve seen a lot of it at UNSW Engineering lately. This past October was an outstanding example.

The month began with Scientia Professor Andrew Dzurak and Dr Menno Veldhorst announcing in Nature that they had built the world’s first-ever quantum logic gate in silicon, showing that two qubits can exchange information in a silicon matrix. This is an essential piece of the architecture for a future quantum computer, and doing so in silicon (rather than with more exotic elements teams overseas have used) builds on the deep history and significant investment already made by the computing industry in silicon. It gives UNSW an enormous advantage in one day making quantum computers a reality.

Then UNSW polymer chemist Cyrille Boyer was feted at Canberra’s Parliament House with the 2015 Malcolm McIntosh Prize for Physical Scientist of the Year by an effusive Malcolm Turnbull at the Prime Minister’s Prizes for Science – the nation’s most prestigious awards for excellence in research. Associate Professor Boyer’s feat was to find innovative ways to mimic nature to create functional polymers and next-generation nanomedicines to treat infectious diseases.

In Sydney, UNSW petroleum engineer Christoph Arns received the 2015 NSW Premier’s Prize for Leadership in Innovation at NSW Government House for his use of micro-tomographic imaging to interpret and characterise the microstructure of rocks and other materials – critical to the development of the successful spin-off company Digital Core.

The following week Simon Birmingham, the Federal Minister for Education and Training, opened a new multimillion-dollar labs to researchers from industry, in what is thought to be Australia’s first such program, modelled on successful initiatives in the United States and Germany.

It was a great end to a great year for UNSW Engineering. We can only do better. And we will.

“Bringing innovation to life”
— Professor Mark Hoffman
Dean of UNSW Engineering

IO new engineering scholarships for women
UNSW has announced 10 new engineering scholarships for women. It is supported by industry and has been supported by the Faculty.

The generous awards are designed to encourage and assist female students to undertake an engineering degree and will be offered to high-school leavers starting university in 2016. Commonwealth Bank of Australia, Hindmarsh Construction, Anap, Orico and Kimberly-Clark have contributed $200,000 for the purpose.

Dean of UNSW Engineering, Professor Mark Hoffman, said it was important to address the gender imbalance in the profession: “7 per cent of engineers are female. It’s clear that the industry is missing the life experience, original thinking and personal perspectives that women can bring to new and advanced engineering challenges we face today.”

Professor Hoffman

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An incredible vision

Through its revolutionary bionic eye research, UNSW is looking to find the solution to some of the most common forms of blindness.

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BIOMEDICAL ENGINEERING

Bionic Vision Australia (BVA) is a partnership between UNSW, the University of Sydney, the University of Melbourne, the University of Adelaide, the University of New South Wales, the University of Newcastle, and the University of Queensland. BVA brings together more than 100 researchers from the Australian National Health and Medical Research Council, the Australian Research Council, and 12 years’ work by the Australian National Health and Medical Research Council.

The project is an advanced stage due to the five years of work completed by the BVA consortium, which was funded by the Australian Research Council, and 12 years’ work before that at UNSW. Despite a grant from the National Health and Medical Research Council, researchers need an additional $10 million over the next five years to continue their valuable work.

If you’re able to help through funding pre-clinical trials, patient care or device manufacturing, please contact UNSW Engineering Development Manager Victoria Miller on 02 9385 5364 or v.miller@unsw.edu.au

Biomedical Engineering

Professor Gregg Suaning and Scientia Professor Nigel Lovell

The bionic eye could change the lives of people with retinitis pigmentosa – the leading cause of blindness in younger people. The degenerative condition affects about 20,000 Australians and two million people worldwide. It tends to strike when patients are in the prime of their lives, often in their 30s, and can lead to complete blindness within a decade. There are no treatments and few ways to predict its onset, progression or severity. A bionic eye also has the potential to transform the lives of up to 196 million people with age-related macular degeneration. Expensive pharmaceuticals can only slow, not reverse, the condition.

The Bionic Vision Australia (BVA) consortium has developed a basic prototype with 24 electrodes that has been successfully implanted in three people with retinitis pigmentosa. ‘It’s been amazing,’ said patient Dianne Ashworth. ‘The more I’ve been doing it, the more natural it feels.’

The device allows patients to see spots of light, called phosphenes, for the first time. With special cameras and algorithms, patients are able to get a sense of distance, with phosphenes getting brighter as they get closer to a still object.

Patients ‘learn’ to use the technology, in the same way a person with a cochlear implant ‘learns’ to hear electrical impulses. The next-generation device should allow for vision that is four times better, potentially allowing patients to have better peripheral vision, avoid more obstacles, improve mobility and perform everyday routines.

Scientia Professor Nigel Lovell says their 99-electrode device is being prepared for clinical trials in humans. A handful of profoundly blind Sydney-based patients will be implanted with the devices and monitored for 18 months. “The device will be fully implanted and it will be much more user-friendly,” Lovell says. “It’s designed to last a lifetime.”

Surgery only takes two to three hours. The only sign of the device is a small disc behind the ear that transmits data and power to the implant, not unlike the one used in cochlear implants. The signals are used to configure the implant to deliver electrical impulses to the back of the eye.

The other vital piece of equipment is a small camera attached to the patient’s choice of glasses. The images from the camera define the stimulation of the remaining nerve cells in the damaged retina, sending signals to the visual cortex of the brain.

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Professor Gregg Suaning and Scientia Professor Nigel Lovell

In a nutshell, it’s bringing those advances to life – which is why we have launched our new Industry Research Fellowships to boost collaboration with business. The fellowships will open up UNSW Engineering’s brainpower and multimillion-dollar labs to researchers from industry, in what is thought to be Australia’s first such program, modelled on successful initiatives in the United States and Germany.

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Chemical Engineering

Chains of life

Multi-award winner Cyrille Boyer is mimicking nature to create functional polymers and nanomedicines to treat infectious diseases.

Associate Professor Cyrille Boyer has won two prestigious awards for excellence in scientific research and teaching. For his innovative work using light to create complex, functional polymers, Boyer won the 2015 Malcolm McIntosh Prize for Physical Scientist of the Year. The $50,000 prize, one of the Prime Minister’s Prizes for Science, honours early or mid-career researchers who have made outstanding achievements to improve human welfare or benefit society. More recently he won the celebrated RJW Le Fèvre Memorial Prize, which recognises outstanding basic research in chemistry by mid-career researchers.

An Australian Research Council Future Fellow, the French national has been developing a more sustainable process to build polymers, which are chains of small, repeating molecules. Natural polymers, such as DNA and proteins, are ubiquitous in the biological world. In our built environment, synthetic polymers are used to make paints, adhesives, textiles and plastics.

As techniques to create polymers get more sophisticated, chemists can design materials with unique physical properties and functions, opening up applications for drug delivery, medical diagnostics, energy storage, and for non-stick and anti-bacterial surface coatings. However, the energy-intensive process to create synthetic polymers requires high temperatures to trigger the necessary chemical reactions, as well as toxic substances, largely derived from non-renewable fossil fuels.

“They are making important breakthroughs to improve our society”
— Professor Ian Jacobs

Boyer has been developing a more sustainable polymerisation process inspired by photosynthesis – the process used by plants, algae and certain bacteria to convert sunlight into stored energy. “By using light we can significantly reduce the energy consumption and carry out the polymerisation process at room temperature,” he says. Boyer and his team can precisely control when and where they introduce the next link into their polymer chains by shining a light. By using lights of different wavelengths, or intensities, they can create links between up to 10 compounds. In a world first, they demonstrated that visible light along with chlorophyll – a natural, non-toxic pigment found in plants – could activate the polymerisation process and produce well-defined, functional materials.

“This is very exciting … because it means we can overcome the limitation of toxicity,” he says.

The team has triggered a similar process using near-infrared light, which has longer wavelengths than visible light and can penetrate a wider range of materials, including human skin. He says this will enable non-toxic polymers to be made inside the body, for things like tissue engineering and wound healing, and in implant surgeries.

Boyer, who is also the deputy director of the Australian Centre for Nanomedicine at UNSW, is using his expertise in polymerisation to develop intelligent, drug-delivering nanoparticles. By tailoring the size, shape and surface properties of these nanoparticles, he can exert incredible control over where they end up inside a cell and when they deliver their therapeutic agents. One such particle, which will deliver antibiotics in combination with nitric oxide or carbon monoxide, could help fight against antimicrobial resistance – a growing problem with potentially catastrophic consequences. A review on antimicrobial resistance predicted drug-resistant infections could kill 300 million people and cost the global economy $100 trillion by 2050.

UNSW President and Vice-Chancellor Professor Ian Jacobs says the University is delighted that Boyer has been recognised nationally for his work. “These prestigious awards honour the best minds in the country – researchers who are making important breakthroughs to improve our society,” Jacobs says.

“See Cyrille Boyer talk about his team’s discoveries at youtube.be/94-4pF18M”
Andrew Dzurak and his team of UNSW engineers have built a quantum logic gate in silicon, making it easier to build the world’s first ultra-powerful quantum computers.

An Australian team of engineers has built a quantum logic gate in silicon for the first time, making it possible to perform calculations between two qubits of information. The UNSW team’s work, which was published in the international scientific journal Nature in October, clears the final hurdle to making silicon quantum computers a reality.

It’s the first time calculations between silicon quantum bits have been demonstrated. To achieve this, the team constructed a device, known as a “quantum logic gate”, that allows calculations to be performed between two quantum bits, or “qubits”. This development completes the physical components needed to realise super powerful silicon quantum computers.

Any conceivable application or software program that would run on a quantum computer is made up of a series of equations, and modelling atomic systems such as biological molecules and drugs. They will be enormously useful for finance and healthcare industries, and for government, security and defence organisations.

“Quantum computers could be used to identify and develop new medicines by greatly accelerating the computer-aided design of pharmaceutical compounds (and minimising lengthy trial-and-error testing); develop new, lighter and stronger materials spanning consumer electronics to aircraft; and achieve much faster information searching through large databases.

In current computing, information is represented by classical bits, which are always either a zero or one. Physically, each bit is typically stored on a pair of transistors, one of which is switched on while the other is off. An electron with “spin” – or magnetic orientation – that is “up” can represent a 0. A counter-clockwise (or downward) spin can represent a 1.

In the quantum realm, particles have a unique ability to exist in two different states at the same time, an effect known as “quantum superposition”. This creates an opportunity to solve complex, data-intensive problems rapidly. For quantum computing, you need an equivalent. In the UNSW design, the data is encoded on the spin of individual electrons, stored in devices that are almost identical to the transistors on existing silicon chips. These single electron spin devices are known as quantum bits (qubits).

In recent years, scientists have been developing systems based on exotic materials and devices, or even light, to build a quantum computer. At UNSW, however, the approach has been to use silicon – the material used in all modern-day microprocessors, or computer chips. Silicon offers several advantages: the material is cheap, it’s already used in almost all commercial electronics, and its properties are well understood because of the trillions of dollars of investment in R&D by the computer and electronics industries.

Silicon electron spins also have very long “coherence times”, which means data encoded on the spin can remain for longer periods than in most materials before the information is scrambled and lost. This is important for performing successful calculations.

In 1998, former UNSW researcher Bruce Kane proposed using silicon as a base material for quantum computing. In a paper in Nature, he outlined the concept for a silicon-based quantum computer in which single phosphorus atoms in an otherwise ultra-pure silicon chip define the qubits. His visionary work spawned an international effort to develop a quantum computer in silicon.

In 2012, Dzurak jointly led a team with Associate Professor Andrea Morello at UNSW that was the first in the world to demonstrate a spin qubit in silicon but this used a single atom, rather than a modified silicon transistor. Last year, Dzurak’s team discovered a way to create a qubit with a device remarkably similar to the silicon transistors used in consumer electronics, known as MOSFETs.

The latest result from UNSW means that the building blocks are now in place to realise a large-scale quantum processor chip.

**Gateway to the future**

**Key research team members**

**Scientia Professor Andrew Dzurak (UNSW)**
- Research team leader. Developed over 2007-2015 the concept, design and fabrication technologies for silicon spin qubits based on modified silicon transistors. Director of the Australian National Fabrication Facility at UNSW and co-leader of silicon quantum computing programs at CQC2T.

**Research Fellow Dr Menno Veldhorst (UNSW)**
- Post-doctoral researcher in Dzurak’s team at the UNSW School of Electrical Engineering and Telecommunications, and lead author on the Nature paper. Jointly developed (with Dzurak and Dr Henry Yang) the design of the SIMOS qubits.

**Dr Henry Yang (UNSW)**
- Post-doctoral researcher in Dzurak’s team at the UNSW School of Electrical Engineering and Telecommunications, and key contributor to the experimental work. Jointly developed (with Dzurak and Veldhorst) the design of the SIMOS qubits.

**Associate Professor Andrea Morello (UNSW)**
- Expert on silicon spin qubit measurement and control, and long-time collaborator with Dzurak.

**Professor Kohei Itoh (Keio University, Japan)**
- Collaborator with Dzurak. Provided isostropically purified silicon wafers for device production at UNSW.
Prime Minister Malcolm Turnbull has set the tertiary sector a challenge: universities must find ways to drive more industry collaboration and help build the nation’s innovative businesses.

UNSW Engineering has answered the call by launching Industry Research Fellowships that will open its amassed brainpower and multimillion-dollar labs and facilities to researchers from industry seeking to improve products, overcome obstacles and solve challenges. In total, 25 UNSW Engineering Industry Research Fellowships have been offered in what is understood to be Australia’s first such program, modelled on successful initiatives in the United States and Germany.

“The purpose is to bring people who work in industry closer to the research that happens in universities, and improve the two-way communication for the development of technology,” says Professor Mark Hoffman, Dean of UNSW Engineering. “When researchers at universities design projects, they often don’t have a strong knowledge of what industry needs. Similarly, industry doesn’t always have a full understanding of the capability within universities. So if we can have people from industry actually working alongside our researchers and students, both sides can better understand the technologies and partner in their development.”

Industry Fellows can spend up to six months on campus full time, or up to a year part-time. Once completed, they can apply to renew, extend or continue their projects. During their stay, Industry Fellows will have access to UNSW research expertise and facilities to work on projects or collaborate with researchers to transfer knowledge to industry or projects to market.

By embedding industry staff in the University, UNSW Engineering hopes to increase its impressive research engagement with business to accelerate the development of technologies with commercial applications. While UNSW Engineering leads Australia in industry collaboration, “it is not as impressive when we compare ourselves to the global leaders of engineering and technology research,” Hoffman says. “We can do better, and initiatives like this will help.” This was highlighted by the Science, Technology and Industry Scoreboard 2015 released by the Organisation for Economic Co-operation and Development, which found that Australia ranked 29th out of 30 in business-university collaboration.

Hoffman acknowledges that the road runs both ways: business needs to connect with universities as much as universities need to connect with business. Corporate Australia also needs a mindset that sees universities as partners. “It takes two to tango,” Hoffman says. “The best place for us to start is to make it easier for industry to engage with UNSW, and show what we can offer.”

How to apply for an Industry Research Fellowship: unsw.to/EngIndustryResearchFellowships

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Moving together
Advisian confirms continued support for transport research position at UNSW.

Global advisory firm Advisian is pleased to continue its collaboration with Professor Travis Waller and his team at the Research Centre for Integrated Transport Innovation (rCITI) and has agreed to support the Professor for Transport Innovation Chair into the future.

Ian McIntyre, the principal of the independent consulting business formerly known as Evans & Peck, says it was an easy decision. “In just four short years, Travis and his team have managed to successfully establish a thriving research group from scratch – that’s no mean feat!”

“We need to be solving a problem. Otherwise what are we doing it for?”
— Professor Travis Waller

The rapidly growing rCITI was established four years ago as a joint initiative of UNSW, NICTA (the national ICT lab) and Advisian to pursue high-level, integrated, interdisciplinary transport solutions. Waller was headhunted from the United States to be centre director and funding from the Australian Research Council and Transport for NSW followed. From having one academic and one PhD student, it now has 10 teaching and research staff, 23 PhD students and more than $5 million in external funding.

The Centre has formed partnerships with industry, government agencies and non-profits. After spending much of his time building the Centre’s profile, Waller says organisations are now seeking its services. “As you begin doing things out in the real world, people start to realise you have the capability and then … success begets success,” he says. “Our largest sponsor has been Transport for NSW. We’ve developed a series of analytical tools to help them anticipate and deal with disruptions and make real-time decisions, like when to change the lanes on the Sydney Harbour Bridge.”

Advisian says the most beneficial aspect of the collaboration is shared knowledge. “Advisian has a proud history of developing innovative and novel approaches to many of our clients’ challenges,” McIntyre says. “With the help of academia, we hope to improve the standard of conversation about transportation and urban planning in government, business, the press and the general public.”

Waller is thrilled the Advisian relationship has been extended and that rCITI’s research will continue to be used for practical purposes. “Engineering research is only engineering research if it makes an impact out in the world,” he says. “We need to be solving a problem. We need to be tackling some issue. Otherwise what are we doing it for?”

UNSW Engineering has a range of centres that allow researchers to work with companies, NGOs and government agencies. Find out more at unsw.to/EngResearchCentres
Thesis helps mine student award

An understanding of both commercial and sustainability mining issues has helped UNSW’s Heather Malli win the Student Engineer of the Year award at Engineers Australia’s NSW Showcase dinner. Malli won the award for her thesis, which analysed carbon sequestration techniques aimed at creating an ecologically and economically sustainable carbon-neutral mine. The judges applauded her demonstration of the project’s commercial aspects while addressing relevant sustainability issues. Other winners were Chemical Engineering alumnus and former Cochlear CEO Dr Christopher Roberts, who was named Professional Engineer of the Year, Barefoot Power chairman David Hind (Entrepreneur of the Year), and Thales Australia’s Christine Chen (Young Professional of the Year).

Add fuel to the fire

UNSW alumnus Tom Burger shares some career insights and inspirations.

Tom Burger graduated from UNSW with a degree in Petroleum Engineering in 2008 and immediately joined international oil and gas giant ExxonMobil as a graduate engineer. He is on the PNG LNG Project, working a 28-days-on, 28-days-off rotational roster in the PNG Highlands as the Process Engineer at the Hides Gas Conditioning Plant.

Why did you choose Petroleum Engineering?

The late Henry Salisch, former Undergraduate Coordinator at the School of Petroleum Engineering, was a huge influence. I knew relatively early on that I wanted to work in the oil and gas industry and was set on becoming a petroleum engineer, but I was unsure where I wanted to study. During year 12, Henry invited me to Sydney to visit UNSW. He made a big impression on me that day.

How has your career unfolded since leaving UNSW?

I joined ExxonMobil and started my career in the Reservoir Engineering Team. I spent three years working in that team, supporting the offshore Gippsland operations with production optimisation, workovers and drilling. I then became the Gas Management Engineer, a coordination role, between the offshore gas platforms and the Longford gas plant. Working with the teams at the Longford gas plant gave me an appreciation for process engineering and an interest in plant operations. I then joined the PNG LNG production team six months before start-up and was lucky enough to be part of the commissioning and start-up of the Hides Gas Conditioning Plant.

What is the major challenge you have faced?

I really wanted an adventure and to work in places like Nigeria, Iraq, Russia or PNG early in my career. My wife, however, was understandably not so keen to relocate. The compromise was that I would rotate. This highlighted how important it was for me to continually share my personal considerations with the company and potential work opportunities with my family.

What character traits do you think are important for engineers to cultivate?

I believe teamwork and leadership are key to being an effective engineer. You can be the smartest person in the room but if you can’t communicate or work in a team your effectiveness will be very limited. Likewise, as an engineer you’re likely to be a leader of a team sometime in your career and having strong leadership skills will be critical to how well the team functions.

Mechanical and Manufacturing Engineering

Something to build on

$67 million redevelopment marks the beginning of another exciting era for UNSW engineers.

When the original UNSW Mechanical Engineering precinct was opened in the 1960s, it put the School at the forefront of innovation. Time, however, moved on and so did the demands of a modern university. “We have been living in a building that was built in 1963,” said the Mechanical and Manufacturing Engineering Head of School, Professor Anne Simmons. “It has barely changed in 50 years, even though we have grown.”

Simmons was involved in every stage of the new complex’s development. It was like she was overseeing the reconstruction of her much-loved family home, except this renovation cost $67 million.

The redevelopment began six years ago, when prominent Sydney businessman Dr Len Ainsworth made a substantial philanthropic donation to UNSW Engineering. The funds from Ainsworth, who has a passion for design and was awarded an Honoris Causa from UNSW for his philanthropic work, allowed for the creation of the Mechanical and Manufacturing Engineering Design Studio. In early 2014, Ainsworth made another significant gift towards the construction of the new precinct. “Engineers are the salt of the earth, in my view – everything has a background in engineering,” he said at the launch. “My gift has helped UNSW educate our next generation of engineers.”

The Dean of UNSW Engineering, Professor Mark Hoffman, says Ainsworth’s generosity allows the School to cater for its 1600 mechanical and manufacturing engineering undergraduates, 200 postgraduate coursework students and 130 postgraduate research students. The precinct also marks a fresh identity for the School, with the newly named Ainsworth Building looking onto the University Mall. Glass windows have replaced concrete walls on the ground floor, and this section has dedicated facilities for undergraduate students. There are two purpose-designed CATS (centrally allocated teaching space) rooms and a café that blends into an informal student space. At its heart is a 350-seat lecture theatre with brilliant acoustics and impressive WiFi.

The new layout breaks down the barriers between staff, students, researchers and academics, with the Ainsworth Building and Willis Annexe bridged by an awning over Willis Lane. Large tilting doors open Willis Annexe’s undergraduate workshops onto the laneway, and students can use this space during practical industry sessions. There are also innovative teaching spaces, including modern high-tech computer laboratories for up to 200 students. Tutors can use partitions to divide the rooms into separate teaching spaces.

The Willis Annexe houses a flight simulator, mechatronics research space, a refrigeration lab, six laser labs (including one equipped with blood-flow analysis technology), machines for tensile and compression testing, an aerodynamics laboratory with four wind tunnels and an outstanding mechanical workshop. On the northern roof of the Ainsworth Building is a new solar thermal energy and solar-energy laboratory.

Hoffman says the new precinct pushes the School forward as an industry leader. “The facilities enhance students’ experiences, increase industry interaction, help us attract the best researchers and academics and, of course, pave the way for significant research advancement.”

Petroleum Engineering

“My gift has helped UNSW educate our next generation of engineers”

— Dr Len Ainsworth
When Dr Audist Subekti enrolled in a Chemical Engineering PhD program at UNSW in 1999, she never realised she would attain two major accomplishments in her four years away from Indonesia. She would achieve a doctorate and become a first-time mother.

“I had two previous miscarriages so I was afraid when I became pregnant in Australia that it would happen again,” Subekti says. “But everything went fine, and then I spent the next four months busily finishing my thesis, breastfeeding my baby and sleeping very little!”

Twelve years later, happily living with her husband and two children in Jakarta, Subekti is the Country Technical Head for Indonesia of multinational engineering company 3M, and takes a lead role in the company’s technical and R&D activities. She is also involved in outsourcing, cost optimisation projects and new product commercialisation. With her involvement, 3M Indonesia has made more than 50 invention submissions and achieved five local patents.

“For me, working is a learning process,” Subekti says. “My boss says that I’m a very positive person, full of passion and I never say no.”

Subekti is across many company divisions including automotive, oil and gas, personal safety, green building initiatives and consumer product design. She’s been a member of several regulatory bodies, is a subject-matter expert and develops safety regulations and standards for oil and gas. She also chairs 3M’s Women’s Leadership Forum (WLF), a global corporate program that encourages the company’s female leaders. WLF is also involved with global charity Project HOPE, which among other initiatives supports women to breastfeed and have regular cervical cancer screening.

After gaining Bachelor and Master degrees in Science, majoring in Chemistry, at the Bandung Institute of Technology (BIT) in West Java, she won a scholarship to study at the University of Auckland. In 1999, she enrolled for her PhD in Polymer Science at UNSW, focusing on synthesising high-performance polymers. “I was here by myself – my husband worked in the oilfields at Balikpapan, Kalimantan and just visited me on his time off,” she says. “I managed to make lots of friends with other students and lecturers. Walking around the UNSW campus and in the city, I found it so multicultural.”

After finishing her thesis, Subekti returned to Indonesia and worked as a BIT lecturer while her children were young. In 2006, she started at 3M as professional support and team leader in the Occupational Health and Safety division. From there, she has risen through the company ranks to the management board.

“I’m a very positive person, full of passion and I never say no”

— Dr Audist Subekti