ISSUE 4 · 2013

PUSHING

Frontiers

SINGAPORE

In Good Company

Big Businesses On NTU Campus

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Coming To NTU In Singapore

World Cultural Council 30th Award Ceremony

Inaugural World Academic Summit

RESEARCH & INNOVATION

NANYANG TECHNOLOGICAL UNIVERSITY

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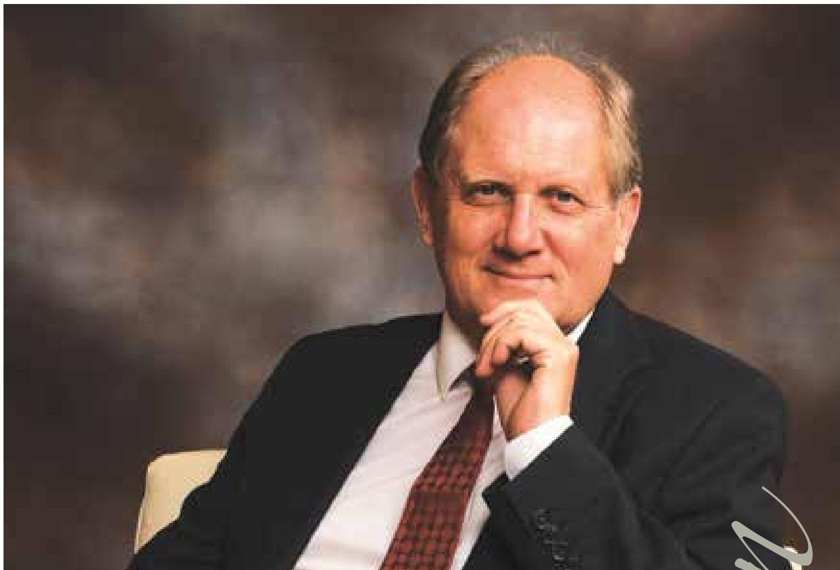


In October, two prestigious events for the global university community will be held for the first time in Singapore at NTU.

The **World Cultural Council Award Ceremony** recognises outstanding scholars whose achievements in science, arts and education have left a deep, positive impact on humanity.

Prof Sir Paul Nurse, a truly iconic scientist of our time, will receive the Albert Einstein World Award of Science. He won the 2001 Nobel Prize in Medicine for his discoveries in cell cycle regulation – work that has brought us closer to preventive treatments and a cure for cancer.

The other winners – Prof Petteri Nisunen and his colleague, Tommi Grönlund, have made inspiring contributions to contemporary arts and fully deserve the Leonardo da Vinci World Award of Arts.

NTU is delighted that following the last ceremony in Denmark, the World Cultural Council presided by Nobel Prize winner Prof Edmond H. Fischer has chosen to host this prestigious international event on our campus this year. This year, five Singapore researchers will also be honoured at the ceremony for making a global impact with their research.

The World Cultural Council Award Ceremony will be twinned with the **World Academic Summit**, which will bring together leaders from industry, higher education and governments to discuss the commercialisation of research and how universities can fuel technological change and economic growth.

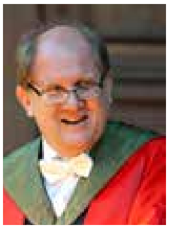
The World Academic Summit is being held for the first time by Times Higher Education which will also be launching its 2013 World Universities Rankings at the Summit.

With NTU's fast-rising global reputation and track record of strong partnerships with industry leaders, Times Higher Education has chosen NTU to be its partner for this inaugural event.

This issue of PUSHING FRONTIERS offers a peek into NTU's extensive ties with global industry. I also hope it will inspire fresh, new collaborations between universities and industry that further expand the frontiers of high-impact science and technology. See you in Singapore in October.

Bertil Andersson

The Honour Roll



NTU President Prof Bertil Andersson

Well-regarded internationally for championing high-impact science and engineering, Prof Bertil Andersson was honoured twice in recent months with honorary doctorates from Edinburgh University and Hanyang University. Both degrees recognise his research in biochemistry and contributions to higher education as well as the fostering of closer ties between Singapore and the United Kingdom and South Korea, respectively.

NTU Provost Prof Freddy Boey

Joining an illustrious list of scientists, Prof Freddy Boey received the Faculty of Medicine Fellowship from Imperial College London. Prof Boey has outstanding achievements in medical technology and was also honoured for his contributions to the development of NTU's new medical school set up jointly with Imperial College London. A renowned serial inventor, he is behind several innovative medical devices including the first-of-its kind hernia mesh approved for sale in the US.

Prof Vijay Sethi and Prof Tan Hun Tong

Making waves on the global scene as the world's top business professor is Prof Vijay Sethi from NTU's Nanyang Business School. He clinched the title from the Economist Intelligence Unit after being judged to have delivered the best lecture at a live "teach-off" in London. Up against 222 professors from 31 countries, he beat strong candidates from leading business institutions. In the 2013 Brigham Young University Accounting Research Rankings, Prof Tan Hun Tong of NBS retained his standing as the world's top accounting researcher for the third year running. Accounting research at NBS moved up two places to fifth in the world and is first in Asia again, based on publication productivity in 11 top accounting journals over the years 2007-2012.

Prof Lee Sing Kong

The Medal for Distinguished Service, the highest medal of honour from Columbia University's Teachers College in the US, was conferred on Prof Lee Sing Kong, Director of NTU's National Institute of Education. He was singled out for his award-winning research in agriculture and his leadership in education, which has helped to create a highly respected teaching workforce in Singapore.

Dr Yuhyun Park

Having received the Eisenhower Fellowship this year, Dr Yuhyun Park, Director of Academic Projects in the President's Office, has been named among 20 emerging leaders from around the world. Dr Park is also CEO and Co-Founder of infollutionZERO and the original developer of the iZ HERO Project that educates children about safe and responsible online behaviour through an online game and exhibits.

Indonesian President Dr Susilo Bambang Yudhoyono

Dr Susilo Bambang Yudhoyono, President of the Republic of Indonesia, was conferred an honorary Doctor of Letters by NTU for his outstanding leadership and public service, as well as his contributions to the university and Singapore. He received the honour from Singapore's President Dr Tony Tan Keng Yam, who is also the NTU Chancellor.

Team Achievements

Big Grants Awarded To NTU Scientists And Engineers

A team led by NTU's Prof Daniela Rhodes has won up to S$25 million from Singapore's Ministry of Education (MOE) under the Academic Research Fund programme. The research project "Telomere Dynamics and Genome Function: From DNA to Nucleosomes to Chromosomes" focuses on the regulation of telomeres – specific DNA regions that play crucial roles in ageing as well as in cancer and other medical conditions.

Another programme grant of up to S$10 million went to a team from NTU's Schools of Physical and Mathematical Sciences and Electrical and Electronic Engineering, led by Prof Nikolay Zheludev, for a project that advances developments in photonics, energy research and low-cost precision manufacturing.

Prof Gerhard Grüber from NTU's School of Biological Sciences is one of the co-leaders of another project that has won a large grant. The awarded project focuses on the development of novel experimental and computational methods to image and model the dynamically changing structures of proteins in infection processes.

Researchers from NTU's School of Materials Science and Engineering and the Singapore General Hospital, led by Assoc Prof Cho Nam Joon, have been selected for a Competitive Research Programme award under Singapore's National Research Foundation to study liver biology, develop new drugs and treat liver diseases.

Solar energy systems research at the Energy Research Institute @NTU (ERI@N) will be boosted by a grant awarded to a project led by Assoc Prof Douglas Maskell under the first Energy Innovation Research Programme (EIRP) grant call on solar energy systems from the Energy Innovation Programme Office (EIPO) and the Singapore Economic Development Board. Asst Prof Wen Yonggang from NTU's School of Computer Engineering has won a grant award under the EIRP grant call on smart grid technologies from the EIPO and the Energy Market Authority of Singapore.

New Research Centres, Collaborations And Programmes

• Nanotechnology will be used at NTU's new **Ocular Therapeutic Engineering Centre** to improve the lives of patients suffering from eye diseases. Working with the Singapore Eye Research Institute, NTU researchers will engineer solutions to treat glaucoma, macular degeneration, diabetic retinopathy and other eye diseases. One novel treatment undergoing clinical trials is *LipoLat*. Here, nanocapsules injected into the eye release a drug slowly over time to combat glaucoma.

Assoc Prof (Adj) Tina Wong (left) and Prof Subbu Venkatraman, Directors of NTU's new Ocular Therapeutic Engineering Centre.

• NTU will engage in food science and technology research and education through a tie-up with the **Netherlands' Wageningen University**. The partnership covers joint research projects on sustainable food production and nutrition-health relationships, as well as the development of undergraduate and Master's programmes involving several of NTU's engineering and science schools.

• Satellite and space research at NTU will be further boosted through a collaboration with **Technion-Israel Institute of Technology (Technion)**. The joint venture will support NTU's 10-year road map to build four nano-satellites under its VELOX programme, and Technion's efforts to launch three nano-satellites by 2015 under its Space Autonomous Mission for Swarming and Geolocation with Nanosatellites (SAMSON).

• The **Nanyang Institute of Technology in Health and Medicine**, a new initiative under NTU's Future Healthcare thrust, provides a cross-disciplinary platform for engineers, scientists and clinicians from NTU, healthcare groups and hospitals as well as industrial partners to advance engineering-enabled solutions to critical problems in health and medicine.

• Students at the **Lee Kong Chian School of Medicine**, NTU's joint medical school with Imperial College London, will be the first in Southeast Asia to do virtual dissection on an Anatomage Table. The human-size touch screen table offers realistic visualisation of full-body anatomy and an interactive 3D experience. NTU's medical school is also pioneering (in Singapore) the use of plastinated bodies. Made durable with plastic, the human cadavers will render traditionally preserved cadavers, which are in short supply, unnecessary.

Meeting And Honouring The Best

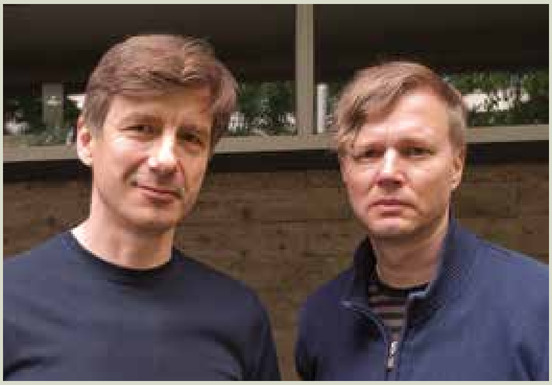
The world meets at NTU at two prestigious international events – the **World Cultural Council 2013 Award Ceremony** and the inaugural **Times Higher Education World Academic Summit**.

Two Big Global Events. One Venue – NTU In Singapore.

The award ceremony of the World Cultural Council has come to Southeast Asia for the first time, with NTU hosting the esteemed event in October. It will be held in conjunction with the inaugural 2013 Times Higher Education World Academic Summit, where renowned scientists and global thought leaders from industry, government and academia will meet to discuss issues and trends important to global research collaboration.

The jury of the World Cultural Council Awards is made up of world-renowned personalities, including Nobel laureates. Two awards will be given out – the Albert Einstein World Award of Science and the Leonardo da Vinci World Award of Arts – along with five special awards for high-achieving scientists and educators in Singapore, the host country.

Prof Sir Paul Nurse, the winner of the 2013 Albert Einstein World Award of Science, is a pioneering British geneticist and cell biologist who won the 2001 Nobel Prize in Medicine. The President Emeritus and head of the Laboratory of Yeast Genetics and Cell Biology at The Rockefeller University, USA, he studies the cell cycle and has furthered our knowledge of the fundamental cellular processes at the heart of cancer and other serious diseases. He is also currently Director and CEO of the Francis Crick Institute, a biomedical research institute, and President of The Royal Society in the UK.



The 2013 Leonardo da Vinci World Award of Arts will be shared by Prof Petteri Nisunen and Tommi Grönlund, both from the School of Arts, Design and Architecture at Aalto University, Finland. The artists are being recognised for their interdisciplinary approach that integrates art, design, architecture and science.

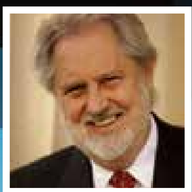
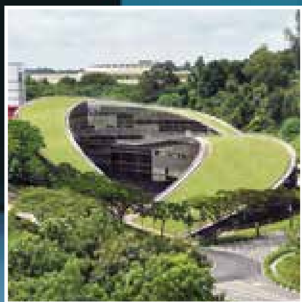
NANYANG TECHNOLOGICAL UNIVERSITY

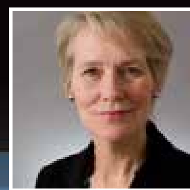
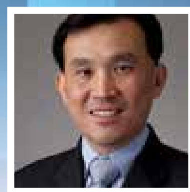
Times Higher Education
and Nanyang Technological University, Singapore present:

THE WORLD ACADEMIC SUMMIT

REGISTER YOUR PLACE NOW!

2-4 October 2013 Nanyang Technological University, Singapore


This high-level summit brings together senior industrial, political and higher education leaders across the world to explore the fundamental role that world-class research universities will play in fuelling the future knowledge economy – pushing the boundaries of our collective understanding, commercialising ideas, attracting industrial investment, collaborating across national borders, sharing and benchmarking best practice, and fostering intercultural understanding.

Key speakers include (clockwise from top left):

Lord David Puttnam of Queensgate
The Open University, UK

Baroness Virginia Bottomley DL
Chairman,
Odgers Berndtson Board Practice

Mr Lim Chuan Poh
Chairman, Agency for Science, Technology and Research, Singapore

Guest of Honour
Mr S. R. Nathan
Former President of Singapore

Also featuring:

Prof Oh Yeon-Cheon
President, Seoul National University, South Korea

Dr Marcus Storch
Former Chairman
Board of the Nobel Foundation

Sir Keith O'Nions
President and Rector,
Imperial College London

Prof Tony Chan
President,
HKUST

Prof Bertil Andersson
President, Nanyang Technological University, Singapore

Mr Phil Baty
Editor, *Times Higher Education* World University Rankings

Prof Ed Byrne
Vice-Chancellor,
Monash University, Australia

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WCC
WORLD CULTURAL COUNCIL

The World Cultural Council's 30th Award Ceremony will also be held at NTU, Singapore on 2 October 2013.

For more information, visit www.wcca2013.org

Prof Sir Paul Nurse
Albert Einstein
World Award of Science
2013

Prof Petteri Nisunen & Mr Tommi Grönlund
Leonardo Da Vinci
World Award of Arts 2013

In Good Company

It has been said you can tell a university by the company it keeps. At the NTU campus in Singapore, university professors and researchers work with the biggest industry and business players to move discoveries from the lab into innovations in the real world, making a real social and economic impact.

Today's world-class universities work hand in hand with industry to create innovations that not just improve lives but also make businesses more cost-efficient and bring about economic benefits.

NTU in Singapore, one of the world's leading hubs of global research and innovation, has become a hotbed for the big players to tap into and find breakthrough solutions.

In the 2012 Times Higher Education university rankings, NTU scored 99.5 in industry income, the 15th highest in the world. The World Academic Summit Innovation Index, published by Times Higher Education in August 2013, ranks academics in Singapore as the second most commercially valuable in the world, with big business pouring in an average of US$84,500 per researcher in exchange for their contribution to worldwide product innovation and development.

NTU has been particularly successful in competing for research funding from the industry, and in the last eight years has struck a record number of tie-ups with big businesses such as Rolls-Royce, BMW Group, Lockheed Martin, Siemens, THALES and Bosch. On the campus are at least 20 laboratories and centres jointly set up with these multinationals, with a number representing the companies' first such foray into Asia.

"University-industry collaborations have evolved into interdisciplinary and multi-contextual partnerships that generate solutions to address global challenges and achieve important breakthroughs. NTU is strongly engaged with industry partners across a broad spectrum of disciplines to develop solutions and create opportunities that lead towards innovations and technological advances for commercialisation," said NTU's Chief of Staff, Prof Lam Khin Yong.

The collaborations range from individual projects to joint labs and centres, and multi-party platforms that bring together multinationals, smaller enterprises as well as universities from around the world.

Courtesy of Vestas Wind Systems A/S

While the industry benefits from working closely with NTU to move discoveries and ideas into the real world, the university's academics and students gain from the research, innovation and educational opportunities such partnerships with global businesses bring.

Advancing Industrial Technologies

Industries have found it beneficial to work with universities on fundamental research which is essential in advancing technologies and developing them into applications and marketable products. Linking up with academia can also provide test beds for new technologies and innovations.

For example, to start an advanced biofilm imaging facility to develop important applications for environmental and water sustainability, Carl Zeiss, the German optical systems pioneer, chose to work with the Singapore Centre on Environmental Life Sciences Engineering (SCELSE) at NTU, a S$120 million outfit funded by the Singapore government. The partners have set up a S$6.5 million joint facility at NTU which is also Carl Zeiss's maiden tie-up in the field of environmental life sciences engineering.

"Working closely with SCELSE, a world-class research group helmed by pioneers in environmental life sciences engineering, has allowed us to explore the unexplored area of bacterial interaction, and harness that knowledge for important projects such as water treatment and public health for the benefit of all Singaporeans," said Ven Raman, Managing Director of Carl Zeiss, Southeast Asia.

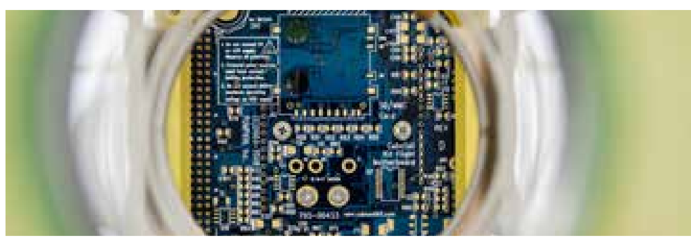
Similarly, British power systems giant Rolls-Royce, a long-standing partner of NTU, has seen the benefit of working with university scientists on fundamental research.

This year, the two brought their partnership to new heights with the S$75 million Rolls-Royce@NTU Corporate Lab. It will have up to 75 researchers and 40 PhD students developing innovations in energy and control systems, computational engineering, and manufacturing and repair technologies. It will boost Singapore's aerospace and transport engineering sector. The lab is the first one supported under the Singapore National Research Foundation's Corp Lab@University scheme.

"NTU and Rolls-Royce share a common vision and awareness of the need to support research and development in fields closely aligned to Singapore's core strengths. The Rolls-Royce @ NTU Corporate Lab is a practical step toward this goal," said Prof Ric Parker, Director of Research and Technology, Rolls-Royce.

He added: **"We have a network of such centres around the world but only two in Asia. This is certainly the biggest in Asia and the most widespread in the field it is looking at. So it is very important to us."**

NTU and Rolls-Royce are of course no strangers. From the first joint research projects dating back to 2005 to the co-founding of the Advanced Technology Centre at NTU in 2009, the alliance was further strengthened last year under the Advanced Remanufacturing & Technology Centre. This partnership between Singapore's Agency for Science, Technology and Research and NTU involves other industry collaborators besides Rolls-Royce and is located at Singapore's eco-business CleanTech Park housing NTU's institutes in green technologies and cutting-edge industry players.



Making its entry into the NTU campus this year is the BMW Group. NTU joins seven other prestigious universities such as the Technical University of Munich (TUM), Georgia Institute of Technology and the Massachusetts Institute of Technology as joint lab partners of the BMW Group.

The newly launched Future Mobility Research Lab at NTU is the first for the BMW Group in Southeast Asia. This new research facility will study and develop key areas relating to future transportation, which includes advanced battery materials for electric vehicles, human-machine interfaces, and mobility patterns and concepts.

Under the ambit of advanced battery materials and human-machine interfaces, the BMW Group-NTU collaboration aims to find solutions to key transport requirements in the most sustainable way possible, especially in the area of electric vehicles, where battery safety, efficiency and being environmentally-friendly is of utmost importance.

"This is BMW's first-ever R&D centre in Asia. That we are the choice partner of BMW Group in Asia is yet another endorsement of NTU's strengths in applied research and our record of strong partnerships with industry leaders," said NTU President Prof Bertil Andersson.

To study how to develop cleaner and "greener" ways of moving people across cities, NTU is also testbedding a driverless electric shuttle manufactured by Induct. Collaborating with Induct and JTC Corporation, the university will explore breakthroughs in autonomous driving, wireless fast charging, and advanced battery technologies for sustainable transportation solutions.

Multi-Partner Platforms

Smaller companies have likewise turned to NTU for solutions. The Joint Industry Programme on Offshore Renewables (JIP), led by the Energy Research Institute @ NTU (ERI@N), is a platform bringing together companies of all sizes.

In aligning global and local companies with complementary technologies and business experience along the same value chain, it streamlines product development processes to drive innovations and technological developments. Under the JIP, NTU gives vital support to small and medium enterprises, helping them gain a foothold in the fast-developing marine energy renewables market.

"Multi-party collaborations like this one provide an ecosystem where participating companies can interact not only with NTU but also, for example, with a customer company, or a supplier, or a solution provider. The companies can leverage the synergistic effects that develop from working in a group," said ERI@N's Director, Prof Subodh Mhaisalkar.

Advanced Biofilm Imaging Facility

- Partners: Singapore Centre on Environmental Life Sciences Engineering at NTU and Carl Zeiss AG.
- Established in 2012.
- Benefits: Advances optics and imaging technologies in a research-applied setting.

Advanced Technology Centre

- Partners: NTU and Rolls-Royce.
- Established in 2009.
- Benefits: Develops Rolls-Royce product-related applications and technologies.

Rolls-Royce @ NTU Corporate Lab

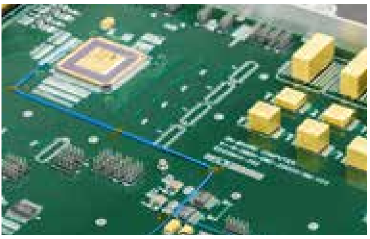
- Partners: NTU, Rolls-Royce and Singapore's National Research Foundation.
- Established in 2013.
- Benefits: Innovative solutions to overcome challenges in large-scale manufacturing and repair, such as reducing noise and emissions.

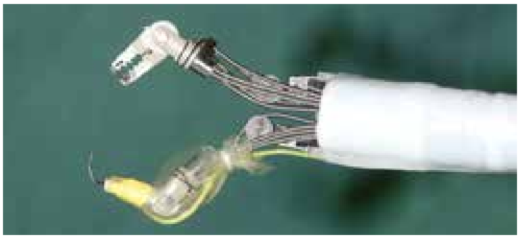
BMW Group-NTU Future Mobility Research Lab

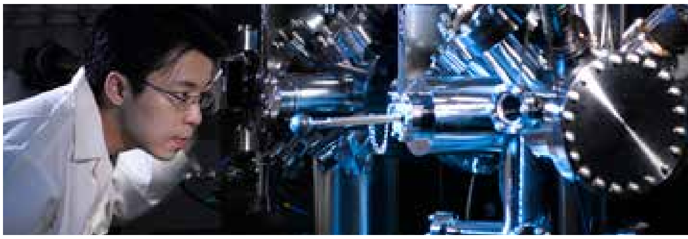
- Partners: NTU and BMW Group.
- Established in 2013.
- Benefits: Develops and advances mobility concepts for future transportation in Singapore.

Joint Industry Programme on Offshore Renewables

- Partners: Energy Research Institute @ NTU; industrial members: DNV, Keppel Corporation, Rolls-Royce, Vestas, ceEntek, CIMNE Singapore, DHI, Lloyd's Register, IBM and TOTAL; associate partners: Norwegian Research Centre for Offshore Wind Technology (Norway), Technical University of Munich (Germany), University of Colorado at Boulder (USA), National Renewable Energy Laboratory (USA), Renewable and Sustainable Energy Institute (USA), Norwegian University of Science and Technology (Norway), Penn State University (USA) and University of Strathclyde Glasgow (UK); major governmental stakeholders: Economic Development Board and Singapore's National Research Foundation.
- Established in 2011.
- Benefits:
  - Cooperative open innovation platform.
  - Alignment of complementary technologies; sharing of resources, costs and knowledge; training of R&D talent.
  - Partnerships with technology leaders and access to advanced facilities.
  - Increased business opportunities, reduced business risks.







For wind energy giant Vestas, the JIP is an important platform meeting sustainability and business goals. Dr Ian Chatting, Vice President of Advanced Technology Programmes and Managing Director, Vestas Technology R&D Singapore, said: **"With the world's energy needs growing rapidly, it is vital that we continue to harness regional competence to develop renewable technologies, such as offshore wind energy, to further reduce the cost of energy."**

Knowledge Gain For Industries And Society At Large

Targeted funding of academic research benefits industries that typically do not engage in research themselves. The Earth Observatory of Singapore at NTU is the first organisation in Asia to receive about S$5 million from the global AXA Research Fund. The funds, including a permanent Chair in Natural Hazards that is currently held by the observatory's Director, Prof Kerry Sieh, aim to support research in natural hazards such as earthquakes, tsunamis, volcanic eruptions and climate change.

"The AXA Research Fund is committed to supporting countries that make academic research a cardinal point of their economic development, and that's the case for Singapore," said Denis Duverne, AXA Group Deputy CEO. **"This new Chair is exactly the kind of excellence that the AXA Research Fund wants to support and to partner with to better understand and prevent risks for society at large."**

Symbiotic Relationship With The Industry

At NTU, all undergraduates undergo a curriculum with a strong industry component – such as internships and industry-related research projects in Singapore and abroad. These allow students to get immersed in industry settings and real-world problem-solving even before they graduate, as well as gain employability in economically strategic job sectors.

Companies can also enrol their employees in the Industrial Postgraduate Programme to pursue a PhD degree while conducting research on a project relevant to their employer.

"NTU has been working closely with its industry partners in making its research relevant and impactful to society," said NTU Provost Prof Freddy Boey, a serial inventor who has developed 28 original patents, the majority of which have been licensed and resulted in five spin-off companies.

"Exchanging and optimising ideas and resources through academia working side by side with industry achieves synergies that bring about greater efficiency, new commercial applications and innovative solutions to the many global challenges we face today," he added.

Toray Water Technology Laboratory

- Partners: Nanyang Environment and Water Research Institute (NEWRI) at NTU and Toray Industries, supported by PUB, Singapore's national water agency and Economic Development Board.
- Established in 2010.
- Benefits: Advances and refines Toray's innovative membrane-based water treatment technologies.

Lockheed Martin-NTU Joint Research Lab

- Partners: NTU and Lockheed Martin.
- Established in 2013.
- Benefits: Advances nanocopper-related technologies, in particular CuantumFuse™, a revolutionary technology developed by Lockheed Martin.

Collaboration with Siemens

- Partners: Nanyang Environment and Water Research Institute (NEWRI) at NTU and Siemens Water Technologies.
- Established in 2009.
- Benefits: Improvements to water treatment and membrane technologies.

CNRS International NTU THALES Research Alliance

- Partners: NTU, THALES and France's Centre National de la Recherche Scientifique (CNRS).
- Established in 2009.
- Benefits: Develops nanotechnologies for microelectronics and photonics industries and governmental institutions dealing with environmental and security issues.

Tie-up with German Aerospace Centre

- Partners: NTU and German Aerospace Centre.
- Established in 2009.
- Benefits: Propels the development of next-generation aeronautical and satellite systems and subsystems, and space science research.

Industrial PhD Programme

- Partners: NTU, Singapore's Economic Development Board and eligible local and multinational companies.
- Established in 2011.
- Benefits: Training to provide skilled manpower for Singapore's economy. Companies gain employees with advanced degrees, skills and experience in academic research as well as new products through industry-related research.

Optical Refrigeration

Laser Cooling Of Semiconductors

By Zhang Jun, Li Dehui and Xiong Qihua

Asst Prof Xiong Qihua is a Nanyang Assistant Professor at NTU's Schools of Physical and Mathematical Sciences (SPMS) and Electrical and Electronic Engineering (EEE). Dr Zhang Jun is a Research Fellow and Li Dehui is a graduate student at the SPMS.

The research findings described in this article were presented during an invited talk at the SPIE Photonics West conference 2013 in San Francisco, USA.

Laser technology is present everywhere in our daily life – in devices for the measuring of light and speed, illumination for entertainment purposes, in industry for cutting and welding of materials, in medicine for surgery, and in consumer products such as DVD players and laser printers.

Typically associated with illuminating or heating, laser rays can also be used to cool down objects, a phenomenon that seems counterintuitive. Though the scientific principle behind object cooling – also called optical refrigeration – through light rays was already proposed as early as 1929 by the German Physicist Peter Pringsheim, laser technology was not invented until 1958 and approaches to using laser light for cooling only developed in recent years.

Laser Cooling Of Gaseous And Solid Materials

Optical refrigeration works basically in the following way: A material (solid or gaseous) becomes excited when irradiated by a red-detuned (low energy) monochromatic laser, resulting in the spontaneous emission of high-energy luminescence light (a process called luminescence upconversion or anti-Stokes luminescence). Due to the energy-loss the material cools down.

The principle, originally proposed by Pringsheim, was first applied to dilute atomic gases, which were successfully cooled down to very low temperatures in the nano-Kelvin regime.

So far, lasers have been successfully used to cool dilute atomic gases and certain rare-earth-element doped glasses or crystals. However, approaches to apply laser cooling to semiconductors proved to be much more difficult.

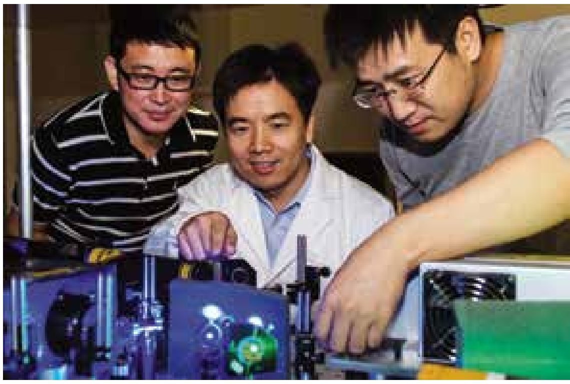


Fig 1: Laser cooling of a CdS semiconductor. Research team members (from left) Li Dehui, Asst Prof Xiong Qihua and Dr Zhang Jun discuss the experimental setup of laser cooling.

In contrast to atoms in gases, atoms in solids do not display translational kinetic energy and momentum since the atoms are "locked" in a crystalline lattice. However, solids have abundant lattice vibrations (phonons), which can provide the extra energy needed for the luminescence upconversion process.

Specifically, excitation dislodges electrons in the solid material and leaves behind a "hole". This electron-hole pair bound by electrostatic interactions, known as "exciton", interacts with the vibrations of the surrounding atoms, the phonons, and leads to conversion of heat into luminescent light. The loss of energy in form of light results in cooling of the material.

This property of solid materials was successfully used in rare earth doped solid materials, which could efficiently be cooled down from room temperature to 110 Kelvin (K) (equivalent to -163.15°C) but not beyond this bottom limit. Below this temperature, the doped materials cannot efficiently absorb the photons of the laser rays that are optimal for cooling.

On the contrary, direct bandgap semiconductors have a higher cooling efficiency and a lower cooling limit – approximately 10 K (-263.15°C) – than rare earth doped materials. If lasers could cool semiconductors down to 10 K, laser cooling could potentially be used to replace cooling with liquid helium.

However, in the last two decades, all efforts to achieve laser cooling of semiconductors using group III-V gallium arsenide quantum wells had failed. The reason is that – although luminescence upconversion can be readily achieved – group III-V semiconductor materials display weak electron-phonon coupling strength, high reabsorption of luminescence due to a large refractive index and high surface recombination velocity.

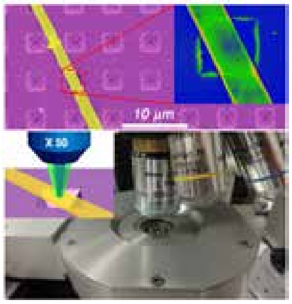


Fig 2: The top panel displays scanning electron microscope images of the nanoribbons suspended across holes in the silicon substrate. The close-up of one suspended part is shown on the right. The bottom panel displays the actual setup to perform the cooling experiment. The device was mounted inside a cryostat to accurately control the temperature. Two lasers were collimated on the same spot on the nanoribbons through a microscope lens.

Efficient Cooling Of Cadmium Sulphide Semiconductors Through Laser

Our research team recently achieved a breakthrough in the efficient cooling of certain semiconductors through laser light. Using red-detuned laser with a wavelength of 514 nm, our team was able to cool cadmium sulphide (CdS) semiconductors from room temperature down to -20°C (Fig 1).

Published in *Nature* as a cover story (*Nature* 493, 504–508, 2013; doi:10.1038/nature11721; Fig 3), the breakthrough experiment is regarded as a milestone in the evolution of solid-state semiconductor optical cryocoolers.

The research team discovered that group II-VI semiconductor CdS nanoribbons exhibited strong exciton-longitudinal optical (LO) phonon coupling, leading to strong luminescence upconversion facilitated by elimination of multiple LO phonons. Pumping by a 514 nm green laser resulted in cooling of CdS nanoribbons from 290 K down by approximately 40 K. Furthermore, cooling down by 15 K could be realised when starting from low temperatures – such as 100 K – and pumping by a 532 nm laser. Respective temperatures of the samples were measured by monitoring the Stokes photoluminescence peak shift through another low-power laser (at 473 nm), which collimated at the same spot as the pump laser (Fig 2).

Fig 3: Magazine cover reprinted with permission from Macmillan Publishers Ltd: *Nature*, 24 January 2013, Vol. 493, No. 7433; copyright 2013. The discovery has also been highlighted in *Nature Photonics* in its 2013 April and May issues.

The success of the laser cooling experiments can be attributed to two factors: Firstly, strong electron-phonon coupling makes it possible to eliminate more than one LO phonon during each upconversion cycle, efficiently removing the heat from the CdS nanoribbons. Secondly, luminescence re-absorption and recycling, which usually generates heat, is prevented due to the nanoribbons' low thickness (100 nm) of less than half the wavelength of the luminescence photons, leading to a high escape efficiency of upconverted photons through luminescence.

This work implies that other group II-VI semiconductors can potentially be laser cooled and opens new ways to investigate different laser cooling materials with strong electron-phonon coupling.

A Plethora Of Applications For Laser Cooling Of Semiconductors

Laser cooling of semiconductors has a multitude of potential applications. On-chip semiconductor optical cryocoolers can be integrated into electronic and optoelectronic devices. Important applications are in cooling high sensitive sensors and detectors such as infrared cameras in space because optical refrigerators are vibration-less, cryogen-free, compact and lightweight as well as highly reliable.

Currently, most types of cryocoolers used in space are mechanical or cryogen-based and come with many disadvantages compared to semiconductor optical cryocoolers. Other possible applications include night-vision goggles or medical devices such as MRI scanners, which require extreme cooling.

Furthermore, a radiation balanced laser or "athermal" self-cooling laser might be possible if a suitable gain medium mechanism to amplify the number of photons in the laser is established in the same laser cooling material. Currently, scaling up the cooling device for useful applications – for instance, to establish laser cooling in a bulk II-VI crystal – poses the biggest challenge. Nanoribbons are still too small to exhibit enough cooling power for the cooling of sensors and detectors.

The Magic Of Chemical Synthesis

By Zhang Hua

Constructing Ultrathin Nanostructures From A Vial

Ultrathin nanostructures hold great promise for various applications such as optical displays, electronic devices, magnets, catalysts and energy conversion and storage. Developing simple and robust methods for the chemical synthesis of ultrathin nanostructures will directly spur developments and innovation in technologies concerning communication, media and small energy-efficient devices such as mobile phones etc.

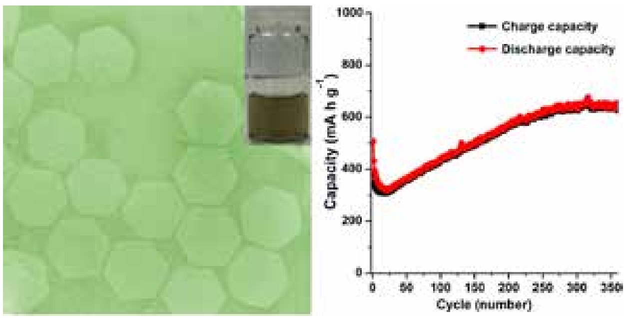


Fig 1. (Left) Transmission electron microscopy (TEM) image of ultrathin CuS nanosheets, and photograph (inset) of the CuS nanosheet solution. (Right) Cycling performance of the CuS electrode tested at a current density of 0.2 A g-1 within a voltage window of 0.005-3.0V.

Ultrathin Nanostructures: What And Why?

The term "ultrathin" is related to the dimensions of an object but is somewhat fuzzy in the scientific community since it does not explicitly specify a size range. Ultrathin nanostructures are usually considered to have at least one dimension approaching the size of one or two crystal unit cells (a unit cell being the smallest unit in the repeated pattern of a crystal), typically in the range below 5 nm.

Increasing interest in ultrathin nanomaterials arises from their attractive properties and various promising applications. One aspect correlating with the decreased diameters of nanomaterials is the relatively increased surface area, which has immediate effects when applied to sensors, catalyst supports, and environmental remediation applications.

Synthesis Methodologies For Metal Sulphide Ultrathin Nanostructures

Various recent breakthroughs in fabrication strategies allow the reproducible and affordable synthesis of such unique structures. However, the synthesis of nanostructures with diameters below 5 nm has so far been limited due to the use of expensive and low-yield techniques such as chemical vapour deposition (CVD). Thus, much recent research in nanotechnology has targeted the development of methodologies that allow the *de facto* synthesis and stabilisation of large numbers of ultrathin nanomaterials with structures that correspond to those predicted in theory.

In particular, ultrathin metal sulphide nanocrystals have drawn tremendous attention owing to their unique properties arising from their exceptionally small dimensions and the resultant quantum size effects that have been demonstrated in many important applications in a variety of fields, such as thermoelectric devices, magnets, and ion conductors. Although the synthesis of metal sulphide nanocrystals has been previously demonstrated, a fundamental challenge still remains in the production of uniform ultrathin metal sulphide nanocrystals with diameters below 5 nm.

Large-Scale Synthesis Of Metal Sulphide Ultrathin Nanostructures Based On The Colloidal Chemistry Method

One goal of our research group is to establish new methodologies for large-scale synthesis of uniform ultrathin metal sulphide nanocrystals. To effectively synthesise such ultrathin metal sulphide nanostructures via colloidal chemical synthesis, delicate manipulation of the interactions between crystal nuclei and ligand molecules is essential to achieve anisotropic growth of the nanocrystals along one specific orientation.

Assoc Prof Zhang Hua is head of the Division of Materials Science at NTU's School of Materials Science and Engineering. The described research project was published in Nature Communications *(2012), 3: 1177; DOI:10.1038/ncomms2181. More details can be found under http://www.ntu.edu.sg/home/hzhang/. Funding support came from the Singapore National Research Foundation under the CREATE (Campus for Research Excellence and Technological Enterprise) programme "Nanomaterials for Energy and Water Management", and through a start-up grant from NTU. Assoc Prof Zhang received one of the two inaugural Small Young Innovator Awards 2012 "for important contributions to novel low-dimensional nanomaterials", conferred by Wiley-VCH, publisher of the nanotechnology journal* Small, *and NTU's 2011 Nanyang Award for "Research Excellence in Materials Technology".*

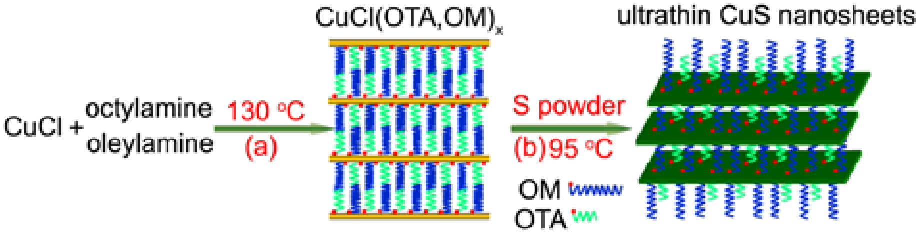


Fig 2. Schematic illustration of synthesis of ultrathin CuS nanosheets. Step (a): The (CuCl(OTA,OM)x) complex is formed by the reaction of CuCl, OTA and OM at 130 °C. Step (b): (CuCl(OTA,OM)x) complex acts as the template for synthesis of ultrathin CuS nanosheets after addition of sulphur (S) powder. OM: oleylamine; OTA: octylamine.

Up to now, several ultrathin metal sulphide nanostructures have been prepared via organometallic or organic solution phase synthesis. However, a general and facile method for the large-scale synthesis of well-defined ultrathin metal sulphide nanostructures had not been demonstrated so far.

Recently, our group succeeded in establishing a general soft colloid templating strategy for the synthesis of high-quality ultrathin metal sulphide nanocrystals with various compositions and phases, i.e. freestanding hexagonal 3.2 nm-thick copper monosulphide (CuS) nanosheets (Fig 1), hexagonal 1.8 nm-diameter zinc sulphide (ZnS) nanowires, orthorhombic 1.2 nm-diameter Bismuth (III) sulphide (Bi_2S_3) nanowires, and orthorhombic 1.8 nm-diameter stibnite (Sb_2S_3) nanowires.

The team has conducted a series of experiments to optimise the conditions for synthesis of high-quality ultrathin metal sulphide nanocrystals. Furthermore the researchers uncovered the formation mechanism of these nanostructures and established a chemistry template effects mechanism responsible for the formation of ultrathin nanostructures (Fig 2).

Due to their unique structural features, ultrathin metal sulphide nanocrystals show interesting properties, which are not only due to the uniform size and morphology, but also the ultra-small thickness features of CuS nanosheets.

The apparent properties of the ultrathin metal sulphide nanostructures are very promising for certain applications. As proof-of-concept, ultrathin CuS nanosheets were used to fabricate electrodes for lithium-ion batteries, leading to superior reversible capacities and cycling stabilities of the batteries, even after 360 cycles (Fig 1).

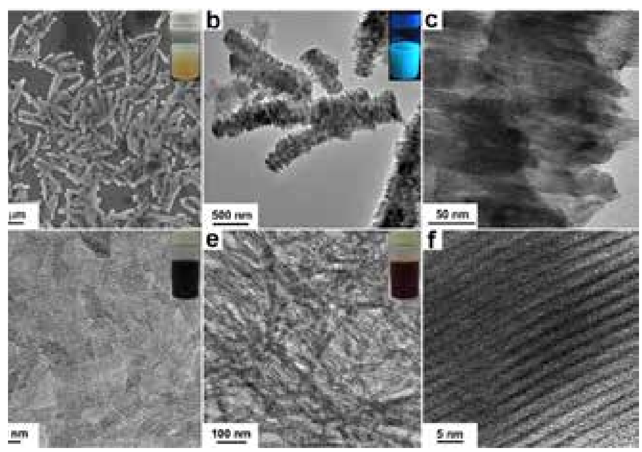


Fig 3. Field emission scanning electron microscopy (FESEM) and TEM images of ultrathin (a-c) ZnS, (d,e) Bi_2S_3 and (f) Sb_2S_3 nanowires. Photographs of ultrathin ZnS nanowire solution without and with 365 nm UV lamp excitation (insets a and b, respectively); photographs of ultrathin Bi_2S_3 (inset d) and Sb_2S_3 (inset e) nanowire solutions.

Robust And Versatile Method For Preparation Of Ultrathin Metal Sulphide Nanocrystals

The soft-templating synthesis mechanism can be used for the facile and high-yield production of novel ultrathin nanostructures with a wide range of applications in sensors, catalyst supports, environmental remediation and energy storage and conversion. So far, our research group successfully synthesised a series of ultrathin metal sulphide nanostructures (Fig 3) and is currently advancing the new method in order to synthesise other ultrathin metal chalcogenide nanostructures such as molybdenum disulphide (MoS_2) and tungsten (IV) sulphide (WS_2). In comparison with the organometallic thermo-decomposition and chemical vapour deposition (CVD) methods for preparation of ultrathin metal sulphide nanocrystals, the new synthetic strategy is environmentally friendly and economical because it uses non-toxic, phosphine-free and inexpensive reagents such as metal chlorides. Moreover, the described synthetic technique results in large amounts (gram scale) and high yields (~100%, without any further size-sorting process) of ultrathin metal sulphide nanocrystals at relatively low costs.

Vibration-Based Interfaces

Technological Advances For Large-Sized Surfaces

By Andy Khong Wai Hoong

Touch interfaces have been widely deployed to facilitate human-computer interactions in smart phones and tablet PCs. More recently, the use of touch interfaces has found applications in out-of-home advertising such as digital signage applications. Existing technologies for touch interfaces typically employ resistive or capacitive properties where the location of a finger on a surface is determined by a change in an electrostatic field.

While such technologies provide high accuracy, they are very costly for large-sized surfaces (i.e. >50 inches). In addition, these technologies do not offer cost-effective solutions for the conversion of after-market devices to touch interfaces since almost all touch technology needs to be pre-fabricated prior to shipment. Effective methods for the conversion of non-display and 3D objects into touch surfaces are also essentially non-existent in the current market. These technologies can be deployed where visual feedback may not be required, such as in home automation where home appliances and electronic devices can be operated by tapping on certain parts of an object or wall.

In contrast to existing resistive/capacitive technologies, a novel vibration-based technology, recently developed by our research team, allows converting any ordinary rigid surface into a touch interface. Prototypes of the technology are equipped with low-cost off-the-shelf sensors that are mounted on the surfaces and detect vibrations generated by impacts. The received signals are used to localise the signal source, which can be a finger or an object tapping or hitting the surface, thereby effectively converting rigid surfaces – made up of glass, wood, aluminium or acrylic-based materials – into touch interfaces.

The invention has several advantages over existing touch interface solutions. Using off-the-shelf piezoelectric sensors offers low-cost solutions for the large-sized (>50 inches) touch interface market. A 60-inch surface requires approximately twelve sensors, each at less than US$0.20. In addition, the new technology allows scaling of the touch interface by mounting the sensors according to specific needs. The sensors can be mounted using adhesive tapes or, for more permanent solutions, epoxy. Furthermore, surface-mounted sensors can be easily integrated into existing manufacturing processes to facilitate mass production.

Since the touch sensor technology is not limited to glass, any existing rigid surface or 3D object can be converted into a touch interface, opening up huge possibilities for applications beyond the immediate touch interface such as in the realm of non-display touch interfaces. These non-display interfaces can be used in industrial and/or commercial applications including non-destructive impact tests for rigid surfaces, detection and localisation of human footsteps for surveillance, home automation applications and human-object interactions.

Asst Prof Andy Khong is from NTU's School of Electrical and Electronic Engineering. He is the recipient of the Junior Chamber International "Ten Outstanding Young Persons Honouree Award 2011" and the "Prestigious Engineering Achievement Award 2012" from the Institution of Engineers Singapore (IES).

More details of the study can be found in the following publications: IEEE Transactions on Multimedia *13(3):487 (2011), DOI:10.1109/TMM.2011.2123084; and* IEEE Transactions on Multimedia, *DOI:10.1109/TMM.2013.2264656.The described research was funded through the Interactive Digital Media (Co-Space) and the Proof-of-Concept (POC) initiatives under the National Research Foundation (NRF). More recently, the research team has tied up with the Institute of Technical Education, Singapore, for the commercialisation of the described technology under the Ministry of Education (MOE)-NRF Translational R&D and Innovation Fund (MOE-TIF) scheme.*

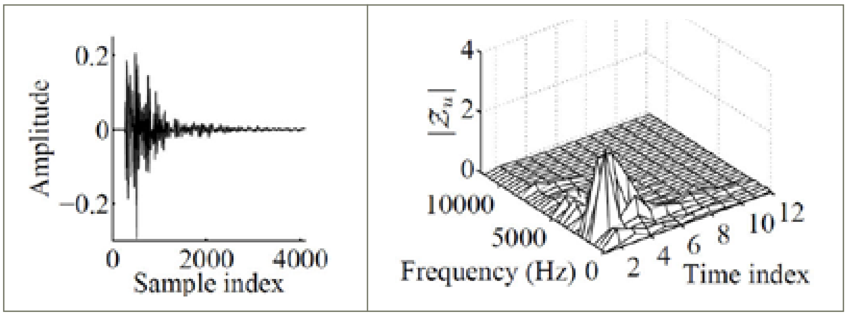


Fig 1. (Left) Time domain received signal of a metal stylus and (right) its Zak time-frequency transform representation on an aluminium plate.

Interdisciplinary Research: From Mechanical Modelling To Signal Processing Algorithms

The technology is based on estimating the location of an impact on a surface through vibration signals that can be generated by fingers or objects such as a stylus. To formulate and address the source localisation problem, the research team employed mechanical vibration theories for thin rectangular plates, the typical structures that are found on common objects such as tables, walls or glass windows. Exploitation of these theories led to the application of well-known mechanical models that explain how different frequencies of vibrating waves propagate at different speeds. In addition, these models allow insights into the dominant frequencies of vibrating waves (mode frequencies) and highlight the importance of transforming a time-domain vibration signal into a time-frequency domain for source localisation.

One approach exploited the uniqueness of each mode frequency across positions on the surface in order to localise impacts. Fig 1 shows an illustrative example of the received signal (left) and the signal's time-frequency domain equivalent using the Zak transform (right). Studies have shown that the amplitude of each mode frequency at a particular position on the surface is unique. Thus, the variance across time between two signals for each frequency is expected to be minimal if these signals were generated from the same location. The location of a tap can therefore be determined by comparing features of the received signal with that of the pre-recorded signals during the calibration phase.

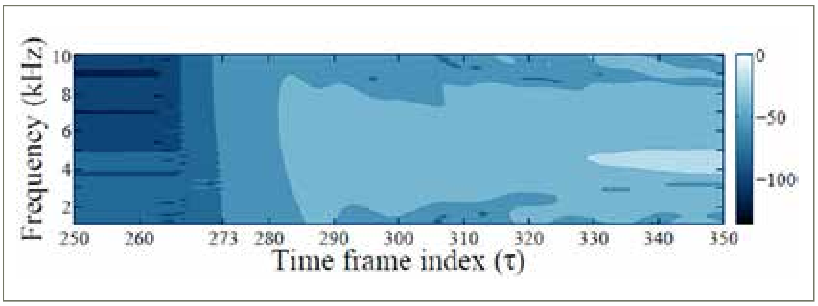


Fig 2. Time-frequency plot of a received signal where the signal onset is determined across a range of frequencies. Darker shades represent signals of lower energy.

Another approach is based on estimating the time-differences-of-arrival (TDOA) in the time-frequency domain. In this TDOA-based approach, estimating the location of an impact is similar to the global positioning system (GPS) by determining the differences in the times that signals originating from one source need to travel to pairs of sensors (i.e., difference of the signal onsets). The novelty of our approach is that the signal onset of each sensor is determined by exploiting a high-resolution time-frequency spectrogram such as shown in Fig 2. The signal onset is then determined using the Hermitian angle defined by the absolute of the complex-valued angle between two complex vectors. The difference in signal onsets between sensor pairs corresponds to the TDOA, which is then used for source localisation.

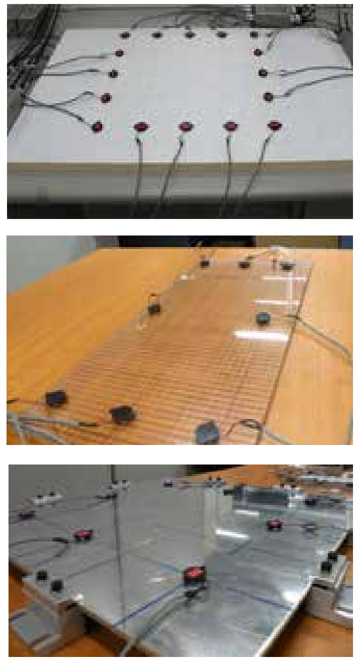


Fig 3. Testing of source localisation using surface-mounted piezoelectric sensors on 3-ply wood (top), acrylic (centre) or aluminium (bottom) plates.

From Models To Prototypes

The developed algorithms were implemented on a real-time digital signal processor and verified on a variety of materials including wood, acrylic, glass and aluminium, as shown in Fig 3. Several prototypes of surfaces converted into touch interfaces were constructed as proofs-of-concept, including a wooden top for gaming applications and flat panel displays for digital signage applications (Fig 4). The research team is currently working with external institutions and NTU's Nanyang Innovation and Enterprise Office (NIEO) to commercialise the novel technology.

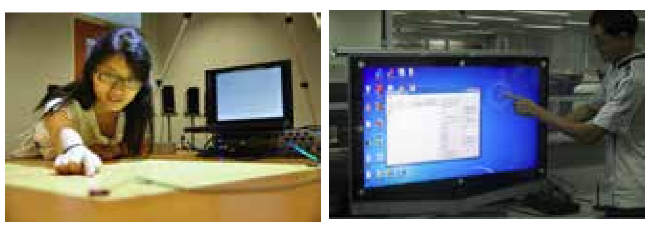


Fig 4. Real-time prototyping on a wooden surface (left) and the conversion of a flat-panel display to a digital signage (right).

BMW i3 Concept Coupé.
Picture credit: BMW Group.

New Mobility Concepts Beyond Fast Cars

The BMW Group–NTU Future Mobility Research Lab

"Sheer Driving Pleasure" – the advertising slogan of BMW, one of the world's premier car manufacturers, only conveys part of the company's visions for personal mobility of tomorrow. With its Future Mobility concepts that aim to integrate new solutions in transportation, safety, convenience and comfort with demands in sustainability and environmental-friendliness, BMW strives to go far beyond producing cars with exceptional driving performances.

The new Future Mobility Research Lab, a tie-up of the BMW Group with NTU, aims to advance these Future Mobility concepts in the setting of the Asian metropolis Singapore.

As part of BMW Group's scheme of joint research labs with key technological universities worldwide, the first such research cooperation for the BMW Group in Southeast Asia aims to tap into scientific knowledge, research know-how and talent pools at NTU to develop solutions for sustainability issues such as high energy-efficient and environmentally-friendly vehicles.

"Singapore offers the setting of a highly-dense, urbanised mega-city inhabited with a highly sophisticated and tech-savvy population and has a genuine interest in mobility and being environmentally-friendly. It also offers a perfect test bed because of its controlled closed enviroment. With its abundance of top talents and think tanks including the researchers at NTU, Singapore became a natural choice for setting up this joint research lab," said Dr Kay Segler, Senior Vice President of BMW AG.

Under the guidance of Prof Subodh Mhaisalkar, Director of the Energy Research Institute @ NTU (ERI@N), and Dr Mirjam Storim, Coordinator of University Cooperations of BMW Group, and equipped with an initial funding of S$5.5 million over the next four years and a team of eleven researchers, the Future Mobility Research Lab will draw from NTU's research strengths in battery technologies, electromobility, transport and innovation.

"Because of very stringent CO_2 emission standards, especially in Europe, every car company, including the BMW Group, needs an electric vehicle solution," said Prof Mhaisalkar.

"The three elements on which we are going to work with the BMW Group – technologies for electric vehicles such as batteries, technologies for mobility research to make our driving experience pleasurable, and technologies for safety solutions – are essentially on the cutting-edge of what is needed in automotive technology and sustainability," Prof Mhaisalkar added.

To develop key aspects relating to future transportation, research projects in the Future Mobility Research Lab will address three areas – next generation batteries for electric vehicles and other applications, human-machine interface, and mobility patterns and concepts.

Advanced Battery Materials

New materials, concepts and reliability technologies will be developed and tested in the battery research programme. The programme will develop methodologies to advance the use of nano-structured materials in order to improve energy density, power density and the cycle life of batteries. The role of new materials for the electrodes as well as thermodynamics-based studies to understand degradation mechanisms, especially in tropical environments like Singapore, and to improve battery safety will also form a key focus of the research.

Human-Machine Interface

Controlling your car with just your brain? Research at the Future Mobility Research Lab will explore possibilities to integrate human behaviour, perception and state of mind into car control. For example, identifying the mood, perception and alertness of the driver through sensors, cameras or touch pads and relaying the information to the car would add intelligence, increase safety and comfort, and reduce the risks of accidents. Likewise, increased information on the environment through features such as laser projections and holographic elements could enhance the driver's performance and car control.

Future Mobility Concepts

Studies on mobility patterns focus on consumer behaviour and acceptance of new mobility offerings for mega-cities such as multi-modal transportation and car-sharing concepts. Other personalised mobility concepts aim to integrate information on real-time traffic and parking situations with individual driving styles. These concepts comprise intelligent mobility services such as wake-up call services that are continuously updated according to actual predictions of required commuting times, intelligent routing systems and integrated parking search systems.

The lab also aims to test concepts developed in European environments in the setting of Singapore that differs significantly in terms of city and traffic management as well as in the behaviour and demands of consumers and drivers.

The new lab will also closely interact with TUM CREATE, a joint research centre of NTU and Germany's Technical University Munich (TUM is also another technological university that is a partner of BMW Group) that is sponsored under Singapore's National Research Foundation's CREATE (Campus for Research Excellence and Technological Enterprise) programme and focuses on electromobility in tropical urban settings.

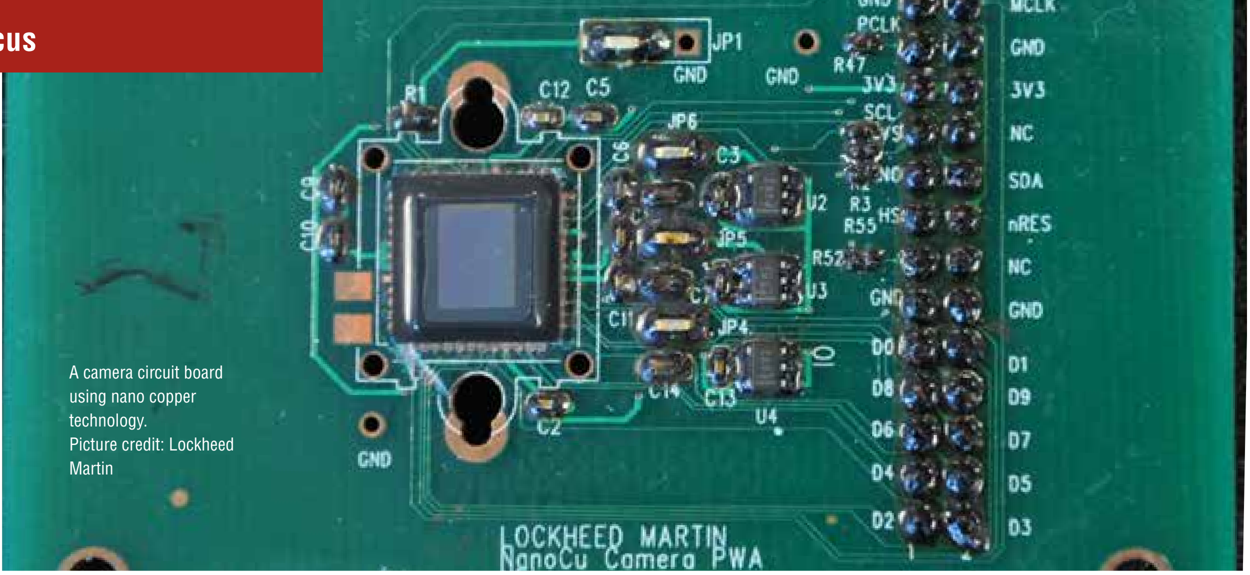
Collaboration with TUM CREATE will include research on advanced battery materials, infocomm technology, embedded systems,

Headup display. Picture credit: BMW Group.

electric vehicle technologies, grid infrastructure and transportation engineering.

"Our partnership with a global leader such as BMW Group is testament to NTU's strengths in electromobility, transport and innovation. As a fast-rising global university with a focus on sustainability research, we are confident this collaboration, the first such in Southeast Asia, will result in important discoveries in sustainable mobility and future motoring," said NTU President Prof Bertil Andersson.

(Left to right) NTU Chief of Staff Prof Lam Khin Yong, NTU President Prof Bertil Andersson, Dr Kay Segler, Senior Vice President BMW AG, and Mr Neil Fiorentinos, Managing Director BMW Group Asia, officially opening the BMW Group-NTU Future Mobility Research Lab.



A camera circuit board using nano copper technology.
Picture credit: Lockheed Martin

Nanotechnologies For Tomorrow's Electronics

The Lockheed Martin-NTU Joint Research Lab

Today's rapid technological developments need ever smaller electrical and electronic components and devices that are highly reliable, safe and affordable. Intrinsic challenges arising from the downscaling of electronics (such as electrical shorts) demand the development of new materials with novel properties and behaviours and increased research efforts in microelectronics and nanotechnology.

Striving to come up with new relevant materials and nanotechnology, the global security and aerospace company Lockheed Martin has started a new research collaboration with NTU.

The Lockheed Martin-NTU Joint Research Lab, located on NTU's main campus, aims to advance nanocopper-related technologies with a particular focus on CuantumFuse™, a revolutionary technology developed by Lockheed Martin.

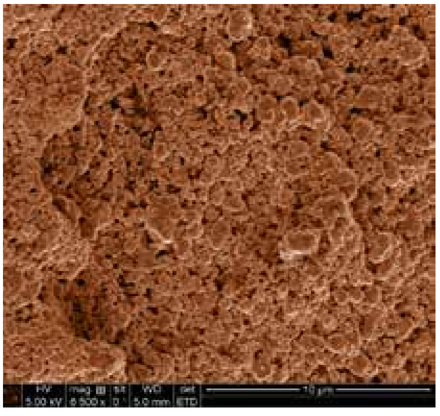
"This collaboration is a good example of how NTU can connect to global industrial partners to collectively develop innovative solutions to many global challenges faced today," said NTU Provost Prof Freddy Boey.

Soldering – A Key Aspect Of Microelectronics Production

Based on nanoparticles of copper, a metal with excellent conductive properties, CuantumFuse™ technology creates a new form of solder to generate high-tech microelectronics for various applications in the commercial market as well as for defence and security purposes.

Lockheed Martin, America's largest defence contractor, has important interests in space technologies, in particular in satellites, which strongly depend on microelectronics components that are reliable even under harsh environmental conditions. Since lead-based solders will be banned in a few years from all countries of the European Union due to environmental concerns and tin-based solders have proven to be unstable and failure-prone, copper has recently come into focus as the material of choice for fusing microelectronics components in high-tech devices.

Copper – in particular in the form of nanosized particles – has many properties that are superior to other metals. In sizes below 10 nm, nanocopper particles can fuse metals at temperatures below 200°C without the need for melting, leading to very strong connections. Moreover, soldering the copper wires in microelectronics with nanocopper does not generate brittle metal alloys (in contrast to tin-based solder). The resulting joints and devices are highly stable, reliable, safe and durable and exhibit high electrical and thermal conductivity.



Top view scanning electron microscope image of copper nanoparticles.
Picture credit: Ms Ng Mei Zhen.

"Nanocopper-based solder is technologically very interesting because you can fuse copper wires at low temperatures, below 200°C, but once they fuse, they are as stable as copper up to its melting temperature [about 1000°C]. That means you can use the solder in high-temperature applications and devices. So we gain not only high reliability, but these joints can also work in harsh environments, which is crucial for applications in transport systems – planes, trains, cars – where temperatures near the engines can be high or the devices are subjected to strong vibrations," said Prof Gan Chee Lip, Director of the Lockheed Martin-NTU Joint Research Lab.

Thus, CuantumFuse™ technology is especially valuable for expensive technologies deployed in satellites and transportation systems and for other high-tech products and devices that need to function under harsh environmental conditions while maintaining high levels of reliability and safety.

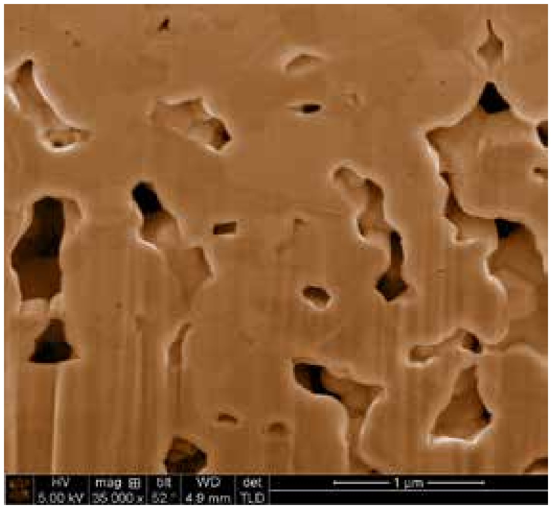
With about 15 to 20 scientists expected to work in the lab when it reaches steady-state, research projects at the Lockheed Martin-NTU Joint Research Lab initially focus on generating and optimising nanocopper particles with respect to parameters such as size, form, surface structure, temperature and pressure conditions. In addition to creating products with ideal fusing properties tailored to specific applications, nanocopper particles developed for the commercial market need to be chemically protected from oxidation and stabilised for long-term storage.

To address these and other challenges such as in 3D packaging – stacking of nanocopper particles under high pressure and high vacuum conditions – and in the scaling up of production processes, the new research lab leverages the expertise and skills of faculty and researchers at NTU, mainly from the Schools of Materials Science and Engineering and Electrical and Electronic Engineering.

Embedding Technologies Into Industrial Processes

Close collaboration between the researchers from NTU and their industry partner ensures that the new technology is aligned to and ultimately embedded into industrial production processes. Due to the distinct properties of nanocopper that allow fusing of copper joints at low temperatures, soldering with nanocopper-based solder can be performed directly on assembled polymer-containing microelectronic devices. Thus, costly re-adjustments to microelectronics assembly processes can be avoided.

The new research lab joins scientists from Lockheed Martin with faculty and students from NTU, starting out with a team of eight researchers. Set up with expected funds of up to S$10 million over



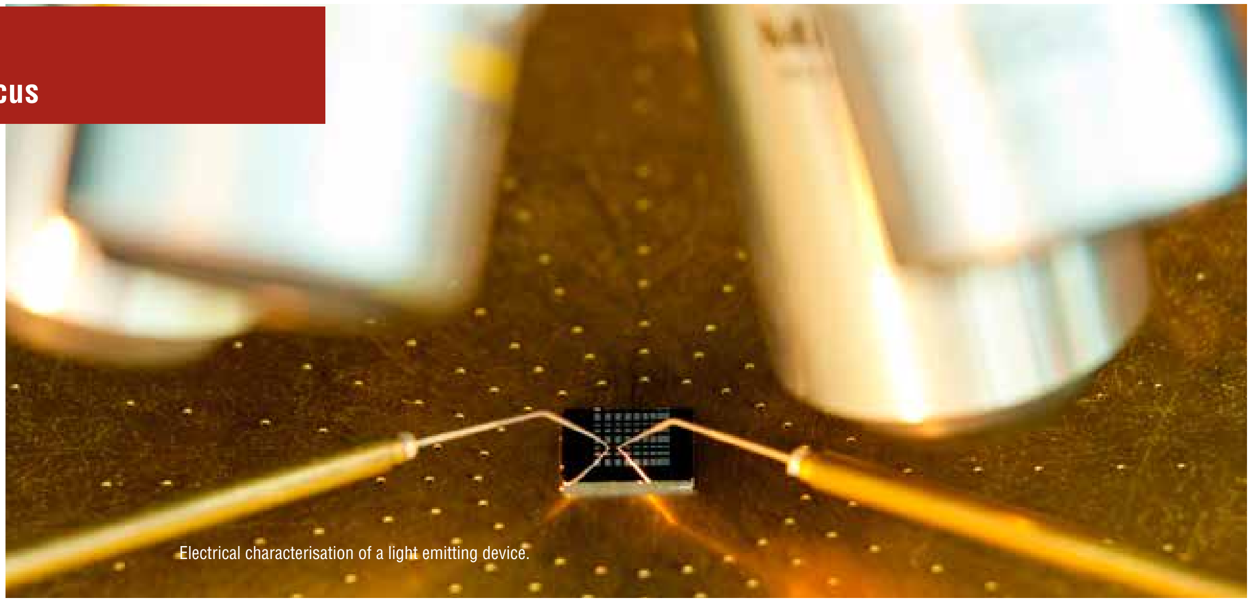
Cross-sectional scanning electron microscope image of fused copper nanoparticles. Picture credit: Ms Ng Mei Zhen.

the next four years, the collaboration will provide a platform for the exchange of knowledge and scientists between Lockheed Martin and NTU. Furthermore, the lab is expected to produce various prototypes of materials and technologies and to host prototype demonstrations.

"We look forward to working with our colleagues at NTU to advance the CuantumFuse™ technology and to identify target commercial markets and applications for this exciting innovation," said Dr Kenneth Washington, Vice President of Lockheed Martin Space Systems Advanced Technology Center (USA).

NTU aims to expand the scope of the lab beyond CuantumFuse™. **"We hope that in the near future, scientists from both institutions will continue to explore other research topics of joint interest in areas such as satellite technology, interactive media and perhaps even deep sea mining,"** said Prof Freddy Boey.

Formalising the Lockheed Martin-NTU Joint Research Laboratory: (From left) NTU President Prof Bertil Andersson; Mr Koh Boon Hwee, Chairman of NTU Board of Trustees; NTU Provost Prof Freddy Boey; Dr Kenneth Washington, Vice President of Lockheed Martin Space Systems Advanced Technology Center; Mr Vikram Verma, President of Lockheed Martin Strategic Venture Development; Dr Susan Ermer, Senior Manager, Fundamental Research, Lockheed Martin Advanced Materials and Nanosystems.



Electrical characterisation of a light emitting device.

A Tripartite Industry-Academia Research Endeavour

The CNRS International NTU THALES Research Alliance (CINTRA)

Two internationally renowned academic insitutions and a multinational industrial heavyweight are brought together in the French-Singaporean joint lab CINTRA.

The collaboration between NTU, France's Centre National de la Recherche Scientifique (CNRS) and the French-based electronics giant THALES was set up to develop nanotechnologies for the microelectronics and photonics industries. Research activites at CINTRA range from purely academic to fully industry-related. Spurring innovations for applications in sensing and communication will also benefit industries and governmental institutions dealing with environmental and security issues.

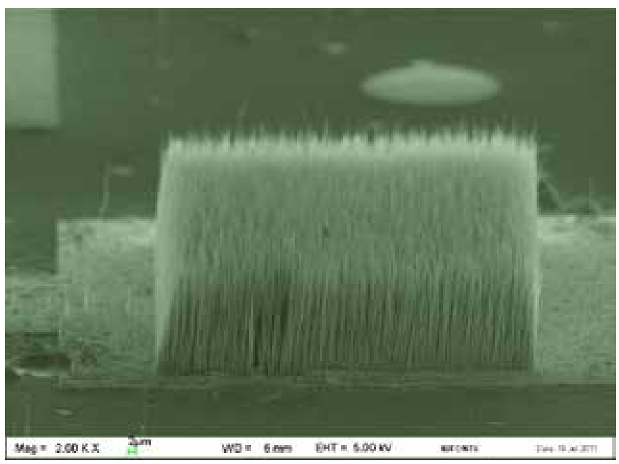
The tripartite research alliance CINTRA builds on NTU's and CNRS' strengths in research and THALES' experience in the global market. As the largest governmental research organisation in France, CNRS also holds strong ties with foreign universities and other academic institutions, with 30 joint labs worldwide. The partnership between NTU and CNRS allows both partners to extend their respective international ties in the Asian and European spheres and to foster the exchange of knowledge, researchers and students.

THALES, a global leader in aerospace, space, defence, security and transportation industries in the areas of opto- and nano-electronics, is already leveraging academic knowhow and manpower through several joint research labs with academic institutions worldwide. CINTRA – launched in 2009 – is the first such research alliance of THALES with an academic partner in Asia.

Turning Upstream Research Into Commercial Applications

With about 50 researchers, including 15 faculty members from NTU, three from CNRS, and one engineer from THALES besides PhD students and research fellows, CINTRA aims to develop novel components in nanoelectronics and nanophotonics with new functionalities and capabilities.

"We use carbon- and nanowire-based nanotechnologies and micro- and nanofibers for three main applications: nanopackaging, sensors, and interactions between microwaves and photonics," said CINTRA's Director, Prof Dominique Baillargeat.



Vertically aligned carbon nanotubes.

"Our main goal is to mix all these technologies, for example to combine electronics and photonics on the same chip for applications in telecommunication or sensing domains," added Prof Baillargeat.

Nanotechnological Research In A State-Of-The-Art Facility

An example of application-driven challenges that the Singapore-French team of scientists will be tackling is the development of enabling technologies such as a fully integrated sensing chip that processes and displays real-time multi-dimensional information, with high energy-efficiency and communication capabilities dedicated to environmental monitoring.

The research alliance model between research institutions and industry realised in CINTRA aims to not only drive research breakthroughs but also to secure intellectual property and innovations through patents and commercialisation. Though emphasis is put on fundamental research, CINTRA is also advancing projects that are directly linked with THALES.

Basic funding of CINTRA comes equally through its three partners. In addition, the alliance with the industrial partner THALES allows the facility to apply for funding under various funding schemes of Singapore's Economic Development Board (EDB) that are reserved for industrial collaborations.

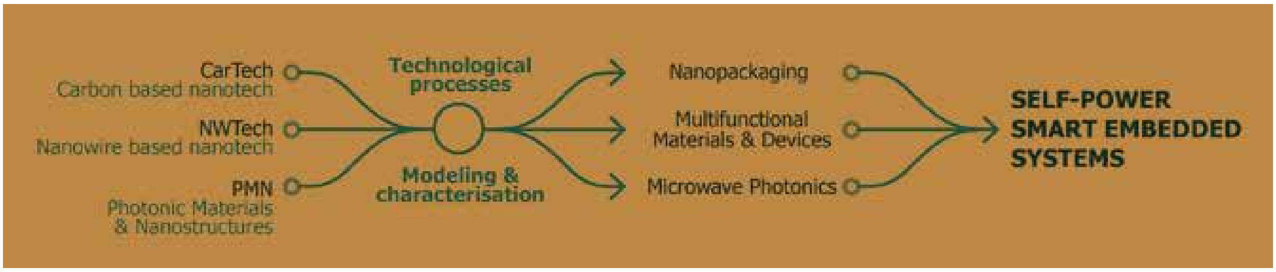
Grooming Talents For Industry

On top of research outcomes, THALES benefits from the tripartite research alliance particularly through the training of postgraduate manpower. As participants in the Industrial Postgraduate Programme – a PhD programme supported by the EDB and coordinated through NTU's Interdisciplinary Graduate School –

Tapering silica microfiber.

PhD students gain critical skills and experiences in academic as well as corporate R&D environments that make them ideal candidates for THALES' workforce. In addition, students from both NTU and CNRS benefit through reciprocal opportunities to study and work in international settings on different continents.

"Being part of CINTRA allows researchers of all levels to use broad academic and industrial expertise and state-of-the-art facilities made available by CNRS, NTU and THALES. Coming to CINTRA is an extraordinary scientific and human experience in a unique environment," adds Prof Baillargeat.



CINTRA research plan.

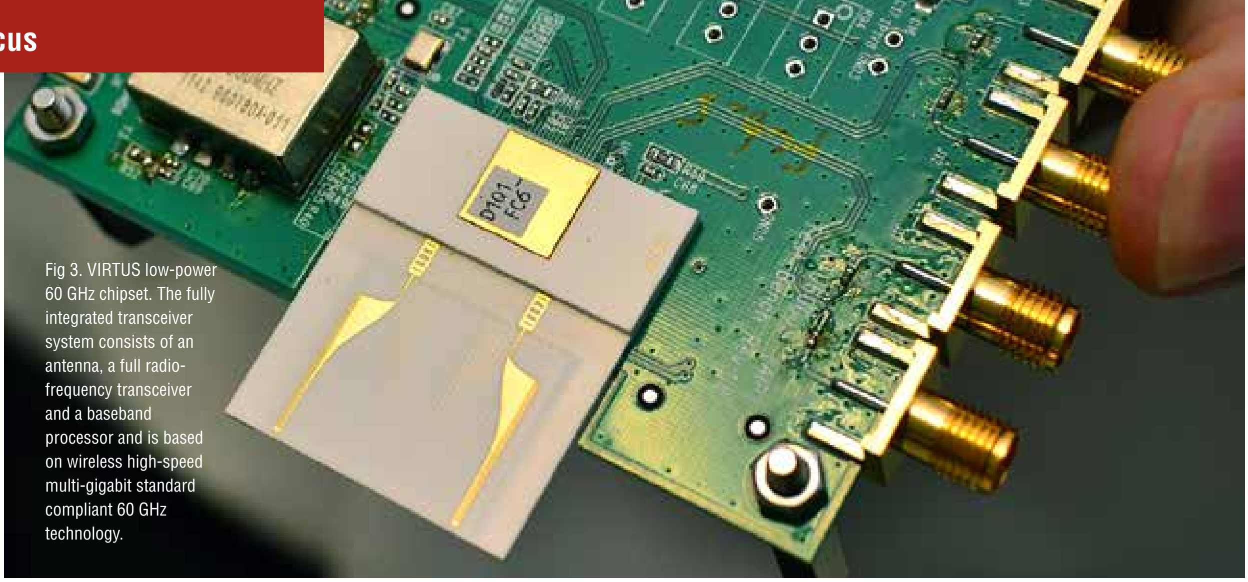


Fig 3. VIRTUS low-power 60 GHz chipset. The fully integrated transceiver system consists of an antenna, a full radio-frequency transceiver and a baseband processor and is based on wireless high-speed multi-gigabit standard compliant 60 GHz technology.

Driving Innovation And Economic Development In Electronic Devices

Low power consumption and high-speed transmission of large data volumes are the most important demands of today's consumer electronics, in particular for portable devices such as mobile phones and – even more so – smart phones.

"We need to design devices that consume very little power so their batteries require less frequent recharging or can last longer per charge," said Assoc Prof Siek Liter, Director of VIRTUS IC Design Centre of Excellence at NTU's School of Electrical and Electronic Engineering (EEE).

Founded in 2010 with funding of S$50 million from Singapore's Economic Development Board and NTU, VIRTUS' mission is to create innovation, knowledge and manpower to fuel Singapore's fast-developing integrated circuit design industry and boost Singapore's future economic growth.

"Singapore wants to shape its integrated circuit design industry to be at the forefront of technology. The centre's objective is to provide innovation and the relevant manpower so the country will be able to draw investors," Assoc Prof Siek said.

VIRTUS currently has more than 100 PhD students, of which more than half are sponsored through scholarships from multinational companies operating in Singapore. Its research focuses on low-power as well as energy-harvesting integrated circuit devices for applications in consumer electronics as well as medical and clean technologies.

"The idea of VIRTUS is to look beyond research," said VIRTUS founder Prof Yeo Kiat Seng (EEE). **"VIRTUS strives to lead the way in integrated circuit design to create innovations through multidisciplinary collaboration involving all our stakeholders, including our overseas partners,"** he added.

Lowering Energy Demands Of Electronic Devices

Low-power integrated circuit design and energy-harvesting devices not only benefit consumer products but also have widespread applications in biomedicine and support Singapore's drive to reduce its water- and energy-dependency. Developments in energy-harvesting devices make use of energy ubiquitously present in the environment such as radio-frequency signals, light or vibrations to charge the devices' batteries wirelessly.

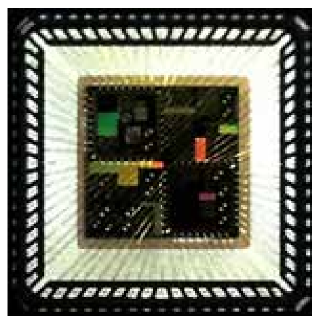


Fig 1. The inside of the batteryless transceiver.

One of VIRTUS' recent inventions in this area is a batteryless fully integrated transceiver that can harvest energy from Wi-Fi nodes or radio waves and achieves a significant power consumption reduction of 11 times compared to conventional transceivers. Developed by the research team of Asst Prof Boon Chirn Chye (EEE), the 2.4 GHz batteryless transceiver, which includes an energy-aware radio-frequency chip (Fig 1), solves the critical problem of high power needs for wireless communication. Applied to the remote monitoring of patients, these transceivers could relieve patients from frequent visits or extended stays in hospitals. Data of vital signs such as heartbeats, respiration and blood pressure,

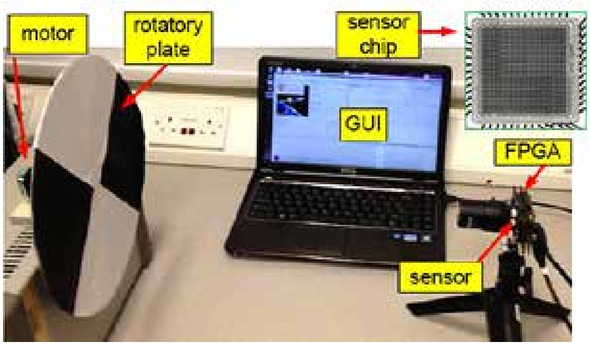


Fig 2. Experimental setup of the high-speed motion detection sensor. The "Asynchronous full-array-parallel ultra-fast motion detection imager" allows the detection of high-speed pixel-parallel motion of an object at the focal plane. Based on new chip design using special algorithms, each pixel in the sensor can individually monitor the change of light and report an event if a threshold is reached. The output of the sensor is not a frame, but a stream of asynchronous digital events and its speed is not limited by any traditional concepts such as exposure time and frame rate. A demo video can be found at: *http://www.ntu.edu.sg/home/eechenss/Research/2012-chip-AER/Motion-Sensor-1.mp4*.

detected by miniature sensors attached to the patients, can now be wirelessly transferred to central locations for recording and real-time monitoring.

High-Speed Motion Camera – More Content in Less Space

A high-speed motion detection image sensor, developed by a VIRTUS research team led by Asst Prof Chen Shoushun (EEE), enables storage of 100-1000 times more video content in the same memory space than achievable through traditional approaches (Fig 2). The "Asynchronous full-array-parallel ultra-fast motion detection imager" can detect fast motion, which is traditionally captured by expensive high-speed cameras, running at thousands of frames per second but with hundreds of times less data, thus drastically reducing the costs of signal transmission, storage and processing. Key applications of the new technology are found in quality control and inspection of industrial processes.

Chipsets For The Superfast Transmission Of High-Quality Video Contents

Syncing of high-quality videos across various electronic devices such as mobile phones, laptops and tablets with the currently available low bandwidth wireless technologies Wi-Fi and Bluetooth is often slow and impaired by noise interference. Researchers from VIRTUS and the Institute of InfoComm Research under the Agency for Science, Technology and Research, led by Prof Yeo Kiat Seng and Dr Ma Kaixue from NTU's EEE, have developed a low-power 60 GHz "System on Chip" named the VIRTUS chipset for the mobile and broadband markets (Fig 3, Top left page).

Applications for the mm-wave integrated circuit technology include wireless display, mobile-distributed computing, live high-definition video streaming and real-time interactive multi-user gaming. A spin-off company will advance development of the low-power 60 GHz VIRTUS chipset.

New Devices For Safety Screening Of Food, Water And Drugs

Drug testing guidelines already require the screening of cellular ion channels, pore-forming proteins that control the flow of ions across cell membranes and play critical roles in the human central nervous system. Recently also applied to food and water safety screening, the future market for ion channel testing technologies is estimated to comprise US$500 million yearly. The "Ion Camera", an invention coming from the lab of VIRTUS researcher Dr Yan Mei (EEE), is a real-time, high-sensitivity and high-resolution ion detection system that comprises a two-dimensional ion-sensitive-field-effect transistor (ISFET) sensor array and an on-chip high-speed readout circuitry (Fig 4). The system is able to detect a variety of ions such as hydrogen, calcium and chloride and can measure their densities and track their movements in real-time. In addition, by applying MEMS microfluidic technology, the multidisciplinary ion-camera chips were developed towards high-throughput DNA sequencing that can also be applied to food safety testing (based on the genetic identification of microbial contaminants), drug discovery and personal genome analyses.

The cutting-edge innovations developed at VIRTUS have recently captured the attention of one of the three largest chip producers in the world. Starting this year there will be more advanced collaborations with these leading foundries in several joint projects with VIRTUS to develop novel solutions in integrated circuit design.

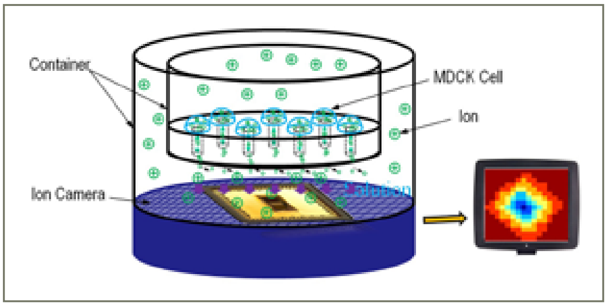


Fig 4. Working principle of the Ion Camera: Treatment of a culture of Madin Darby Canine Kidney (MDCK) epithelial cells with a test substance results in an altered ion flow through the cells' ion channels. Ion movements can be detected in real-time by the ion camera. The innovative sensor performance – better spatial resolution (64x64), better sensitivity and fast frame rate (1200 fps) – is achieved by combining traditional ISFET pH sensor design with advanced complementary metal oxide semiconductor (CMOS) image sensor technology.

Optical Engineering: Development of a low-cost camera to monitor glaucoma in the anterior chamber of the eye.

Centre For Optical And Laser Engineering

Supporting Singapore's Future Precision Engineering Industry

Optical Engineering – instruments and technology that source, detect and control visible and invisible forms of light and radiation – is used in a multitude of devices such as digital cameras, smart phones, microscopes, DVD players and the optical computer mouse. Research and development (R&D) in these devices merges technological advances in optical and laser engineering. Optics and lasers also play key roles in high-tech precision manufacturing and measurement systems as well as in biomedical diagnostics and medical treatments and hold big growth potential both in the local and global markets.

In close collaboration with companies, NTU aims to advance research in optics and laser under its new Centre for Optical and Laser Engineering (COLE).With a funding of S$30 million from Singapore's Economic Development Board (EDB), NTU and various industry and research sources, the new centre aims to facilitate joint industry-academia research in optical and laser engineering and to support small and medium-sized enterprises in Singapore to gain a foothold in the global competition.

"Optics will be one of the major drivers of technology in the 21st century," said NTU's Provost Prof Freddy Boey. **"Together with our partners, COLE will focus on high-value manufacturing solutions targeted at the industry and will bring about greater efficiency as well as new commercial applications. Going forward, we expect that more industrial partners will join us in growing the local R&D scene and keep Singapore at the cutting edge of technology."**

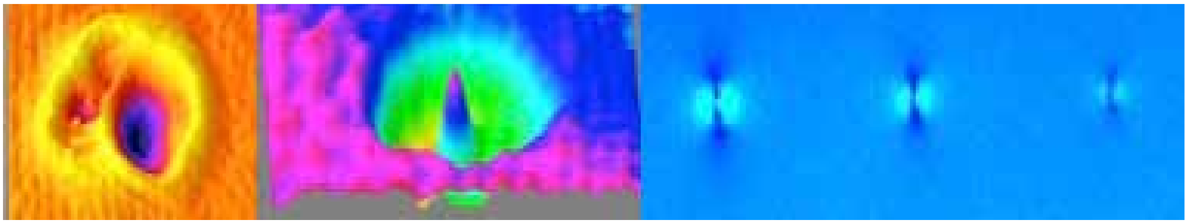
Located at NTU's School of Mechanical and Aerospace Engineering (MAE), COLE aims to develop innovative devices and streamlined processes and to train manpower in optical and laser engineering for Singapore's precision optics industry. By offering the option to specialise in Optical Engineering as part of its Master of Science in Precision Engineering degree programme, NTU is already responding to the growing demand for optical and laser engineers.

Skilled Manpower For Singapore's Optical Engineering Industry

COLE not only aims to become an R&D hub in optical engineering but also to orchestrate and advance education and training to meet future demands in skilled manpower. Reaching out to society, research institutes, associations and industry, COLE engages in technology transfer, conferences and exhibitions, student mentorship programmes as well as specialised courses and workshops targeted at students and professionals.

Under the Industrial Postgraduate Programme supported by the EDB, eligible local and multinational companies with local R&D efforts in optics and lasers can enrol employees under COLE to pursue their PhD on research projects relevant to their employer. Through R&D training of the postgraduates both in industrial and academic settings, the programme produces a pool of skilled manpower for Singapore's future precision optics industry.

In addition, companies can benefit from the pool of undergraduate engineering students enrolled in NTU's Master of Science in Precision Engineering degree programme through engaging the students in short-term industrial research projects.



Laser damage detection and profiling using patented technologies developed at COLE.

Industrial Partnership Scheme For R&D And Marketing

Under the versatile Industrial Partnership Scheme, companies can draw knowledge and expertise from academia through interactions with faculty across the university, attend workshops and seminars, use equipment and facilities at NTU, engage NTU students in research projects and utilise COLE's close association with the Optics and Photonics Society of Singapore as a marketing platform, e.g. through R&D showcases at exhibitions and conferences.

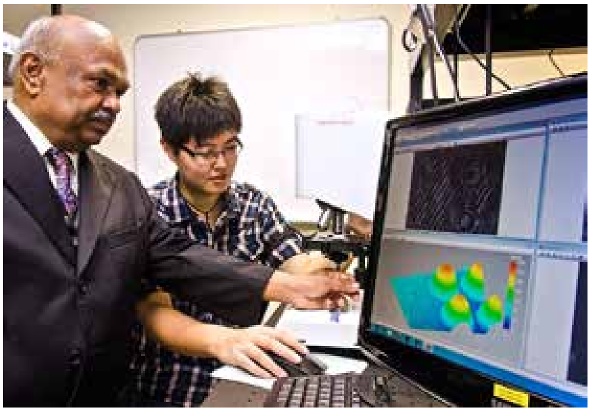
Several diverse approaches to collaborative research projects – sponsored, collaborative or contract – allow individual solutions tailored to the needs of industry partners. Based on individual agreements with the university that require industry partners to contribute funding in relation to their level of engagement, seven Singaporean companies – Sunny Instruments Singapore, WaveLab Scientific, JM Vistec System, Life Technologies Holdings, Disco Hi-Tec (Singapore), Opto-Precision, Precision Optical Systems Singapore – and three multinational companies – KLA Tencor, Edmund Optics and SICK Pte Ltd. – have tied up with NTU under the Industrial Partnership Scheme to date.

R&D At Cole: The Collaborative Projects Scheme

Joint research projects between NTU's engineering schools and individual industry partners are supported under the Collaborative Projects Scheme. Research at COLE focuses on three key areas: computational optics, optical metrology and instrumentation, and laser processing and patterning.

"In recent years, NTU has developed many new optical and laser technologies, such as a patented lens-less 3D microscope, which allows us to take a photo and focus on the details later. We have also been successful in developing precision laser systems, which improve emerging technologies, such as 3D printing and nano-patterning. Optical and laser engineering research at COLE will accelerate the growth of the precision engineering and biomedical sectors in Singapore and beyond," said COLE's Director Prof Anand Krishna Asundi from NTU's MAE.

Under four initial joint projects, NTU will work with industry partners to develop lens-less microscopes, new ways of 3D measurements beneficial for structural engineering, and new devices with higher resolution and lower costs for medical imaging and other biomedical applications. Another joint project under this scheme brings together scientists and engineers from NTU's MAE and the world's largest oilfield services company Schlumberger to research mechanical properties of drilling rods.

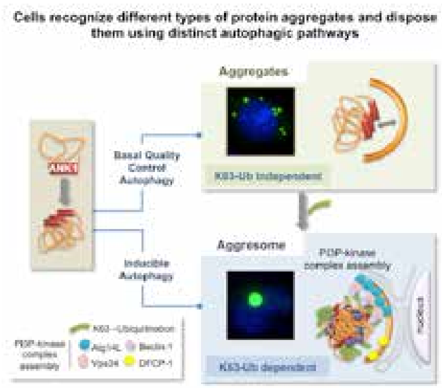


COLE's Director Prof Asundi (left) working with his student to use the patented Holoscope for 3D measurement of micro-objects.

To extend its research activities even further, COLE is already starting to engage in research collaborations with top international optical engineering research centres – the Centre for Laser Aided Intelligent Manufacturing at the University in Michigan, USA; the Institute of Technical Optics at the University of Stuttgart, Germany; the Centre for Optics Research and Education at Utsonomiya University, Japan; and the Institute of Optics at the University of Rochester, USA. These signify the beginning of a new international research consortium in the area of optical and laser engineering.

In Focus stories by Nicola Wittekindt

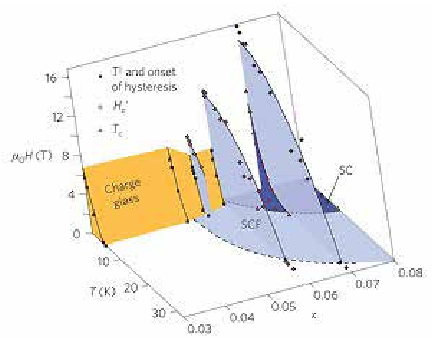
New Insights Into Key Cellular Mechanisms Pave The Way For Novel Treatments For Neurodegenerative Diseases



Neurodegenerative diseases such as Parkinson's disease and Alzheimer's disease are associated with aggregates of proteins that fail to be cleared from brain cells by the cells' proteolytic systems. A study led by Asst Prof Esther Wong from NTU's School of Biological Sciences, in collaboration with US scientists from the New York Albert Einstein College of Medicine, Mount Sinai School of Medicine and Boston University Medical School, finds that inclusion of the protein synphilin-1 (Sph1) in protein aggregates promotes autophagy, a degradative mechanism that sequesters and discharges protein aggregates and other dysfunctional cellular components. The researchers further show that small protein aggregates are mainly removed through basal quality-control autophagy while disposal of large protein aggresomes is achieved through inducible autophagy. In addition, the study demonstrates that the ANK1 peptide domain of Sph1 is both necessary and sufficient for basal as well as inducible autophagic clearance. The study has implications on the development of therapeutics for cellular disorders that are associated with dysfunctional protein aggregates.

The article "Molecular determinants of selective clearance of protein inclusions by autophagy" was published in Nature Communications *(2012) Vol. 3: 1240; DOI:10.1038/ncomms2244.*

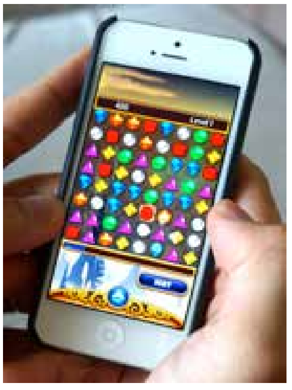
Unravelling The Electronic Structure Of High Temperature Superconductors



Phase diagram of the glassy region and of the onset of superconducting fluctuations in $La_{2-x}Sr_xCuO_4$.

The complex electronic structure of high temperature superconductors poses immense challenges in determining how these materials lose their electrical resistance and how to modify them to make this transition occur above room temperature. Assoc Prof Christos Panagopoulos from NTU's School of Physical and Mathematical Sciences, together with an international research team, elucidated the processes that are involved in the transition from plain insulators such as La_2CuO_4 to unconventional superconductors through doping with strontium ($La_{2-x}Sr_xCuO_4$). Their study indicates a charge ordering instability due to a disproportionation of electrons – an intrinsic property of these superconductors – that is linked to the emergence of high temperature superconductivity, and demonstrates that the superconductor insulator transition is not an abrupt transition. Understanding the electronic properties of these materials is essential for innovations such as power lines using superconducting wires that do not lose electricity in transit. In addition, superconductors exhibit special magnetic properties that could allow for levitated, frictionless trains and stronger, more durable permanent magnets like those used in wind turbines.

The article "Emergence of superconductivity from the dynamically heterogeneous insulating state in $La_{2-x}Sr_xCuO_4$" was published in Nature Materials *(2012) Vol. 12: 47; DOI:10.1038/NMAT3487.*



Regular Video Game Play Improves Performance On Tasks That Use Similar Mental Processes

Frequent training of specific cognitive abilities in a video game can improve subsequent performance in tasks that share common underlying demands and mental processes, according to a recent study by Asst Prof Michael Donald Patterson and graduate student Adam ChieMing Oei from NTU's School of Humanities and Social Sciences. After one month of playing for an hour a day, study participants who had played an action game had improved their capacity to track multiple objects in a short span of time, while players of hidden-objects, match-three-objects and spatial-memory games improved their performance on visual search tasks. This is the first study to show that video game playing using smart phones can lead to cognitive improvements and to demonstrate that different video games can lead to different improvements.

The study "Enhancing cognition with video games: A multiple game training study" was published in PLoS ONE *(2013) Vol. 8(3): e58546, DOI:10.1371/ journal.pone.0058546.*

A Novel Low-Cost Nano-Structured Material To Generate Renewable Energy And Clean Water

Assoc Prof Darren Sun, demonstrating the TiO_2 membrane-based advanced water reclamation system.

A novel nanomaterial, formed by mixing a polymer with Titanium dioxide (TiO_2) and in some cases carbon, copper oxide or zinc oxide, has an extraordinarily wide range of potential uses in energy, environmental and health issues. As discovered by Assoc Prof Darren Sun from NTU's School of Civil and Environmental Engineering, TiO_2, a cheap and abundant material, exhibits photocatalytic, hydrophilic and anti-microbial properties. Due to their photocatalytic properties, membrane-embedded TiO_2 nanofibers, nanotubes or nanowires enable water-splitting reactions with high efficiency comparable to those of expensive Platinum compounds, generating energy in the form of hydrogen and cleaning wastewater at the same time. TiO_2's hydrophilic properties allow the easy flow of water through TiO_2 membranes while retaining contaminants such as salts, making the membrane applicable for forward osmosis desalination and pressure-retained osmosis techniques. In addition, TiO_2's anti-microbial properties render the membranes suitable for anti-bacterial and highly oxygen-permeable bandages. Furthermore, Assoc Prof Sun's research group recently developed black TiO_2 polycrystalline sheets that can be applied as flexible solar cells or to increase the capacity and life-span of thin Lithium Ion batteries commonly found in small devices when used as the battery's anode. A new start-up company will help to commercialise this highly versatile product.

The research was published in Water Research *(2013) DOI:10.1016/j.watres.2012.12.044;* Energy Environ. Sci. *(2013) Vol. 6: 1199, DOI:10.1039/C3EE23349A; and* J. Mater. Chem. *(2012) Vol. 22: 24552, DOI:10.1039/C2JM34142E.*

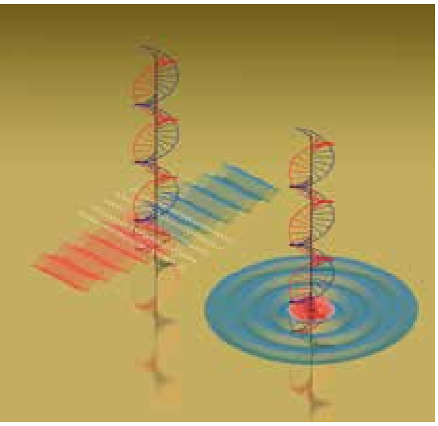
Assoc Prof Darren Sun recently won the President Award from Tokyo University of Science, Japan, for developing the Titanium dioxide technology for pollutant removal, water reclamation and generation of hydrogen from water.

SynPhNe: A Platform For Recovery From Paralysis After Stroke

Dr John Heng (right) and Banerji Subhasis (left), wearing the arm gloves.

Rehabilitation after stroke is a long and cumbersome process with often limited success and high patient dropout rates. The Synergistic Physio-Neuro Stroke Rehabilitation Device (SynPhNe), developed by a team of researchers led by Dr John Heng and PhD student Banerji Subhasis from the Robotics Research Centre at NTU's School of Mechanical and Aerospace Engineering, has shown impressive results in improving patients' physical abilities beyond the levels reached by conventional rehabilitation therapy. SynPhNe consists of patented computer software connected to a specifically designed neural sensor headset and a sensor arm glove, and allows the coordinated training of the patient's brain and body abilities. Conveniently usable at home, the multi-modal associative learning system requires the patient to follow instructional videos for limb movements while the sensors provide feedback on the stress, attention, activation and relaxation levels of both brain and muscles. Immediate feedback enables the patients to learn, adjust and control the brain-body coordination of the affected muscles. Patients who had reached a progress plateau after several months of conventional treatment achieved significant progress in their ability to carry out everyday tasks after using SynPhNe for a 4-week trial period. A start-up company is being planned to commercialise a portable version of the SynPhNe stroke therapy kit for rent or at-home rehabilitation.

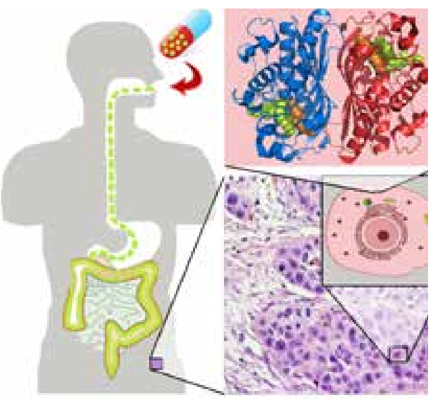
Precise Directing Of Optical Data Signals to Electronic Devices


Picture Credit: Samuel Twist.

A new generation of on-chip optical interconnects can convert data information directional and efficiently from optical to electronic devices. An innovative study, led by NTU graduate Dr Jiao Lin and the Microoptics group from NTU's School of Electrical and Electronic Engineering together with researchers from Harvard School of Engineering and Applied Sciences, USA, discovered a way to precisely control the directivity of data signals. Using a nanoscale coupler made up of a thin sheet of gold, incoming light is converted into surface plasmon polaritons (SPPs) – the oscillations or 'waves' formed by the electrons at the surface of a metal. Tiny slit perforations in the gold sheet device – featuring a distinct herringbone structure – direct the incoming light depending on its polarisation. Left- and right-handed circular light will be routed to the left or right, respectively, while linear polarised light will be routed equally in both directions. Thus, manipulating the polarisation of the light signal allows precise directing of the data signal. In addition, the new plasmonic device can be applied to circular structures that create radially convergent and divergent SPPs. The innovation has important applications in optical information technology and optoelectronics.

The study "Polarization-controlled tunable directional coupling of surface plasmon polaritons" was published in Science *(2013) Vol. 340: 331; DOI:10.1126/science.1233746.*

Direct Monitoring Of Drug Efficacy In Cells And Tissues


The path of a drug from pill to drug target.

The efficiency with which a drug reaches and interacts with its target proteins in cells is critical for the outcome of drug therapies. Drug-target engagement can vary significantly during therapy and in individual patients, bearing risks of inherent or acquired drug resistance. In addition, the adverse effects of drug therapies are often caused by excessive or off-target drug binding. Due to the lack of suitable methods to monitor drug-target engagement directly in cells and tissues, drug efficacy is measured indirectly in downstream cellular responses. A new method discovered by a research team led by Prof Pär Nordlund from NTU's School of Biological Sciences allows measuring drug-target engagement directly in cell lysates of mammalian cell cultures. The novel cellular thermal shift assay (CETSA) measures changes in the thermal melting curves and thus stabilisation patterns of target proteins exposed to different temperatures and varying drug concentrations. The isothermal dose-response procedure applied in the CETSA yields characteristic fingerprints of drug-target engagement and allows validating drug binding in cancer cell lines and monitoring of drug transport and activation processes, off-target effects, drug resistance and drug distribution in tissues. Since the new method will likely be a valuable tool at many steps of drug development, several pharmaceutical companies have already expressed interest in research collaborations.

The study " Monitoring drug target engagement in cells and tissues using the cellular thermal shift assay" was published in Science *(2013) Vol. 341: 84; DOI:10.1126/science.1233606.*

Tan Chin Tuan Centennial Professor

Inventor Of Sustainable Energy Solutions

Prof Gehan Amaratunga

Nanotechnology – the manipulation of matter at the atomic or molecular level – opens up new horizons in fields such as electronics and energy management. Using the science of the very small to make energy generation and storage more sustainable is what motivates sustainable electronics pioneer Prof Gehan Amaratunga.

Since August 2012, Prof Amaratunga has been contributing to the university's "green" energy drive as the second Tan Chin Tuan Centennial Professor appointed at NTU. The prestigious endowed Tan Chin Tuan Centennial Professorship is funded by the Tan Chin Tuan Foundation, a philanthropic organisation in Singapore. At NTU's School of Electrical and Electronic Engineering, Prof Amaratunga leads several important projects in energy-saving electronic systems.

His research interests lie in power electronic devices and integrated circuits as well as the use of nanotechnologies for energy. Working on integrated power conversion circuits, he pioneered the integration of logic level electronics for signal processing and high-voltage power transistors in a single microchip. His research into the electronic applications of carbon nanotubes led to the first demonstration of the nanotube-polymer composite solar cell.

He is also interested in developing devices for maritime sensing and monitoring applications.

Giving the Tan Chin Tuan Centennial Professorship Public Lecture in September 2012, Prof Amaratunga provided captivating insights into the opportunities that arise from deploying nanotechnology in energy generation and storage, in particular, the enhancement of energy storage devices like batteries and supercapacitors through the use of nanosized materials. The NTU-Cambridge Joint Programme in Semiconductors for Energy Conversion and Control, which Prof Amaratunga was instrumental in establishing at the School of Electrical and Electronic Engineering, now brings together research talents from both NTU and Cambridge University. This initiative involving graduate students is well-funded by Singapore's National Research Foundation under the Cambridge-CREATE partnership. As part of the tie-up, Prof Amaratunga co-organised with Cambridge University two well-received joint workshops on semiconductors for energy conversion and control.

"NTU is privileged to have Prof Amaratunga share his vast knowledge with the global scientific community through talks, seminars and the annual Tan Chin Tuan Centennial Professorship Public Lecture. He is also an asset to NTU in our continued conversations and tie-ups with major industrial partners to develop innovations that harness the full potential of nanotechnology," said NTU's Provost, Prof Freddy Boey.

"Being both a researcher and a savvy technopreneur, Prof Amaratunga has been a huge source of inspiration to faculty and students within the Power Engineering division and across the College of Engineering. We are pleased that he remains highly committed to working with us on various key projects here in NTU," added Prof Yoon Soon Fatt, Chair of the School of Electrical and Electronic Engineering.

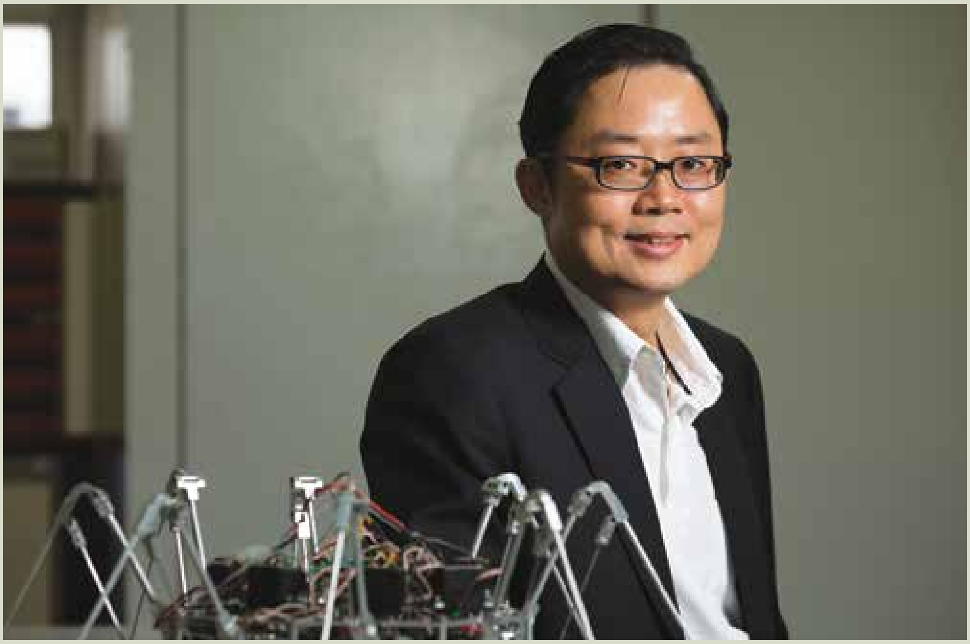
In parallel to his appointment at NTU, Prof Amaratunga holds the 1966 Chair and Professorship in Engineering at the University of Cambridge, where he is head of Electronics, Power and Energy Conversion in the Department of Engineering. For the past two years, he has also been the Chief of Research and Innovation at the newly formed Sri Lanka Institute of Nanotechnology. This has given him, as he puts it, the opportunity to direct research where "the best minds are focused on some of the most urgent problems of sustaining humankind on the planet without destroying it" – food, water, energy and health issues. These are also very much priority areas at NTU, a world leader in sustainability.

Prof Amaratunga's work has resulted in 32 patents in the field of novel power electronic device structures. He is the founder and was Chief Technology Officer and Executive Director of power management integrated circuits company Cambridge Semiconductor Ltd, which commercialised a new generation of power and mixed-signal integrated circuits for power management with venture capital investment. To date, the UK company has shipped more than one billion integrated circuits. Prof Amaratunga continues to serve as its Chief Scientific Officer.

He is also the founder of Enecsys, another company in the UK that develops and markets grid-connected micro inverters and monitoring systems for solar energy harvesting in homes and businesses. Prof Amaratunga has been the Director and Founder of Nanoinstruments Ltd, which was acquired by Aixtron AG, a leading provider of deposition equipment to the semiconductor industry. He is also a founder of two start-ups – Wind Technologies, specialising in generators for wind turbines, and Camutronics, a company dealing in power semiconductor devices.

Prof Amaratunga chairs the steering committee of the Nokia-Cambridge University Strategic Collaboration on Nanoscience and Nanotechnology and heads the Nokia-CU Nanotechnology for Energy Programme. He is a member of the Investment Advisory Board of New Energy Solutions, a Danish venture capital fund.

An Elected Fellow of the Royal Academy of Engineering, he received the Royal Academy of Engineering Silver Medal in 2007. He has published over 500 archived journal and conference papers with a total citation count of over 12,000 and an H–index of 62.



Reinventing Surgery

Assoc Prof Louis Phee Soo Jay

For as long as he can remember, Assoc Prof Louis Phee has been driven by two passions – medicine and engineering – that at one time seemed irreconcilable. He eventually chose engineering as his career path, but managed to merge both interests when he won a PhD scholarship to Italy's Scuola Superiore Sant' Anna in Pisa to do a research programme in Medical Robotics and Mechatronics.

Since then, Assoc Prof Phee has been a developer and inventor of medical technologies and devices that help to improve medical treatments and surgical procedures.

One of his earliest inventions – a robotic colonoscope that he co-developed during his time in Italy – is now being produced by a company in Europe. Another invention, an automatic prostate biopsy system that Assoc Prof Phee developed when he was a research scientist at the Singapore General Hospital, is being marketed through the spin-off company Biobot Private Ltd.

"I've always wanted to be an engineer and a doctor at the same time," said Assoc Prof Phee, who is head of the Division of Mechatronics and Design at the School of Mechanical and Aerospace Engineering.

His most recent invention is also his most successful so far. Inspired by the chilli crab dish – a Singaporean favourite – Assoc Prof Phee, in collaboration with the National University Hospital in Singapore, engineered a flexible robotic endoscope equipped with tweezers and a cutting tool resembling the claws of a crab. Manipulated through a control console in the operating theatre, the Master And Slave Transluminal Endoscopic Robot – or MASTER for short – allows doctors to enter the gastrointestinal tract through the mouth to perform surgery in the stomach quickly and safely without leaving any scars.

Following successful patient trials, MASTER is now well on its way to becoming the tool of choice for abdominal surgeries worldwide and a standard equipment in operation theatres.

"The work that I do has a direct impact on patients, and the feeling that I get is incredible, especially now that we have seen MASTER working so well in patients," said Assoc Prof Phee. **"I see them wake up and go home the same day, which wasn't possible before. It's nice to know the work of an engineer made that possible."**

MASTER is currently being fine-tuned and commercialised under NTU's spin-off company EndoMaster.

"It's very fulfilling to see your product develop and grow from the initial concept to its commercialisation," said Assoc Prof Phee, who is co-founder and CEO of EndoMaster.

Assoc Prof Phee has received honours for his inventions, such as the President's Technology Award (2012), The Outstanding Young Persons of Singapore Award – Honouree (2007), the Singapore National Academy of Science Young Scientist Award (2006) and NTU's highest honour for innovation and entrepreneurship (2013). His work also won "Best Show" at TechVenture and "Best Pitch" at the inaugural Action for Community Entrepreneurship and Exploit Technologies Investor Forum in 2012, achievements that were instrumental in winning over business investors for EndoMaster.

EVENTS

2nd NTU-Warwick Symposium on Neuroscience

Organised by the School of Biological Sciences, NTU

20 – 21 September 2013

Venue: School of Biological Sciences, NTU, Singapore

http://www.sbs.ntu.edu.sg/NewsandActivities/Documents/Events/NTU_Warwick_2013.jpg

1st Lübeck-Singapore Symposium on Viruses

Organised by Lübeck University, Germany, and the School of Biological Sciences, NTU

30 September – 1 October 2013

Venue: School of Biological Sciences, NTU, Singapore

http://www.sbs.ntu.edu.sg/NewsandActivities/Documents/Events/Lubeck_Singapore_Symposium_2013_150513.jpg

World Cultural Council 30th Award Ceremony

Co-organised by World Cultural Council and NTU

2 October 2013

Venue: NTU, Singapore

http://www.wcca2013.org/

THE World Academic Summit 2013

Senior industrial, political and higher education leaders from across the world gather to explore the fundamental role that world-class research universities will play in fuelling the future knowledge economy.

Co-organised by Times Higher Education and NTU

2 – 4 October 2013

Venue: NTU, Singapore

http://www.theworldacademicsummit.com

2nd Ajou-NTU Symposium on Future Scopes and Challenges in Biomedical Research

Co-organised by Ajou University, South Korea, and the School of Biological Sciences, NTU

3 – 4 October 2013

Venue: School of Biological Sciences, NTU, Singapore

http://www.sbs.ntu.edu.sg/NewsandActivities/Documents/Events/Ajou_NTU_2013.jpg

Offshore Renewable Energy Conference 2013

Organised by the Energy Research Institute @ NTU (ERI@N)

29 – 30 October 2013

Venue: Marina Bay Sands, Singapore

http://erian.ntu.edu.sg/Conference_Workshop/OREC%202013/Pages/Home.aspx

Asia Smart Grid & Electromobility Conference 2013

Organised by the Energy Research Institute@NTU (ERI@N)

29 – 30 October 2013

Venue: Marina Bay Sands, Singapore

http://erian.ntu.edu.sg/Conference_Workshop/ASGE%202013/Pages/Home.aspx

Linking Industry And Academia

Prof Subodh Mhaisalkar

Prof Subodh Mhaisalkar returned to academia after more than ten years in the industry to seek answers to scientific problems that he could not get in the industrial setting – and became a technopreneur in the process.

"Coming to NTU gave me the opportunity to take my industry experience into a research setting where I can ask fundamental scientific questions that I was not able to investigate further in an industry lab," says Prof Mhaisalkar, Professor at NTU's School of Materials Science and Engineering (MSE) and Executive Director of the Energy Research Institute@NTU (ERI@N).

Yet, Prof Mhaisalkar greatly cherishes his experience in the microelectronics industry that has given him invaluable insights into mindsets and processes in the private sector. This knowledge makes him an ideal mediator and facilitator of interactions between NTU and its partners from industry and business.

With ERI@N focusing on practical and translational research in many energy-related problems, Prof Mhaisalkar has enlarged the university's connections with companies in the energy sector. Working with NTU in the area of photovoltaics, Bosch, a multinational leader in engineering and electronics, is the first partner in ERI@N's extensive portfolio of more than 30 industry partnerships that include on-campus joint laboratories and centres with global industry leaders such as BMW, Rolls-Royce, IBM, Vestas and Gamesa.

"Working with industry players makes our research practical and solution-oriented. Furthermore, our PhD students get trained to understand and resolve real-world issues and they are more likely to find jobs as a result," Prof Mhaisalkar says of his motivation for linking up with the industry.

At NTU, Prof Mhaisalkar has been the Director of the Advanced Materials Research Centre (2004-2011) and Director of the Nanoscience & Nanotechnology Cluster (2005-2008). Under his leadership, ERI@N has raised S$220 million in research funding since the institute's launch in 2009.

Prof Mhaisalkar's research interests are in printed electronics, sensors, photovoltaics, supercapacitors and batteries. His research efforts at MSE and ERI@N led to the founding of his own start-up company, Printed Power Pte Ltd, which focuses on energy harvesting and storage. He has also filed several patents for innovations in electronic materials, solar cells and battery-related technologies.

A graduate of Ohio State University, USA, Prof Mhaisalkar received the Ohio State Professional Achievement Award in 2012. He also won the George E Smith Award from the Institute of Electrical and Electronics Engineers (IEEE) in 2008. Prof Mhaisalkar has published more than 250 journal papers with a citation of about 3,000.

6th World Entrepreneurship Forum

Co-organised by the Action Community for Entrepreneurship (ACE) and NTU

30 October – 2 November 2013

Venue: Grand Copthorne Waterfront Hotel, Singapore

http://www.world-entrepreneurship-forum.com/Events/Annual-Meeting/Singapore-2013

The 7th International Conference on Information Theoretic Security (ICITS 2013)

Co-organised by the School of Physical and Mathematical Sciences, NTU, and Centre for Quantum Technologies, National University of Singapore

28 – 30 November 2013

Venue: NTU@one-north, Singapore

http://www.spms.ntu.edu.sg/mas/conference/icits2013/

Fourth International Symposium on Electronic System Design (ISED 2013)

Co-organised by the School of Chemical Engineering, NTU, and the Institute for Infocomm Research, A*STAR, Singapore

12 – 13 December 2013

Venue: NTU, Singapore

http://ised.seedsnet.org/

The Fourth Asian Spectroscopy Conference (ACS 2013)

Organised by the School of Physical and Mathematical Sciences, NTU

15 – 18 December 2013

Venue: School of Physical and Mathematical Sciences, NTU,
Singapore

http://apps.spms.ntu.edu.sg/conference/ASC2013/default.aspx

7th International Symposium on Environmental Hydraulics 2014 (ISEH VII)

Co-organised by NTU and National University of Singapore

7 – 9 January 2014

Venue: Nanyang Executive Centre, NTU, Singapore

www.iseh2014.org

International Conference on Flavor Physics and Mass Generation

Organised by the Institute of Advanced Studies, NTU

10 – 13 February 2014

Venue: Nanyang Executive Centre, NTU, Singapore

http://www.ntu.edu.sg/ias/upcomingevents/FPHY14/Pages/default.aspx

Fostering Entrepreneurship In Academia

Dr Lim Jui

Dr Lim Jui is the CEO of NTU's Nanyang Innovation and Enterprise Office (NIEO), which facilitates the transformation of NTU's research into market-ready products and services. He is also the Programme Director of the Singapore-Stanford Biodesign Programme, a joint venture between Singapore and Stanford University that aims to train the next generation of medical technology innovators in Asia. Dr Lim also serves on the National Research Foundation's (NRF) TechVenture Steering Committee, the NRF's Technology Incubator Scheme, and the Singapore-MIT Alliance for Research and Technology's proof-of-concept grant programme.

Q&A

What is the significance of innovation and entrepreneurship for universities?

Universities have always been places of discoveries and inventions but the translation of these ideas into marketable products and services of practical utility has been infrequent and inconsistent. However, examples of academic research discoveries like Penicillin that led to far-reaching medical, social, and economic benefits show that universities should engage and invest in efforts to translate discoveries and inventions into useful products.

How can a university foster innovation and entrepreneurship among its researchers and students?

Fostering innovation requires changes in mindsets and culture. One way is to introduce structure and discipline beneficial for innovation processes, for example, through pedagogy and team project work. In entrepreneurship, role models are important as they challenge existing mindsets and provide assurance and encouragement for aspiring entrepreneurs. At NTU we have platforms that bring enterprising faculty and students into contact with successful technopreneurs and businessmen and provide thought-provoking and challenging experiences that help to prime these potential entrepreneurs.

What can industry and universities gain from working together in research and development?

Through working with academia, industry gets access to cutting-edge research they typically do not do by themselves. Working with universities helps them innovate and turn ideas for solutions into goods and services of practical utility and widespread benefit.

Universities, on the other hand, gain insight into the industry's current and future requirements and capabilities, the scientific challenges they face, as well as their unique perspectives on the shared goal of innovating to meet real-world needs.

As CEO of Innovation and Enterprise at NTU, what are your immediate and long-term plans to advance innovation and entrepreneurship at NTU?

In the short term, we plan to further engage the NTU community to identify and realise ideas that we can commercialise. We have several educational programmes that support this, such as mentorship and entrepreneur-in-residence programmes, the World Entrepreneurship Forum, make-a-thons, and hack-a-thons.

In the medium and longer term, the NIEO itself will likely be spun out into a company. This will provide us with greater operational flexibility, agility and incentives to successfully commercialise the technologies under our charge.

In the commercialisation of NTU's technologies, entrepreneurship is just one outlet. Licensing is the other.

How successful has NTU been in translating and commercialising research outcomes?

Since the inauguration of NTU in 1991, more than 60 start-up and 30 spin-off companies have been created and we have licensed about 80 technologies to industrial collaborators. Most of our start-ups and spin-offs so far have arisen from our own research work.

In the last five years, NTU has also been highly successful in engaging industry in collaborations.

What are the challenges NTU faces in the pursuit of excellence in innovation?

A major challenge is to engage faculty and students in innovation processes. At NTU we aim to develop incentives, resources and structures to support potential inventors in improving the quality and competitiveness of their ideas and aligning them to market dynamics and needs. Another challenge is to secure venture capital for start-ups.

NTU is a member of the Global Entrepreneurship Monitor project. What is the objective of this study?

The Global Entrepreneurship Monitor project is the largest on-going global study of entrepreneurial attitudes, aspirations and activities. Dubbed GEM, it provides governments, businesses and educators with valuable insights into the state of entrepreneurship in their respective countries and aids the design of policies and programmes for entrepreneurs.

In the 2012 survey, Singapore ranked second, just behind the USA, for total entrepreneurial activity among 25 selected economies globally.

NTU is also a founding member of the World Entrepreneurship Forum (WEF). What are your aspirations for the WEF and for this year's forum that will take place in Singapore?

The World Entrepreneurship Forum was founded as a global entrepreneurship think-tank. Its members make recommendations and develop global actions to tackle our world's problems in an entrepreneurial way.

As a founding member and through hosting WEF 2013, NTU aims to be seen as a thought leader in entrepreneurship and to strengthen our strategic relationships with global leaders in entrepreneurship. We look forward to deepening our understanding of entrepreneurship-related issues and advancing entrepreneurship policies and initiatives.

WEF 2013 will also create awareness of Singapore and NTU's vibrant entrepreneurship ecosystem, where entrepreneurs and innovators can quickly connect to markets, capital and talent.

How can innovation and entrepreneurship at NTU contribute to Singapore's economic development?

NTU, as a pillar in Singapore's higher education, has a responsibility to help Singapore gain greater economic independence and performance through innovation and enterprise.

You were a clinical surgeon earlier in your career. What made you switch to a career of promoting academic entrepreneurship?

After having been a clinical doctor, specialising in anaesthesia and intensive care, for several years I was looking for new challenges. I found the business of bringing new technologies to life highly interesting and my training in medicine proved invaluable.

In between medicine and my current role, I was in venture capital with Bio*One Capital, the investment arm of the Singapore Economic Development Board, and I ran a medical device start-up called Merlin MD.

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