UNIVERSITY OF Southampton

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New Boundaries | Issue 19 | November 2014

Innovation in prosthetics

Cutting-edge joint and prosthesis design

Imaging the world
Diagnosing killer diseases, solving crime and detecting forgery

Preventing wear and tear
Sustainable solutions to real-world problems

Tackling malaria
Using mobile phone data to reduce deaths

In this issue

Welcome to *New Boundaries*, , the University of Southampton's research magazine. In this issue, you will discover how our researchers are addressing some of the most challenging issues facing society today, from diagnosing killer diseases using surface chemistry, to saving electricity by utilising online auction platforms.

Millions of people across the world live with some kind of prosthesis, from joint or valve replacement to artificial limbs. Collaborative research at Southampton is using innovative measures in surgical procedures, computational analysis, 3D printing and stem cell technology to improve prosthesis lifespan and comfort for users. Find out more on page four.

A discovery made at Southampton 40 years ago has been changing the way killer diseases are diagnosed, how crimes are detected and how forgery is spotted in the art world. Find out what part gold has to play in this story on page 10.

Reducing waste, extending equipment life and reducing the carbon footprint of mechanical systems are some of the key barriers to efficient and cost-effective processes. On page 16, discover how our partnerships with industry are resulting in the prevention of wear and tear.

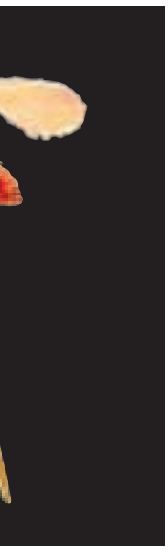
As climate change continues to make the headlines, we are constantly looking towards sustainable forms of power, and efficient ways to use and store electricity. Researchers at Southampton are investigating online auction platforms and storing electrical energy from the National Grid in batteries, as key ways to use electricity responsibly. Find out more on page 22.

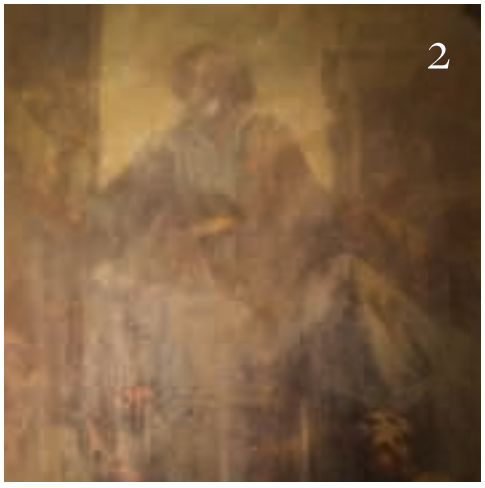
On page 26, join the debate between Dr Mickey Chopra, Chief of Health at UNICEF and Dr Andy Tatem from Geography at the University, about the issues associated with malaria and how research at the University is helping to eliminate this preventable disease.

Please send us your feedback

You can view past issues of *New Boundaries* online at **www.southampton.ac.uk/research**

We are keen to receive any feedback you have about *New Boundaries*. If you have any comments or suggestions, please send them to newboundaries@southampton.ac.uk





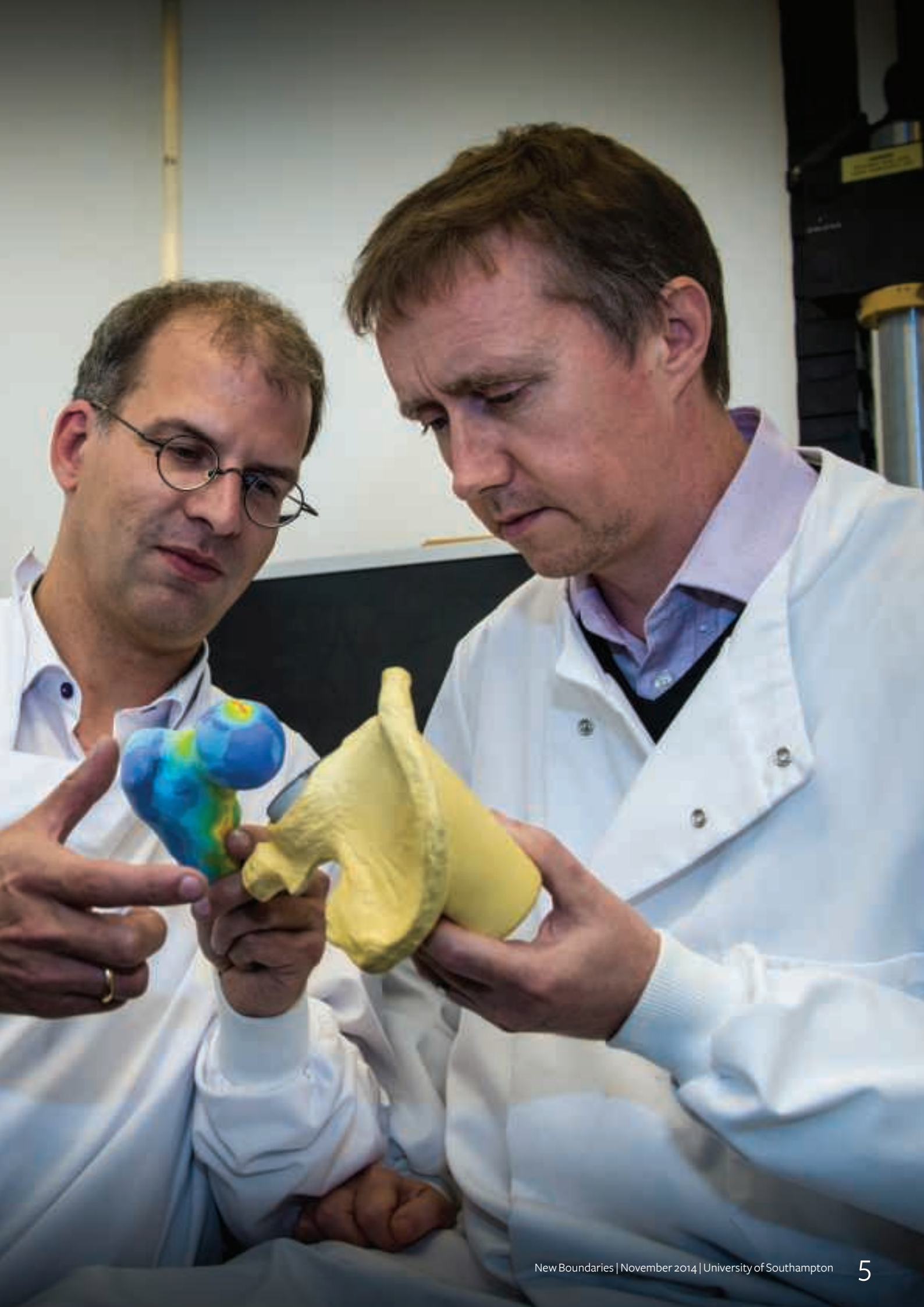
More highlights

Innovation in prosthetic technologies

Southampton research is changing the futures of thousands of internal and external prosthesis patients across the globe. Through innovative measures in sensory technology, surgical procedures, computational analysis, 3D printing and stem cell technology, the lifespan of joint replacements is becoming longer, and the effectiveness of prosthetic limbs is being optimised.

"Southampton technology and our ongoing research activities are supporting the move towards individualised treatments for patients."

Professor Martin Browne (pictured above right), Head of the Bioengineering Sciences Research Group



"We're hoping that the development of an intelligent sensor will be the first step leading to the 'holy grail' in prosthetic limbs – a fully automatic, self-adjusting smart socket interface for amputees."

Dr Liudi Jiang,
Senior Lecturer

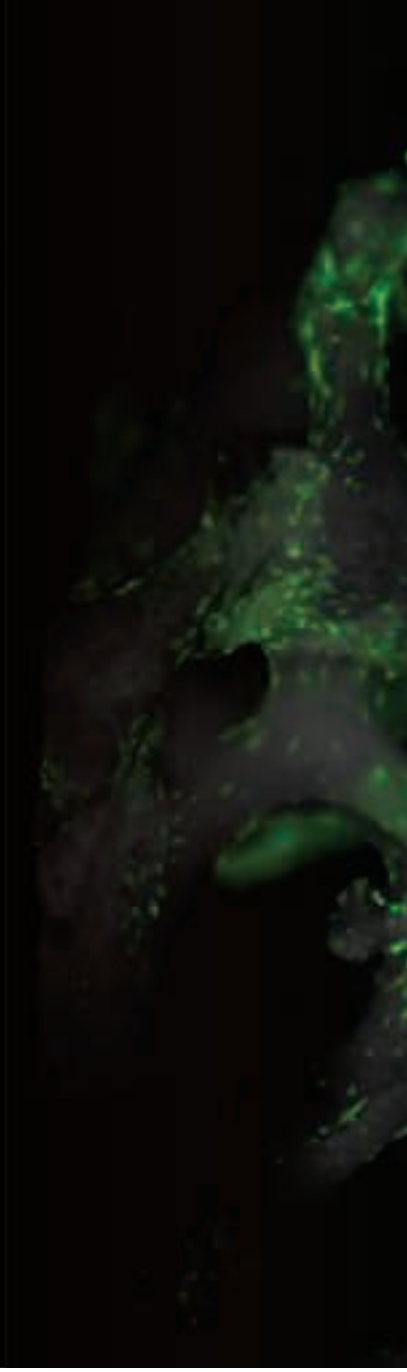


Image of human stem cells from bone marrow, on a bone scaffold, with a green marker to show viable, living cells

Sensing technology

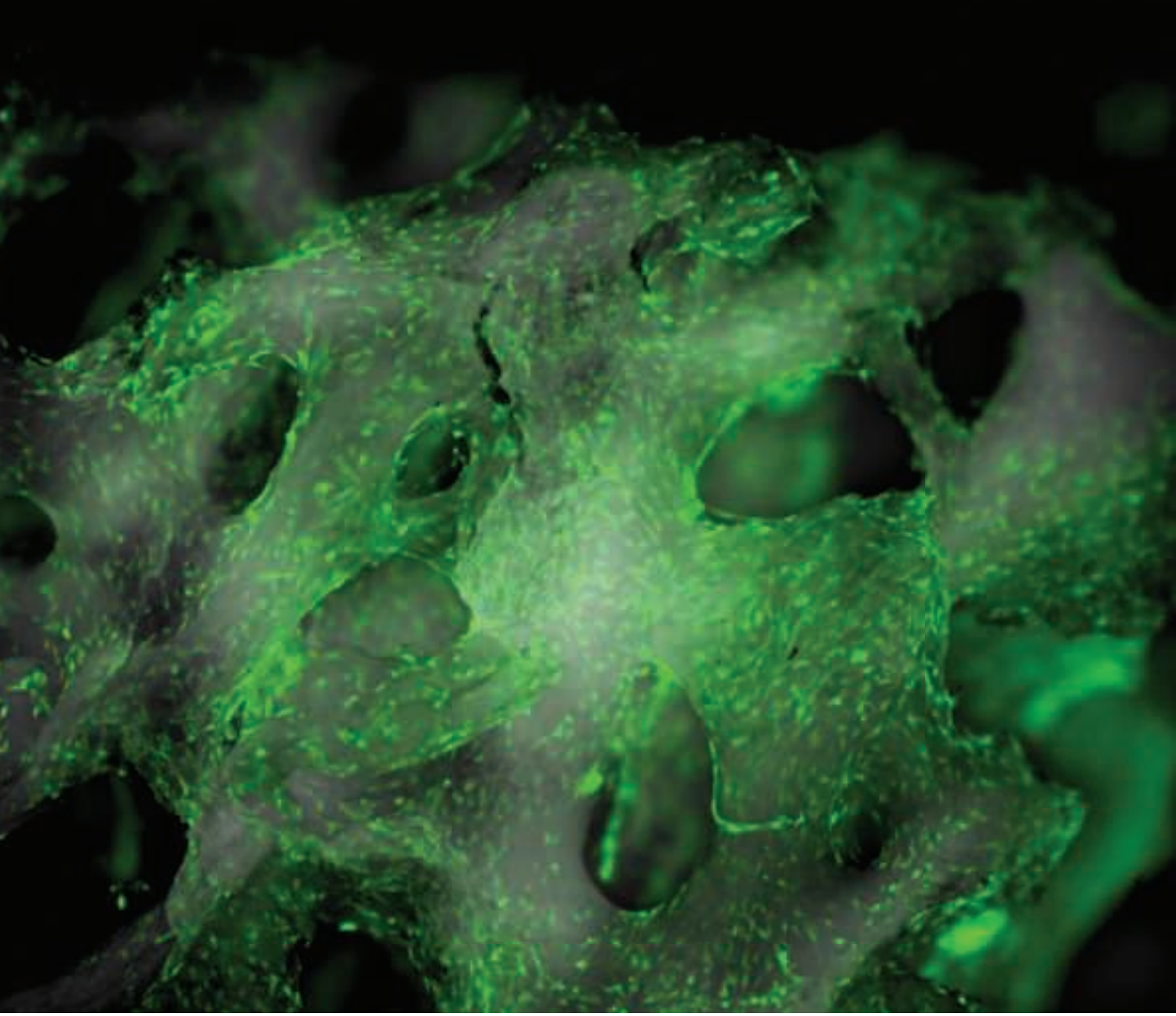
Academics in Engineering Sciences, Health Sciences and Medicine are addressing the medical needs encountered by joint replacement patients and amputees through three distinct technological approaches. "Ill-fitting replacement lower limbs can be a significant cause of pain, further complications and discomfort in amputees," explains Senior Lecturer Dr Liudi Jiang. "The majority of the 50,000 lower-limb amputees in the UK use prosthetic limbs, attached to the residual limb through a socket, with no two residual limbs being exactly the same shape or size," she continues.

Liudi is leading a Medical Research Council funded translational project to develop interfacial pressure and shear sensors, fitted between the stump and socket, to assist prosthetic socket fitting and identify potential problems before dangerous sores and blisters can develop. Professor of Bio-engineering and Tissue Health, Dan Bader, is working alongside Liudi in an interdisciplinary team. He explains: "Mechanical forces during physical activities of the amputee can lead to breakdown of soft tissues at the stump, which can prove very difficult to heal and will inevitably result in distress for the patient. We are developing an interfacial sensor to help reduce pain, discomfort and ulceration, which are all frequently experienced at the socket interface due to poor fit."

The intelligent sensor will allow clinicians to quickly and accurately assess socket fit at the outset. The wireless interface will also monitor changes to socket fit over time, alerting patients of the need to adjust their socket or their activities, to prevent ulcers from forming. This relatively practical and potentially low-cost solution could substantially reduce amputees' follow-up visits to their rehabilitation centres, giving them a better quality of life and at the same time, reducing healthcare costs.

Dr David Moser, Head of Research at Chas A Blatchford & Son Ltd, who are partners of the Southampton research team, says: "This is a tremendously exciting project which has the potential to transform socket technology as a whole in lower limb prosthetics. We anticipate that from the development of this technology we will reach a new level of understanding and uncover the as yet unclear 'dynamic' qualities of limb loading and socket fit. This step is crucial for the development of the next generation of socket technology products and future artificial limb controls."

Liudi comments: "We're hoping that the development of the interfacial sensor will be the first step leading to the 'holy grail' in



prosthetic limbs – a fully automatic, self-adjusting smart socket interface for amputees. What's more, the technology could be used in a whole host of other medical instances. For example it could be used in shoe insoles for people with diabetes, and in wheelchairs and mattresses for people whose mobility is severely limited."

Computational modelling

While these innovative intelligent sensors are most commonly used for amputees who are victims of trauma from the military, road accidents or diabetes, joint replacement surgery is more commonly associated with older people who have degenerative joint conditions, but who want to continue to live full, active lives after joint replacement surgery.

Professor of Biomechanics, Markus Heller is pioneering the use of computational modelling in artificial joint replacement, to enable surgeons to implant prosthetic joints that are unique to the requirements of the individual. As such, the joints have increased lifespans and can enhance the quality of life that patients can expect to have after surgery.

He explains: "Surgeons have to rely on their experience to best perform joint replacement surgery to ensure long-lasting function based on an individual's bone geometry, bone quality and surrounding muscular structure. There are currently no solutions to support their decision process by reliable, quantitative information on the expected joint mechanics and functional outcome." The Southampton team has developed a 3D musculoskeletal model, with data on the variations in bone shape and tissue density, which has enabled advanced biomechanical assessment of the joint reconstruction. The development of this specialised software allows the automated positioning of implants. It also enables clinicians to modify implant size and position, to address individual patient needs, meaning that optimal, functional outcome of joint surgery is no longer dependent on the surgeon's prior experience and training.

Markus adds: "Joint replacement surgery substitutes worn-out joint tissues with artificial components. These artificial components will also fail eventually, some after only a few years, with nearly 10 per cent of all joint replacement operations in the EU each year taking place to replace prosthetics that have worn out. The intention is that this technology will lead to increased patient safety and improved lifespan of joint replacement prosthetics."

"What we have is a living composite with the patient's bone stem cells. We discovered how to control stem cells on nanosurfaces and were able to induce hard tissue to form directly onto an implant surface, enhancing bone integration and reducing the prospect of revision surgery."

Richard Oreffo (pictured above right),
Professor of Musculoskeletal Science

Stem cell technology

30-50 per cent of patients who undergo hip replacement surgery will require revision surgery, and as a result, bone augmentation. Currently, donated bone is usually used in these operations; however this is costly, dependent on availability and can lead to complications including infection and immunological rejection. Southampton researchers have developed a unique approach linking nano-bioengineering and stem cell research, which could transform treatment for 4,000 UK patients each year and reduce a huge cost burden on the NHS.

Over the past decade, Professor Richard Oreffo at the University of Southampton and Douglas Dunlop, Consultant Orthopaedic Surgeon at Southampton General Hospital and at the University have developed a translational research programme to drive bone formation using patient skeletal stem cells. "This work, demonstrates the practicability of using patients' own bone stem cells to drive bone formation as well as biocompatible 'scaffolds' to create a 'living bone composite', essentially regrowing a patient's own bone," explains Richard. This year, the team has completed their first hip surgery with a 3D printed implant and bone stem cell graft, which will provide a new socket for the ball of the femur bone to enter. Behind the implant and between the pelvis, doctors have inserted a graft containing bone stem cells.

Richard says: "What we have is a living composite with the patient's bone stem cells. The stem cells will act like a glue to help with tissue integration. We have discovered how to control stem cells on nanosurfaces and will ultimately be able to induce hard tissue to form directly onto an implant surface, enhancing bone integration and reducing the prospect of revision surgery."

The 3D printed hip, made from titanium, was designed using the patient's CT scan and CAD CAM (computer aided design and computer aided manufacturing) technology. It was designed to the patient's exact specifications and measurements, with the graft acting as a filler for the loss of bone. The graft used in this operation is made up of a bone scaffold that allows blood to flow through it. The patient's own bone marrow cells were added to the graft to provide the source of bone stem cells to encourage bone regeneration behind and around the implant. The 3D printing of the implant in titanium, from CT scans of the patient and the stem cell graft is cutting-edge and offers the possibility of improved outcomes for patients.

Richard adds: "Fractures and bone loss due to trauma or disease are a significant clinical and socio-economic problem. Growing bone at the point of injury alongside a hip implant that has been designed to the exact fit of the patient is exciting and offers real opportunities for improved recovery and quality of life."

Ceramic technology

A significant problem encountered by patients is reactions to metal ions in implants. Professor Martin Browne, Head of the Bioengineering Sciences Research Group and Dr Alex Dickinson, have been working as part of a Technology Strategy Board Knowledge Transfer Partnership with the development team at Finsbury Orthopaedics Ltd and Aurora Medical Ltd, to develop a ceramic alternative that circumvents the possibility of metal sensitivity reactions.

Martin explains: "There has been a great deal of media coverage on how metal-on-metal resurfacing hip replacement surgery can cause further medical problems to patients. The longer-lasting, biocompatible, ceramic hip resurfacing method we developed, has been bought by DePuy International Ltd, and is suitable to treat a patient group that is currently without a successful solution: the young female osteoarthritis sufferer."

The future for prosthesis design

The work being undertaken at Southampton is leading to a revolution in development, effectiveness, and lifespan of prosthetic joints and limbs. Through new and innovative ways of designing prosthetics, our research is changing the lives of thousands of patients across the world. Martin explains: "In common with a number of my colleagues, I have seen first-hand how debilitating conditions such as arthritis can be on bones and joints, and current practice does not always have a satisfactory outcome. We need to find innovative solutions – as tissue engineering progresses, we may be moving away from the inert man-made materials currently used, towards biological solutions." He adds: "The option of using tissue engineered cartilage is not viable yet, but as we progress towards this, the idea of hybrid artificial and tissue based materials, as demonstrated by Richard and his colleagues, is something I believe will become more prominent. It is technology like this, together with the prosthetics and computational research being undertaken at Southampton, that is supporting the move towards individualised treatments for patients."

Key facts

- There are 50,000 lower-limb amputees in the UK and the majority use artificial limbs.
- Nearly 10 per cent of all joint replacement operations in the EU each year are to replace prosthetics that have worn out.
- 30-50 per cent of patients who undergo hip replacement surgery will require revision surgery, and as a result, bone augmentation.
- Research at Southampton is leading to a revolution in development, effectiveness, and lifespan of prosthetic joints and limbs.

To find out more about the artificial intelligent sensor technology, visit **www.southampton.ac.uk/engineering/prosthetic_sensor**

To find out more about the ceramic hip replacement research, visit **www.southampton.ac.uk/engineering/ceramic_hip**

Imaging the world

A groundbreaking Southampton discovery, made 40 years ago, is still impacting on fields ranging from cancer diagnostics to crime scene forensic analysis, to drug detection, and establishing the origins of works of art.

In the 1970s the technique known as Surface Enhanced Raman Spectroscopy (SERS) was discovered by Professors Martin Fleischmann, Patrick Hendra and Jim McQuillan at the University, and is now used in pioneering research on a global scale.

The team found that by roughening the metal surface upon which they had placed the molecules that they were examining, they could increase the Raman signal by which they could detect these molecules, by a million times more than they predicted, giving a molecular fingerprint. This allowed them to detect molecules in far smaller quantities than ever before. In 2013, the University's Chemistry department was awarded a National Chemical Landmark blue plaque by the Royal Society of Chemistry, to mark the 40-year anniversary of the discovery.

"SERS is arguably the most sensitive method of analysis on surfaces that anyone has ever come up with," comments Patrick. "We realised," comments Jim, "that we had uncovered an extraordinary effect, but didn't anticipate how important it would become; Martin Fleischmann's inspiration was key to the discovery."

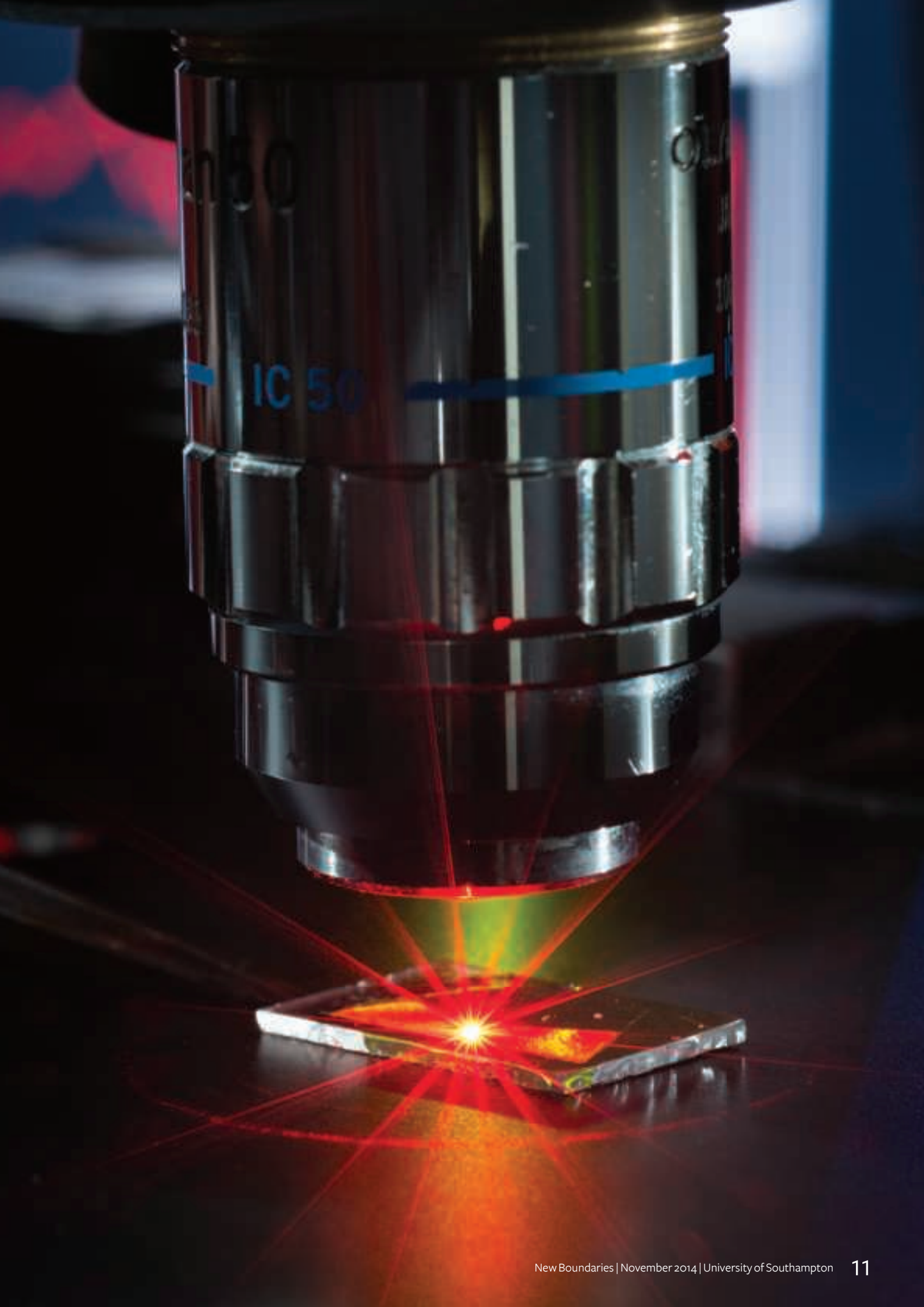
Professor David Phillips, Royal Society of Chemistry Past President says: "The practical application of SERS in chemistry, genetics and healthcare is of vital scientific importance, from the detection of cancer genes to DNA fingerprinting."

The power of nano-gold

Dr Sumeet Mahajan, Senior Lecturer in Life Science Interface at the University is taking SERS to the next level, using the technique to advance stem cell therapy. This type of science is in its infancy, but has the potential to change the way we treat cancer and other life-threatening diseases, by replacing damaged or diseased cells with healthy ones. One of the key limitations of stem cell therapy is identifying the right cells to use for different therapies; a fundamental problem being addressed through this new research, funded by the Engineering and Physical Sciences Research Council (EPSRC).

Sumeet says: "Stem cells could hold the key to tackling many diseases. They develop into all the various kinds of cells needed in the body – blood, nerves and organs – but it is almost impossible to tell them apart during initial development, without complex techniques, even with the most advanced microscopes.

Until now, scientists have used intrusive fluorescent 'markers' to track each cell, but this can alter or damage the cells and render them useless for therapeutics. Sumeet adds: "By using SERS, we can use very tiny particles of gold, less than 1,00th of the width of a human hair, as 'nanoprobes' to enter cells. We have been able to look at adult stem cells on a molecular scale to distinguish one from another, meaning we can still use the cells for therapeutic purposes." Through this, Sumeet and his team have been able to enhance the observation of the natural vibrations of molecules within the cell and make this otherwise almost invisible motion, easily detectable. "This makes us able to detect abnormalities and changes induced by the physical or chemical environment at the molecular level within cells," he adds.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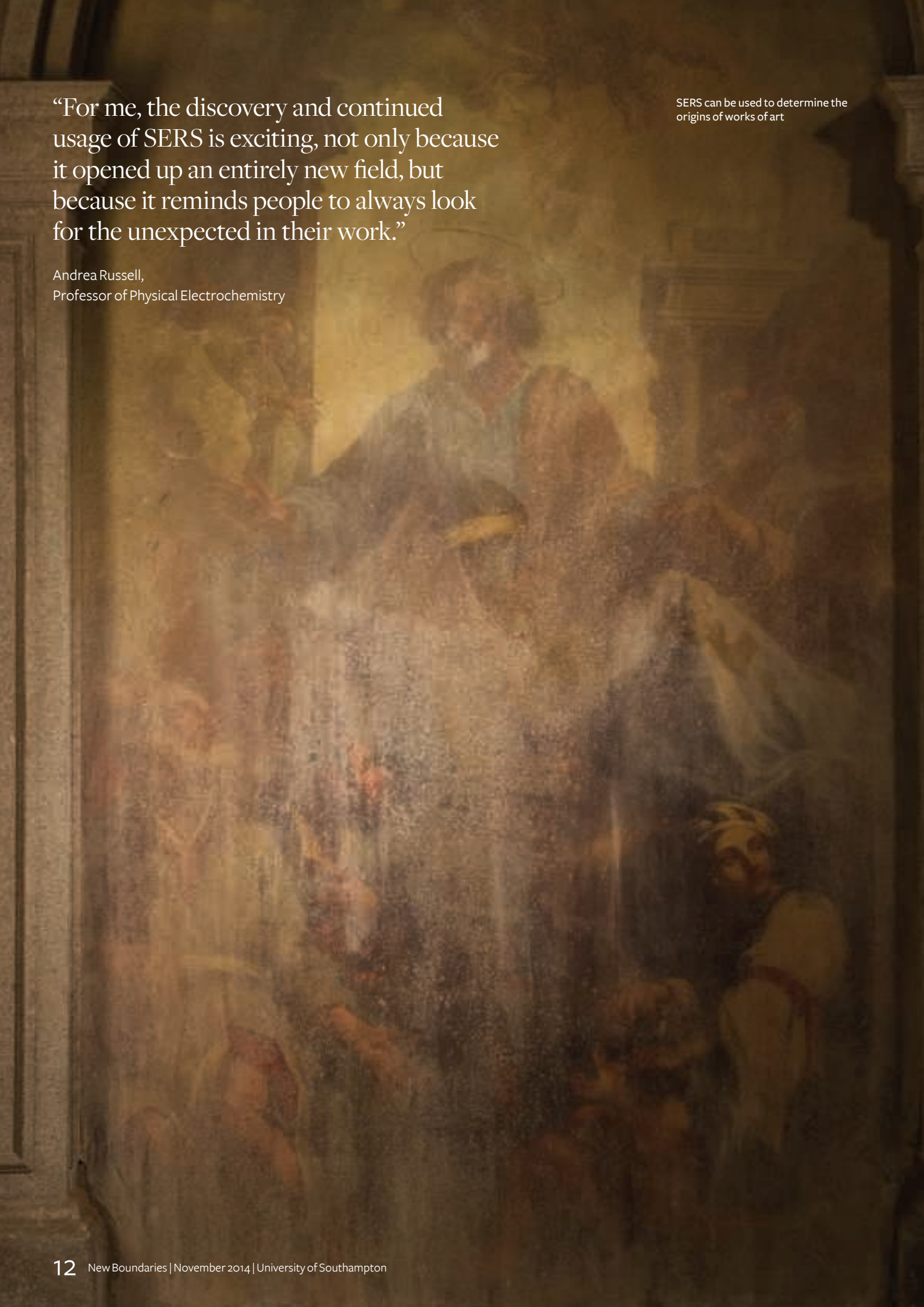


SERS can be used to determine the origins of works of art

"For me, the discovery and continued usage of SERS is exciting, not only because it opened up an entirely new field, but because it reminds people to always look for the unexpected in their work."

Andrea Russell,
Professor of Physical Electrochemistry

Sumeet is collaborating with major pharmaceutical companies to further develop the work for better drugs. Together with AstraZeneca through an industrial CASE (iCASE) award, the nanoprobe approach is being harnessed to understand the bioavailability of drugs inside cells, to improve cell-based assays in the drug discovery pipeline. His research also means that stem cell and other cell-based therapies could be advanced much further than the current most common uses, such as bone marrow transplants.

He comments: "Scientists studying neurodegenerative diseases such as Parkinson's disease believe replenishing a patient's depleted dopamine-generating cells, may be an effective treatment. However, in order to avoid fatal complications, we must be sure we are using the right type of replacement cells, which the work we are doing at Southampton is enabling us to do. In addition, the technique can also allow us to see if drugs are working effectively in cells, can be used to diagnose and treat diseases, and also help achieve further insight into fundamental biological processes currently not possible with other techniques."

Electrochemical SERS

Professor Phil Bartlett from Chemistry has been working with SERS for 10 years, and is now looking at the application of the technique in bioterrorism. "We've been using SERS and electrochemistry to detect small differences in the DNA that comes from bacteria. The reason we do this is because we can then determine if the strain of bacteria is particularly unpleasant, or is actually just a closely related strain that isn't as serious," Phil explains.

He adds: "When you have an incident where there is a threat from an unidentified material or bacterium, being able to quickly take the material, extract DNA and then work out what it is, means that you know what you are dealing with. If you know what it is and you respond very quickly, you have more chance of protecting people. We are looking at how we can use SERS to do this."

Phil is also working with Professor of Physical Electrochemistry, Andrea Russell, to combat the problems faced in maintaining the stability of the roughened metal surfaces that are used in experiments using SERS. Andrea explains: "Traditionally prepared SERS surfaces are not very stable. Their performance degrades with time and they cannot be easily reused. Their inherent roughness means that it is difficult to understand the specific adsorption site of the molecules under investigation."

Over the last five years, Andrea and Phil have been developing a SERS substrate that addresses all of these issues. Andrea adds: "Our sculpted substrate is prepared by the electrodeposition of the surface through a self-assembled colloidal crystal template of latex spheres. The resulting surfaces are smooth, reproducible, can be cleaned, and have excellent shelf lives." Together with Phil and colleagues at the University of Cambridge, Andrea has explored how the parameters that define our substrates (sphere diameter, film thickness, and metal) influence the SERS enhancements obtained. "We are now focusing on using our substrates to explore a variety of electrochemical problems and other sensing applications such as drugs detection," she adds.

SERS' usage in the advancement of world-changing research continues to grow, and the possibilities for future applications of the technique are endless. With thousands of references to the technique cited in published papers so far, more and more people are exploiting this area for their research.

Andrea adds: "For me, the discovery and continued usage of SERS is exciting, not only because it opened up an entirely new field, but actually, because it reminds people to always look for the unexpected in their work."

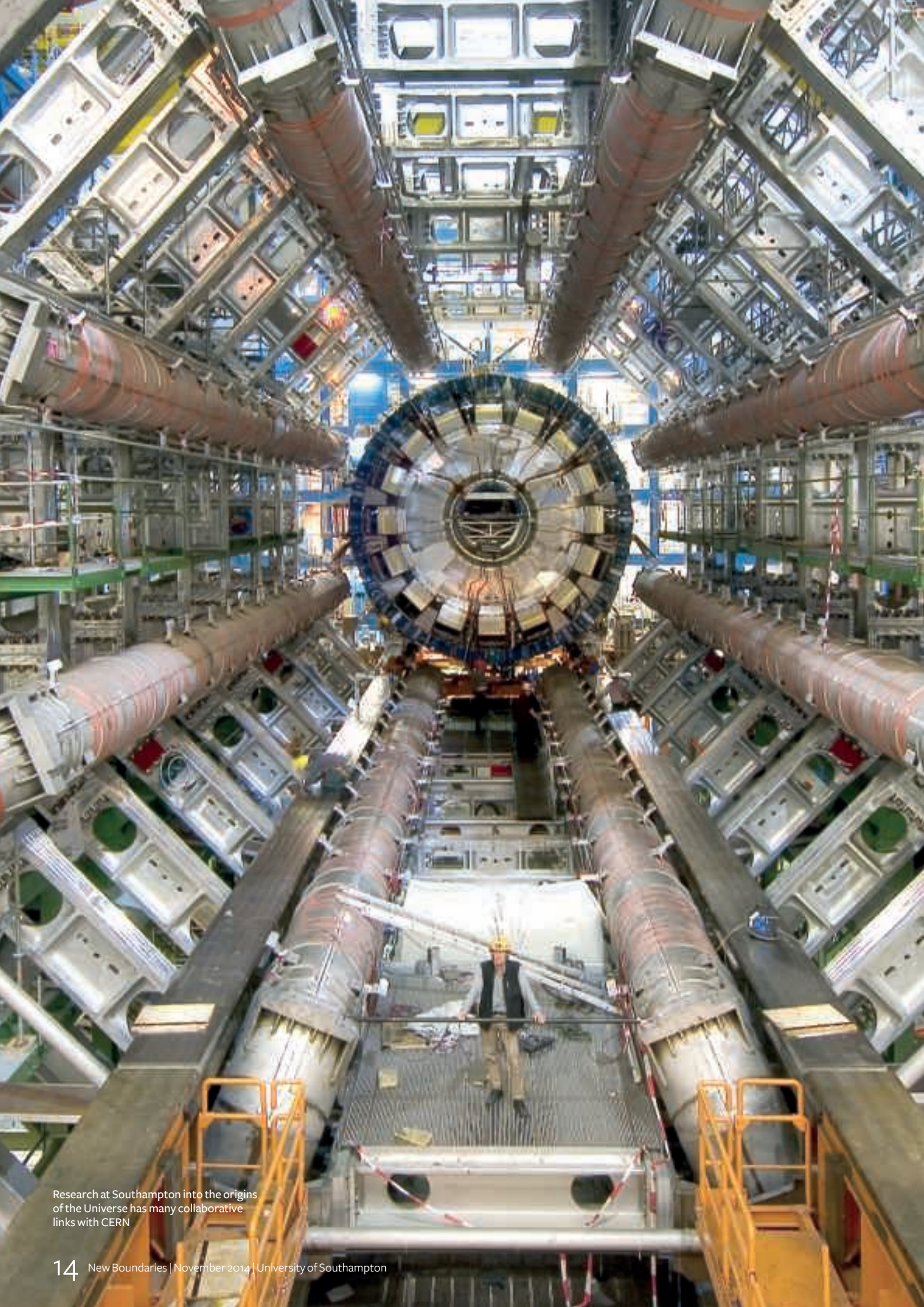
For more information on SERS and its applications, visit **www.southampton.ac.uk/weareconnected**

Key facts

- Surface Enhanced Raman Spectroscopy (SERS) was discovered over 40 years ago at Southampton and is now used in pioneering research on a global scale.
- SERS can increase the signal by which molecules on surfaces can be detected, by a million times.
- SERS has practical applications in chemistry, the environment, genetics, medicine and healthcare and is of vital scientific importance, from the early detection of diseases such as cancer, to DNA fingerprinting.
- Research at Southampton is using SERS to monitor how effective drugs are, and to predict how dangerous certain bacteria are by looking at their DNA.

"The practical application of SERS in chemistry, genetics and healthcare is of vital scientific importance, from the detection of cancer genes to DNA fingerprinting."

Professor David Phillips,
Royal Society of Chemistry Past President



Research at Southampton into the origins of the Universe has many collaborative links with CERN

Exploring the Universe

Research at Southampton is investigating the origins of dark matter, dark energy and the difference between the amount of matter and antimatter in the Universe. *New Boundaries* talks to Professor Chris Sachrajda, Director of the Southampton Theory Astrophysics and Gravity (STAG) Research Centre about his research.

The fundamental question of how the Universe formed and evolved has been asked for thousands of years, and with each step forward in understanding, new questions emerge, explains Chris. With the recent discovery of the Higgs Boson at the Large Hadron Collider (LHC) at the European Laboratory for Particle Physics (CERN) in Geneva, the very successful Standard Model of particle physics was completed, leaving the next generation of issues still to be understood.

"These issues include the origin of the dark matter and dark energy – which dominate the Universe, the mechanism that generates the difference between the amount of matter and antimatter present in the Universe, and how to reconcile the two major successes of 20th century physics, quantum mechanics and general relativity. We carry out research to try to find solutions to these issues," Chris says.

Strong nuclear force

STAG incorporates three research groups from Southampton: Astronomy, Theoretical Particle Physics and Gravity, and aims to explore issues of fundamental physics and astronomy. Chris's own research centres on the understanding of the strong nuclear force – the force which binds the protons and neutrons together in atomic nuclei – and which at a fundamental level governs the interactions between quarks.

"Together with Professor Jonathan Flynn and Dr Andreas Juttner at Southampton, I work with collaborators at the University of Edinburgh, Columbia University in New York, and the Brookhaven National Laboratory (BNL) on Long Island, to explore quantum chromodynamics – the theory of strong interactions between quarks and gluons, which make up hadrons such as the proton and neutron," says Chris.

"We make precise predictions and then compare them with experimental results hoping for a discrepancy which would signal the presence of new physics and provide a clue for physics beyond the Standard Model," he adds.

Chris and his team use Southampton's supercomputer *Iridis* for theoretical developmental work, as well as performing simulations on the powerful BlueGene/Q machines at Edinburgh and in the USA. In addition STAG has many collaborative links with CERN.

Physics partners

"CERN is by far the most important particle physics facility in the world and so, as a major particle physics group, we need to maintain strong links with CERN to keep abreast of latest developments and in turn to influence future strategies," says Chris. "All members of the Theoretical Particle Physics Group are regular visitors to CERN and most of us have spent several years there, either before coming to Southampton or during periods of sabbatical leave or frequently both – I myself have spent almost eight years in total at CERN."

Professor Sacha Belyaev, from STAG is one of the few theoretical physicists who are full members of the CMS experiment, one of the two experiments which discovered the Higgs Boson at CERN. "His role, and that of several other members of our group, is to help devise tests of the latest theoretical ideas," says Chris. "CERN also provides a base for more theoretical research, and the newest member of our group, Dr James Drummond, is spending this semester at CERN to investigate aspect of the relations between field theory and string theory," he adds.

For more information on Chris's work and STAG, visit **www.southampton.ac.uk/stag**

Preventing wear and tear

Reducing waste, extending equipment life and reducing the carbon footprint of mechanical systems are some of the key challenges facing society today. Research at Southampton into green tribology is helping to address these issues.

"We link world-class research groups in key disciplines at the University. Our work is core to future transport and energy-efficient machines, the control of emissions and low-maintenance renewable energy systems."

Dr Ling Wang,
National Centre for Advanced Tribology at Southampton

Tribology is the essential science of all interacting surfaces in relative motion, is immensely important to the successful operation of engineered machines and natural mechanisms of all scales, and demands multifunctional surfaces , explains Dr Ling Wang from the National Centre for Advanced Tribology at Southampton (nCATS).

"In any process where two materials rub against each other, tribology plays a part," she says. "In order to improve the performance of a material we can modify its surface by adding a coating or changing the surface texture so that wear is reduced," she adds.

Large investment

nCATS was established in 2008 following an Engineering and Physical Sciences Research Council (EPSRC) Science and Innovation Award – a £10m grant from the EPRSC, industry and the University representing the largest ever investment in UK tribology research. "nCATS is an interdisciplinary centre that aims to solve next-generation tribological design issues and enable surface interactions to occur with minimal energy loss and impact on the environment," says Ling. "We link world-class research groups in key disciplines at the University . "Our work is core to future transport and energy-efficient machines, the control of emissions and low-maintenance renewable energy systems," she adds.

Research projects at nCATS range from investigating the formation of skin wrinkles for cosmetic applications, and using computational modelling to improve the comfort of wet shaving, to improving the fuel efficiency of ships using anti-foul coatings, and enhancing the reliability and performance of renewable forms of energy.

Green or environmentally-friendly tribology emphasises the green or clean technology aspects of wear, friction and lubrication of interacting surfaces, which is important for energy and environmental sustainability. nCATS research in this area has recently received a £3m Green Tribology Platform Grant funded 50 per cent by EPSRC and 50 per cent by eight companies: Lloyd's Register, Wartsila, TWI, Teer Coatings Ltd, NPL, International Paints, Dstl and BP Castrol.

Interdisciplinary team

Led by Professor Robert Wood, Director of nCATS, an interdisciplinary team from the fields of chemistry, tribology, mechanical engineering, surface science, materials science and manufacturing, are using a range of modelling and experimental approaches to develop green tribological solutions.

Indeed, Southampton is a key partner in the European-wide WINDTRUST project, which aims to enhance the wind energy sector by improving turbine reliability. The effectiveness of wind energy generation depends on wind turbine reliability and the ability to minimise down-times. WINDTRUST, which started in 2013, aims to improve the competitiveness of the wind energy sector by further enhancing the design of three key components: the rotor blades, the power electronics and the wind turbine controller.

For the blades, the use of carbon fibre will be optimised for a better cost-efficiency, while power electronics will be made more reliable through a new design that involves fewer and better integrated components. At the same time, WINDTRUST will evaluate several control algorithms in order to improve the detection of faults and the prevention of failures, thus contributing to the overall reliability of wind turbines. The result of the three-year project is that the new components developed will be fitted onto an onshore 2MW prototype turbine. The results will be used for implementation on larger turbines and off-shore locations.

Economic gains

As part of the project, Robert will be working in close collaboration with leading wind turbine blade manufacturer LM Wind Power from Denmark. He says: "We are looking forward to gaining insight into what causes the blades of wind turbines to become damaged and how to develop solutions that allow increased blade life and improved material selection."

Increasing the performance and durability of these elements will positively affect the economic outcome of wind energy projects. "The project is very practice-oriented. It will add practical experience to the existing theoretical data and be of direct use for the industry," said Mauro Villanueva, Technology Development Director of Gamesa and Coordinator of WINDTRUST.

As well as the expected gain in performance, WINDTRUST will perform a thorough cost-analysis and develop a business plan for each of the new components, thus providing the tools for a successful market uptake.

In addition to WINDTRUST, Ling and her team have been looking at wind turbine gearbox bearing failures with the aim of understand the mechanism behind the failures and provide solutions to improve cost efficiency and reliability of wind power as a sustainable energy source.

"In collaboration with Vestas Wind Systems we have been investigating a particular failure mode called white structure flaking that occurs in bearings in the gearboxes," says Ling. "Currently the failure caused by white structure flaking results in a new gearbox for a wind turbine, which costs £300,000. The failure rate is high, so turbine manufacturers, operators, bearing manufacturers and gearbox producers are all concerned about this."

Oil efficient

In collaboration with Shell Global Solutions and colleagues in Electronics and Computer Science at the University, Ling is investigating oil quality and degradation. Oil is used as a lubricant in many types of machines and engines, but a lot of good oil is wasted when oil is changed prematurely, which has an impact on cost and the environment.

Ling explains: "We normally take a car to the garage and have its oil changed once a year or after a certain amount of mileage to prolong the life of the engine, but we don't really know whether it needs to be changed this frequently. We have developed a cheap oil quality sensor, which can be fitted to an engine that monitors oil degradation."

The impact of this research is two-fold. The sensor can be used to help users, lubricant manufacturers and operators to decide the exact time oil needs to be changed, saving money. "This will also have an impact on the environment, as it will reduce the amount of oil needed to maintain an engine, but also reduce the amount of waste oil being disposed of," says Ling.

"The thing that sets our research centre apart from others is that every project is applied science that solves problems for industry. Tribology touches every area of science; it is closely linked to applications and solving real-world problems," Ling adds.

For more information on tribology research at Southampton, visit **www.southampton.ac.uk/ncats**

Key facts

- Tribology is the essential science of all interacting surfaces in relative motion.
- Green tribology emphasises the green or clean technology aspects of wear, friction and lubrication of interacting surfaces.
- Currently the failure caused by white structure flaking results in a new gearbox for a wind turbine, which costs £300,000.
- An estimated 300 million tonnes of bunker fuel oil consumed annually.
- Tribology projects at Southampton include investigating the formation of skin wrinkles for cosmetic applications and enhancing the reliability and performance of renewable forms of energy.

"The thing that sets our research centre apart from others is that every project is applied science that solves problems for industry. Tribology touches every area of science; it is closely linked to applications and solving real-world problems."

Dr Ling Wang,
National Centre for Advanced Tribology at Southampton

Power and influence

With the situation in Ukraine hitting the headlines in recent months, the question for politicians and legal experts seems to be: was Russia justified in taking back control of Crimea? *New Boundaries* talks to Dr Matthew Nicholson about the legality of the situation.

Q *What is your area of research?*

My area of research is international law. In particular I am looking at international law as a profession, and how it is perceived. My research focuses on debating the legality of what is going on in the world, relating to power structures and law's influence.

Q *What are the main challenges in international law?*

My overall sense is that we are in a phase of radical turbulent change in structures and patterns of thinking about the function of law in global deliberative processes.

When facing current challenges the usual response is to revert to old patterns of legal thinking and established ways of trying to tackle issues. My argument is that we need to use under-explored patterns of thought from disciplines such as philosophy or literary studies to redefine what international law is and how it is practiced.

Q *What does your research involve?*

I have just finished a project looking at various English legal cases that involve the doctrine of Act of State, which deals with litigation between two non-state individuals, where as part of the factual background to the case, the conduct of a state, such as the USA, is relevant.

Recently the English courts have decided that some cases – involving allegations of torture or violent extraordinary rendition, for example – cannot be heard because they have the potential to embarrass a foreign state. The rule of law is effectively being dis-applied and that raises potentially troubling questions about the relationship between law, politics, and power.

Q *What are your thoughts regarding the legal situation in Ukraine?*

The usual questions asked are: Did Russia act lawfully by taking control of Crimea? And: Is the USA right to impose sanctions on Crimea and Russia in relation to alleged illegal activity? If you say that Russia has behaved unlawfully, you have to ask what that means in the context of the invasion of Iraq by a US-led coalition in 2003 and NATO intervention in Kosovo in 1999.

The big picture is about the power and influence that plays out under the banner of law. There is a power game between Russia and the USA with a range of global economic, social, and political issues in the background which are compressed into the language of law. Russia has made an argument about self-determination in relation to Crimea, resulting from the referendum held there, but the USA and its allies have voiced concerns regarding the legitimacy and legality of that exercise.

The result is that it is not entirely clear what the winning argument is, but there are many that have some credibility. Law struggles to work with fluid, dynamic situations like this but the fact that it struggles might tell us something about how law itself can be rethought.

Q *What about the alleged shooting down of flight MH17?*

The alleged shooting down of Malaysia flight MH17, where 298 people lost their lives, is an example of the fluidity of the situation in Ukraine. It has been seized upon by all sides and as a result there has been a fast-forwarding of the investigation. The British-American line seems to be that this was done by separatists in eastern Ukraine, supported by Russia, over whom Russia has a large degree of control, and therefore Russia has to take some responsibility.

The key point is that there hasn't been an independent investigation yet and efforts are still ongoing to put that in place. It seems prejudicial to the investigation for politicians across the world to be describing what they believe happened; this could affect the impartiality of the investigation.

It seems clear that some politicians in the USA and UK are using this tragic situation to get traction on the broader crisis in Ukraine and put pressure on Russia. So again we can see law or quasi legal processes serving as a way of compressing or simplifying broader social and political tensions and conflicts. The binary language of legal and illegal can't get to grips with the full range of social, political and cultural tensions in a situation such as that in Ukraine, but that inability is usually ignored.

Q *What got you interested in this area of research?*

I was drawn to international law out of a frustration that human rights and global justice issues are not dealt with in the same way across the world; that power seems to prevail over justice. And I was interested in how power distribution and power structures affect legal practice. This motivated me to think about the whole profession of international law and how it is constructed.

Q *Is Southampton a good place for early career researchers?*

Southampton is a great place to do my research as there is a lot of support for early career researchers here. The Southampton Law School has a good reputation and we have a variety of different experts on a whole cross-section of legal issues. For me this means that colleagues such as Dr David Gurnham, who works with law and literature, and Dr Andrew Serdy, who researches in international law, can advise me on my research and any papers I might submit for publication.

For more information on Matthew's research on international law, visit **www.southampton/law/matthewnicholson**

Green electrics

Worldwide numbers of electric cars and trucks are set to rise from 1.7 million to 5.3 million by 2020. In the UK, the anticipated pressure that charging these vehicles will cause to the National Grid's energy supply is a vital challenge that needs to be overcome. University of Southampton computer scientists have designed a new pricing system based on online auction platforms, to make charging electric vehicles more effective.

"Plug-in hybrid electric vehicles are expected to place a considerable strain on local electricity distribution networks. If many vehicles charge simultaneously, they may overload the local distribution network; so their charging needs to be carefully scheduled."

Dr Enrico Gerding,
Electronics and Computer Science

Research at Southampton into electric vehicles includes the electric AC Cobra, designed and developed by Professor Andrew Cruden

Optimised charging

The researchers have devised a system where electric vehicle owners use computerised agents to bid for the energy to charge their vehicles, and to organise time slots when a vehicle is available for charging.

Dr Enrico Gerding, who is one of the academics leading this research, explains: "Plug-in electric vehicles are expected to place a considerable strain on local electricity distribution networks. If many vehicles charge simultaneously, they may overload the local distribution network; so their charging needs to be carefully scheduled."

Enrico and his colleagues have designed a system which allows users to enter their details, including at what point they will need to use their car, and how far they are planning to drive. This scheduling process not only takes pressure away from the grid by charging vehicles in a logical 'order', but it also saves those users money who can be more flexible with their charging allocation.

Dr Sebastian Stein, who is undertaking this research alongside Enrico says: "Users can input a time when they plan to depart, and the system can reprice their usage if they depart earlier. We want people who actually need their cars to have what they need, so it is important that people are truthful about their requirements."

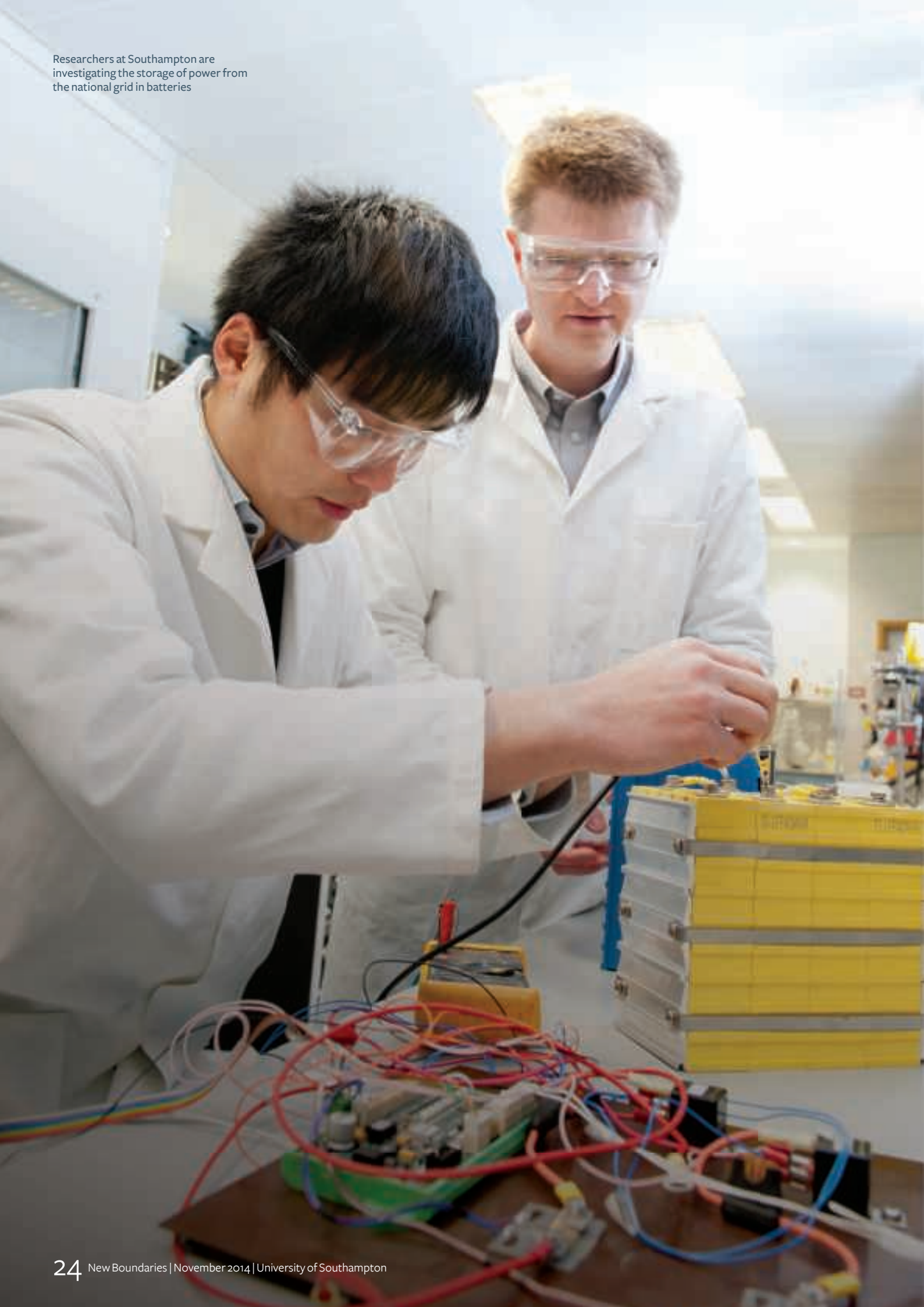
The electricity infrastructure in the UK is not currently built to support the number of electric vehicles there are expected to be in use in the UK by 2020. "The local transformers which step down high voltage to low voltage, have been built for the electricity demands of a normal household, and they are already frequently at the top of their capacity. An electric vehicle draws at least the same power again as a normal household, so it doubles the energy consumption, which could be a huge problem," explains Enrico.

Strong incentives

The proposed system that the team are developing incentivises people to be honest and flexible about their transport requirements. For example, for people who arrive home from work and don't plan to use their car again until the morning, the system can charge the vehicle at an off-peak time, and the user will pay less than if they need to charge their car at a peak time.

"For us, it is all about incentivising the scheduling for the user," comments Sebastian. "The way we do this is by lowering the charging costs the more flexible you can be. What's more, the system should be very straightforward to use. All the user needs to do is tell the system what time they need their car, and everything else will be done automatically."

The team are expanding on their idea by looking at intelligent software components for this mechanism, which can detect the usual usage levels of individual cars, and can participate in the auction process on the owner's behalf. Enrico and Sebastian are currently working with international car manufacturer Toyota, to help them assess the market for setting up this mechanism within the Toyota system. Enrico says: "The key problem for us at the moment is establishing whether we need a complex system that offers more flexibility to the user, or a simpler system that offers fewer flexible options for their charging schedule. Our priority however, is to ensure that the day-to-day commercial and personal users of the system can understand it." They have developed the website www.bid2charge.com, which turns the charging mechanisms into a game to test how users will interact with them.



Researchers at Southampton are investigating the storage of power from the national grid in batteries

Sebastian is currently writing a research proposal in collaboration with Aston University, to extend this work to consider a vehicle-to-grid (V2G) setting, where electric vehicles can give back power to the grid to support it at times of high demand and users can make a profit from selling this energy.

Storing power

Professor of Power Electronics Machines and Drives, Suleiman Sharkh and Professor of Energy Technology, Andrew Cruden, have received funding from the Engineering and Physical Sciences Research Council (EPSRC) for a three-year project on V2G. Two Southampton alumni have provided the equipment needed to undertake this research. REAP systems, founded by Dr Dennis Doerffel, designed, manufactured and installed the Energy Storage Solution based on Yuasa cell technology and the bidirectional grid-connected charger is designed and built by Dr Mohammad Abusara from HiT Power.

Using this charger, Suleiman and Andrew have been able to test the feasibility of charging and discharging batteries, and model ways to make the process more energy efficient, using smart grids with internet technology to control the system. They are undertaking this work in collaboration with colleagues at the universities of Sheffield, Warwick, Liverpool and Strathclyde in the UK and Huazhong and Tsinghua in China.

"As electric vehicles become increasingly popular, it should be possible to link their energy storage capacity to the national grid," Suleiman explains. "This should help relieve the grid and even out the peaks and troughs of power generation and storage during the times in the day when they are not being used."

Feasible solution

"We need to understand more about the practicalities of using car batteries in this way, whether the process would wear out the battery too quickly or cause too much inconvenience for the driver," explains Suleiman. "Like us, our university partners are also involved in cutting-edge research in this area which could transform the energy generation and transport in years to come," he adds.

In the medium term, it is important that we are focusing resources into the development of more effective electric vehicles. "The government is paying real attention to the development of electric vehicles, as they are currently the only feasible solution to reducing carbon emissions in the transport sector," Sebastian says. "The Committee on Climate Change, an advisory group to the government, recommends that by 2040, all new cars need to be zero-emissions vehicles. As such, we will see a huge rise in electric cars in the UK."

To find out more about the efficient charging schedule, visit **www.southampton.ac.uk/ecs/chargingschedule**

"As electric vehicles become increasingly popular, it should be possible to link their energy storage capacity to the national grid. This should help relieve the grid and even out the peaks and troughs of power generation and storage."

Suleiman Sharkh,
Professor of Power Electronics Machines and Drives

Mobile phones combat malaria

Globally, 3.4 billion people are at risk of malaria, a preventable and treatable mosquito-borne illness. According to the World Health Organization, there were an estimated 207 million cases in 2012 and 627,000 deaths.

Image: Dr Tony Brain/Science Photo Library

Dr Mickey Chopra, Chief of Health at UNICEF asks Geographer Dr Andy Tatem at the University, what Southampton is doing to help eradicate malaria.

Dr Mickey Chopra, (BSc Medical Sociology; BM Medicine, 1992), Chief of Health, UNICEF:

UNICEF is the world's leading organisation for children and child rights in over 190 countries, where we work with families, local communities, business partners and governments to help every child reach their full potential.

My role at UNICEF is as Chief of Health. I am the lead technical and policy advisor with regards to how UNICEF should be prioritising investment in health issues. We have a total budget of £6bn; 56 per cent of this is used for health-related projects such as preventing malaria.

Malaria is one of the top three leading causes of childhood deaths, but what makes it even worse is that it is a preventable disease. The use of long-lasting insecticidal nets (LLINs) and more effective treatment and diagnosis programmes can result in a remarkable decline in deaths caused by the disease.

Within the next 20 years it is our aim to reduce the number of child deaths globally to 20 in every 1,000; this is not far from the child mortality rates in Europe, the UK and USA. We have the interventions to achieve these reductions, particularly with Malaria. Countries such as Zambia, Ethiopia, and Rwanda, which have scaled up the use of LLINs, diagnosis and treatment regimes have seen malaria almost disappear, and have brought the disease under control.

One of the major issues with malaria is regarding migration. As infected people move around they carry the malaria parasite to new locations. In areas such as South Africa, where malaria is almost absent, the people are less resistant to the disease. However, when malaria is introduced back into local mosquito populations through infected travellers from another area of the continent, such as Mozambique, being bitten, the population is very vulnerable and susceptible to infection and increase risk of death.

This is where the research at Southampton could help combat this deadly, but preventable disease.

Dr Andy Tatem, Reader in Geography:

Southampton research is at the forefront of the worldwide battle to eradicate Malaria. Funded by the Bill and Melinda Gates foundation, our research is changing the way we are tackling the elimination of malaria in individual countries and across continents.

We are harnessing anonymised mobile phone usage data to map the movements of populations in and between malaria 'hotspots'. Understanding the movements of a country's population can be crucial in eliminating malaria. Attempts to clear the disease from an area can be ruined by highly mobile populations quickly reintroducing the parasite. As part of the Malaria Atlas project, we have created population mobility maps with anonymised mobile phone usage data from the National Vector-borne Diseases Control Programme (NVDCP) in Namibia.

Previously, the only data available to us on population mobility were occasional household surveys and some border crossing information, but anonymised mobile phone usage data give us incredible detail on how millions of people are moving around over time periods of months and years. Now that 90-95 per cent of the population are using mobile phones, we have an incredible amount of data at our disposal.

By combining the results of these studies with information about diagnosed cases of malaria, topography and climate, we have been able to identify geographical 'hotspots' of the disease and design targeted plans for its elimination. Specifically we have helped with the targeting of insecticide-treated bed net distributions in Namibia in 2013, and will continue to help the NVDCP prepare for a large-scale net distribution in 2014 and the deployment of community health workers.

Our findings suggest it may be possible for malaria elimination to proceed like a ratchet, tightening the grip on the disease region-by-region, country-by-country, until eradication is ultimately achieved – but without the need for a globally coordinated campaign.

After elimination in a region, malaria importation poses a constant threat, which our research is helping to tackle. Because humans and mosquitoes carry the malaria parasite from endemic areas across international boundaries and within countries, it is crucially important to monitor and contain outbreaks and avoid endemic transmission from restarting.

Now 40 countries and sub-regions around the world have targets of totally eliminating malaria from their borders, using the guidelines laid out by us in collaboration with the World Health Organization on how to conduct elimination feasibility assessments, using evidence from mapping, mobile phone analysis and mathematical modelling.

Our work is also having a global impact beyond malaria elimination. As the Director of the WorldPop project (www.worldpop.org.uk), I collaborate with colleagues in Demography and Social Statistics to map population distributions in low-income countries. The WorldPop website provides open access to spatial demographic data which can be used to help tackle challenges such as, poverty, public health, sustainable urban development and food security.

Our maps and data are helping charities, policy-makers, governments and researchers to make decisions which affect the quality of people's lives. These could be as diverse as predicting the spread of infectious diseases, planning the development of transport systems or distributing vital aid to disaster zones.

For more information on Andy's research, visit **www.southampton.ac.uk/geography/andytatem**

In brief

Fit for the frontline

Southampton researchers, with assistance from the Ministry of Defence, have conducted the first study to identify the hearing requirements of British soldiers fighting on the frontline.

The study, which provides an important and novel insight into the frontline experiences of British infantry personnel, identified 17 auditory tasks, such as hearing grid references and locating enemy movement in maize fields, carried out on operational duties abroad.

By identifying these tasks, researchers will be able to develop new auditory fitness for duty measures to determine the impact of hearing loss among infantry personnel and ensure that personnel are given appropriate training and equipment before deployment.

Zoë Bevis, from the University's Institute of Sound and Vibration Research (ISVR) says: "This new information allows us to better understand the challenges faced by our frontline soldiers."

She explains that soldiers felt their hearing was impaired when they performed multiple tasks or when they were in a stressful environment. "The study emphasises how important it is for the infantry to hear important signals while maintaining their situational awareness. Participants felt their hearing played a fundamental part in their safety and their ability to carry out the job expected of them," she adds.

Caging water

Southampton researchers are using a pioneering method of 'caging' water molecules to study the change in orientation of the magnetic nuclei at the centre of each hydrogen atom at cryogenic temperatures.

Water molecules can exist as one of two isomers, depending on how the spins of their two hydrogen atoms are orientated: ortho, where the nuclear spins are parallel to one another, and para, where the spins are antiparallel.

Together with colleagues at the University of Nottingham and Columbia University in New York, our researchers have trapped water molecules inside ball-shaped carbon molecules. This allows the molecules to be cooled, without freezing, so that the change in form (or isomer) of the molecules can be monitored.

"Currently, mechanisms for this conversion are not completely understood, nor how long it takes the molecules to transform from one spin isomer to the other," said Salvatore Mamone, a postdoctoral researcher in the Magnetic Resonance Group in Chemistry, at Southampton.

"To study this, we had to figure out how to reduce the strong intermolecular interactions that are responsible for grouping of molecules and lowering the rotational mobility of the water molecules – the answer was to cage them in fullerene spheres."

ME treatment

A collaborative study by Southampton researchers and colleagues from the University of Cumbria reveals that NICE guidelines, which state that severely affected patients with ME should have access to specialist care, are not being met by many NHS Trusts across England.

It is estimated that ME, otherwise known as chronic fatigue syndrome (CFS), can affect up to 250,000 people in the UK. It leaves people with debilitating physical and mental fatigue and pain. Severely affected individuals can become housebound, wheelchair or bedbound and dependent on carers for all basic activities of daily life.

The study surveyed all 49 NHS specialist ME/CFS adult services in England in 2013 and found that over a third of specialist adult ME/CFS services in the NHS provide no service to severely affected patients. A further 12 per cent of trusts provide only minimal or occasional help to housebound patients, primarily due to lack of funding.

Clare McDermott, NIHR School for Primary Care Research funded Doctoral Research Fellow at Southampton, led the study and comments: "People with severe ME/CFS should be able to seek specialist help even when they are housebound. We were surprised by the lack of services and access to services that our survey revealed."

The Southampton team are now conducting a pilot study to evaluate a community-based intervention that will aim to reach the most severely affected people with ME/CFS.

Top business incubator

The University of Southampton SETsquared incubation centre, part of the collaboration between the universities of Bath, Bristol, Exeter, Southampton and Surrey, has been named the number one university business incubator in Europe and second in the world. SETsquared is the enterprise partnership that accelerates businesses and boosts enterprise for the five partners.

At Southampton, SETsquared success stories include a number of companies from across a wide range of industries and sectors. They include established companies such as PrimerDesign, which developed the world's first swine flu detection kits; to emerging businesses such as SoftIron that has developed the world most energy-efficient computer hardware.

The ranking, published in June by the University Business Incubator (UBI) Index, places SETsquared as one of the world's leading three incubators, ahead of SCUT Science Park at South China University of Technology and just behind The Rice Alliance for Technology and Entrepreneurship at Rice University, Houston.

Dhruv Bhatli, Co-founder and Director of Research at UBI Index, said: "SETsquared did really well on our Global Benchmark and beat numerous business incubators based at top universities. They are one of the best incubation places in the world and certainly the best in Europe, as evidenced from their performance on our global benchmark."

In brief

Causes of antisocial behaviour

Southampton researchers are investigating the causes of Conduct Disorder in teenage girls and boys to examine the underlying neurobiology of the condition and to try to understand why boys are more likely to develop the disorder than girls.

Conduct Disorder (CD) is a psychological condition that affects children and adolescents and is associated with aggressive and antisocial behaviour. Typical problems associated with CD include teenage pregnancy, difficulties integrating into working life, drug abuse, delinquency and chronic health problems.

"It costs society ten times as much to raise children with Conduct Disorder to adulthood as children without the condition, and they are at greater risk of developing mental and physical health problems in adulthood," says Dr Graeme Fairchild, Senior Lecturer in Clinical Psychology at the University.

In collaboration with 12 other research institutions across Europe, the University will share over £4.8m of European Union funding to conduct a large scale study of girls and boys with CD. "The FemNAT-CD study will involve studying the development of the brain and the body's stress system in children and teenagers with CD and a typically-developing comparison group. We will also study a range of risk factors for antisocial behaviour such as bullying, migration, post-natal depression in mothers and negative peer influences," says Graeme.

Speed of light

Research at Southampton and Imperial College London, has found that nanostructures with an asymmetric design trigger the emission of tuneable light at terahertz frequencies, which could have an impact on photonic and optoelectronic devices across a broad range of applications, including medical imaging and security scanning.

Led by Dr Simone De Liberato, the team found that quantum wells – 2D nanostructures formed of several layers of semiconductor alloys placed on top of each other like a sandwich – can enhance light emission in a technological challenging spectral range.

The team showed that by shining light on a 2D asymmetric nanostructure with a laser that is tuned at resonance with the electronic transitions that can occur in the nanostructure, in addition to the scattered laser light, the emitted light at other frequencies can be tuned simply by changing the laser power.

Nathan Shammah, from the University's Quantum Light and Matter group says: "Due to the large oscillating dipole and high density of electrons that characterise these 'artificial atoms' formed of asymmetric 2D structures, the control of light-matter coupling can be greatly enhanced, triggering spontaneous light emission, similar to what occurs in LEDs lamps.

"This new mechanism is perfectly suited for the terahertz frequency range, which is placed above the current Wi-Fi bandwidth and below the visible light spectrum, where the lack of practical light emitters constitutes a serious technological gap."

Combating cerebral palsy

PhD student Afrah Almuwais is investigating how games played on the Wii Fit balance board may improve balance and confidence in children with cerebral palsy.

There has been considerable interest in the therapeutic value of these games since the launch of the Wii Fit balance board in 2008. Games played on the Wii Fit require people to move their entire body, shifting their weight from side-to-side, which is a treatment similar to what is already being carried out in clinics.

Afrah explains: "I find children have a real lack of motivation to do the standard exercises recommended for treatment of cerebral palsy. By using the Wii Fit, children can do their exercises in a fun way, with their friends and families, on an equal level.

"A lot of the direction about posture and movement given by physiotherapists is sometimes ignored, but with the reward of achieving a better score on the game by moving the body in a particular way, children are more inclined to take notice."

Afrah hopes to use this readily available technology to allow children to play equally with their friends and siblings, while improving their balance.

Calling the shots

Film researchers at Southampton are analysing the involvement of women behind the camera in UK film since 2000 and embarking on a study of the history of women filmmakers in the 21st century.

Dr Shelley Cobb and Professor Linda Ruth Williams have been awarded £590,000 by the Arts and Humanities Research Council (AHRC) to consider the impact of the UK Film Council's initiative between 2000 and 2011 to encourage women's career progression in the industry.

"Women are becoming more prominent in film with directors such as Phyllida Lloyd (*Mamma Mia*) and Jane Campion (*The Piano*), but we want to know more about their roles elsewhere in the industry," says Linda.

"Fewer than 20 per cent of people who work in key production roles are female," explains Shelley. "Numbers of men and women entering film school are roughly 50:50, but there is some evidence that women's careers stall in their thirties. We want to learn more about why this happens."

Together with project partners, the British Film Institute (BFI), Women in Film and TV UK, Birds Eye View, the media and entertainment union BECTU, Harbour Lights cinema and Shetland Arts, the researchers will carry out around 50 interviews with women who work as editors, writers, cinematographers, directors, producers and executive producers to record their experiences.

For more information on these stories, visit **www.southampton.ac.uk/research**

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