Lloyd's Register Foundation

UNIVERSITY OF Southampton

ICON

International Consortium of Nanotechnologies

Review 2016

www.lrf-icon.com

ABOUT US

Building a safer world *with* Nanotechnology

The International Consortium of Nanotechnologies (ICON), led by the University of Southampton and funded by the Lloyd's Register Foundation, aims to build capacity and knowledge in the application of nanotechnologies to support safety of life and property.

Societies and communities around the world face major challenges linked to climate change, population growth, energy security and the availability of food and water. In response, innovative technology, in areas such as smart materials, energy storage and generation and big data, is being developed to ensure the critical infrastructure on which modern society relies is able to satisfy growing demands.

ICON intends to develop a network of nanotechnology experts from academia and industry to help address the 'Grand Challenges in Nanotechnology'. ICON will also support the development of more than 50 new international nanotechnology experts, 19 of whom have started or are about to start specific research projects, who will spend their training considering safety issues and advancing knowledge within a specific field related to the themes identified in the Foresight Review of Nanotechnology (2014).

The Lloyd's Register Foundation is a charity that helps to protect life and property and support education, engineering-related research and public engagement.

ADDED VALUE

COMMITTED OVER

£900,000 OF RESEARCH FUNDING

LEVERAGED OVER

£2,000,000 OF INSTITUTIONAL & INDUSTRIAL FUNDING

Dr. Themis Prodromakis
ICON Project Director,
University of Southampton

The Foresight Review of Nanotechnology (2014) reviewed the state of play and assessed the impact of nanotechnology in sectors relevant to the Lloyds Register Foundation Following this, we submitted a successful proposal to the Foundation and ICON was born.

As you will read in these pages, ICON's first year has been very exciting and impactful. We have focused on setting in motion the recruitment of the Lloyd's Register Foundation Doctoral Students that are developing nineteen unique programs that surpass geographical and disciplinary boundaries. We are also attracting an exciting international audience willing to engage in the ICON network and growing this sustainably.

Our activities span across industrially relevant challenges, through the active involvement of global companies, all the way towards addressing fundamental scientific questions that could bring disruptive benefits to our society; all because life matters.

As ICON grows, we are looking in further developing our social media presence for enhancing the public understanding of risk and the new opportunities nanotechnology brings for making the world a safer place. We are confident that our scholars will be the best ambassadors for communicating this.

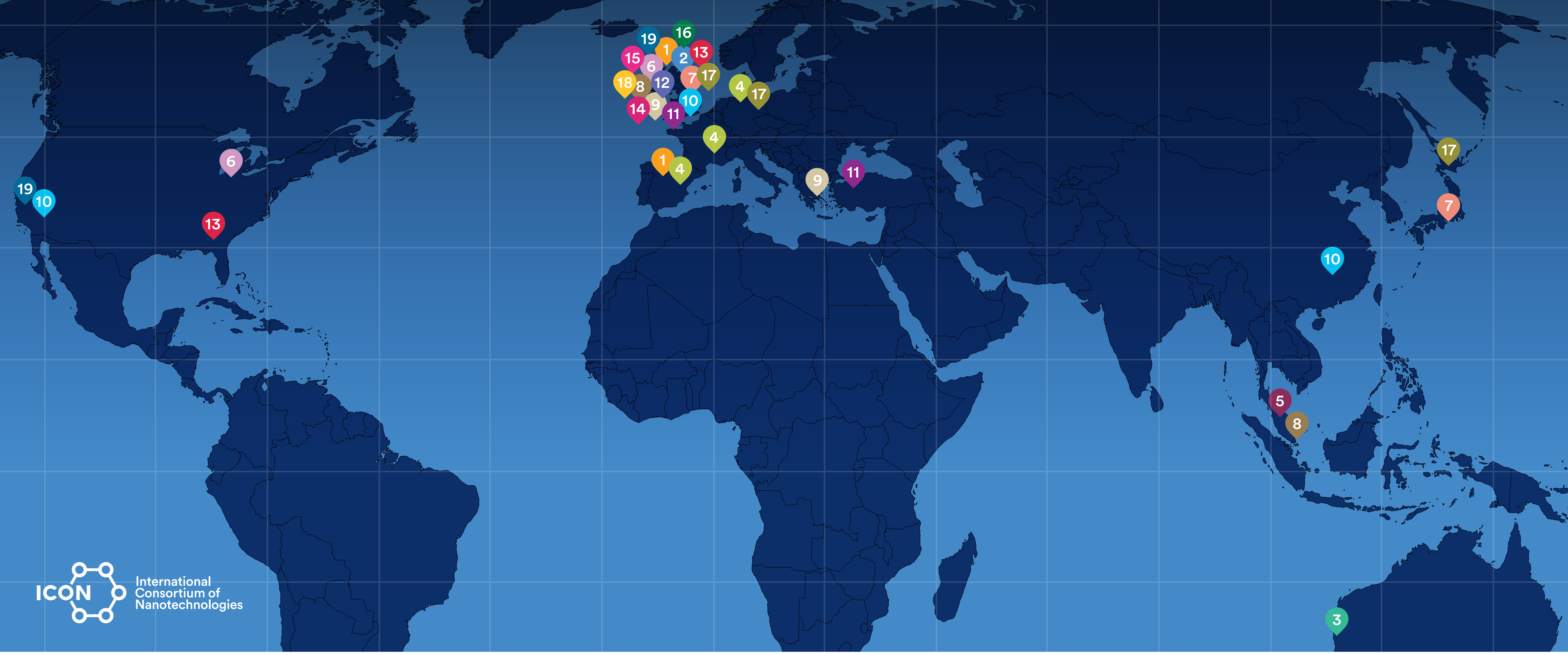
I hope you will enjoy reading about our research and the progress we are making in meeting the Foundation's charitable aims.

ICON International Consortium of Nanotechnologies

The mission of the Lloyd's Register Foundation is to enhance the safety of life and property and to advance public education. In pursuit of this, nanotechnology and its applications are undoubtedly going to have an impact on the sectors and communities we serve. But the question is how? This is where ICON and its network of nanotechnology experts together with its research and education programmes comes into play.

ICON has got off to a great start. It's challenge going forward is to translate the end-user inspired work it has started into outcomes and impact for the benefit of society.

Professor Richard Clegg
Foundation Chief Executive,
Lloyd's Register Foundation



PROJECTS FUNDED

19

Australia
France
Germany
Greece
Japan
Malaysia
Singapore
Spain
Turkey
UK
USA

COUNTRIES INVOLVED

11

PROJECT LOCATIONS

35

INDUSTRIAL STAKEHOLDERS

20

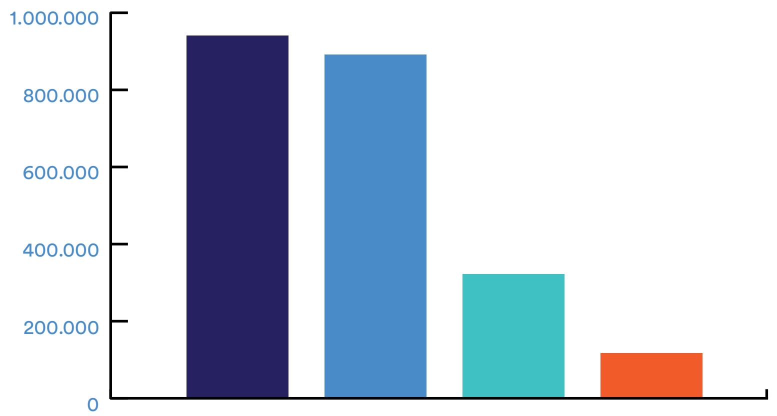
- Cobham Wireless (UK)
- Conoco Phillips (UK)
- Costain (UK)
- Dow Corning (US)
- Eight19 Ltd (UK)
- European Thermodynamics (UK)
- Haydale Ltd (UK)
- MIMOS Ltd (Malaysia)
- Morganic Metal Solutions (UK)
- Nanomagnetics Instruments (UK)
- Nanotypos (Greece)
- National Physical Laboratory (UK)
- Nokia Bell Labs Ltd (US)
- NTT Basic Research Laboratories (Japan)
- OPS Structural Engineering (UK)
- RIKEN (Japan)
- Statoil (UK)
- Thomas Swann & Co (UK)
- Total UK (UK)
- WISEN Innovation (UK/China)

PEOPLE INVOLVED

99

12 students
43 supervisors
7 PMB members
6 Theme Leads
31 reviewers

THE ICON PROJECTS IN NUMBERS



Funding

- Value of grants awarded: **£940,000**
- Matched by Institutions: **£890,000**
- Industrial funding: **£323,000**
- Other funding (including charities, research councils etc.): **£118,000**

Geographical Distribution

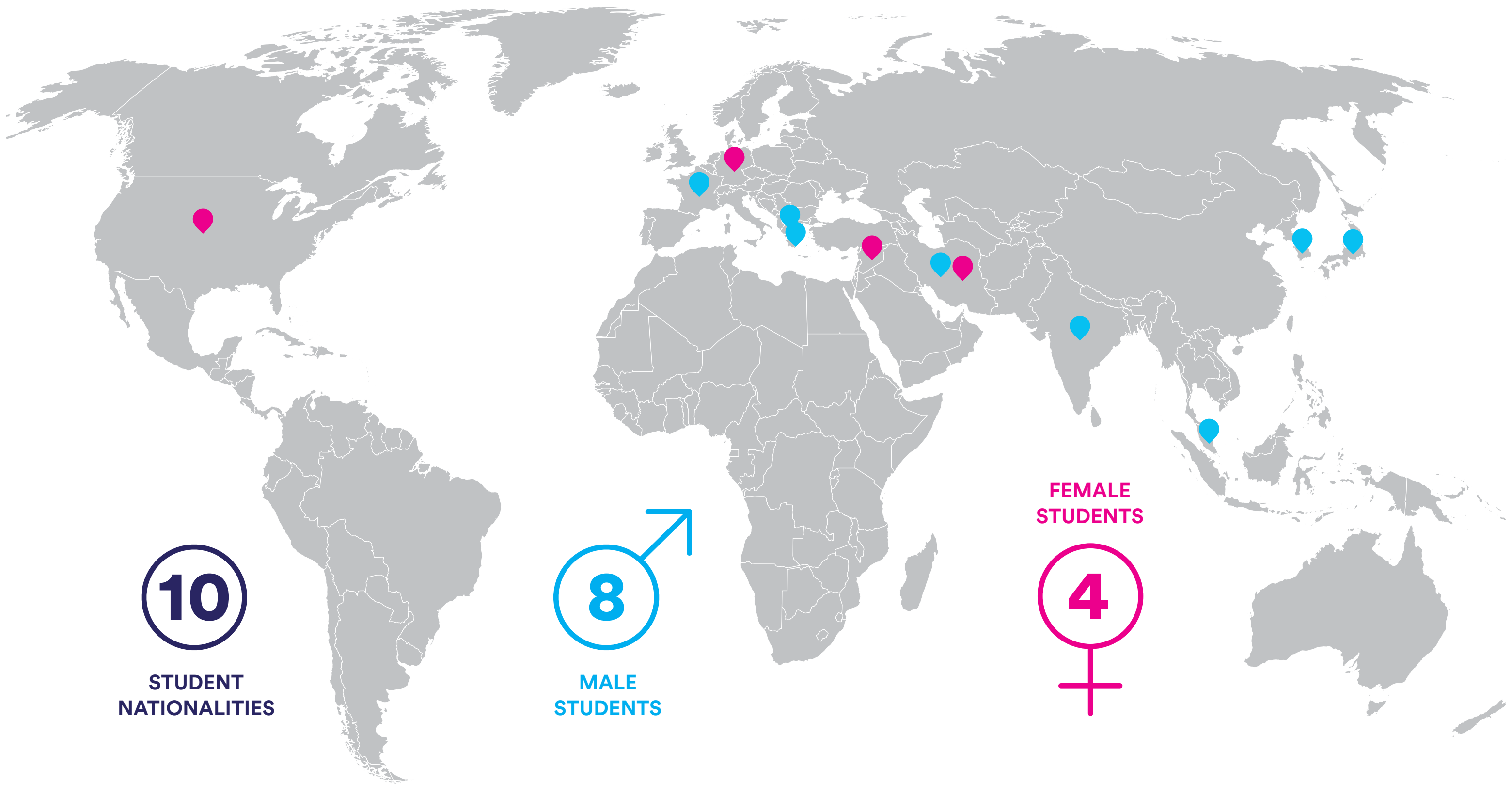
Of lead institutions:

15	1	2	1
Europe	Asia	North America	Australasia

Of partner institutions:

8	5	2	0
Europe	Asia	North America	Australasia

Equality, Diversity & Inclusion



RESEARCH THEMES

Sensors

Nanotechnologies bring several benefits in the deployment of sensors via new manufacturing techniques that allow cost-effective up-scaling (e.g. nano-imprint lithography, self-assembly) of distinct technologies but also the miniaturization of sensing elements for achieving higher integration densities that can in principle enhance the overall monitoring reliability and decision making of embedded platforms.

THEME LEAD:

Alain Nogaret (University of Bath)

Alains research group focuses on low dimensional electron systems confined by microscopically inhomogeneous magnetic fields, and micromachined transmission lines that propagate electrical impulses and mimic biological nerve fibres.

Smart Materials

For advanced functional "smart" materials to thrive in the industrial world, we need to understand: a) current manufacturing processes, b) possible integration of these materials in components or classical material systems, c) industry needs for performance and reliability, and d) the requirements for new assembly processes and manufacturing techniques in order to realise this. Functional "smart" materials could be attractive in applications requiring self-cleaning and/or self-healing properties (recovery of the material's initial response) and many more.

THEME LEAD:

Nicole Grobert (University of Oxford)

Nicole Grobert's research group focuses on the synthesis, processing, and characterisation of novel carbon and non-carbon based nanomaterials, including nanoparticles, nanotubes, nanorods, graphene and other 2D nanomaterials.

Computing and Communications

Computationally efficient concepts, for example neuromorphic computing and quantum simulations, can be exploited for processing big-data and relax the excessive requirements on bandwidth and overall power consumption. In addition, On-node processing is essential for sensing platforms that are embedded within a host system to ensure energy efficiency and reliability.

THEME LEAD:

Bernabe Linares Barranco (University of Seville)

Bernabé Linares-Barranco's research group focuses on exploiting nano-scale devices for event-driven learning and processing via circuit design for telecommunication circuits, VLSI emulators of biological neurons, VLSI neural based pattern recognition systems, hearing aids, precision circuit design for instrumentation equipment, bio-inspired VLSI vision processing systems, and VLSI transistor mismatch parameters characterization.

Data Management

The ability to miniaturise pervasive sensors via nanotechnology imposes great challenges on data storage and transmission. Pre-processing of big data is essential for relaxing bandwidth requirements. Other innovations include emerging ultra-dense memory concepts and ultra efficient algorithms for processing, encrypting and communicating data without compromising on reliability.

THEME LEAD:

Ling Wang (University of Southampton)

Ling Wang's research group focuses on condition monitoring for tribological systems.

Nanotechnology and Risk

It is crucial that all nanotechnology innovations are developed responsibly and are not to be misused or generate any unexpected consequences. ICON will strongly adhere to this principle and all developments will go hand in hand with the necessary safety, standards and risk assessments.

THEME LEAD:

William Keevil (University of Southampton)

Bill Keevil's research focuses on environmental healthcare within biological sciences.

Energy and storage

Pervasive sensors require extremely efficient data management for short-term applications. Long-term applications however necessitate extremely efficient mechanisms for storing or scavenging energy from the environment.Numerous opportunities exist for energy harvesting that stem from phonon engineering, radiation, thermoelectric, metamaterials, pressure, acoustic and vibration transduction, as well as harvesting power from biological reactions (glucose, methane, bio-mass, enzymatic, etc). Opportunities for storing energy are equally broad; new supercapacitors architectures and the shrinkage of employed electrodes show great promise for improving on performance.

THEME LEAD:

Eric Yeatman (Imperial College London)

Eric Yeatman's research group focuses on on optical devices and materials, micro-electro-mechanical systems (MEMS), and other topics.

EVENTS

Lloyd's Register Foundation International Conference 2016

The Lloyd's Register Foundation flagship International Conference, held on 13 and 14 October 2016 in London, brought together grant holders, public, academia and industry. The conference featured keynote speakers, presentations and early career 'master classes' spanning all areas of Foundation grants funding. ICON was delighted to have the opportunity to network with the wider Foundation community at the Conference as well as introduce them to the ICON's vision.

Friday 14 October
Accelerating the uptake of research
Grand challenges

Thursday 13 October
Public understanding of risk
Tomorrow's safety

ARTICLES

Five ways nanotechnology is securing your future

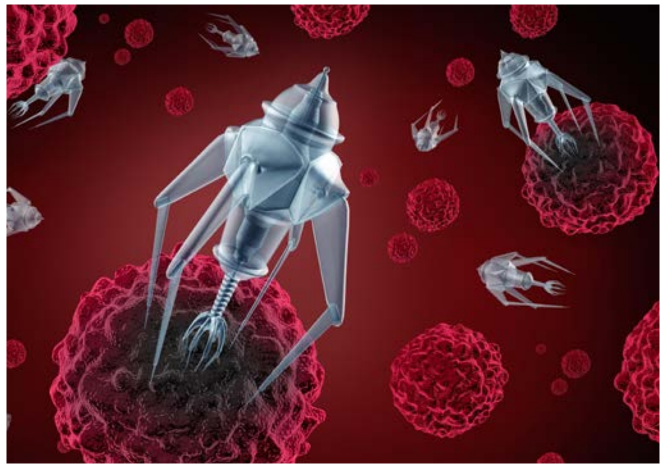
22 March 2016

Dr. Themis Prodromakis
ICON Project Director,
University of Southampton

The past 70 years have seen the way we live and work transformed by two tiny inventions. The electronic transistor and the microchip are what make all modern electronics possible, and since their development in the 1940s they've been getting smaller. Today, one chip can contain as many as 5 billion transistors. If cars had followed the same development pathway, we would now be able to drive them at 300,000mph and they would cost just £3 each.

But to keep this progress going we need to be able to create circuits on the extremely small, nanometre scale.
A nanometre (nm) is one billionth of a metre and so this kind of engineering involves manipulating individual atoms. We can do this, for example, by firing a beam of electrons at a material, or by vaporising it and depositing the resulting gaseous atoms layer by layer onto a base.

The real challenge is using such techniques reliably to manufacture working nanoscale devices. The physical properties of matter, such as its melting point, electrical conductivity and chemical reactivity, become very different at the nanoscale, so shrinking a device can affect its performance. If we can master this technology, however, then we have the opportunity to improve not just electronics but all sorts of areas of modern life.



The full article was originally published in The Conversation on 22 March 2016 and was republished by the Independent on 23 March 2016.

FULL ARTICLE:
https://theconversation.com/five-ways-nanotechnology-is-securing-your-future-55254

ACTIVITIES

ICON Outreach Activity

The ICON network is committed to supporting relevant outreach activities with the aim of building a safer world with nanotechnology. For example, during British Science Week, members of the public were given the opportunity to see inside the state-of-the-art cleanroom complex at the University of Southampton, home of the best set of nanoelectronics and photonics fabrication capabilities in the UK. Visitors had the opportunity to learn about the cleanroom fabrication process through assembling their own silicon chip key rings.

In addition children learnt about nanofabrication through dressing up in cleanroom 'bunny suits' and making their own microfluidic jelly chips.

Engagement with events at the regional and national level are an important way to communicate nanotechnology developments with the general public. ICON intends to encourage all those associated with the network to consider how they may contribute to enhancing safety and benefit society, as well as generate impact with excellent research.

Our Worldwide Projects

1 Reconfigurable nanowires phononics for temperature sensing

LOCATIONS: Imperial College London, London, UK | University of Salamanca, Salamanca, Spain

Nanotechnology opens up novel opportunities to develop sensors and energy convertors that can be used in a wide range of applications. Due to their small size and increased functionality they can be integrated into systems with low “real-estate” cost while offering real-time asset monitoring for increased control and energy efficiency. An area where nanotechnology can have a large impact is phononics – the science of controlling heat conduction in systems – and thermoelectric (TE) applications. Decreasing the structure size allows electrical transport but hinders phonon (heat) transport. Thus, nanowire (NW)-based systems can boost the performance of TE generation and cooling, and may enable key absent technologies such as on-chip heat management and storage, heat recovery and information processing in thermal form for systems such as heat sensors and generators. In the proposed work, the combined control of phonon and electron transport will be used to implement temperature sensing and data processing. This will be achieved by fabricating semiconducting NWs for phonon-filtering with Schottky barrier contacts for electron energy filtering. Nanoscale metal-semiconductor (MS) contacts have the ability to increase the Schottky barrier height that controls hot electron injection from the metal into the semiconductor. It is known that the introduction of high potential barriers in the carrier stream increases the Seebeck coefficient and thus increases the open circuit voltage for a given temperature difference.

STUDENT: Ali Hamid

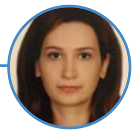
Ali Hamid was born in Iran in 1993. He lived in Iran for 14 years and then moved to Dubai to complete high school. During this time, he and his friends held many discussions on the need for low power devices for portable applications such as mobile phones. Small devices, low power and good heat management systems are essential to maintain long battery life and reliability in portable electronics. These discussions triggered an interest in micro- and nanochip design and manufacturing. He then studied Nanoscience and Nanotechnology (Bsc) at the University of Leicester (2012-2015), to understand the basics of nanotechnology. That course was followed by an MSc in Nanoscience and Nanotechnology in the University of Glasgow (2015-2016), to learn more about nanoelectronics and its fabrication methods. He joined the Electrical and Electronic Engineering Department in Imperial College London in November 2016 to work as a PhD student on the use of nanodevices for heat management applications. In his project he will investigate the use of reconfigurable nanowire field effect transistor technology for thermal management to increase the lifetime of integrated circuits and explore ways in which the thermo-electric/-ionic effect can simultaneously be exploited for battery charging.

2 Perovskite structure nanocrystals for light harvesting and light emission

LOCATIONS: University of Cambridge, Cambridge, UK

This project aims to develop new functional nanoparticles, based on lead halide perovskite materials, for use in light emission and in solar cells. These show extremely promising properties and have the potential to further advance both solar cells and also solid state lighting. In common with many other semiconductor families, there are issues to address concerning the use of low levels of potentially toxic elements (here, lead). Though quantities of these materials used are very low, understanding of the correct protocols to handle such elements safely, through process manufacture, use and disposal is critical and will form an important component of the project.

STUDENT: Zahra Andaji Garmaroudi



My research and work experience have been on nanotechnology innovations that could help to boost solar power, which is a technology that can be a key component of our future, green energy supply system due to its easy availability, cleanness and cheap energy resources.

3 Fast night vision imaging - enhancing road safety for drivers and pedestrians

LOCATIONS: University of Western Australia, Perth, Australia

For civilian and paramilitary applications, uncooled thermal imagers are the least weight and most cost-effective. However, the most serious shortcoming of un-cooled thermal imagers is the trade-off between thermal sensitivity and speed of response preventing applications in high speed/motion environments. This project aims to overcome this limitation in thermal imagers by using microscale engineering of a nano-porous silicon.

STUDENT: Yaman Afandi

My name is Yaman Afandi. I am a PhD chemical engineering student at the University of Western Australia, Perth, Australia. I am from Aleppo, Syria. I graduated from King Abdulaziz University, Jeddah, Saudi Arabic, with a Bachelor of Science in Physics in 2004. I received a scholarship to study at the same university to complete my Master of Science degree in Physics in 2011. My project in master was about microwave measurements of dielectric properties of nitride ceramics. I worked on cavity perturbation technique to measure dielectric properties at high frequencies, and some other characterizations techniques such as XRD, FTIR and SEM to study the structural changing of nitride ceramics after exposing to microwave radiation. I have a great passion for research and science. I received a reward as the second-best presentation in a local science and engineering forum in KAU in 2011. I participated in a poster in International Symposium on Compound Semiconductors 2010 in Japan. I published a research paper in 2011. After I received my master degree, I worked as a lecturer in Al-Farabi College, Jeddah, Saudi Arabia and was responsible for arranging scientific projects and workshops to promote understanding some physical concepts. I also arranged similar projects for young students in primary and middle school.

4 Continuous knowledge acquisition embedded devices based on novel nanotechnology synaptic emulators for enabling enhanced security in everyday life situations

LOCATIONS: University of Sevilla, Sevilla, Spain | Jacobs University, Bremen, Germany | CEA/LEI, Grenoble, France

Mobile devices are already permanent companions in our every day life. They can be good candidates to monitor our environment, track our habits, and detect novel unforeseen situations to trigger alarm signals. However, this would require intensive and continuous computations, impossible to perform with today's technological solutions without discharging the batteries of our mobile devices in a few minutes. Here we propose to exploit learning systems with novel nano-scale learning devices, that result in ultra low power and very high density microchips, capable of performing powerful cognitive tasks, like detecting novelty within routine habits. In present days, Neuroscience is achieving an unprecedent rate of continuous discoveries, unvealing many intrigue details on how the brain learns profound cognitive meanings from continuous sensory data. Computational Neuroscience is the field which tries to understand the computing principles within the brain by developing software programs that follow the internal brain operations, as discovered in biological Neuroscience.

STUDENT: Charanraj Mohan

Charanraj Mohan did his Bachelors' degree in electrical and electronics engineering under affiliated institution of Anna University, India. He is the recipient of HERITAGE (Europe-India partnership)- Erasmus Mundus fellowship for his Masters' in electronics, communication & signal processing at University of Seville, Spain. Presently, he is with the neuromorphic group at Institute of Microelectronics, Seville, Spain. His area of interest includes sub-micron technology circuit design and memristive device applications

5 Detection of low concentration hydrogen gas using highly sensitive three-dimensional palladium decorated graphene encapsulated in poly (methyl methacrylate)

LOCATIONS: Universiti Teknologi PETRONAS, Perak Darul Ridzuan, Malaysia

Hydrogen gas (H2) is known as one of the cleanest and most promising energy sources for future energy related applications in transportations and power generations due to its energy density, renewability, and ecofriendly in nature. However, the use of hydrogen gas is associated with serious safety concerns since it is highly flammable due to low spark ignition energy (0.02 mJ) and explosive when mixed with air at volume concentrations higher than 4%. Thus, systems utilizing hydrogen as an alternative fuel requires fast, accurate and constant monitoring for the leaks. In this research work, graphene foam doped with palladium nanoparticles will be developed as the sensing element as it has large surface area that provides huge, highly sensitive and selective gas adsorptive capacity. The proposed graphene foam sensor will have fast response and recovery time that lead to low power consumption and miniaturization of the device.

STUDENT: Adel Eskandar Samsudin

Adel Eskandar Samsudin received his Bachelor's degree in Science (Industrial Physics) from Universiti Teknologi Malaysia (UTPM) in 2010. He later joined Universiti Teknologi PETRONAS (UTP) for his Master's program in Electrical and Electronics Engineering focusing on the improvement of dye solar cells utilizing light scattering and kinetics enhancement. He worked as a research officer at the Centre of Innovative Nanostructures and Nanodevices (COINN) where he overseer the operation and maintenance of scientific instruments for fabrication and testing of dye solar cell panel. He also involved in the team for various research activities such as drafting research grant proposal, conducting short courses and developing dye solar cell learning/educational kit for national nanotechnology awareness program. His current research outcome includes paper publications and awards (gold and silver) at the international exhibitions.

6 Ultrafast nanostructuring of wide bandgap SiC for electronics in harsh environments

LOCATIONS: University of Michigan, Ann Arbor, USA | University of Michigan, Ann Arbor, USA

The LRF doctoral student will conduct a collaborative project between research groups at the University of Michigan (UM) and the University of Southampton (UOS) to study nanostructuring of wide-bandgap (WBG) SiC, and application to electronic devices capable of operating under harsh environments (resistant to high-temperature, corrosion, mechanical stress, background radiation). A new approach for localized control of electrical charge transport in SiC is proposed based on non-thermal nanostructuring on ultrafast (femtosecond) time scales. Such materials modifications are anticipated to provide both breakthrough technologies for SiC electronics, and a new enabling technology for realizing resistive memory devices (RRAM). Localized structural transitions may be achieved via irradiation with an ultrafast laser.

STUDENT: Minhyung Ahn

Minhyung Ahn is a doctoral student in the Electrical Engineering and Computer Science Department at the University of Michigan. He was born in South Korea and finished his Bachelor's degree in Electrical Engineering at Seoul National University. He is currently studying ultrafast (femtosecond) laser interactions with wide bandgap silicon carbide as a means of modifying structural and electronic properties.

7 Single electron manipulation in silicon nano-wire for quantum technologies

LOCATIONS: University of Southampton, Southampton, UK | Tokyo Institute of Technology, Tokyo, Japan

Quantum Technology is considered to achieve innovation in secure communication, high performance computing, simulation, sensor, and metrology. However, the manufacturing challenges must be overcome to integrate quantum structures for real industrial applications, because of the extremely fragile character of quantum states subject to environmental disturbances like line-edge-roughness, thickness-non-uniformity, random dopant fluctuations, and interfacial defects.

In this project, we will develop a manufacturing process technology of silicon nano-wire and manipulate single electron for quantum technologies. The primary goal of this project is to understand the transport mechanism in silicon nano-wire at the single electron level. This will be important for the application to new definition of the current. A 'quantum' redefinition of the SI system of physical units is presently under discussion, based on the fundamental physical constants of nature.

STUDENT: Kouta Ibukuro

Kouta Ibukuro is a graduate student at the School of Electronics and Computer Science, the University of Southampton. His PhD project aims to understand the transport mechanism in silicon nano-wire at the single electron level, which plays a crucial part in quantum-mechanical redefinition of the Ampere in the SI unit using the Si based single-electron-pumps. This project is funded by the Lloyds Regiter Foundation, EU EMPIR project, and UoS in collaboration with NPL, RIKEN, and NTT. Prior to his move to Southampton, he completed his BSc (Physics) program at the Department of Physics, Waseda University in Tokyo, Japan. He also spent an year in the UK as an exchange student at the Department of Physics and Astronomy, University College London, which was supported by a scholarship from Japan Student Services Organization (JASSO), affiliated to Ministry of Education, Culture, Sports, Science and Technology, the Government of Japan.

8 Hierarchical fibre reinforced nanocomposites for multifunctional improvements in safety

LOCATIONS: Imperial College London, London, UK | NTU, Singapore

Certain nanomaterials, particularly carbon nanotubes (CNTs) and graphenes, offer the potential for fundamental improvements in mechanical performance and functional properties of composites. Individual nanocarbon structures have been shown to have a significantly higher strength than any other known materials (>50 GPa), combined with excellent stiffness, high lateral flexibility, high aspect ratio, and low weight; in addition, they have good electrical and thermal conductivities, and interesting optoelectronic characteristics, all relevant to (multi)functional performance. There is a large body of work on nanocarbon composites often showing useful improvements but at a relatively modest scale, based on the introduction of only very low loading fractions. Whilst assemblies based on pure nanocarbon constructs have demonstrated significant promise, creating a new class of strong macroscopic materials is challenging.

STUDENT: Hugo de Luca

Hugo is based in the Department of Materials at Imperial College London. He has a background in nanotechnology and is particularly interested in the scalable synthesis of carbon nanotube on carbon and silica fibres, their interfacial properties, and potential for use in hierarchical composites.

9 Nanoparticle sensor arrays on flexible substrates

LOCATIONS: NTUA, Athens, Greece | Imperial College London, London, UK

The Electronic Nanomaterials and Devices research group of NTUA has developed a strain sensor which is defined by a pair of interdigitated metallic electrodes with nanoparticles being deposited in the gap between them and arranged in a 2-D configuration. This sensor exhibits much higher sensitivity than conventional metal film sensors, indeed comparable to that of semiconducting strain sensors.

This project will explore fabrication and real time reading of nanoparticle sensor arrays. The proposed high sensitivity, strain sensor arrays show potential for monitoring deformations to estimate structural fatigue and for the early detection of cracks in large marine, aerospace and civil structures enhancing safety. Other application areas include vehicles and train rails, safety equipment, environmental monitoring, homeland security as well as robotics and prosthetics.

STUDENT: Vaggelis Aslanidis

Vaggelis Aslanidis studied Physics at the Physics Department of the University of Crete. He has a master degree from the Department of Applied Mathematics and of the National and Technical University of Athens, on the Monte Carlo simulation and electrical characterization of RRAM devices. Presently, he is a PhD student at the same Department, studding the nanoparticle sensor arrays on flexible substrates.

10 Nano/micro-electro-mechanical-system self-powered sensors for infrastructure safety monitoring

LOCATIONS: University of Southampton, Southampton, UK | UC Berkeley, Berkeley, USA | Central South University, Changsha, China

Much of the UK's existing infrastructure is old and no longer safe. In its State of the Nation Infrastructure 2014 report, the Institution of Civil Engineers stated that none of the sectors analysed were 'fit for the future', and only one sector was 'adequate for now'. Existing infrastructure is challenged by the need to increase load and usage – whether the number of passengers carried, the number of vehicles, or the volume of water used – and by the requirement to maintain the existing infrastructure while operating at current capacity. To ensure structural integrity and operational safety as infrastructure ages and deteriorates, long-life and dynamic structural health monitoring systems must be developed to detect infrastructure strain and to provide clear warning signs when the infrastructure is in danger.

11 Graphene Hall-effect nanosensors to optimise high current superconducting tapes for applications in 'smart' power grids

LOCATIONS: University of Bath, Bath, UK | Middle East Technical University (METU), Ankara, Turkey

There is an urgent need for new scanned sensors to map and characterise current flow around microscopic defects in second generation high temperature superconductor (2G-HTS) tapes being developed for applications in energy storage and transmission. Existing semiconductor and semimetal magnetic field sensors for magnetic imaging have fundamental physical limits and the 'smart' material graphene, a single atomic layer of carbon, has the potential to revolutionise the field due to its very high conductivity, tolerance to nanopatterning and high tensile strength. Within this PhD project novel graphene-based sensors will be developed for nanoscale magnetic imaging which will be smaller, more durable and able to detect much lower fields. Device development will take place in collaboration with partner company NanoMagnetics Instruments who will provide CVD graphene and test prototype sensors in their scanning probe magnetic imaging products.

12 Development of liquid infused surfaces as novel antifouling materials for mineral scale prevention

LOCATIONS: University of Leeds, Leeds, UK

Precipitation of mineral deposits on the surface of domestic and industrial installations is a persistent issue, calculated to have an estimated economic cost of 0.2% of global GDP. The most common treatments employed to control mineral scaling generally involve the use of chemicals or a nano-filtration system. The former solution is economically viable, however has a significant environmental footprint. The latter suffers from the need for high energy consumption coupled with limited efficiency with monovalent ions.

The project brings together expertise in nanotechnology and surface engineering to deploy novel, environmentally-friendly antifouling materials to effectively mitigate mineral build-ups. This will be achieved through two strands of research focus. Firstly, prevention of mineral surface crystallization process, and secondly, if fouling has already occurred, minimizing the adhesion strength of the fouling layer to the substrate to facilitate easy detachment and cleaning. This alternative approach has been deployed successfully in the control of bio-fouling (e.g. paint preventing growth of subaquatic organisms on ships) but as yet remains an entirely new approach for mineral scale prevention.

13 Additive manufacturing of millimetre wave wireless sensors based on nanoparticle inks for pervasive IoT sensing and 5G communications

LOCATIONS: Heroit Watt University, Edinburgh, UK | Georgia Institute of Technology, Atlanta, USA

The implementation of wireless sensor nodes using nanomaterials at millimetre waves based on inkjet/3D printing paves the way for sensor miniaturization due to the small sensor footprint as a direct consequence of the small wavelength. Antenna based sensing techniques will be used where the presence of objects, or gases, humidity or temperature in the designed antenna environment leads to a change in its electromagnetic behaviour such as radiation pattern and input impedance characteristics which in turn result in measurable parameters for sensing applications. Such sensing techniques minimize the energy requirement of the developed sensors.

The project effectively combines two timely trends for 5G communications and IoT and additive manufacturing and 3D printing of nanotechnology based materials, and aims to reduce cost, footprint and energy requirements. There are numerous applications within the 5G and IoT framework which the results of this work can be applied including environmental sensing, asset aging and degradation due to humidity, temperature or mechanical degradation, but also communication, presence detection, through wall radar, and collision avoidance in autonomous vehicle systems.

STUDENT: Spyros Daskalakis

Spyridon-Nektarios Daskalakis received with excellence his Engineering Diploma and the M.Sc. in Electronic and Computer Engineering from Technical University of Crete (TUC) in 2014 and 2016, respectively. His current research interests include low-cost wireless sensor networks and RF energy harvesting. Particularly he focuses on backscatter scatter communication, batteryless sensors, PCB design, low cost software defined radio, environmental sensing and RF energy harvesting. He is co-founder of kaloudia.com platform. Finally he was the recipient for two short term scientific mission grands form COST Action IC1301 WiPE in Electrical and Computer Engineering, Georgia Institute of Technology (2016) and in Centre Tecnològic de Telecomunicacions de Catalunya (2015). His interests are inkjet and 3D printed technologies for flexible electronics. Especially using nanomaterials at millimeter waves which are suitable for 5G communications and IoT reducing fabrication time and cost.

14 Development of a nano-structure deposition process to integrate energy harvesting materials and heat management systems into single-piece, hot, structural elements such as exhaust/fluid manifolds

LOCATIONS: Coventry University, Coventry, UK

This project will integrate thermo-electric heat scavengers and attendant heat management systems into a single-piece, high thermal conductivity, structural part made of nano-structured Copper (free of toxic Beryllium). This will allow optimum energy harvesting from the waste heat of hot fluids. Single-piece manufacture will enable improved safety through vastly improved leak-tightness and structural integrity of the installation with minimised space usage. Copper is a relatively abundant metal, ideal for heat management applications due to its high thermal conductivity. However, bulk copper is too weak at temperature to provide structural strength. The ultimate strength of a material comes from the chemical bonds that hold it together. Like a zip fastener, it is hard to pull the zip apart (break the bonds) all at once. However, materials have very small defects ("dislocations"), which can move easily through the material, sequentially breaking individual bonds (like a zip unfastening) to generate permanent deformation (plasticity). Thus, bulk materials are generally very much weaker than their theoretical strength. Industrial trial and error has found that introducing different atom sizes, particles, grain boundaries and plastic work, can all increase the strength of a material. Even test-size affects the measured material response; "smaller is stronger".

15 Stronger, lighter, safer, materials by length scale engineering and a next generation, nano particle free, 3D additive manufacturing process

LOCATIONS: Coventry University, Coventry, UK

This project will exploit a new "joined up" understanding of plastic deformation to design smart, 'length-scale engineered' materials that have increased strength, adequate ductility/toughness for safe use, and self-healing properties. It will produce nano-enabled materials using a new, safer, additive manufacturing route, and design rules for more sustainable, safer (higher performance/lifetime in harsh environments) and energy efficient components (reducing weight for equal strength). The ultimate strength of a material comes from the chemical bonds that hold it together. Like a zip fastener, it is hard to pull the zip apart (break the bonds) all at once. However, materials have very small defects ("dislocations"), which can move easily through the material, sequentially breaking individual bonds (like a zip unfastening) to generate permanent deformation (plasticity). Thus, materials are generally very much weaker than their theoretical strength. Industrial trial and error has found that introducing different atom sizes, particles, crystal boundaries and plastic work, can all increase the strength of a material.

16 Structural health monitoring with graphene-silicone strain sensors

LOCATIONS: University of Bath, Bath, UK

The detection and localization of structural damage with sensor networks will prevent catastrophic bridge collapses, reduce inspection costs while providing increased public safety, assist with infrastructure maintenance, help design appropriate retrofit measures, safeguard modifications to existing infrastructure, improve seismic risks assessment, assess load carrying capacity, assist with emergency response efforts by informing evacuation and traffic control. Concrete strain gauges cost $15k/sensor which amounts to $1.3M for the 86 SHM sensors of the Bill Emmerson Memorial Bridge. In contrast, the graphite/silicone sensors of our pressure imager cost ~10 cents/sensor.

17 Preparation and characterisation of a rechargeable battery based on a conductive polymer and aluminum in an ionic liquid electrolyte

LOCATIONS: University of Bath, Bath, UK

Energy storage devices like rechargeable batteries have currently a minor contribution to the challenges of the energy conversion to sustainability. Nevertheless, the growth of renewable energies will define the energy storage devices as an indispensable element of the power grid. Therefore, it is necessary to overcome the main problems of current high performance batteries like safety, an upper capacity limit and confined raw material resources. This project proposes the concept of a non-aqueous rechargeable battery characterised by safe cell reactions, a high storage capacity and earth-abundant materials like aluminum and conductive polymers.

STUDENT: Theresa Schötz

Theresa Schötz is a Chemical Engineer, BTU Cottbus-Senftenberg University of Technology, Germany, MSc. in Electrochemistry and Electroplating Technische Universität Ilmenau. She was private tutor for physics and mathematics and secured internships at AREVA GmbH, Erlangen on several projects. Research assistant at Technische Universität, Ilmenau on electrodeposition and characterisation of PEDOT/Pd nanoparticles, internships in the University of Salento, Lecce, Italy on cathode materials of conductive polymers doped with metal nanoparticles and at Hokkaido University in Japan on a rechargeable aluminum/polymer battery in ionic liquids.

18 Assessing the potential risks of 2D nanomaterials in the environment

LOCATIONS: Imperial College London, London, UK

Engineered nanomaterials (ENMs) can have extraordinary intrinsic properties and have aroused enormous interest in their potential technological applications. However, before widespread implementation, it is critical to understand the potential fate and behaviour of ENMs if released into the environment, either accidentally or deliberately. In particularly, it is important to understand how the ENMs can affect organisms in stream sediments and soils.

This project will assess the potential environmental hazards of 2D nanomaterials, such as graphene and graphene oxide, which have been mooted for a wide range of applications, including those intrinsically involving environmental exposure, such as water treatment. The project will use very powerful imaging and characterization techniques to reveal the underlying pathways for the influence of these materials as they partition through a waste water treatment plant to the environment to stream sediments and soils. The student will also assess the resulting toxicological effects on ecosystems.

19 Scalable manufacturing of few-layer van der Waals materials from bulk

LOCATIONS: UC Berkeley, Berkeley, USA | Imperial College London, London, UK

Advances in nanoscale materials and nanomanufacturing offer a way to improve the performance of integrated devices. Traditional silicon manufacturing is hindered by the enormous expense of shrinking geometries and the difficulty of managing waste heat. Nanoscale materials, specifically van der Waals (vdW) materials, offer a possible solution. These are a class of materials composed of atom-thick layers, with appealing mechanical, electrical and optical properties. While graphene is renowned for its ability to transport electrons "ballistically", other layered materials can also exist stably in air as a single atomic layer. In particular, transition metal dichalcogenides (TMDCs) such as molybdenum disulfide (MoS2) offer desirable properties as few- or monolayer films. Monolayer MoS2 exhibits a direct bandgap, which is ideal for applications in optoelectronics, such as photovoltaics and energy storage. These materials are expected to see widespread adoption, including in optical, electronic, sensing and biomedical devices. Accessing monolayer graphene and TMDCs repeatably, as part of a predictable high-yield manufacturing process, will be critical to realizing these applications.

This project targets mechanical exfoliation, which receives less attention than competing techniques such as chemical vapor deposition (CVD) and atomic layer deposition (ALD), but yields monolayers with unrivaled electronic quality. Our project seeks to overcome the mechanical limitations of manual, low-yield exfoliation processes, by developing an automated, repeatable process with controlled yield and throughput. The far superior electronic performance of these materials compared to those made by competing processes demands investment to turn exfoliation into a viable manufacturing process.

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