IN-PART

Showcasing university research for industry collaboration

issue 3 | November, 2015

IN-FOCUS: ADVANCED MATERIALS

FUTURE MATERIALS

ATOM-THIN MoS_2

A method to scale-up MoS2 production for flexible electronics

The Zepler Institute: University of Southampton

NANOPARTICLES

CRYSTALLIZED QUANTUM DOTS

Metal-induced crystallinity control

Okinawa Institute of Science & Technology

3D PRINTING

POLY-CERAMIC COMPOSITES

Customizing architectures with magnetic particles

Northeastern University

INDUSTRY INSIGHT

RAINBOW SYNCHROTRON

Opportunities to probe the fundamental character of materials

Diamond Light Source

IN-PART

EDITORIAL

Section content writers:
Edwin Colyer
Scientia Scripta

Subeditors:
Robin Knight
Emma Brown

Design, layout
and arrangement:
Alex Stockham

CONTACTS

Press/Communications:
Alex Stockham
T: +44 (0)114 222 4615
E: alex@in-part.co.uk

Company Directors:
Patrick Speedie
T: +44 (0)114 222 4614
E: patrick@in-part.co.uk

Robin Knight
T: +44 (0)203 754 6741
E: robin@in-part.co.uk

IN-PART

Sheffield - London

Registered Office:
Kroto Innovation Centre
Sheffield, S3 7HQ

T: +44 (0)114 222 4614
E: info@in-part.com
W: in-part.com

A NOTE FROM THE EDITOR

Welcome to IN-FOCUS

Welcome to the third edition of IN-FOCUS. A contextualised digest of university-developed technologies available for commercialisation; this magazine features opportunities to collaborate with the world's finest research.

In our final IN-FOCUS of 2015 we shift our attention to Advanced Materials.

Possessed with the ability to control objects on the nanoscale, scientists are now able to create materials with remarkable properties. Friction-free conduction and intra-regional strength-varying composites are just two examples. In the following pages we highlight the latest developments in research, which through collaborative exchange will lead to huge advancements in everyday life.

From universities on both sides of the Atlantic, the innovations featured in this edition encompass future materials, catalysis, manufacturing, sensing & monitoring, aerospace & transport, polymers and more. All opportunities seek interaction with businesses through IN-PART for knowledge transfer, co-development, commercialisation and licensing partnerships.

Each university technology is signposted by a ( ). Further information about opportunities featured, alongside a facility to make contact with the associated university, can be accessed by registering to *in-part.com*. Our philosophy is to enable the translation of academic research into technologies for the benefit of society.

As well as universities contributing to this publication - whose interaction represents a vision to rightly place industry partnerships as an integral step in developing next generation innovations - we would like to thank our publication sponsor, Diamond Light Source, along with the Universities of York and Bradford, and the Zepler Institute, for providing fascinating insights into their research (showcased on our Feature Editorials section).

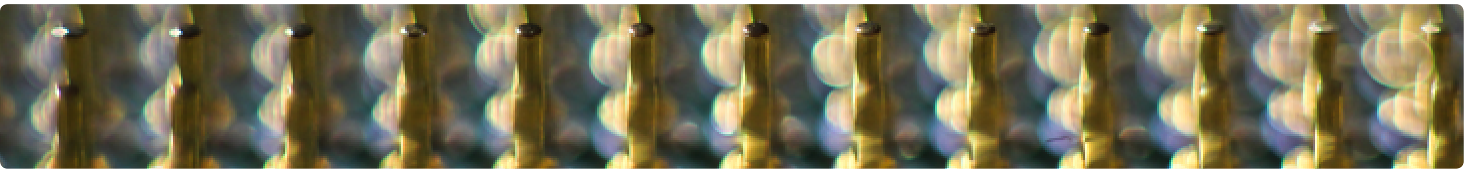
It's been an amazing second year for IN-PART, having welcomed 25 new universities and over 500 R&D professionals to the platform. In the new year we'll be expanding to cover US institutions, as well as those in Australia and the Far East. There are exciting times ahead, and we look forward to continuing to bring people together to further the development of life-changing technologies.

Alex Stockham
IN-PART Communications Manager

Printed by Pinnacle Images, London
Cover image: © Wisky / Fotolia
Contents page image credit: Chris Isherwood - CC BY-SA 2.0 / ellencanderson - CC BY-SA 2.0

IN-FOCUS

Advanced Materials | November, 2015



FEATURING RESEARCH FROM:

Prifysgol Aberystwyth University

University of Bradford — Making Knowledge Work

University of Bristol

Brunel University London

CUNY — The City University of New York

University of Cambridge enterprise

University of Exeter

the University of Greenwich

Heriot Watt University

University of Huddersfield

King's College London

University of Leeds

Loughborough University

Northeastern University — Center for Research Innovation

OIST

Plymouth University

Princeton University

University of Salford Manchester

University of South Wales Prifysgol De Cymru

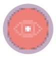
University of Strathclyde Glasgow

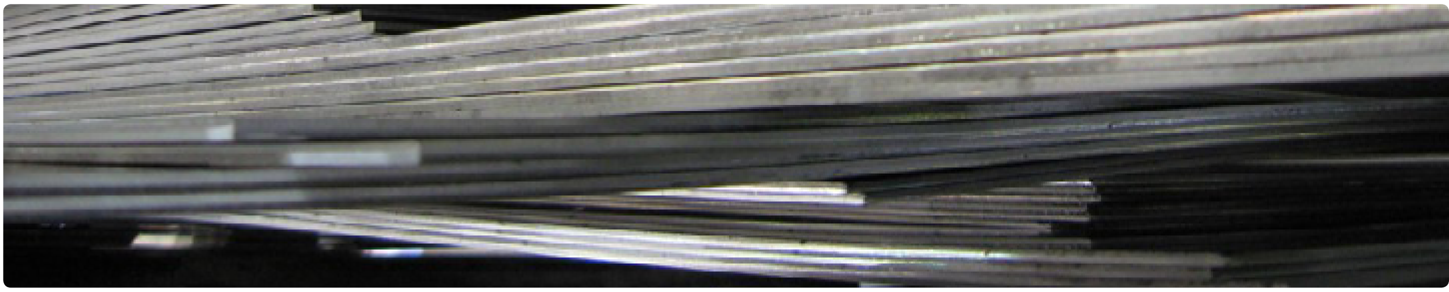
Swansea University Prifysgol Abertawe

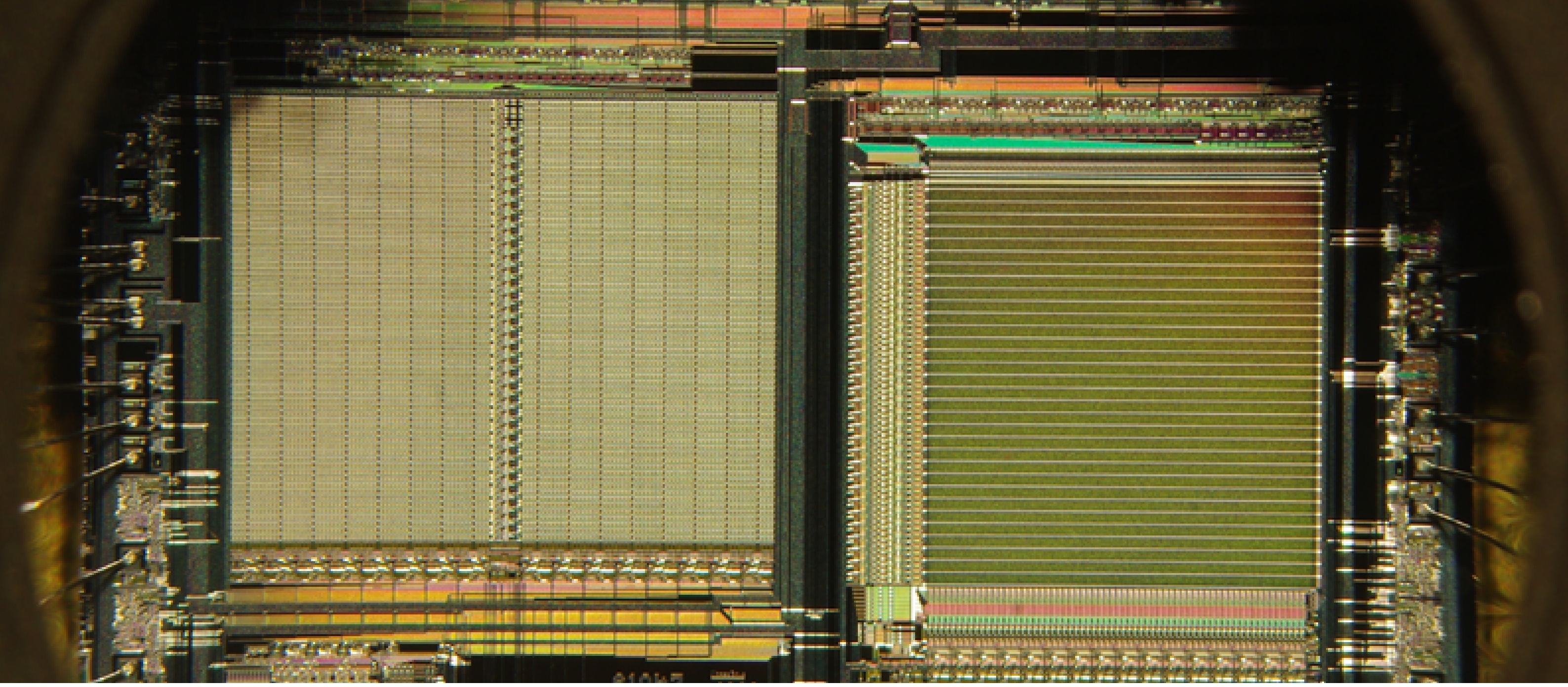
University of York

Zepler Institute

Contents

 = **IN-PART** collaboration opportunity





Nanoparticles, Catalysis and Electronics

Small is big in science at the moment. With an impressive arsenal of tools and techniques to manipulate matter with molecular precision, scientists are able to create novel materials and even minuscule machines with remarkable, customized properties. Nanoscale innovations are finding applications across all industry sectors from medicine to electronics.

1.1 NANOPARTICLES

Although the term is relatively new, we've actually been using nanoparticles for thousands of years. They occur naturally as proteins, polysaccharides and viruses as well as inorganic compounds including silicates and crystalline metals. Since ancient times they have been used in ceramics, glass pigments and metallic lustres.[1, 2]

So what's all the hype? Today, thanks to powerful microscopy, we can actually see what we are dealing with. Moreover, scientists and engineers can now design and manufacture nanoparticles with bespoke characteristics. With dimensions of 1-100nm, atomic forces and quantum effects often come into play where nanoparticles are concerned, endowing them with some surprising properties and functionality.

Nanoparticles are garnering particular attention in relation to packaging and delivering other molecules in a targeted fashion, for example, improving the solubility of hydrophobic compounds or delivering therapeutic drugs to target cells or locations in the body.

Nanotechnology researchers at King's College London (KCL) have successfully produced hollow nanoparticles that are able to carry two 'loads' - one on the surface, the other contained inside the particle *(Figure 1)*. Using the nanoparticles, the KCL team has created contrast agents that work across imaging techniques, allowing healthcare professionals to image using different methods in a single scan (e.g. MRI and optical, positron emission tomography and SPECT).

The scientists have demonstrated how a magnet core and a fluorescent shell can improve the efficiency of radiolabeling for dual PET/SPECT scanning. They have also developed bimodal particles suitable as a contrast agent for optical and MR imaging.

Reducing the number of scans

for patients has many benefits for patients and hospitals alike: reduced costs, lower exposure to radioactive labels and lower patient doses. The nanoparticle agents also help to reduce autofluoresence, thus improving the resolution of images .

The KCL team is now looking for a commercial partner interested in evaluating and developing the particles for supply as research tools or to address specific clinical applications.

KCL is also ready to license novel fluorescent nanoparticles that could replace dyes and quantum dots in numerous research and industrial applications.

Rather than coating nanoparticles in dyes (which tend to be unstable), they attach polymers to the particles' surfaces. This conjugation gives the particles 'tunable' fluorescent properties: the wavelength they emit is determined by the chemistry of molecules on the nanoparticle surface. Adding a targeting ligand or magnetic or paramagnetic molecules to the particles turns them into powerful fluorescent probes and markers. They do not suffer from the quench or decay experienced with dyes and do not make use of any heavy metals, making their disposal much easier and less costly than for quantum dots.

KCL is trialling the technology for point-of-care medical testing, but licensees can tune the emitted wavelength and adjust particle size to suit their own applications.

Manufacturing nanoparticles is by no means an easy feat. The delicate crystallization process can have a profound effect on the size and quality of the particles and hence their physical properties.

Scientists from the Okinawa Institute of Science and Technology (OIST) have found that adding nano-sized clusters of metals into amorphous silicon can induce and control crystallization. By manipulating the metal clusters the researchers are able to define crystal orientation and structure (amorphous, monocrystalline or polycrystalline) in Si, Ge and SiGe quantum dots *(Figure 2)*. OIST is looking for industrial partners to license or further develop the patent-protected process.

OIST also wishes to license its novel magnetic nanoparticles. Stable in air, they have low coercivity and high saturation magnetization, making them ideal for magnetic media, for example disk read-and-write heads and high frequency electronics. The particles are also biocompatible and could be used as vectors for transporting therapeutic agents using a magnetic 'beacon', for example in local hypothermia treatments for cancers.

1.2 CATALYSIS

New materials easily earn the 'advanced' eponym when they exhibit dynamic physical properties or engineered chemical activity. Sometimes, though, it is easier simply to borrow from nature.

Scientists from Princeton University have used the *Acidimicrobiaceae bacterium A6*

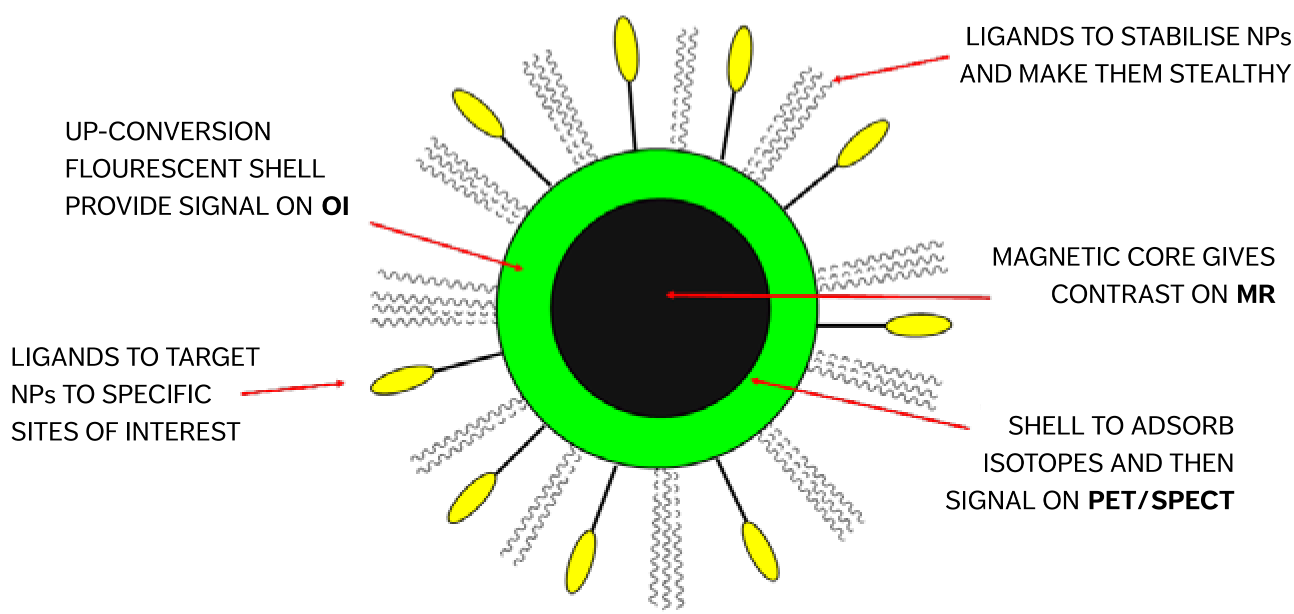


Figure 1. ***King's College London's multi-functional, doped core-shell nanoparticles:*** An illustration of one of KCL's Multimodal Nanoparticles (NPs), highlighting how its various features permit application to Optical Imaging (OI), Magnetic Resonance imaging (MR), and/or PET/SPECT.

to remove toxic metals and organic compounds from water. The bacteria are able to reduce oxidized metals, metalloids and radionuclides, even uranium and copper. This reduction is coupled with the degradation of many organic contaminants. The bacteria thrive in hostile acidic conditions and without any energy-intensive aeration.

The researchers wish to form industrial collaborations to develop and commercialize technologies for waste and water treatment plants, groundwater remediation and bioleaching.

Scientists from OIST welcome licensees for their patent-protected nano-catalysts. The nanoparticles do not sinter, have a prolonged lifespan and superior catalytic activity compared with palladium.

Alongside palladium, titanium dioxide (TiO_2) is another common industrial catalyst. The surface of the TiO_2 crystal provides an ideal environment for substrate bindings, although its specific catalytic properties depend on whether it is in its anatase or rutile form.

Inspired by pollen grains, Brunel University has developed a method to produce biomimetic nanoparticles of TiO_2 that dramatically increase the available surface area of the catalyst which, in some cases, has made reactions a million times faster.

Brunel is ready to license the technology, with significant commercial opportunities in three areas: production of clean drinking water in remote areas (in combination with UV treatment); pollutant, chemical and carbon dioxide capture; and the delivery of oxygen enriched air in urban areas.

The University of York also has a novel catalyst production method ready for further development and commercialization. Researchers have developed a one-step, water-free method for producing silver carboxylates, compounds used today as efficient precursors of silver nanoparticles. The new synthetic process is much more cost efficient than current thermal decomposition and chemical vapor production.

Current demand for silver nanoparticles is growing due to their increasing use in antimicrobial applications, biosensor materials, composite fibres, cryogenic superconducting materials, cosmetic products and electronic components.

1.3 NANO-ELECTROMECHANICAL SYSTEMS

The relentless pursuit of faster, smaller, more powerful and more efficient electronic devices has driven researchers to the very limits of their capabilities. The wonderful world of microelectronics is shrinking down to the nanoscale.

At nanoscale dimensions, the rules start to change. Materials behave differently as quantum effects begin to change their behaviour and properties. The slightest misalignment

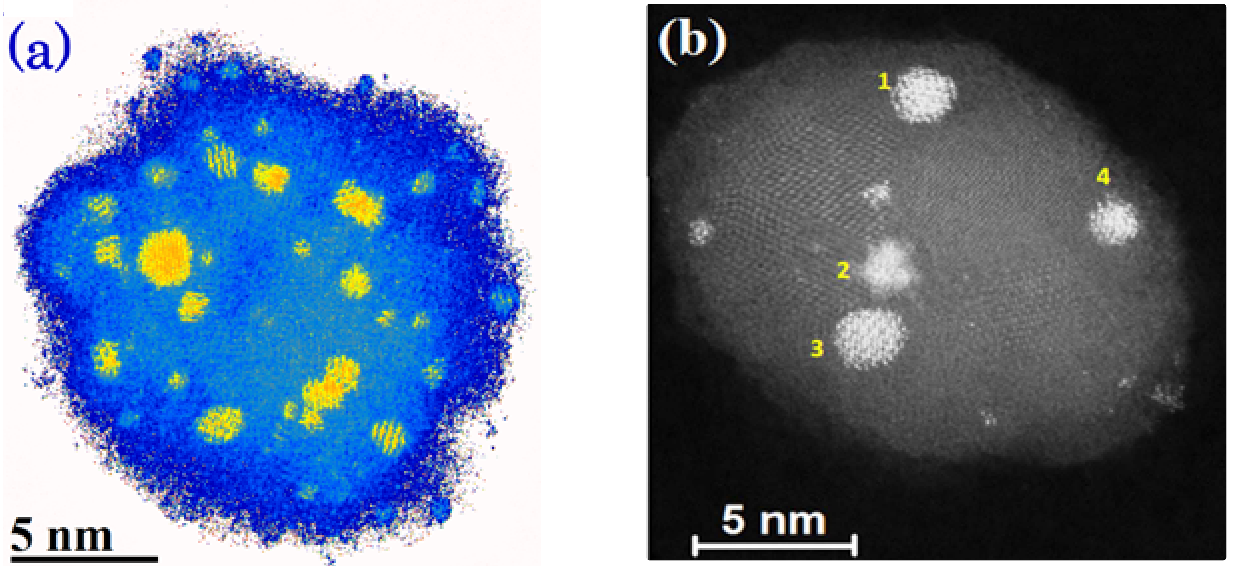
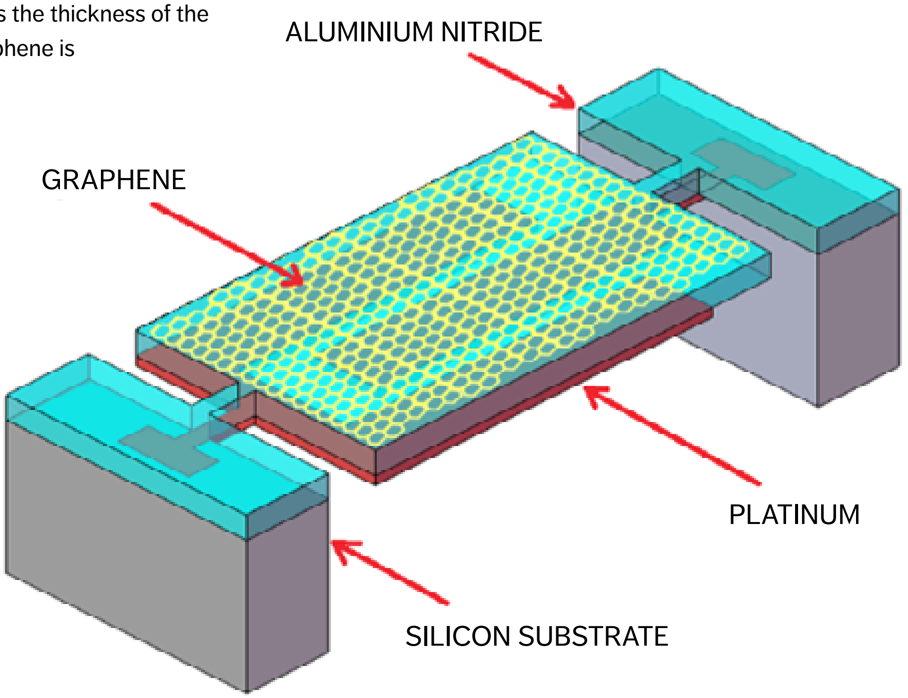


Figure 2. ***The Okinawa Institute of Science & Technology's quantum dots:*** (a) The yellow areas in this image are silver nanoclusters, which have monocrystalline structure and are used to induce crystallinity in an amorphous silicon nanoparticle, the blue area. (b) HR-TEM micrograph in which crystal planes with deferring orientations are visible in the proximity of the silver nanoclusters.

Figure 3. ***Northeastern University's NEMS sensor :*** An illustration of the [G-AlN NPR](). The high frequency bulk acoustic mode of vibration bottom electrode, and an electrically floating top electrode which acts to confine the excitation field across the thickness of the piezoelectric layer. In this prototype graphene is employed as an ultra-thin and light top electrically floating electrode.



of molecules, defects in the three dimension packing of atoms or trace contamination can dramatically alter the properties and performance of engineered nanoelectronic components.

Bridging the electrical and mechanical realms, nanoscale electromechanical systems (NEMS) will certainly play a key role in the further shrinkage of electronics. These devices can convert electrical signals into a mechanical action (movement of a switch, for example) or vice versa. They are frequently deployed as biological and chemical sensors, especially to detect very low concentrations of substances, for example chemicals or pollutants in the air.

As nanoscale switches, NEMS have emerged as promising, smaller alternatives to standard transistor technology based on superconducting materials. They exhibit large on-off current ratio, near-zero off state leakage current and power efficient operation.

However, frictional forces are significant at the nano-scale, so switches tend to be quite unreliable as they often 'stick' between the switch terminals.

- Inventors from the Massachusetts Institute of Technology (MIT) have incorporated a non-conducting deformable spring-like molecular layer between the switch terminals to reduce friction and thus increase reliability. The stiffness of the layer is engineered to lower the required actuation voltage so the nano-switches are compatible with standard semiconductor transistors, but with superior transconductance and a fast switching time (11 ns). The technology is available for exclusive and/or non-exclusive licensing.
- Northeastern University in the US also boasts a next generation NEMS with high performance sensors and radio frequency communication applications. Replacing metal electrodes with graphene material, researchers have dramatically improved the sensitivity, limit of detection and detection speed in NEMS-based sensors *(Figure 3)*.

They have also observed high performance and intrinsically switchable filters and oscillators for radio frequency communication applications. The NEMS are extremely thin and light, with comparable or even higher electrical conductivity than gold electrodes 100 times thicker.

1.4 SEMICONDUCTOR & ANODE TECHNOLOGY

Back in the traditional world of microscale electronics, research and innovation continues to transform industry, helping to make manufacturing cleaner, greener and energy efficient.

The aluminium industry, for instance, has been forced to meet strict targets to reduce costs and emissions. Although production has shifted to locations with cheaper sources of electricity, the depressed market price of the metal continues to exert significant pressure on the industry.

Seemingly small changes can have a dramatic impact, however. Simply by replacing conventional carbon anodes used in the production of aluminium metal from alumina, companies are able to cut their greenhouse gas emissions significantly and save energy.

The University of Leeds has patented a metallic inert anode technology that has much greater conductivity than graphite anodes and could cut energy consumption (and hence costs and emissions) by a quarter. The new anode is also cheaper and requires less energy to manufacture, further helping to lower costs and the environmental impact associated with greenhouse gases.

In small-scale pilots anodes have operated for up to five weeks at 850°C without corrosion. The University of Leeds now seeks a partner for product development and commercialization. A patent has also been filed for a redesigned Hall-Héroult cell which has the potential to further increase productivity and reduce energy usage in the extraction of titanium or rare earth metals.

A second invention from the University of Leeds has the potential to change the face of manufacturing in the electronics industry. Scientists have found an efficient way to remove oxides from surface substrates, an important preparative step prior to the growth of nanostructures.[3] The technology is much faster than conventional gallium (Ga)-assisted and hydrogen (H)-assisted cleaning .It also yields extremely smooth surfaces with limited pitting without the need for applying thick layers of protective buffer. Homogeneous, smooth surfaces improve the quality of quantum dot crystal growth.

The University of Leeds wants to negotiate commercial licenses, sales and investment opportunities with partners from industry, VCs and brokers. The University also seeks collaborators to help it develop a programme for application-based design, fabrication and characterisation of III-V semiconductor materials.

Although semiconductors are already used in bulk by the microelectronics sector, it is currently difficult to measure their electronic spin polarization – a necessary step in quality control.

Researchers at Plymouth University have developed a technique by inducing the Spin Hall Effect (SHE) across the material and then measuring the tunnelling magneto-resistance (TMR) between a ferromagnetic material and the semiconductor sample.

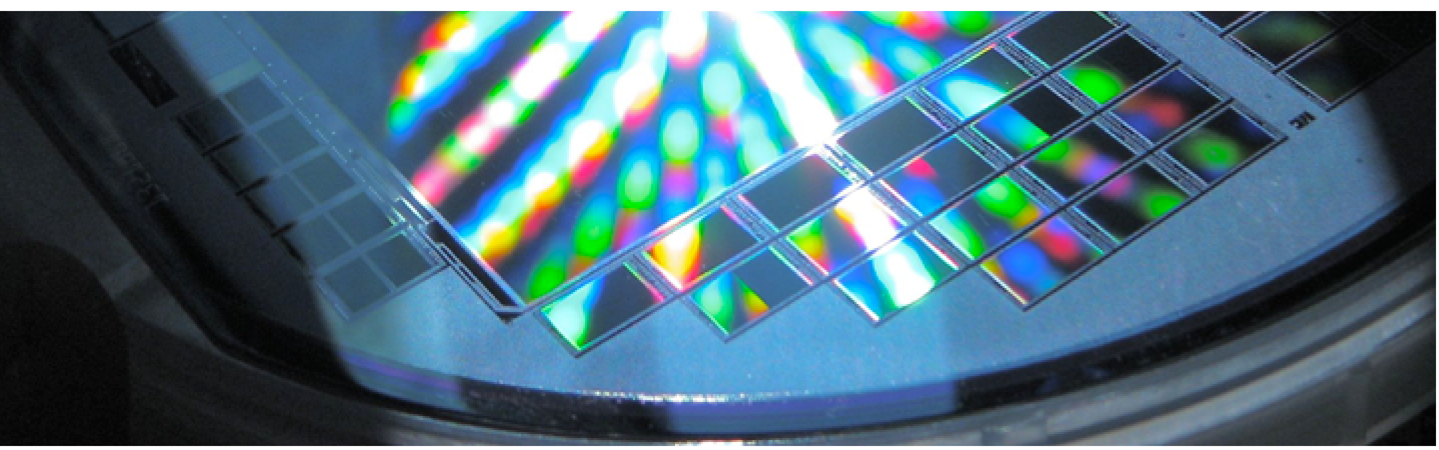
The Plymouth team hopes to license out its prototype for further development. The primary market for the system would be universities and businesses wishing to test novel semiconductor materials.

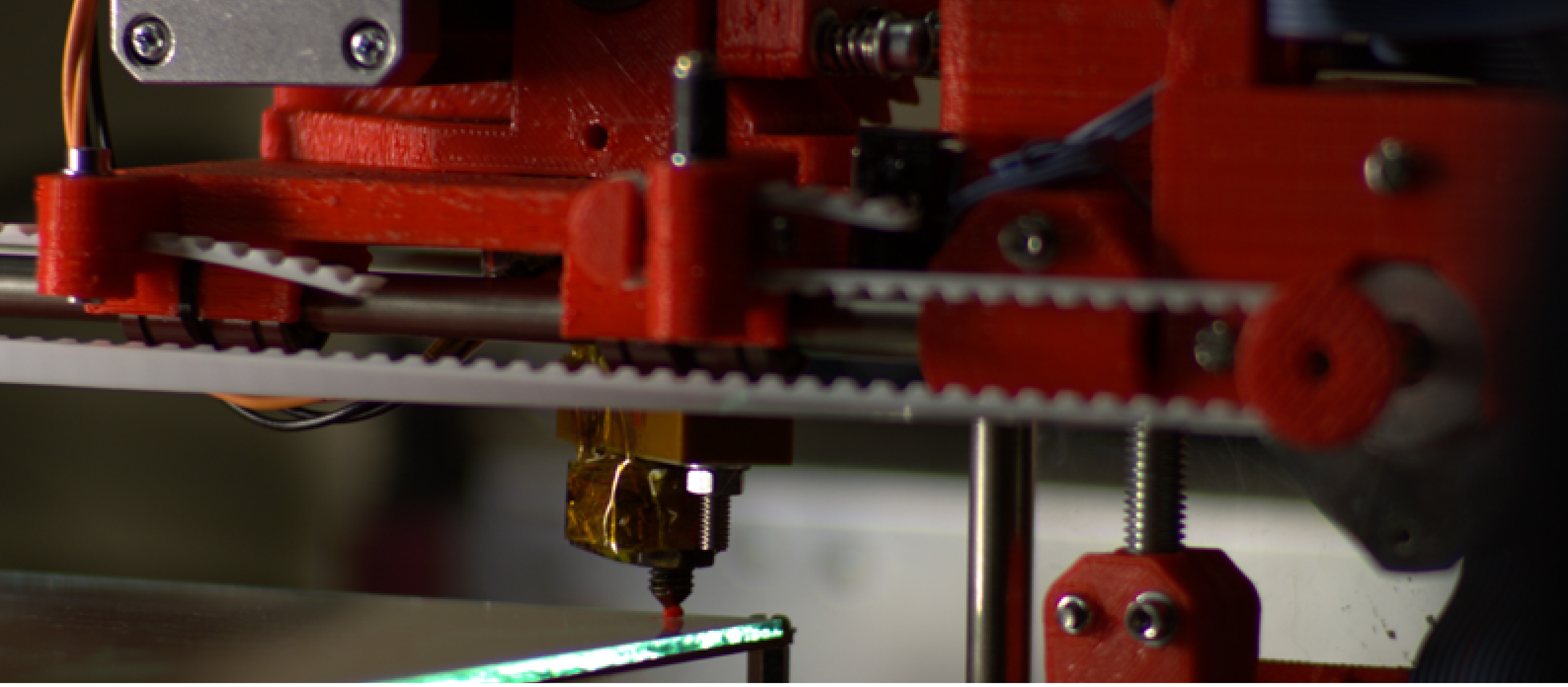
REFERENCES

1. Sciau, P. *Nanoparticles in Ancient Materials: The Metallic Lustre Decorations of Medieval Ceramics*, The Delivery of Nanoparticles, Dr. Abbass A. Hashim (Ed.), ISBN: 978-953-51-0615-9, InTech.

2. Colomban, P. *The Use of Metal Nanoparticles to Produce Yellow, Red and Iridescent Colour, from Bronze Age to Present Times in Lustre Pottery and Glass: Solid State Chemistry*, Spectroscopy and Nanostructure. Journal of Nano Research; **8**: 109 132 (2009).

3. Li, L. H. et al. *In-assisted desorption of native GaAs surface oxides*. Applied Physics Letters; **99**: 061910 (2011).





DENNIS VAN ZUIJLEKOM / CC BY-SA 2.0 - CROPPED

Advanced Materials Technologies

Advanced materials are already transforming our world. Engineered, often at the molecular level, for specific properties and functionality, they are finding their way into medical and environmental technologies, smart sensors, aerospace and many industry applications. It is win-win for companies ahead of the curve as they launch high performance products that help to solve some of society's greatest challenges.

2.1 FUTURE MATERIALS

Although graphene seems to grab all the headlines, it is not the only advanced material to hold great promise. Molybdenum disulfide (MoS_2) also boasts many of the same properties. Two-dimensional films of this substance have remarkable and unique electronic and optical properties while crystals of MoS2 make excellent contact electrodes and circuit interconnects.[1]

Current preparation techniques for MoS_2 fail to produce more than tiny flakes just a few microns in size. Scientists from the Zepler Institute at the University of Southampton have developed an industrial fabrication method that 'grows' atomically thin sheets of MoS2 from the bottom up by chemical vapor deposition at room temperature. The technique is fully compatible with conventional industrial photolithography.

The process is available for industrial scale-up to make large-scale sheets of centimetre dimensions.

A team from the Okinawa Institute of Science and Technology (OIST) has made a nanosheet from polymeric materials which adapts its optical properties in response to the pH of its surroundings *(Figure 4)*. At certain pH levels the sheets roll up to form scrolls; this alters their optical properties, but also makes them suitable for carrying a load, for example a therapeutic drug.

OIST seeks industrial partners to license or develop the technology, perhaps for targeted, pH-triggered drug delivery, biosensing or catalysis.

Scientists at the University of Bristol, meanwhile, have produced a new material that can emit a special kind of laser light with specific orbital angular momentum states *(OAM - see Box 1)*.

Bristol's technology is three times smaller than standard systems for producing OAM light - small enough to integrate on a microchip or create large arrays. It is suitable for chip-to-chip interconnects as well as for complex optical manipulation systems for biophysics research *(Figure 5)*. The novel emitter is tunable (i.e. reconfigurable to emit specific OAM states) and can even work in reverse as an OAM detector.

Not all future materials have to be out-of-the ordinary. Research by the Sustainable Environment Research Centre (SERC) at the University of South Wales has led to the discovery of a smart, sustainable way to produce a commodity material: silica.

Silica, a primary constituent of sand, is abundant in nature, but as a natural resource, it must still be mined or extracted from natural supplies. Now there is a method which closes the loop in the silica life cycle, turning recycled glass into a silica desiccant, widely used in electronics packaging to control moisture and humidity.

The process uses low quality waste glass which cannot be reprocessed conventionally back into glass products. The silica is a much higher value end product and helps to reduce imports of silica from unsustainable sources. The new process never requires a temperature above 120°C and only needs ambient pressures, so is more cost effective than conventional silica production.

The research team at the University of South Wales' Sustainable Environment Research Centre (SERC) is looking for partners to develop the process for other market applications such as specialty silica, matting agents for paints and coatings; inks and printing; digital print media; an abrasive in toothpaste; flavour carriers for perfume and oils; and as a free flow agent in powdered food. The SERC brings together researchers from biology, engineering, chemistry, and physics to address the energy security and environmental challenges of the new millennium.

2.2 GRAPHENE TECHNOLOGIES

At last we come to graphene, the new wonder material that promises revolution in electronics, aerospace,

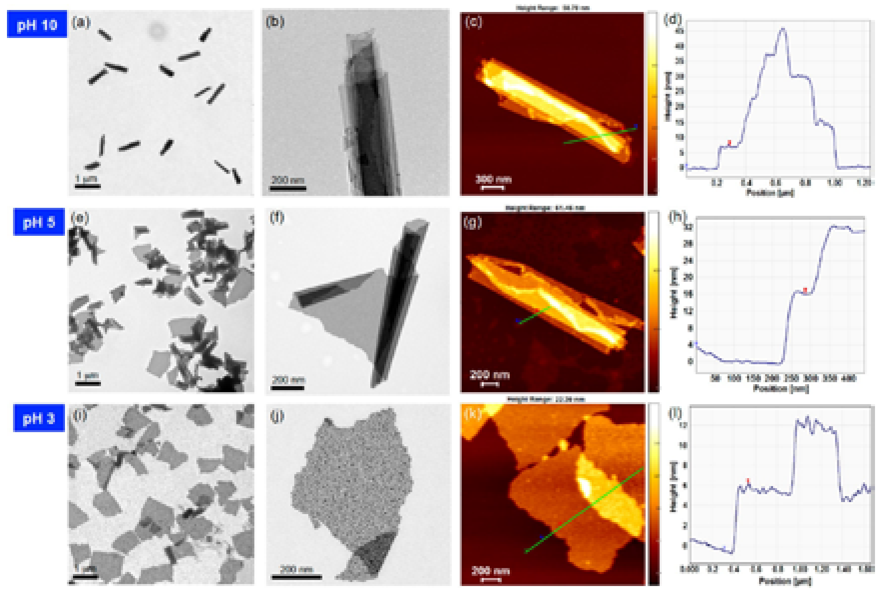


Figure 4. ***pH-responsive nanosheets from OIST :*** Optical micrographs, AFM scans, and AFM profiles of pH-responsive nanosheets at pHs of 10, 5 and 3. As pH is increased from 3 to 10 the sheets roll up into scrolls, which have different optical properties and can be used to carry a therapeutic load.

BOX 1 : ORBITAL ANGULAR MOMENTUM

The simplest form of OAM is an optical vortex – a beam of light whose phase varies in a corkscrew-like manner along the beam's direction of propagation. The OAM carried in such a field means it can trap and rotate small particles and living cells, making it like an 'optical spanner' for use in biophysics, micromechanics or microfluidics.

Applications of this phenomenon are still in the early phases of development, but could include super-high optical data storage, enhanced data transmission, imaging, metrology and communications.

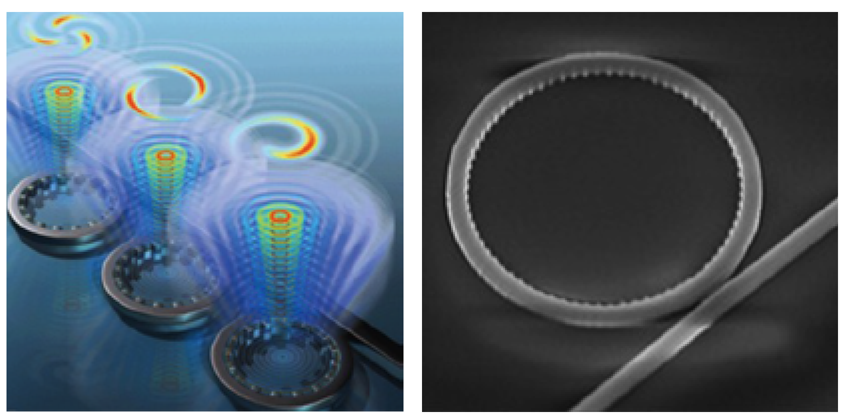


Figure 5. ***The University of Bristol's OAM laser sources :*** An illustration and optical micrograph of the compact laser source integrated onto a chip.

medicine and beyond! First isolated by Professors Andre Geim and Kostya Novoselov at the University of Manchester in 2004, this two-dimensional material possesses remarkable physical, chemical, electrical and optical properties; including conductivity, mechanical strength, flexibility and transparency.

Hundreds of research and development projects around the globe are finding ways to exploit this rising star of materials science.

2.2.1 Graphene Production

But before the graphene revolution becomes reality, industry needs to develop reliable, cheap methods to produce high grade graphene material. Current methods include exfoliation from graphite, growth from gases on metal crystals and decomposition of carbon-containing solids such as fullerenes and silicon carbide. All these methods have their drawbacks, however, due to high temperatures, complex chemistry or the formation of competing carbon-rich, stable surface phases.

A method developed by scientists at Aberystwyth University grows graphene on a layer of diamond which is heated until the graphene is of the required thickness. The University is currently seeking industry collaborators to develop this technology which promises cost effective production of high quality material to meet the rising demand.

Although it is hard to find a university that isn't involved with graphene somewhere in its research portfolio, only a handful of institutions actually have technologies and prototype products ready for commercial development.

The University of Exeter expects its GraphExeter material to replace the conventional indium tin oxide (ITO) films currently used on mobile device touchscreens. Experts suggest that world reserves of indium are quickly running out and may not last more than a decade, so carbon-based GraphExeter is a timely alternative.

The new material has optical transparency over a much broader spectrum than ITO with comparable electrical conductivity. GraphExeter is also very flexible, so suitable for wearable electronics too.

The University is now looking for partners to commercialize the technology through collaborative or licensing agreements.

2.2.2 Graphene Applications

In Wales, a team from Swansea University has integrated graphene into a novel biosensor for point-of-care diagnostics that will detect biomarkers in patient samples to assess cancer risk.

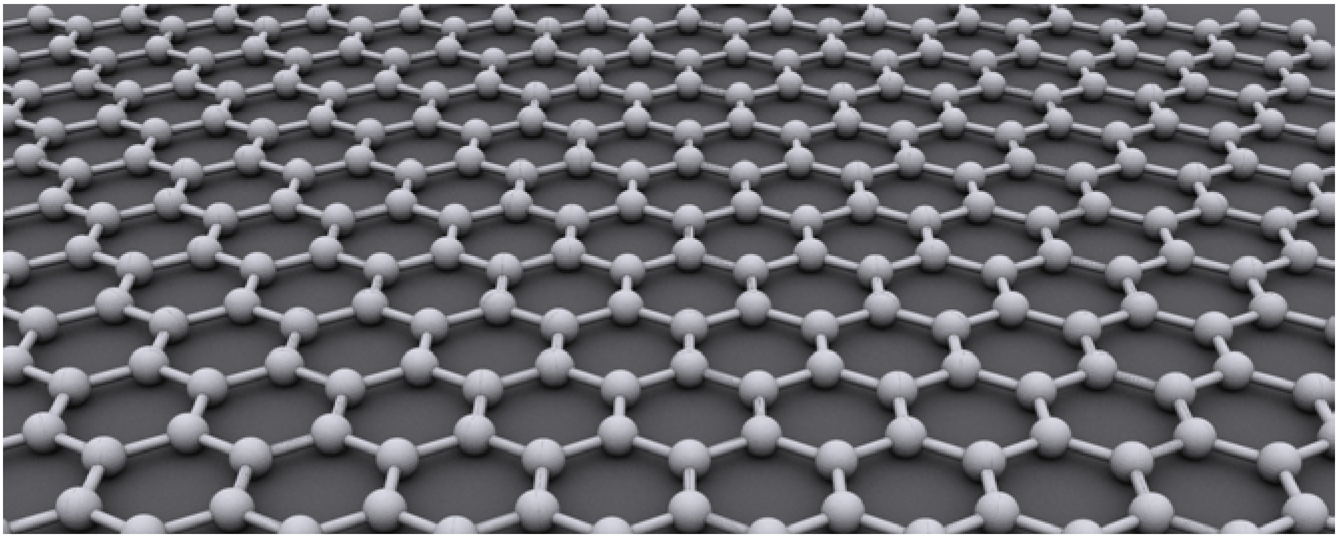
The biosensors use a silicon nanowire structure and graphene to create a high surface-to-volume ratio that increases the sensitivity of the assay. The scientists pattern graphene using semiconductor processing techniques, then attach a number of bioreceptor molecules to the surface. These receptors can bind to, or target, specific cancer marker molecules found in blood, saliva or urine.

In tests, the graphene biosensor detected 8-hydroxy-2'

BOX 2 : TERAHERTZ TIME-DOMAIN SPECTROMETRY

A technique to probe the properties of materials using picosecond pulses of terahertz frequency electromagnetic radiation, generated using a laser. The detector picks up how the sample material affects the amplitude and phase of the source wave. Many materials interact with the pulse in unique ways, producing a distinctive 'fingerprint' readout.

Many materials are transparent to terahertz radiation, allowing instruments to identify samples within packaging or at a distance. The radiation is non-ionizing and therefore safe for analysing biological samples.



-deoxyguanosine, (8-OHdG); a by-product of DNA oxidation and a marker of carcinogenesis at concentrations as low as 0.1 ng/mL, which is almost five times more sensitive than other bioassay tests. The graphene biosensor works quickly, completing a full sample analysis within minutes. Commercialization of the graphene biosensor in a rapid, point-of-care tool has significant market potential.

The University of Leeds has used its expertise in graphene production and manipulation to create a detector suitable for terahertz time-domain spectrometry, a relatively new technique for non-destructive materials analysis, testing and 'finger-printing' *(see Box 2)*.

Researchers have successfully manipulated graphene and used it as an on-chip terahertz detector and emitter.[2] Even without optimization, graphene's performance is equal to the incumbent – and highly honed, low temperature gallium arsenide (GaAs) semiconductor used in the titanium-sapphire pumped lasers currently found in terahertz devices.

The researchers expect graphene will be the enabling technology for system designers to create cheaper and higher specification terahertz detection systems. They are now looking to engage with external organizations that want to develop or license the technology for specific applications.

2.3 ADDITIVE LAYER MANUFACTURING & NANOSCALE STRUCTURING

Additive manufacturing, or 3D printing, is revolutionizing the manufacturing sector. Metal and polymer products are built up in shapes that would be impossible with conventional extrusion or moulding methods. However, engineers have struggled to adapt the printing approach for polymer-ceramic composites.

By using fibres that contain or are coated in a magnetic material, researchers from Northeastern

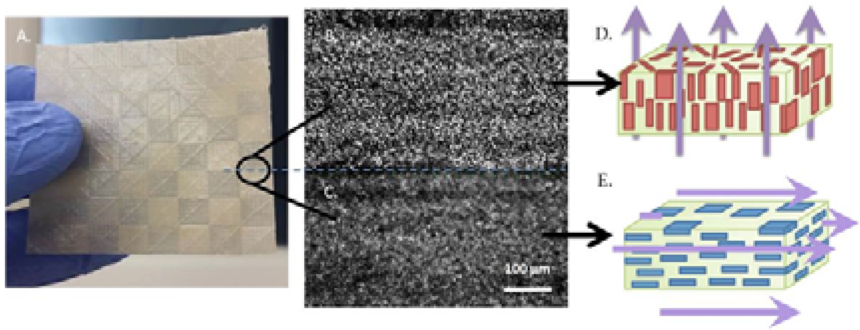


Figure 6. ***Northeastern University's architecture-control ALM technology :***
(A) 3D printed chess board demonstrating alumina platelet orientations; (B) Optical microscopy images at 10x magnification out of place alignment; and in-plane alignment (C); with corresponding platelet orientation depicted in (D) and (E). The resin consisted of 0.5% volume magnetic alumina platelets.

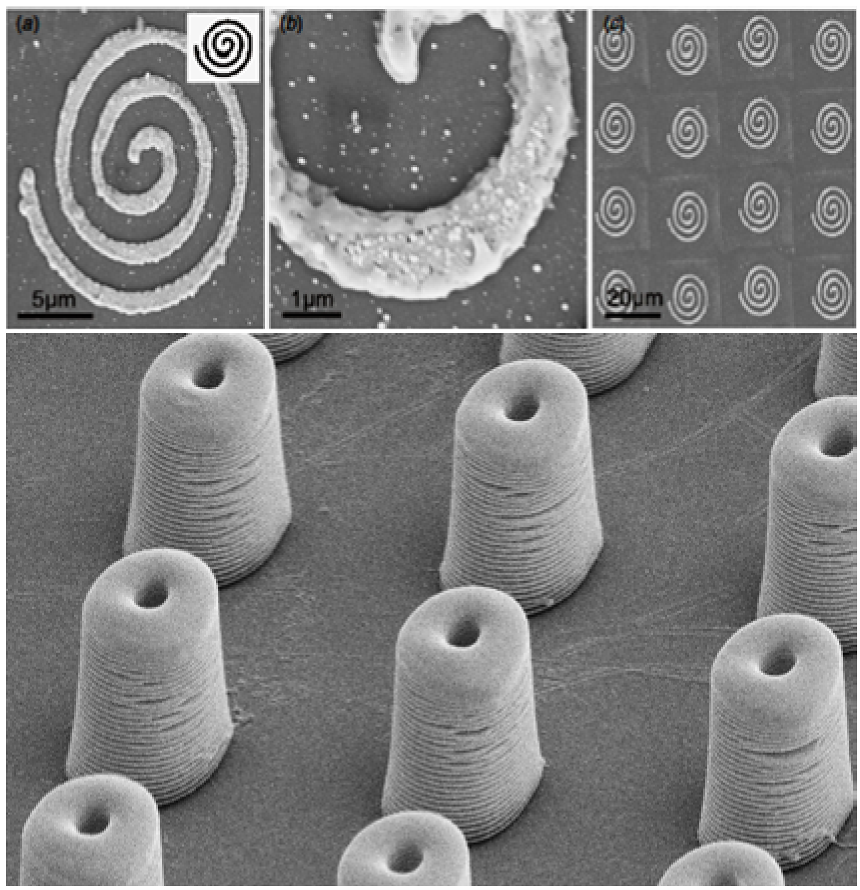


Figure 7. ***Zepler Institute's image-projection based microscale laser machining :***
(Top: A, B & C); Subtractive machining via laser ablation in thin films for a total machining time = 1 laser pulse. (Bottom); Additive machining via laser polymerisation, resulting in formation of sub-micron resolution complex structures. Both approaches have been used for the fabrication of cm-sized objects, bioscaffolding, 3D waveguide structures, component trimming & marking.

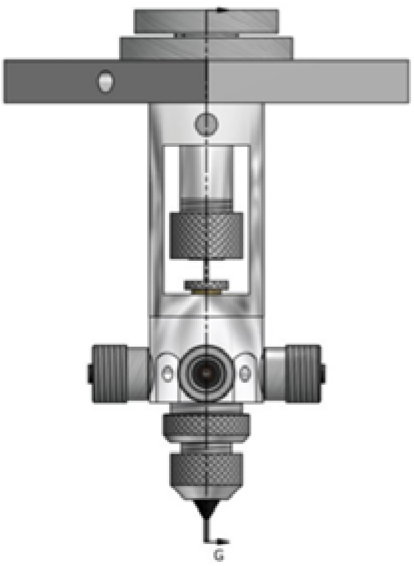


Figure 8. ***Printing medical devices and prosthetics from King's College London :***
A side view of the 3D printer head according to one embodiment of the invention

University in the US found they could control the orientation and spatial distribution of particles in a composite mix as it was being printed. Most interestingly, the scientists could print a homogeneous material with varying properties, i.e. flexible in one area, and stiff in another *(Figure 6)*.

Potential industrial partners are encouraged to collaborate in developing applications in biomedicine, electronics and the military as well as retrofitting the technology to existing 3D systems.

A team at King's College London (KCL) has used a novel two-component silicone to 3D print medical devices and prosthetics.

Typically, facial and body prostheses are manufactured by a lengthy multi-step process that involves taking an impression from the patient, hand carving the missing defect, creating a two or three part stone mould into which the colour-matched silicone is poured. It is extremely time-consuming, involving five to six patient visits and the exquisite skills of the prosthetist.

The 3D printing approach uses a custom print head and a biocompatible two-part silicone to create room-temperature curing silicone objects *(Figure 8)*. It is suitable for complex reconstructions of limbs and facial features as well as bespoke prosthetic limb coverings. To programme the print run, healthcare professionals capture images of patients' defects during a single appointment using stereophotogrammetry. The digital file is manipulated using CAD and delivered to 3D printers by control software to produce finished prosthetic components that are fitted at a second appointment.

Collaborators on this technology now seek partners to further develop and commercialize the system and/or supply of facial and body prostheses. This could be through a hardware and consumables supply model or via a service provision model. The intellectual property owners are also open to licensing the technology for application to other fields with options for exclusivity if appropriate.

Using technology currently deployed in cinemas, researchers at the Zepler Institute in Southampton have developed a micro-manufacturing system that can machine centimetre-sized complex structures, with sub-micron resolution, within minutes. Its single electronic beam makes use of a digital micromirror to spatially pattern laser pulses; an entire structure can be machined with just one laser pulse *(Figure 7)*.

The system has already etched identification codes to the surface of bulk diamond, but it is also suitable for single pulse laser ablation, component trimming, forensic-level security marking and for fabricating waveguides and light-coupling structures.

A fully-automated prototype machining device, currently under construction, will be tested by several UK and EU commercial laser-machining companies during early 2015, but additional partners are welcome.

2.3.2 Nanostructuring

Materials scientists at the University of Exeter have created a system that enables operators with real-time control of lasers in additive layer manufacturing (ALM).[3]

The RAM-ALM prototype uses non-intrusive spectral analysis of Raman scattering to analyse, in real-time, the selective laser sintering process during component fabrication. The wave scattering contains a wealth of information on the material's structure, topology and the processing conditions - making it a quick, relatively unobtrusive alternative to traditional *ex-situ* surface profiling methods for assessing surface roughness.

The technology has a European patent, but the researchers now want to develop and commercialize the technology.

Plasma processing also shows promise for surface nanostructuring. Researchers from the University of Salford are currently looking to form a commercial partnership to develop a route to market for a novel plasma-enhanced chemical vapor deposition (CVD) and etching process. It is possible to control the etch and/or deposition rate and manipulate surface structures and crystallinity at substantially reduced temperatures so it is ideal for thermally sensitive materials such as plastics and composites.

2.4 NANOSENSING

Thanks to their large surface area-to-volume ratios, one of the most prolific uses of nanoparticles is as absorbents in novel sensor technologies. Doping nanoparticles with targeting agents, such as bioreceptors, antibodies or specific substrate molecules, can also raise detection thresholds.

The University of Cambridge has adapted a nanotechnology-based 'electronic nose' and used it to detect femtogram quantities of target molecules in liquid media. It can screen for up to 16 different analytes or biomarkers in one sample. The lab-on-a-chip technology is highly portable, phenomenally sensitive and cheap to make using conventional electronics fabrication technologies.

Similar in concept to a quartz crystal microbalance (QCM) the nano-nose is a film bulk acoustic resonator *(FBAR - see Box 3)*. Researchers have designed resonators that support two different fundamental resonant modes at different frequencies which enables parallel sensing within the same unit sensor. Control of the piezoelectric microstructure allows a resonance to be produced that is not significantly affected by a liquid on the surface.

The University now wishes to find a collaborator to take the concept towards commercial development.

The University of Leeds also has a lab-on-chip prototype which it wants to develop for point-of-care diagnoses in cardiovascular disease, cancer, stroke and neurodegenerative conditions.

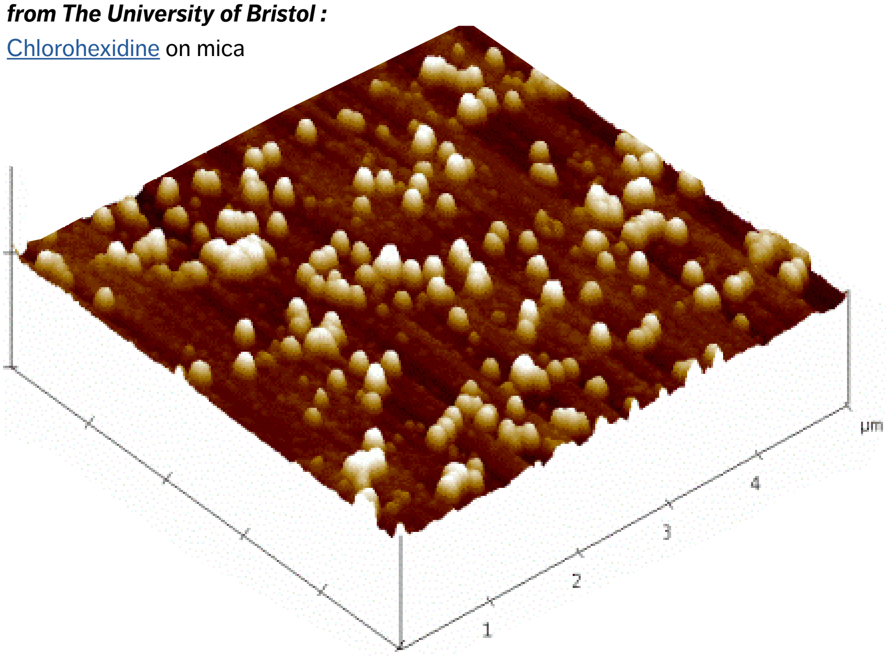
The device works by correlating the relative intensity of fluorescence emissions at specific wavelengths by the rare earth ions to the biomarker it targets in blood. The instant analysis takes place *in vitro* following conjugation of rare earth ions to biomarkers in a drop of blood.

BOX 3 : FILM BULK ACOUSTIC RESONATORS (FBARS)

An inverse piezoelectric effect generates a standing acoustic wave with a well-defined resonant frequency. When a mass hits the surface of the resonator it changes the resonant frequency; this change is detected and correlated to the detection of a mass at the resonator surface.

One of the most important issues that prevents the commercialization and widespread use of these devices is the frequency shift over temperature which can generate false-positive/negative responses. Liquid media suppress resonance, so FBAR devices have low sensitivity in liquids.

Figure 9. ***Antimicrobial nanoparticles from The University of Bristol :*** Chlorohexidine on mica



2.5 MEDICAL MATERIALS

Some of the most exciting applications for advanced materials are in the medical sphere, where specially designed and manufactured materials have enhanced properties: dynamic adjustments to physical shape or biochemical functionality. These smart properties often come from nano-level structuring using coatings, particles and films.

Northeastern University, for example, wishes to develop several high energy plasma deposition processes that change the structure of the surface of medical implants or devices by adding or stripping electrons and atoms. Through this process, the surface properties of the implanted device can be altered, for example to add powerful antimicrobial properties, or to promote or prevent host cell attachment.

Researchers at the University of Bristol have found a different way to give materials long-term antibacterial properties using nanoparticles that contain chlorhexidine, a biocide used widely in healthcare products and devices *(Figure 9)*. [4]

The nanoparticles release chlorhexidine over a prolonged period (at least 4 months). Importantly, this antimicrobial effect does not lead to an increase in resistant strains.

The researchers are looking for partners to help commercialize the technology in areas including dentistry, medical implants, fabrics, paints and wound dressing. Pilot studies are underway to test the effect of chlorhexidine nanoparticles on skin

BOX 4 : MICRONEEDLES

Microneedles are typically applied to the skin as small patches. The underside of the patch is covered ultra-thin spikes which painlessly pierce the skin to increase its permeability to a wide range of topically applied therapeutics.

Studies show microneedles compare favourably with subcutaneous injections, with better delivery efficiency, faster absorption and a potential for achieving equal maximum drug concentrations at significantly lower doses. Microneedles also improve patient compliance through easy self-administration with minimal discomfort.

healing rates and industrial partners are invited to consider collaborating in developing this product.

OIST offers potential partners access to a nanoporous tantalum film that can help to reduce the risk of biofilms spreading over the surface of implanted medical devices. This film has 'smart' hydrophobicity: initially it is super-hydrophilic (enhancing integration of the device with host tissues), but repeated exposure to water makes it more hydrophobic, massively reducing the risk of contamination. It is suitable for orthodontic and orthopaedic applications.

Metallic stents made from magnesium alloys have the benefit of being bioabsorbable, so they slowly 'dissolve' once they have done their job. But they are not used widely due to their cost and the risk of breakage during manufacturing and implantation.

The University of Strathclyde has developed a process that improves the tensile strength of this naturally brittle material so it is more suitable for medical applications.

The patented process effectively refines the grain of the alloy using a technique called severe plastic deformation. Since it can deal with very long (theoretically infinite) billets, it is useful for industrial implementation.

The University is seeking commercial partners for scaling-up and/or supporting further research into testing of different metallic materials for bioabsorbable stents.

A major recent transformation in medical devices has been the development of microneedles to aid topical and localized drug delivery. Scientists from the University of Greenwich have developed a platform technology for efficiently coating microneedles *(Box 4)* with the active ingredient. Coating efficiencies reach 96% and deliver small molecules with high loadings (5-7 mg) per microneedle array *(Figure 10)*.

The University of Greenwich seeks commercialization partners including hospitals, pharmaceutical companies, pharmacies and clinics to collaborate in further R&D, clinical trial or to license the technology.

REFERENCES

1. Tang, P. et al. *Graphene-Like Molybdenum Disulfide and Its Application in Optoelectronic Devices*; **29**(4): 667 677 (2013).

2. Hunter, N. et al. *On-Chip Picosecond Pulse Detection and Generation Using Graphene Photoconductive Switches*. Nano Lett. **15**(3): 1591–1596 (2015).

3. Beard, M. A. et al. *Using Raman spectroscopy to monitor surface finish and roughness of components manufactured by selective laser sintering*. J. Raman Spectroscopy; **42**: 744–748 (2011).

4. Barbour, M. E. et al. *Synthesis, characterization, and efficacy of antimicrobial chlorhexidine hexametaphosphate nanoparticles for applications in biomedical materials and consumer products*. International Journal of Nanomedicine; **8**: 3507 3519 (2013).

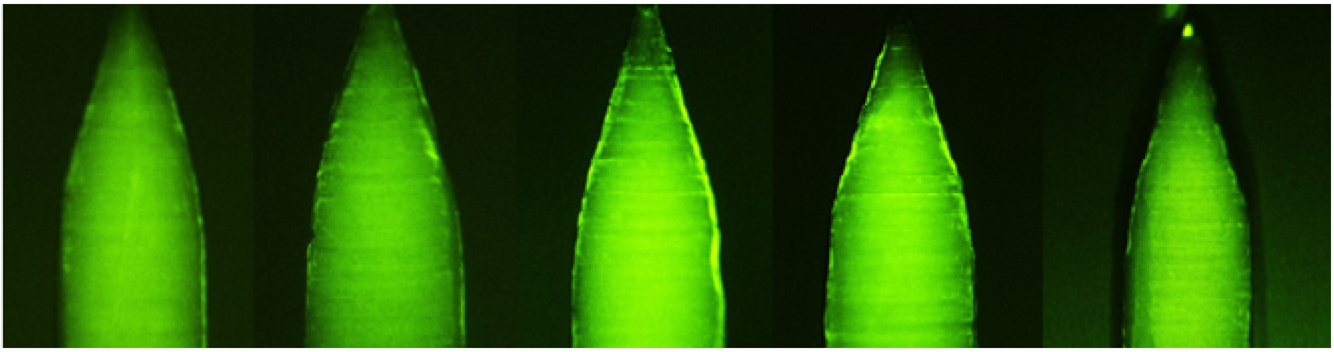


Figure 10. ***Coating technology from The University of Greenwich :*** Fluorescence lighting up the uniformity in coating technique

Materials for Transport and Aerospace

Who cannot fail to feel awe and wonder when they hear the roar of a fighter jet, see the immensity of an Airbus 380 or watch space rockets soar into space? The aerospace industry has always been at the forefront of material science and research continues to meet its demand for materials that are ever stronger, lighter, cheaper and safer.

3.1 HIGH-PERFORMANCE COMPOSITES

Carbon fibre reinforcement in thermoplastic composites is a staple ingredient for aeronautical engineers in their search for materials that combine strength and flexibility with lightweight properties.

Innovative technology developed at the University of Leeds allows researchers and engineers to produce high quality thermoplastic pre-pregs using so-called spread tow re-enforcing fibre *(see box 5)*. Spread tow sheets are weaved from flat tapes rather than threads of bundled fibres. These spread-tow pre-pregs have a number of advantages which make them ideal for rapid, cost-effective production of complex and lightweight composite products as well as stitchless, multiaxial, non-crimp fabrics.

The technology is ready for commercial licensing, portfolio trade sale and investment partnerships.

In contrast with carbon fibre composites, self-reinforced (or all-polymer) composites are extremely tough, but have relatively low stiffness and strength. They consist of an oriented polymer fibre or tape held in a matrix made from the same polymer.

The University of Leeds has invented self-reinforced composites that overcome the typical stiffness-toughness dilemma by hybridizing carbon fibres with self-reinforced polypropylene (SRPP) to create a new material that has an optimal combination of stiffness and toughness. These composites possess a unique combination of impact/crash resistance that are generally difficult to achieve in man-made materials.

The possibility of manufacturing these materials in high volumes makes this material extremely attractive to the automotive industry where the use of carbon fibres is still expensive.

3.2 AEROSPACE TECHNOLOGY

Combining clever design, engineering and materials science, Brunel University has found a unique way to reduce aircraft noise. Most noise reduction has focused on the sound generated by aircraft engines, but Brunel has turned its attention to the significant noise caused by the spinning turbine blades and the movement of air across the aircraft body.

The research group has now demonstrated the effectiveness of a serrated device which can be fitted along the trailing edge of a blade or wing. The saw-tooth serrations are filled with special material to suppress sound from vortex shedding in the space between teeth. Tests show the solid saw-tooth significantly reduces broadband noise; the special material limits high frequency 'leakage' noise and tonal noise from vortex shedding.

The researchers believe that their new trailing edge device could be improved using other metal foams or materials of different porosity, permeability and flow resistivity. They also seek partners to develop advanced manufacturing techniques to incorporate the design into fan blades, propellers and wind turbines.

Engineers from Swansea University are also helping to reduce aircraft noise, this time from wing flaps. Flaps produce dramatic inefficiencies in flight because of the pressure leakage around the gap between the normal wing and the flaps.

The Compliant Morphing Flap Transition (CMFT) combines newly engineered materials to give the system flexibility in some directions but stiffness in others. CMFT morphs into its three-dimensional curved shape thanks to several internal components that can bend and twist at the same time *(Figure 11)*.

The inventors are looking for collaboration with commercial airline, helicopter and wind turbine manufacturers who could benefit

BOX 5 : PRE-PREGS

Advanced thermoplastic composites are commonly manufactured from pre-impregnated ('pre-preg') materials. The reinforcing fibres are assembled as a unidirectional tape or as a woven fabric, then 'fixed' within a chosen thermoplastic resin. The final composite material may be formed from multiple layers, or lamina, of reinforced polymer.

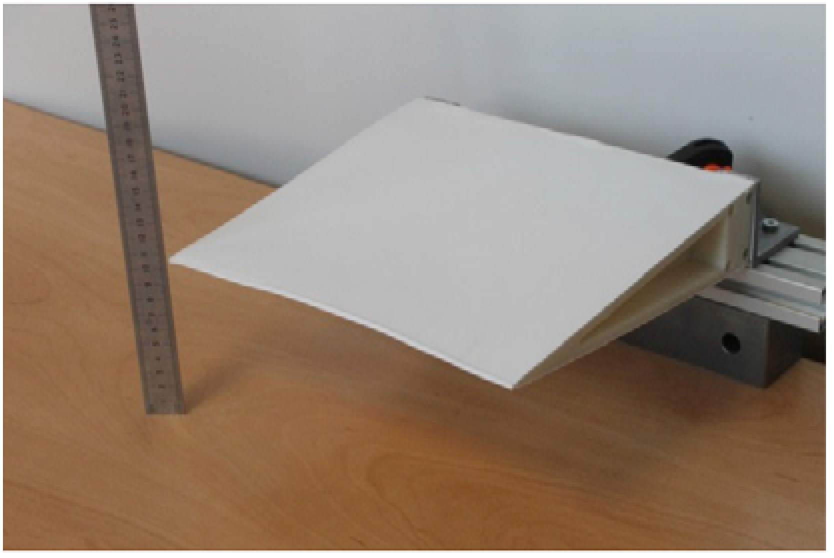


Figure 11. ***Swansea University's turbulence solution :*** Prototype of the Compliant Morphing Flap Transition being out to the test; (upper) at rest and (lower) deformed, demonstrating the large range of motion and smooth shapes achieved.

significantly from CMFT's ability to reduce drag. In aeroplanes, the design will lessen fuel consumption and reduce wing flap noise which is particularly loud during take-off and landing.

Another common way to couple better performance with manufacturing cost savings for aeroplanes and automobiles is through the use of tailored shear blanks. These sheets, which are made so their thickness or properties vary along their length, help manufacturers to optimize the amount of material they use in vehicle assembly.

A new process advanced by scientists at the University of Strathclyde is able to produce much longer bars, plates and sheets than conventional shear blank production. The new method, tested on aluminium, copper, magnesium, iron and titanium, results in refined structure, improved strength and adequate ductility.

The scientists have also shown how the process can also produce blanks with constant thickness by transitions in hardness, or blanks of sharp or gradually varying thickness.

The technology is protected by European and US patents, but the University now wants to find commercial partners who can scale up the process, support further research and/or license the technology for their own applications.

3.3 RAIL TRANSPORT TECHNOLOGY

Rail travel may be one of the oldest forms of long distance travel, but although it receives little coverage in the popular press, innovation is never far away. New technologies, materials and processes all contribute to the safe and efficient running of rail services.

Loughborough University has two rail-related technologies available for commercial licensing and further development.

The first, called Repoint, is a breakthrough in rail track switching that promises to improve safety, reduce maintenance and improve capacity. Using only off-the-shelf components, the new fault-tolerant rail switches are fail-safe: were the multiply-redundant actuation mechanisms to fail and the points 'stick' mid-track, a train would still not be derailed.

The predicted benefits equate to savings worth millions of pounds in costs and capacity when applied across the whole UK network. There are around 35,000 track switches on the UK mainline network alone and the export market is likely to be many times that of the UK, as many countries are experiencing serious capacity pressures which could be relieved by the new switching system.

The University has received funding to pursue commercialization, but remains interested in collaborating with industry partners or potential users in other sectors.

Loughborough has also developed a landslide warning system that rail operators may find useful for tracks at risk from unstable slopes.

Slope ALARMS is a patented, award-winning technology which measures acoustic emissions caused by soil movement – offering potentially life-saving, real-time monitoring and warning when the threat of a landslide is imminent.

The highly sensitive sensor detects displacement rates as low as 0.01 mm per minute and it picks up changes in the displacement rate within a few minutes of the change occurring. The system's inventors are now looking for partners to support its global commercialization.

Heriot-Watt University's new condition monitoring system for reinforced concrete also has potential application in the rail industry, as well as in general construction and beyond.

Corrosion of the steel reinforcement in concrete structures is a world-wide problem, particularly along roads where salt from winter grit spreading speeds up the process. It is crucial that those responsible for the maintenance and safety of bridges and other concrete structures can monitor the extent to which water and ions penetrate the concrete. Early warning of water

ingress can schedule preventative maintenance programmes.

The new system provides real-time information on the temperature and hydration; water and ionic movement within the concrete cover-zone. Engineers could use this critical data to model the structural performance of the concrete.

The networked sensors are embedded within the concrete and can be accessed remotely via a self-powered device. The sensors have no moving parts so are extremely robust and require no maintenance.

The research team wants to hear from commercial partners with an interest in using the patent-pending technology within major civil engineering projects or in supporting further technology development.

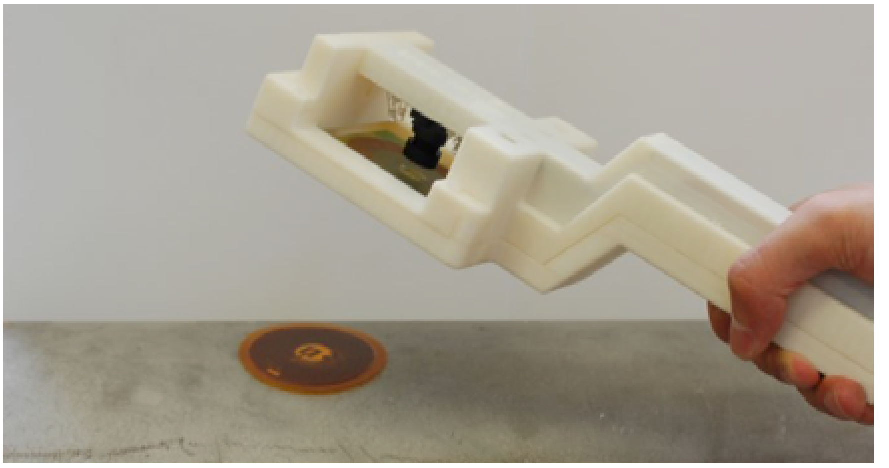


Figure 12. ***Inductosense from the University of Bristol :*** A wireless, non-destructive testing system for monitoring of usually inaccessible & embedded structures

3.4 SENSORS, MONITORING AND EVALUATION

The advancement of smart materials and their incorporation into modern sensor technologies is creating a burgeoning market for extremely reliable and highly sensitive non-destructive sensing and monitoring systems and devices.

One of the biggest problems engineers have to solve, however, is how to power these sensor systems, which usually contain electronic components.

The University of Bristol's Inductosense technology solves the problem in a simple way: its sensors are passive and power-up only when the measurement probe passes nearby through a phenomenon called non-contact inductive coupling - the same principle used in wireless charging pads used for some mobile devices. The detection wand induces just enough power for the sensor to send its data packet to the wand *(Figure 12)*.

Sensors can be placed in areas that are usually inaccessible (for example inside a turbine or along oil or gas pipelines) or even embedded into a structure such as an aircraft wing.

The Bristol team is evaluating the potential for a spin-out company based on this technology and would like to talk to companies about their needs and potential applications.

Sensors developed by researchers from the Zepler Institute at the University of Southampton get their power from a different source: vibration. Instead of using batteries, which have a limited lifetime and consequential maintenance issues, the novel wireless sensors harvest power from ambient vibrations using an innovative piezoelectric device.

The credit-card sized device is easy to retrofit and requires no further maintenance, so is ideal for monitoring conditions in difficult to access locations such as aircraft engines or gearboxes. Tested on a helicopter, the sensor generated 240 μW – enough to transmit measured data every 10 minutes.

A second energy harvester, measuring 55 x 55 x 3 mm is believed to be the world's thinnest non-MEMS electromagnetic energy harvester. It generated 450 μW of power in helicopter trials.

Both the sensor and energy harvester are available for further development and licensing.

Non-destructive testing and monitoring is absolutely essential in engineering to assure the structural integrity and quality of components before they are deployed. Cruising at 40,000 feet is no time to discover cracks in aeroplane engine parts!

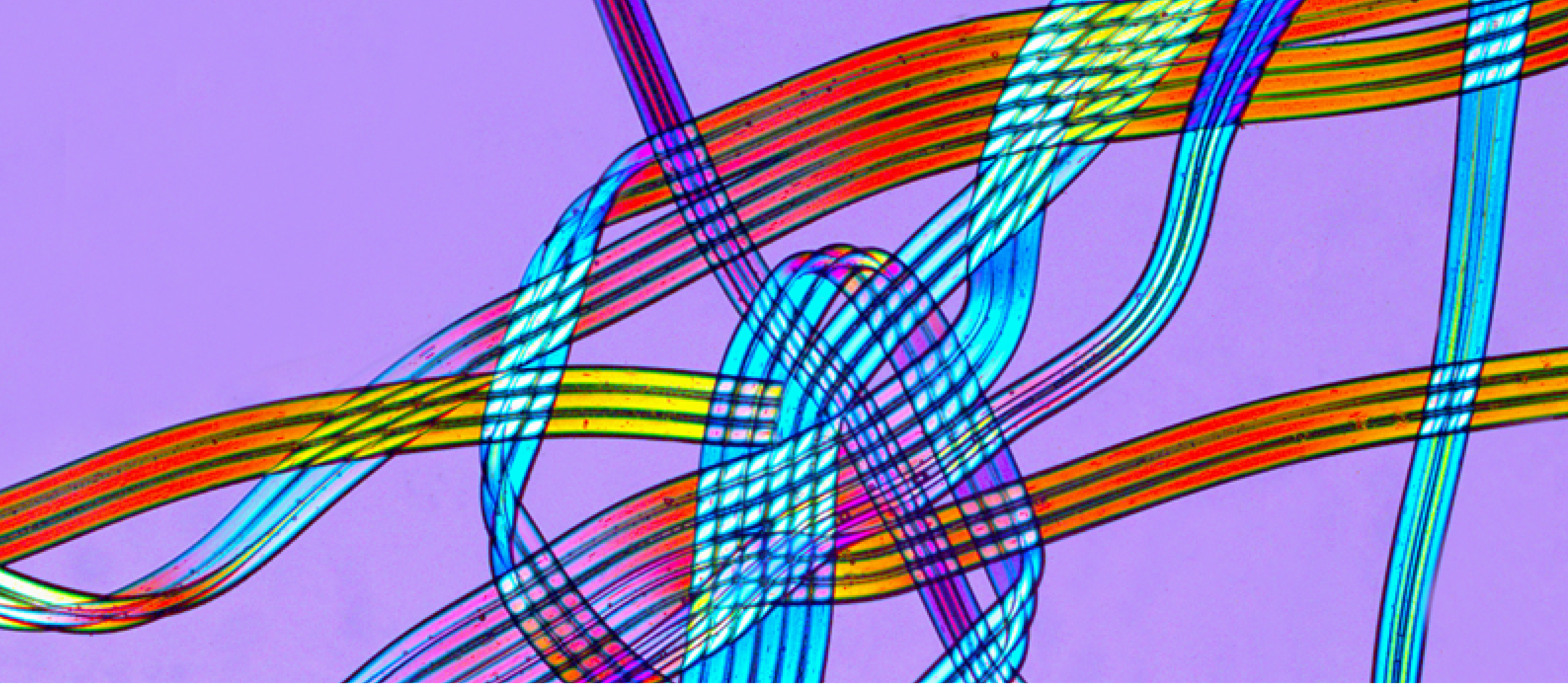
The Centre for Ultrasonic Engineering (CUE) at the University of Strathclyde has developed a variety of automated inspection techniques that combine unique elements of sensors, robotics and advanced signal processing.

The suite of technologies incorporates innovations in path planning and control, data registration and analysis algorithms that collect and use the non-destructive evaluation data. Novel visualization software helps to model the structure of complex shaped components.

A proof-of-concept demonstrator, built in conjunction with Eddyfi and the National Nuclear Laboratory, has highlighted the positive benefits of the technology in terms of throughput, accuracy and reliability. The system is fully scalable and flexible to suit any component sizes and geometries.

Integrated into the system is Eddyfi's conformable eddy current array for near surface defects. Additional through-imaging sensors such as ultrasonic and surface imaging visual devices are also integrated for flexibility and are dependent on end-user applications.

The facility would like to hear from interested companies to evaluate the world-wide market for this non-destructive quality control technology with a view to commercialization.



PHOTON 400 750 / CC BY-SA 4.0 - CROPPED

Polymeric Materials

Industry is spoilt for choice. When it comes to choosing a polymer or plastic, there is usually a product with perfect properties. From the vast library of commodity and specialist polymers on the market, manufacturers will look for the one that suits them best. And the choice just keeps on growing as scientists continue to develop high performance polymers that take the idea of 'smart' to new levels.

4.1 SYNTHESIS & TREATMENT

One of the benefits of using polymers in manufacturing is that they are still relatively cheap and easy to produce, at least compared with alternative specialist and performance materials. Scientists are constantly developing new synthetic methods to help industry keep costs low, even for small volume, complex polymer products.

One of the trickiest polymer materials to make is the so-called Janus nanoparticle *(Figure 13)*. With two physically distinct regions within or on the surface of the particle, these non-uniform, nanoscale polymer products are difficult to mass produce. Current syntheses are cumbersome, multi-step procedures that often involve lengthy process times.

Researchers from Princeton University in the US have now developed a continuous, rapid and cost-effective preparation route using a method which they have named Flash NanoPrecipitation (FNP). The patented FNP technology prepares nanoparticle composites with amphiphilic copolymers; Janus particles made this way are particularly suited for use as emulsion stabilizers, in drug delivery and medical imaging.

The Princeton scientists are now seeking appropriate partners for the further development and commercialization of this technology.

Specialist polymer nanoparticles are often used to create thin films, for example as critical layers in energy storage and semiconductor components. However, it is important to prevent the phenomenon called dewetting in which the film ruptures and forms droplets instead.

A team from the City University of New York (CUNY) in the US has invented a non-intrusive, additive method to prevent the dewetting of a polymer or polymer composite thin film. The scientists have found that deposition of a seed layer onto the substrate material helps to maintain the structure of the thin film. In the case

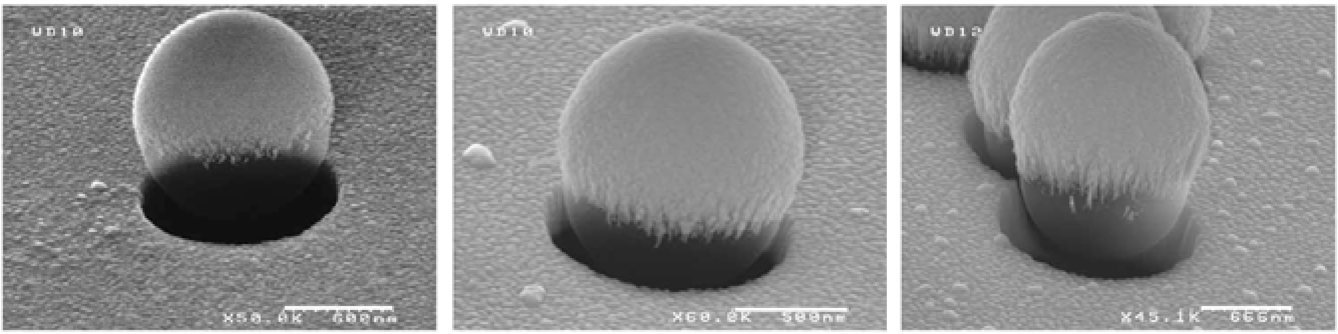


Figure 13. ***Bi-functional nanoparticles :*** SEM micrographs capture three Janus Nanoparticles, each displaying two distinct physical regions with different compositional ratios of polystyrene and gold *(Source: Thibault Honegger / CC BY-SA 3.0 - Cropped)*

of polymer-nanoparticle composites, the nanoparticle and seed layer can even be the same material, so there is no need to remove the seed layer after application of the thin film. This new method will simplify the fabrication of thin-film technologies and devices such as ceramic capacitors.

Now available for exclusive and non-exclusive licensing, the technology seeks co-development, especially for applications in semiconductor fabrication and optical thin films.

4.2 POLYMERS FOR REMEDIATION

During the summer of 2015, hundreds of thousands of residents in the North West of England had to boil their tap water for weeks because supplies had been contaminated with the parasite Cryptosporidium.

Such large-scale contamination is fortunately rare, but protozoan pathogens are always a risk. These organisms are ubiquitous in the environment, have an extremely low infectious dose and are resistant to standard chlorination disinfection procedures.

Scientists from Heriot-Watt University in Scotland have invented a polymer-based technology that removes pathogens like these from water. Filters coated in the polymer improve *Cryptosporidium* recovery and filter performance. Studies have also shown how the polymers could be used to verify the effectiveness of UV treatment as the viability of pathogen oocysts affects their binding to the polymer.

The University is seeking industry input and support from water suppliers or filter manufacturers.

From water to oil, novel polymers are also helping to clean up pollution from major oil spills too. Unfortunately many of the current methods for cleaning up oil – burning, skimming and the use of toxic chemical dispersants – cause their own environmental damage.

Thanks to research at CUNY, clean up companies now have an eco-friendly alternative that is non-toxic and fully recyclable. The scientists have developed a biodegradable gelling agent using sugar-based molecules extracted from renewable sources. The invention uses a unique gelation procedure which helps to solidify oils (crude oil and vegetable oils) at room temperature when they are in contact with water, for example a slick on the sea *(Figure 14)*.

Only a small amount of the gelation agent is required (about 5% volume/volume). In one test with a diesel-water mixture, the scientists managed

Figure 14. ***Burning split oil :*** A biodegradable polymeric agent developed at City University New York could prevent this in the future *(Source: US Navy / CC0)*

to recover 80% of the diesel from the gel using vacuum distillation, so most of the diesel and gelling agent can be recycled.

The agent is available for immediate licensing, with opportunities for sponsored research collaborations, including in other areas where gelation is important, for example in the cosmetics and food industries.

4.3 HYDROGELS FOR BIOMEDICINE

The gelling action of polymers is one for the most exciting advances in smart polymer development over the past few decades. Scientists have produced gels with some astonishing properties: shape shifting, 'remembering' 3D structures and soaking up many times their own weight in water.

Researchers at the University of Strathclyde have produced a selection of bio-compatible hydrogels that provide an excellent growth environment for stem cells.

Strategies to regenerate lost cells and tissues using stem cell therapy have thus far shown limited success. The ability to maintain cell survival, control migration of cells to the desired site of injury, induce differentiation into specific cellular types and aid integration of cells into existing functional tissues have proven to be the major hurdles to success.

However, scaffolds of Strathclyde's hydrogels encourage stem cells to expand and differentiate into various cellular types. The hydrogels seem to promote stem cell migration, survival and integration and are currently being optimized for *in vivo* applications.

Using simple, cheap and non-animal-sourced hydrogel material, the scientists have successfully replicated the stiffness of the brain and shown that the hydrogel medium allows stem cells to replicate, survive and turn into neurons.

The University is looking for potential partners and companies interested in the commercial development of *in vivo* medical applications.

Researchers at the University of Huddersfield, meanwhile, are using polymer gels as a matrix for *in vitro* cell studies and 3D culturing. They have developed a novel method for 3D rapid prototyping of soft materials with cell culture applications. This method can integrate multiple materials, cell types and growth factors into a single 3D cell culture construct.

Methods to incorporate multiple materials and cell types into tissue culture substrates are extremely valuable for medical research to mimic the extracellular matrix. The Huddersfield team is able to layer soft materials upon one another within a single gelled construct. The shape of the structure can be controlled and the layers of material are clear to see.

The same techniques can also be used to immobilize cells into scaffolds, which has great potential for tissue engineering.

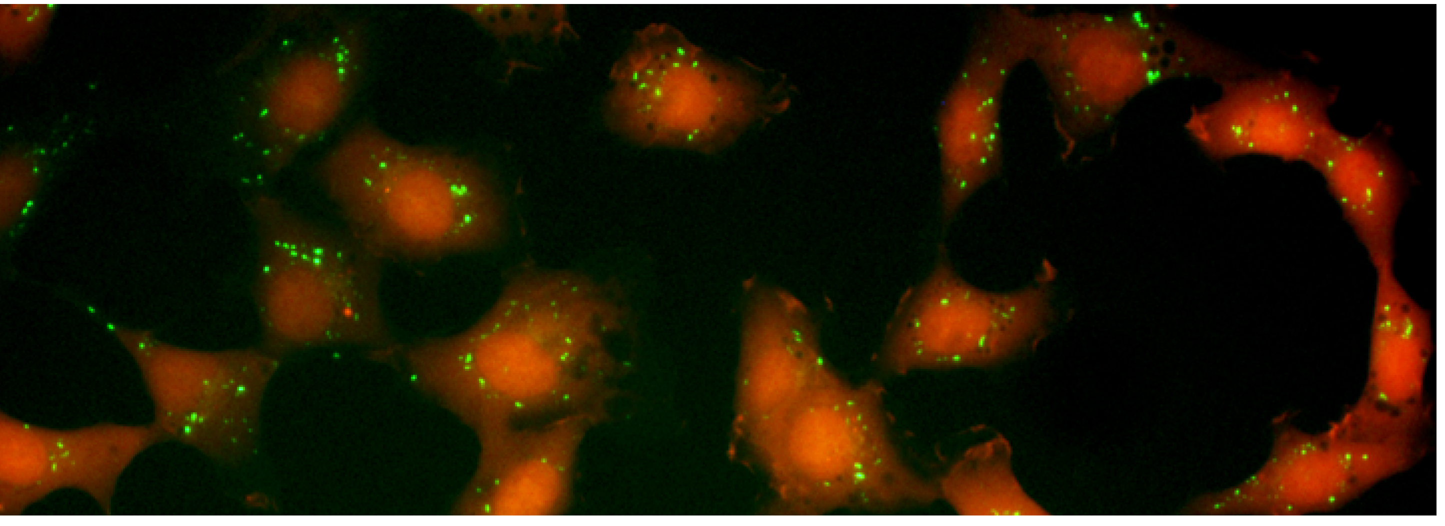
The researchers want to work with R&D partners to develop the protocols further and explore options for commercialization.

The University of York has expertise in the dynamics of self-assembly in polymer gels and networks, in particular in how networks assemble independently, or in combination with others.

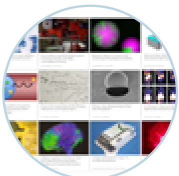
The researchers have developed materials which use specific non-covalent interactions between molecules to self-assemble into multi-functional, multi-network materials, for example robust, responsive gels in which one network provides strength while the other provides a response to a trigger stimulus (e.g. light, pH, etc.).

This molecular-scale assembly programming has allowed the team to create gels in a wide range of different fluids including petroleum, food oils and water. The gels can also incorporate nanotechnologies such as dendrimers, nanotubes, graphene and drug delivery micelles. These units are trapped within the gels until the gel undergoes a triggered breakdown.

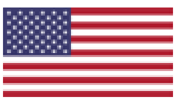
The University would like to hear from interested partners who wish to collaborate in further research and explore possible applications for these materials.



2015 Review



50 universities from the UK, US & Asia
300+ collaboration opportunities
1000+ R&D reps. from 500+ businesses



US launch with 6 East Coast Universities; Princeton, Rockefeller, UPenn, Northeastern & CUNY

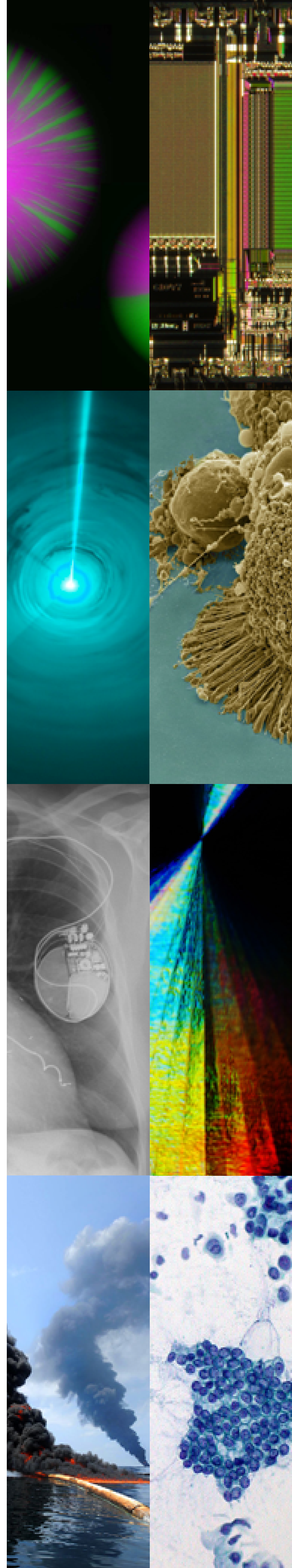
Facilitated 100+ collaborations between businesses and universities

Crowned a Northern Star:
One of the top-10 tech start-ups in the North of England

'It's not about cold calling' - IN-PART's ideas for improving UK tech transfer feature in Times Higher Education

IN-PART

www. **IN-PART** .com



UNIVERSITY HIGHLIGHT:

Transforming Advanced Materials Research

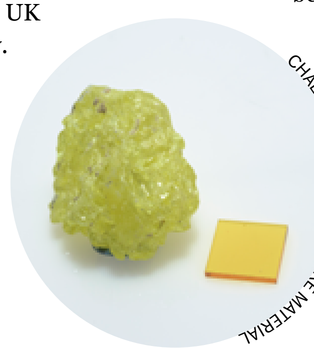
Next-generation optoelectronics materials and functional textiles

ZEPLER INSTITUTE

REVOLUTIONISING THE MANUFACTURE AND USE OF SPECIALISED GLASS

The Chalcogenide Advanced Manufacturing Partnership (ChAMP) is a £3.1M project, led by Southampton's world-renowned Optoelectronics Research Centre (ORC), to revolutionise the manufacture and use of specialised glass (chalcogenides) in a range of products, from optical fibre and infrared lenses to electronic devices, including logic and memory.

ChAMP researchers at Southampton, together with partners in the Universities of Exeter, Oxford, Cambridge, Heriot-Watt, and in industry, are dedicated to establishing the UK as a world-leader in chalcogenide glass technology. Traditionally, many chalcogenides are known for having high levels of impurities, leading to high optical loss and inconsistent mechanical properties. ChAMP researchers have focused extensively on improving the manufacturing process to remove contaminants and can now consistently produce high-quality glass with exceptionally low-loss rates.



CHALCOGENIDE - RAW TO PURE MATERIAL

Their expertise in novel thin-film fabrication coupled with access to the University's ultra-high purity raw material processing facility has also led the Southampton researchers to develop manufacturing techniques for radically new and advanced materials.

THE ZEPLER INSTITUTE, UNIVERSITY OF SOUTHAMPTON:

The University of Southampton's Zepler Institute is one of the largest research centres in photonics and nanotechnology in Europe, with over 300 staff working across a broad range of disciplines. Underpinning much of the research is a core capability in advanced materials – including 2D materials, energy harvesting devices, flexible electronics and nanofabrication. Here we highlight two of the Institute's major new projects which are transforming materials research and accelerating the translation through to application.

A team lead by Dan Hewak, Professor of Optoelectronics at Southampton and ChAMP Principle Investigator, has successfully fabricated and characterised large-area 2D films of molybdenum disulphide (MoS_2) at room temperature, using a process scalable to any size wafer. Due to its exceptional carrier mobility, MoS_2 is widely believed to be a strong contender for the next-generation of electronics which will soon take over as the silicon chip reaches its fundamental limit. However, adoption of the material has been limited as until now, it has only been commercially available in small flakes.

"Using flakes of MoS_2, which are typically only a few hundred square microns in size, to make devices is time-consuming, inefficient and does not provide a practical route to rapid prototyping" says Professor Hewak. *"For these new materials to be adopted in mainstream electronics, they must be compatible with the semiconductor processing lines used in the mass production of electronic chips."*

The new industrially-scalable and controllable deposition methodology developed by Hewak and his team has enabled the purification and synthesis of large-area films to a consistency and purity level not available commercially. They have also developed a technique to deposit these wafer-scale films onto any material substrate, paving the way for the large-scale manufacture of a wide variety of devices, including flexible and transparent optoelectronics, gas sensors, memory devices and photovoltaics (PV).

TECHNICAL TEXTILES

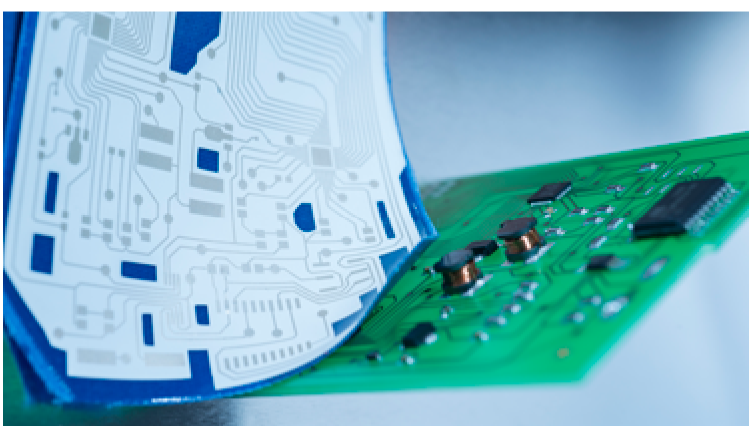
SMart and Interactive Textiles (SMIT), fabrics with electronic functionality, are an area of increasing interest with low-tech consumer products such as photochromatic t-shirts readily available: rapid growth is projected for high-tech applications such as military and biomedical.

A new £2.8M EPSRC-funded project, Novel manufacturing methods for functional electronic textiles, led by Southampton, is developing new materials and manufacturing methods for this next-generation of wearable technologies. The project unites Southampton's experts in electronics and electrical engineering with leading advanced textiles researchers from Nottingham Trent University and industry to extend the functionality of textiles beyond appearance and physical properties to capabilities such as sensing, data processing and user-interaction

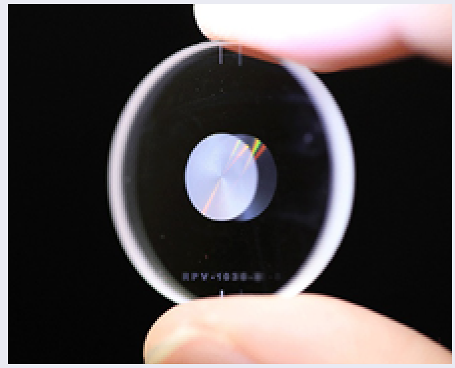
The research will lead to new manufacturing assembly methods that enable the reliable packaging of advanced electronic components, such as microcontrollers, in ultra-thin die form within a textile yarn. These electronic yarns (EYs) will have the appearance of simple standard textile yarns, but will in fact comprise super-thin flexible circuits surrounded by classical textiles like polyester, cotton, wool or silk and be connected to conductive wires. The ultimate goal is to incorporate the EYs into the textile in a way that protects the electronic components and interconnects from the rigours of use, whilst maintaining the feel, drape and breath-ability of the fabric.

"This is a fantastic opportunity to further the developments we have made towards the practical integration of electronics and sensing functionality in textiles," says Steve Beeby, Professor of Electronic Systems and Devices at Southampton and Principle Investigator on the project. *"Nottingham Trent bring highly complementary expertise in yarn and textile manufacture and, with the assistance of our industrial partners, we hope to achieve some real impact from this research."*

The ubiquity of textiles, used for example in clothing, home furnishings as well as medical, automotive and aerospace applications makes them one of the most common materials with which humans come into contact. By revolutionising the way that SMIT are produced, the potential to apply their huge range of functionalities wherever textiles are present will be unlocked.



SCREEN PRINTED FLEXIBLE ELECTRONICS



5D '*SUPERMAN MEMORY*' CRYSTAL: UNLIMITED LIFETIME DATA STORAGE

Southampton scientists have experimentally demonstrated the recording and retrieval processes of five dimensional digital data by femtosecond laser writing. The storage allows unprecedented parameters including 360 TB/disc data capacity, thermal stability up to 1000°C and a practically unlimited lifetime. The nanostructured glass offers vast storage, drawing comparison with the "memory crystals" used in the Superman films. It was recently named as one of the Telegraph's top-ten ground-breaking University research projects.

"Using ultrafast lasers to drive self-assembled periodic structures in glass, I believe we have created the smallest embedded structures ever produced by light" says Project-lead, Professor Peter Kazansky. *"Our next step is to develop a solution offering eternal memory and we are now seeking industrial partners to bring this exciting emerging technology to market."*

WORK WITH US:

Speak to the Zepler Institute today about joint and sponsored research, commercialisation and consultancy. Together, we can push the frontiers of materials research and help to bring new innovations to market.

www.zeplerinstitute.com/contact-us

Tom Carr, Zepler Institute Business Development Manager:

t.j.carr@southampton.ac.uk

INDUSTRY INSIGHT:

Diamond Light Source: Open for Business

Employing synchrotron radiation to probe the character of materials

The UK's synchrotron facility, Diamond Light Source, produces X-ray, infra-red and ultraviolet beams of exceptional brightness for research purposes. This brilliant light, combined with state of the art technological platforms, is extensively used by the scientific community to undertake structural, chemical and imaging investigations of a broad range of materials on very fast timescales and under industrially relevant conditions. Diamond's capabilities are very well suited to a wide variety of materials research applications ranging from aircraft fan blades to catalysts, hydrogen storage materials and batteries to high performance coatings, and fuel additives and complex formulations for the pharmaceutical and consumer products industries respectively.

Based in south Oxfordshire, Diamond opened its doors for academic users in January 2007 with industrial users following a year later. A growing facility, with 25 operational experimental stations and a further six under construction and commissioning, we currently welcome over 8,000 researcher visits every year from academia and from industry. The industrial user programme at Diamond is continuously growing with 90 companies from 12 countries now making use of our facilities through a range of services and collaborations. More than 25% of our academic users also collaborate with industrial partners, highlighting the significant role of synchrotron facilities in applied materials research.

Diamond's Industrial Science Committee provides guidance on opportunities for a wide range of industries to be engaged in research at Diamond and identifies industrial research priorities that help to shape the operational strategy of Diamond. Companies which have been or are currently represented on the committee include GlaxoSmithKline, AstraZeneca, Johnson Matthey, Infineum, Rolls-Royce, Evotec, Shell, Unilever and National Nuclear Laboratory.

In order to facilitate the use of Diamond by researchers working in industry, an Industrial Liaison team has been established, comprising highly qualified scientists experienced in a range of techniques areas, enabling the translation of diverse research problems into meaningful analytical solutions. With flexible access and support from synchrotron staff, large science facilities are now accessible to all researchers from industry and we count large multinationals, SMEs and start-ups among our clients. We offer a range of services including a full experimental design, data collection and analysis service, ideal for those with limited time or experience of the techniques.

CRYSTALLOGRAPHY IN ACTION AT DIAMOND

HOW CAN DIAMOND HELP WITH MATERIALS RESEARCH?

Broadly speaking, the materials characterisation facilities at Diamond fall into three main technique categories; diffraction for structural analysis of material from the atomic to macro scale; spectroscopy for chemical analysis of local atomic structure in materials and imaging, with a wide variety of imaging techniques including high resolution and high speed tomography and phase contrast imaging. A key benefit of synchrotron facilities like Diamond is the ability to perform *in situ* and *in operando* experiments, closely mimicking the conditions experienced by the sample during processing and monitoring changes in real time.

Of great interest to industry is Diamond's I12 Joint Engineering, Environmental and Processing (JEEP) facility which can be used to mount samples over a metre long and up to 2 tonnes in weight and position them with micron accuracy. Engineers from Rolls-Royce tested innovative surface treatments for fan blades of the Trent 1000 engine, the engine that powers the Boeing 787 Dreamliner. Using JEEP they obtained detailed, *in situ* information which will help them develop new processes, improve material properties and reduce costs.

In a world where consumers are demanding more from their products in terms of sensory perception and functionality, rapid innovation into market is key to growth. Scientists from Unilever worked with Diamond Industrial Liaison Scientists to gain significant insight into the behaviour of haircare formulations, accelerating the project to a working prototype for home use trials. Dr Ian Tucker from Unilever comments;

"The excellent facilities, flexibility and 'can-do' attitude at the Diamond Light source aligned well with our project needs and objectives. Without this contribution we would not have our current best prototype option to hand. An excellent partnership which bodes well for the future."

diamond

COLLABORATION FOR INNOVATION

While proprietary access remains a popular route for clients as it guarantees priority access and full confidentiality, participation in collaborative projects is also a useful way to develop technologies. Three such projects are:

- Diamond and Johnson Matthey were among 18 partners in a Europe-wide consortium, CARENA (CAtalytic REactors based on New mAterials), a large EU-funded collaborative project creating technologies that enable efficient conversion of light alkanes and CO2 into higher value chemicals.
- Diamond, UCL and Johnson Matthey have formed a collaboration to study how methane can be upgraded to higher value chemicals.
- Diamond, Ilika Technologies, the University of Cambridge, and Rolls-Royce have received funding as part of an Innovate UK grant to develop new alloy compositions for gas turbine engines with better thermo-efficiency than current alloys; increasing performance, reducing CO2 emissions and reducing noise levels at take-off.

As the applications of Diamond's facilities span a wide variety of techniques and industry sectors, an extensive range of case studies are available *(www.diamond.ac.uk/Industry/Case-Studies)* including Johnson Matthey describing their work on platinum speciation in three way catalysts, HP describing how Diamond experiments helped to design nanoscale pigment dispersions for display applications, Infineum highlighting their work on controlling crystallisation in fuels and biofuels and GlaxoSmithKline outlining how the high resolution powder diffraction capabilities at Diamond helped with a manufacturing issue. These diverse examples demonstrate the opportunities that using Diamond could bring to your research activities.

If you would like to learn more about working with Diamond or have an idea to discuss, we'd be delighted to hear from you. Please do contact us on *01235 778797* or at *industry@diamond.ac.uk*.

WRITTEN BY:

Dr Claire Pizzey

Dr Claire Pizzey is Deputy Head of Industrial Liaison at Diamond Light Source. She works closely with the Industrial Liaison team and industrial partners providing a multi-disciplinary approach to solving real-world problems.

UNIVERSITY HIGHLIGHT:

Ultra-high-precision Polymeric Innovations

UNIVERSITY of BRADFORD

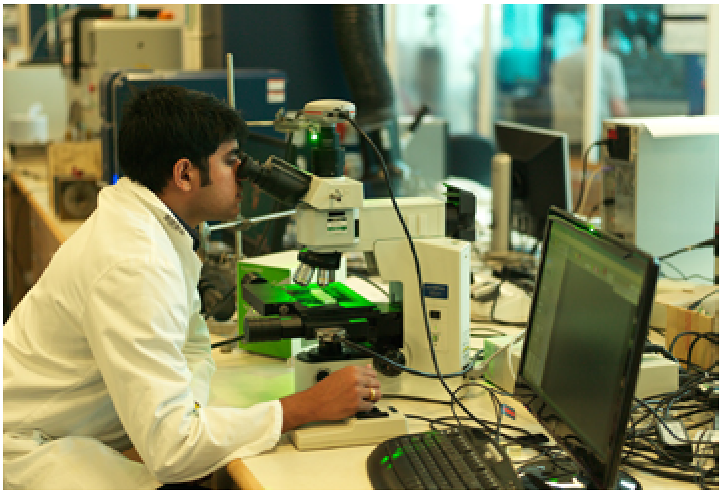
World-leading materials expertise and facilities

The Polymer Interdisciplinary Research Centre (IRC) laboratories at the University of Bradford form part of the wider Polymer IRC partnership with the Universities of Leeds, Durham and Sheffield. They are world leading research laboratories for polymer, polymer composite/nanocomposite and associated materials processing, including biomaterials and pharmaceuticals, with 40 advanced manufacturing lines for melt phase, solid phase and reactive processing, extensive characterisation, and computer modelling.

A few materials-focused research and knowledge transfer centres work closely together to carry out commercially relevant research for the Polymer IRC. The Centres are Advanced Materials Engineering and Centre for Polymer Micro and Nano Technology.

The Centre for Polymer Micro and Nano Technology has many years of expertise in producing ultra-high precision, high value polymer devices for a range of markets. These include medical devices in orthopaedics, drug delivery systems, surgical tools, diagnostic devices; diffractive, refractive and free-form optics; and automotive sensor components, sealing components, and injectors.

The Centre has spent many years developing process interrogation techniques to address quality issues in the mass production of components faced by manufacturers due to limitations in process and product control, variations in the quality of raw materials, and difficulty in obtaining appropriately skilled personnel to support the processes.



TAKING A CLOSER LOOK : A UNIVERSITY OF BRADFORD RESEARCHER ZOOMS IN

The Centre can provide rich data sets describing the material storage, drying and handling pre-processing steps, plastication, injection, cooling and post process properties such as shape, and mechanical and optical properties. These data sets can be accessed online using wireless sensor technologies and Ethernet-based data acquisition systems and give manufacturers the necessary intelligence to address quality issues. The Centre has very close links with Autodesk and their team responsible for ASMI (Autodesk Simulation Moldflow Insight). Autodesk is software capable of modelling flow and cooling in the process.

The Centre works with commercial clients on a weekly basis to develop new products, innovative materials, and process understanding. Clients range from global commodity material providers to optimise material processing to smaller UK SMEs developing new healthcare technology products.

The Centre is particularly experienced in Knowledge Transfer Partnerships (see case study). Using the Centre's expertise and equipment, knowledge gained during the Precision Polymer Engineering (PPE) Ltd KTP has created innovative techniques for the processing of elastomer materials which was previously impossible. Using the simulation modelling software has saved the company time and setup costs by avoiding manufacturing risks in early development stages.

CASE STUDY:

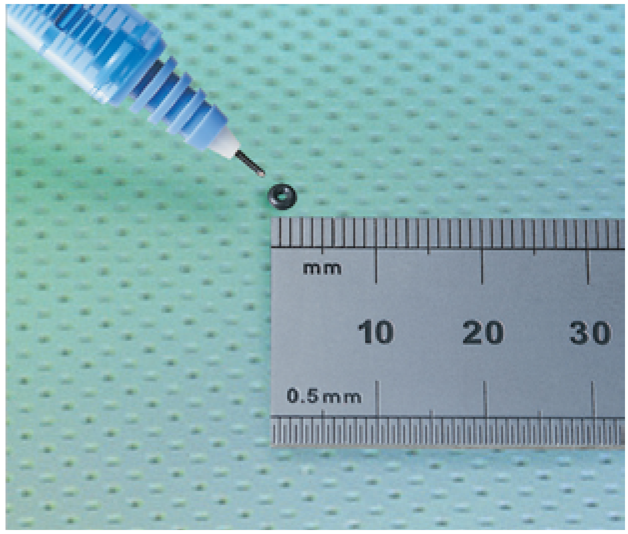
STATE OF THE ART MICRO PRODUCTS FOR PPE

We worked with Precision Polymer Engineering (PPE) Ltd, a leading provider of high performance O-rings, elastomer mouldings and sealing solutions, on a Knowledge Transfer Partnership (KTP) to develop a state of the art production facility for the manufacture of micro-sized products in a broad range of elastomer materials. The objective of the project was to create an industry leading capability for the provision of micro parts in critical applications.

The objective of the KTP was to develop a consistent and repeatable process, providing the highest quality micro-parts to address sealing requirements for industries such as micro-fluidics. High quality micro-elastomer parts can then be used to replace PTFE and PEEK materials to provide a more robust sealing solution.

"It's been a good experience with opportunities to grow in niche markets and increase sales and profits. The University have been excellent. The selection of the associate and a good relationship with the University are very important." - Paul Haworth, Global Product Development Manager, Precision Polymer Engineering Ltd.

Precision Polymer Engineering's employees have gained new micro-moulding technology and software knowledge and experience in related magnification, measurement and robotic techniques. As a result of the project the company are investing in the development of this knowledge as part of their strategic plan.



O-RING FROM POLYMER PRECISION ENGINEERING LTD.

The Associate (graduate) has become a permanent employee in the company and is responsible for setting up a micro manufacturing cell.

By establishing a flexible state of the art production facility for manufacturing micro-sized elastomer material products, the company have developed a niche customer offering in a difficult market. This is resulting in a more competitive offering, opening up new growth markets, and cementing their position as the leading provider of sealing component solutions in the future.

KTP is a UK-wide graduate recruitment programme funded by Innovate UK with 40 years of success. KTPs can help your business improve productivity and performance to stay competitive by forming a partnership with a university and accessing our skills and expertise. The University of Bradford have facilitated over 80 KTPs with many small and large organisations. Across the UK, KTP has worked with over 3,000 organisations and 6,000 graduates.

CONTACT:

If you would like to talk to us about materials expertise or our KTP or other business services, please get in touch:

- Website: *www.bradford.ac.uk/business*
- E-mail: *ktp@bradford.ac.uk*
- Tel: *01274 236000*
- Twitter: *@bradfordimpact*

TECHNOLOGY IN FOCUS:

High sensitivity, photonic silicon biosensor with simple camera readout

UNIVERSITY of York

Silicon is the most important semiconductor material for the electronics and photovoltaics industries today, and it has become the cornerstone of our knowledge-based society. Increasingly, silicon's photonic properties are being developed to the extent that multinationals such as IBM and Intel are now introducing chips that transport data optically rather than electrically to improve the operating speed and capacity of datacentres and supercomputers.

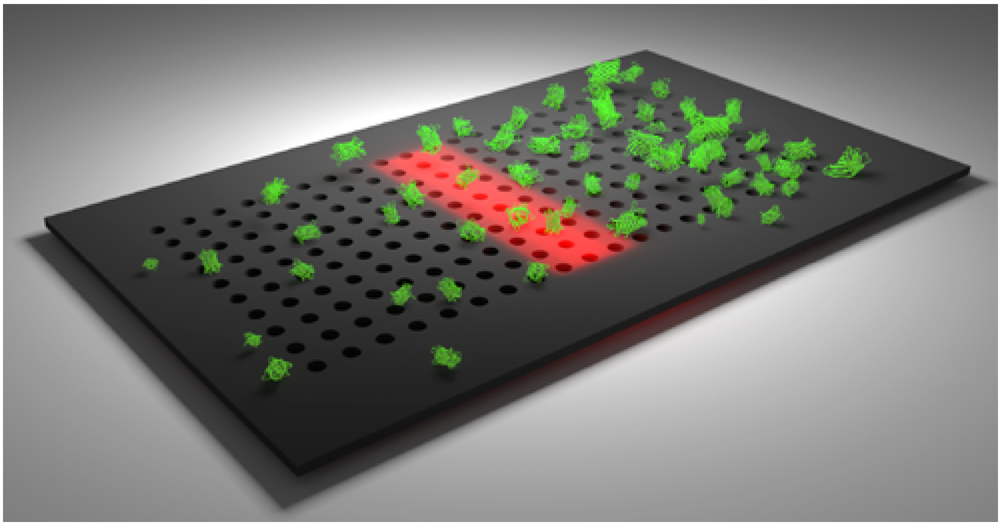
Building on the success of this sophisticated silicon technology established by the microelectronics industry, researchers are now developing another mass-market opportunity for silicon photonics, namely sensing technology for the personalised healthcare market. Imagine a smartphone attachment that is able to monitor the state of a person's health at any given moment, that can sense infections, detect viruses and provide early warning of infections or tumours.

Silicon photonic biosensors present one of the most sensitive disease biomarker detection technologies available, as exemplified by the high performance instruments offered by, amongst others, Genalyte (www.genalyte.com). A key issue is that expensive readout tools are often required which present a major hurdle towards the introduction and wider market penetration of the technology. The challenge is therefore to translate this high performance technology into a simple footprint, low cost, stand-alone device.

Researchers at the University of York are now developing such a technology. Their solution is based on a photonic crystal that supports localised resonances when excited by laser light *(fig. 1)*. The sensor affords label-free readout, so can use biomedical samples directly, it can operate autonomously and can be built for less than US $10 when mass-produced. Despite being so simple, it is very sensitive and can detect clinically relevant concentrations of biomarkers in the nanomolar range.

The sensor consists of a resonant grating that is illuminated by a semiconductor laser of fixed wavelength. The grating surface is functionalised with DNA, an antibody or an apatamer which ensures that the sensor only responds to specific biomarkers *(figure 2)*. The position of the grating resonance shifts when the target biomarker binds to the surface *(figure 3)*. The resulting shift is directly picked up by an imaging sensor such as a CMOS camera or a smartphone camera *(figure. 4)*. The ability to pick up the resonance shift and therefore the biomarker binding event without additional instrumentation represents the unique feature of the sensor, i.e. the readout can be transmitted directly and wirelessly to a smartphone or a computer for interpretation and analysis.

Figure 2.
Artist's impression of the operation of the sensor. The photonic crystal is designed such that the position of the resonance on the sensor surface depends on the density of molecules bound to the surface.



The device can be sensitised for any biomarker for which antibodies are available, so could cover a broad range of applications. The market for medical diagnostic applications covers both Point of Care and Home Healthcare diagnostics, both of which are growing at a yearly rate of near 10% and expected reach US$10bn worldwide by 2020. Personalised Healthcare is a major driver and there are clear opportunities for integrating the technology with smartphone devices which would open up even larger markets.

Antimicrobial resistance (AMR) is another major application. AMR has been identified as one of the major healthcare issues of the 21st century and is expected to cost the global economy up to 3.5% of reduced GDP due to premature death, estimated at a total value of 100 trillion USD. Advanced diagnostics technology will reduce the impact of antimicrobial resistance and therefore significantly reduce this cost.

Biofilm detection is a further large market. Industrial biofouling and biocorrosion is estimated to cost industry over $200 billion per annum in the US alone, suggesting that the market for detecting biofilms as a prerequisite to prevention could be valued in the billions of US dollars.

The key benefit of the technology is that it is intrinsically simple and robust without compromising performance. Together with appropriate biochemical functionalisation, it can be sensitised for any disease for which antibodies are available. The inventors have developed essential know-how that makes the biosensor commercially viable as a high-sensitivity, low-cost solution and they are keen to develop new IP together with commercial partners.

RESEARCH DEVELOPMENT

2011: *Slotted photonic crystal cavities with integrated microfluidics for biosensing applications,* T.F. Krauss, et al. Biosensors & Bioelectronics 27, 101–105

2014: *Silicon nanostructures for photonics and photovoltaics*, T.F. Krauss, et al; Nature Nanotechnology 9, 19-32

2015: *Spatial resolution and refractive index contrast of resonant photonic crystal surfaces for biosensing*, T. F. Krauss, et al; IEEE Photonics Journal, 7, 3, 6801810

THE AUTHOR & INVENTOR:

Prof TF Krauss is a full professor at the University of York, UK, where he leads the Photonics research group and the cleanroom facility in the York Nanocentre. He has published 280 refereed journal articles, with 12000 lifetime citations and an “h” factor of 59, as well as 5 patents. His expertise is in the design and fabrication of photonic crystals and photonic nanostructures where he has made pivotal contributions that turned photonic crystals from an academic curiosity into the ubiquitous concept in Photonics that they are today. At York, he was recently appointed Strategy Champion “Technologies for the Future” with the remit to enhance technology research university-wide.

thomas.krauss@york.ac.uk; *www.york.ac.uk/physics/photonics*

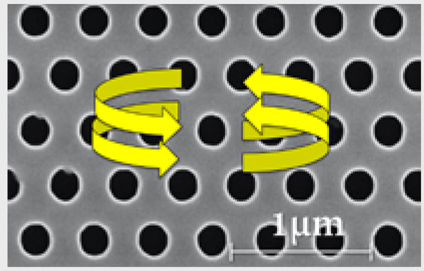


Figure 1. Scanning electron micrograph of a photonic crystal (hole spacing = 420nm) with superimposed illustration of an optical resonance. The photonic crystal operates as a sensor because the resonance wavelength is dependent on the local refractive index.

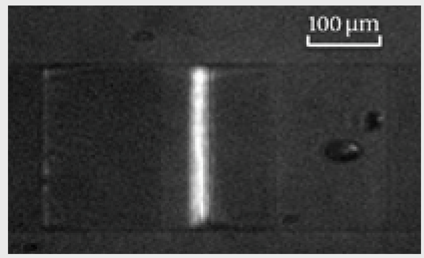


Figure 3. Experimental demonstration of the sensor operation illustrating the observed line of resonance. As the refractive index changes, e.g. through the binding of biomarkers, the line moves across the field of view. The position of the resonance line is therefore directly proportional to the concentration of biomarkers to be measured, which can be read out directly by a simple CMOS/smartphone camera. Depending on the particular molecule to be detected, we already achieve a detection limit of 10-100 nmol by this method, a value that can be improved with further research.

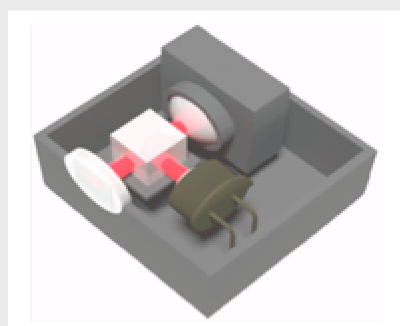


Figure 4. Illustration of the complete sensor, consisting of a laser, beamsplitter, resonant photonic crystal and CMOS camera. The readout camera can be directly connected to a smartphone for interpretation. The total cost of the components is less than US $10.

IN-PART

Searching for the latest university research for collaboration & co-development?

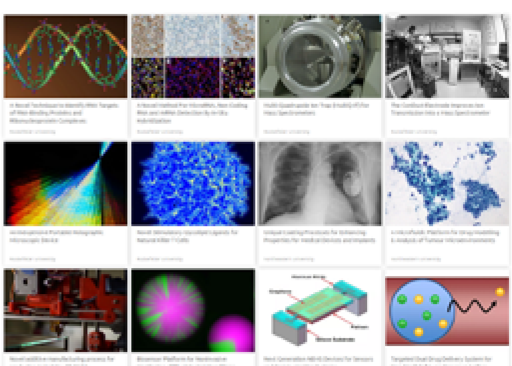
The IN-PART platform is a mind-store of innovation from the frontiers of science, technology and engineering, all seeking collaborative partnerships with businesses

Register at in-part.com for free access* to:

Over 300 collaboration opportunities from 50 world-leading universities

Personalised alerts of the latest IN-PART submissions within your chosen area(s) of interest

A contact function to submit questions, information requests, and feedback to university TTOs



UNIVERSITY OF CAMBRIDGE enterprise
PRINCETON UNIVERSITY
Penn
KING'S College LONDON
TODAI TLO
The Rockefeller University
UNIVERSITY OF LEEDS
UNIVERSITY OF BIRMINGHAM
University of BRISTOL
ZEPLER INSTITUTE
The University of York
CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

*Access exclusive to industry R&D Professionals