PROFILE BOOKLET

Physical Sciences, Social Sciences & Humanities

OXFORD UNIVERSITY INNOVATION

UNIVERSITY OF OXFORD

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AUTOMOTIVE, AEROSPACE & SPACE

Increasing turbine efficiency by design

Oxford University's Engineering Department has developed an unconventional approach to high-pressure vane design which delivers improved engine/stage efficiency for gas and steam turbines.

Turbine design matters

Turbines are a critical component in the majority of the world's primary energy conversion. Alongside the familiar application to aircraft jet engines, gas and steam turbines are the core of much electricity generation. Accordingly, there is an ongoing desire to improve turbine efficiency, lower CO_2 emissions and to provide greater operating flexibility and reliability - ideally whilst reducing costs!

A new but compatible design

Researchers at Oxford University have developed FLOvane, a fully lofted oval vane design, with improved efficiency of the nozzle guide vane section of the turbine. The flow in this region is highly complex and can generate significant losses. Furthermore, by gradually blending the vane geometry to a rectangular exit duct it ensures new design is entirely compatible with customer's existing turbine geometry.

The FLOvane invention is beyond the idea stage. Back-to-back Computational Fluid Dynamics (CFD) analyses of two current industrial gas turbines with conventional and FLOvane-modified geometric forms were completed. CFD predictions for the FLOvane-modified designs show improved aerodynamic performance characteristics; reduced heat load; improved cooling performance; improved thermal–mechanical life; and improved stage/engine efficiency.

The mechanisms for improved performance include reduction of secondary flows, reduced mixing of coolant flow with the mainstream flow, reduced skin friction, and improved coolant distribution. Stage-analysis showed increased isentropic efficiency of 0.33% points with surface-integrated heat load reduced by 45.0%.

Back-to-back analysis using standard design methods suggested the possibility of cooling flow reductions of 30% in an optimised design, giving 1.2% points increase in stage efficiency.

Looking for a development partner

This technology is relevant to all turbine manufacturing companies. In addition to licensing the patent, the researchers at Oxford University can offer their development expertise in adapting an industrial partner's proprietary aerodynamics design to use the new approach. Expected steps in a development plan for the technology would be to undertake a CFD study to characterise the expected benefits followed by an on-engine test with the goal of then exploiting the technology in production.

Patent

Patents covering this invention have been granted in the United States, Japan, and Europe. OUI would like to talk to turbine design and manufacturing companies that are interested in developing this design.

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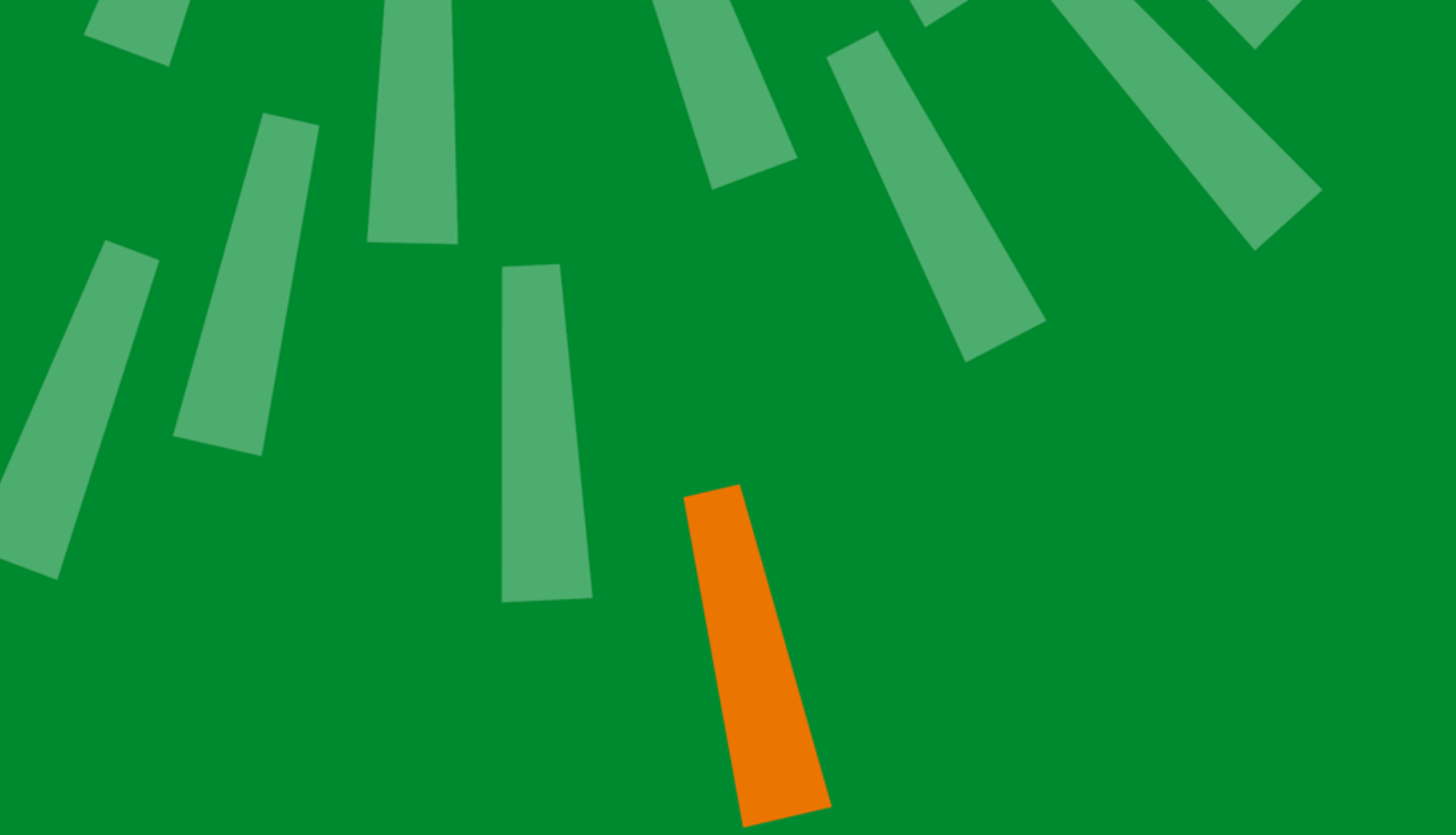
Technology Transfer from the University of Oxford



CATALYSTS, ENZYMES & REAGENTS

Combating antibiotic resistance

Oxford researchers have developed the functionality of a new type of rhodanine based inhibitor, ML302, which selectively targets bacterial MBLs involved in antibiotic resistance.

A global issue

Antibiotic resistance is considered to be the most important global public health issue as an increasing number of therapies have become less effective in treating various bacterial infections. The World Health Organisation calculates that this growing threat costs the US health system alone $21 billion to $34 billion per year. Another report from the Chief Medical Officer for England compares the threat to that of climate change, whilst the European Centre for Disease Control estimates that multidrug-resistant infections cost the EU over €1.5 billion per year and cause 25,000 deaths. There is a strong social and commercial need to tackle the issue but there are very few new antibiotic treatments available.

A pressing clinical need

Beta-lactams are the most widely used class of antibiotics and are therefore among the most important medicines currently in use. The use of beta-lactams is presently compromised by resistance mechanisms, most importantly by beta-lactam hydrolysis, which breaks down the antibiotic and renders it ineffective. Inhibitors for one sub-class of beta-lactamase have been developed and successfully applied but no clinically useful inhibitors have been reported to date for the Class B metallo-beta-lactamases (MBLs) and there is a consequent need to develop potent and selective inhibitors for MBLs.

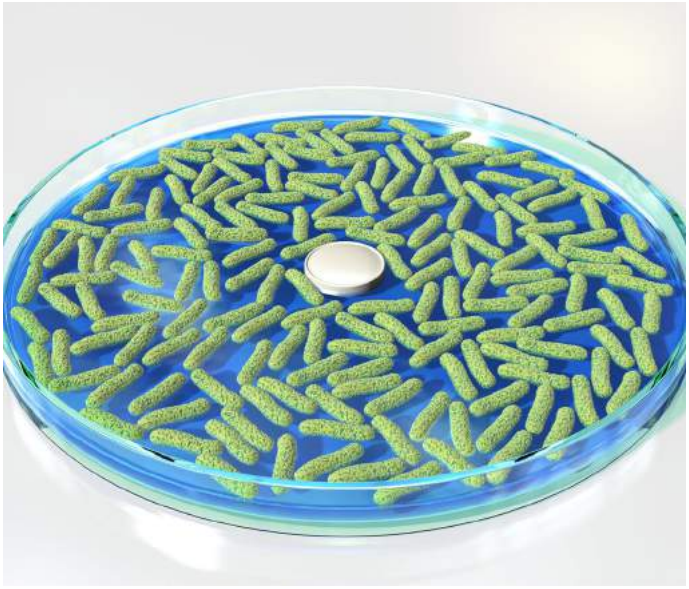
An effective solution

Research at the University of Oxford has demonstrated the functionality of a new type of rhodanine based inhibitor, ML302, which selectively targets bacterial MBLs involved in antibiotic resistance. ML302 undergoes hydrolysis to yield a thioenolate fragment (ML302F), a highly potent broad-spectrum MBL inhibitor.

The thioenolate prevents the MBLs from inactivating beta-lactam based antibiotics by reversibly binding at their active sites. This compound series could effectively be used to treat various infections by co-application of the inhibitor with a beta-lactam antibiotic, thereby expanding the lifetime of currently used medication.

Licensing opportunity

The research is the subject of a Nature Chemistry paper and a patent application has been filed to cover the compound series and Oxford University Innovation welcomes contact from parties interested in licensing this opportunity.



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Technology Transfer from the University of Oxford

Metal-free Catalysts

Oxford scientists have developed a novel class of metal-free catalysts based on Frustrated Lewis Pair chemistry, which offer excellent activity and selectivity in industrially applicable hydroboration and dehydrogenation reactions.

Transition-metal catalysis

Transition-metal catalysts are extensively used in large-scale industrial processes in the pharmaceutical industry. The use of homogeneous catalysts for such transformations offers a number of advantages, including excellent activity and selectivity under mild conditions, and in the presence of sensitive or reactive functional groups.

The ability to readily tune the reactivity of the metal-centre through selection of the appropriate ligands is also a major factor in the diverse range of applications that have been found for such catalysts.

Transformations facilitated by transition-metal catalysts underpin the majority of synthetic routes to pharmaceutically active compounds.

Towards a sustainable future

Despite the evident advantages of using transitionmetal catalysts in synthesis, there are issues with cost, toxicity, and sustainability. Some of the most widelyused homogeneous catalysts are based on metals that will potentially become unavailable in the next 30 years, as commercially viable deposits become exhausted.

Many transition-metals are toxic, and regulatory controls require their removal from pharmaceutical products. This adds a step to the production process, and therefore additional cost. Sustainable, non-toxic alternatives are, therefore, of significant interest to the industry.

A new class of metal-free catalysts

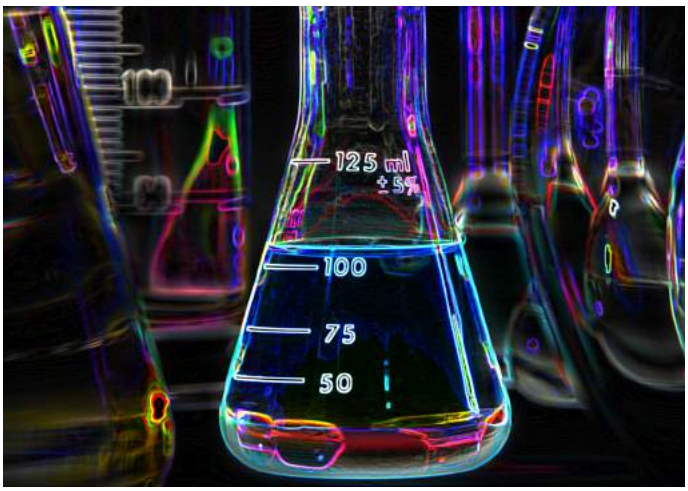
Oxford researchers have developed a new class of metal-free catalysts, offering excellent activity in selective hydroboration and dehydrogenation reactions. The reactivity of the catalysts is based on “Frustrated Lewis Pair” chemistry, and offers the following features:

- Metal-free system
- Highly tuneable reactivity
- Selective hydroboration under mild conditions
- Tolerant to sensitive functional groups
- Low catalyst-loadings
- Modular design to fit a range of applications

The Oxford compounds also demonstrate activity in C-H bond activation under mild conditions and the potential to activate a range of small molecules, such as CO_2 and CO. The dehydrocoupling reactions can also be used to produce polymers with inorganic backbones, offering applications in electronic devices.

Commercialisation

The compounds and applications thereof, are the subject of a UK priority patent application with the potential for international coverage. The activity of the catalysts towards hydroboration and dehydrogenation has been extensively tested and work is ongoing to uncover the full potential of this new class of molecules. Oxford University Innovation is seeking industrial partners to support commercialisation of this technology.



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Technology Transfer from the University of Oxford

Catalytic double bond migration

Available to license: A low-cost, high-performance photocatalytic method for the isomerisation of terminal olefins to yield internal olefins in high yields and under mild conditions.

Oxford University researchers have developed a novel photocatalytic process for the isomerisation of terminal olefins to high value internal olefins.

Internal olefins – global demand

A strong demand for internal olefins exists across both the petrochemical and fine chemical industries. Internal olefins are widely used in paper sizing, drilling mud, cutting fluids and for lubrication based oil. When derivatised further, internal olefins have applications as agrochemicals, pharmaceutical intermediates, and surfactants. Internal olefins can be considered environmentally benign and offer a higher surface activity in comparison with corresponding terminal olefins.

The deficiencies in internal olefin production

Internal olefins are produced by the isomerisation of readily available terminal olefins. These complex processes require high temperatures, expensive precious metal catalysts, and large solvent volumes. Owing to the high-temperatures, side-reactions such as skeletal rearrangements are common, reducing conversions to the desired product.

Products are often contaminated by the catalyst, which must be removed through a further distillation step. The isomerisation reactions must be conducted in the absence of light and oxygen, and at high pressures for optimum performance, adding further complexity and cost to the process. As many aspects of the current production methods are undesirable, the many lucrative applications of internal olefins have yet to be fully realised.

A green and high performance process

Oxford researchers have developed a low-cost, high-performance process for the isomerisation of terminal olefins to internal olefins through a novel photocatalytic procedure.

The new process offers the following advantages:

- Exceptional conversions (up to 100%)
- Mild conditions
- No requirement for exclusion of oxygen
- No solvent required
- Facile separation of reaction system and catalyst recycle
- No additional purification
- No side-reactions

Implementation of the Oxford process has the potential to address the global demand for internal olefins and other in-demand double bond migration chemicals.

The invention is the subject of a patent application with the potential for international coverage.

Oxford University Innovation would like to speak to companies interested in low-cost internal olefin production with decreased environmental impact.

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Technology Transfer from the University of Oxford

Novel iron catalysts for the production of alpha-olefins

Oxford researchers have developed a new and sustainable iron based catalystic system for the production of alpha-olefins from CO2and /or CO.

A growing alpha-olefin market

Alpha-olefins consist of a family of organic compounds characterised by having a double bond at the primary (or alpha-) position, which translates into an enhanced reactivity of the molecules. The global alpha-olefin market is expected to continue to witness a rise in demand from end-use industries such as automotive, chemical and plastic.

The production of alpha-olefins from syngas (CO and H_2) is known as Fischer-Tropsch synthesis (FTS) and typically proceeds through an iron-based catalyst.

However, the olefin to paraffin ratio in the products is relatively low, and requires a further dehydrogenation process. In addition, commercial catalyst preparation processes often result in high carbon emissions and require high energy consumption.

Novel FTS Catalyst

Researchers at Oxford University have developed a novel and sustainable method for the preparation of iron-based FTS catalysts with **low or even no emissions using very low energy inputs**. The new catalytic system allows a high conversion of carbon dioxide (CO_2) and/or carbon monoxide (CO) and hydrogen (H_2) with selective formations of desired olefins.

Potential applicability of the alpha-olefins includes the generation of:

- Fine chemicals and oil field chemicals
- Surfactants for detergents and personal care
- Polyalphaolefin based synthetic lubricants
- Plasticisers and automotive
- Polymers such as polyethylenes
- Polyolefin co-monomers

Commercialisation

Oxford University Innovation Ltd. has filed a priority patent application on the technology and welcomes discussions with companies interested in licensing it for commercial development.

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Technology Transfer from the University of Oxford

Novel iron catalysts for the production of jet fuels

Oxford researchers have developed a novel and sustainably formed catalytic system for the hydrogenation of CO_2 and or CO to form the desired jet fuels.

Synthetic jet fuels

Jet fuels are a type of aviation fuel consisting of a mixture of different hydrocarbons with carbon chain lengths that varies from C8-C16 and C5-C15. While conventional jet fuels are obtained through a series of distillation and refining processes from fossil fuels, synthetic jet fuels are made from syngas ($CO/CO_2 + H_2$) in a catalysed process called Fischer-Tropsch synthesis (FTS).

The use of these synthetic jet fuels has become highly popular in recent years with their properties being evaluated and accepted as equivalent to conventional fuels. In addition, a significant reduction in pollutants such as SO_x, NO_x, particulate matter and carbon emissions have been observed through their use, meaning the air quality around airports could be increased.

Despite the benefits associated with the use of synthetic jet fuels, their formation through iron-based FTS typically involves higher energy input and more emissions in the catalyst preparation. Also the catalyst performance is not ideal in terms of catalyst activity and selectivity.

Novel FTS catalyst

Researchers at Oxford University have developed a novel and more sustainable method for the preparation of ironbased FTS catalysts with low or even no emissions but high performance. The new catalytic system allows for the formation of jet fuels from the hydrogenation of carbon dioxide (CO_2) and/or carbon monoxide (CO).

The technology opens a new area of research in which atmospheric CO_2 could be trapped and used for the generation of these highly valuable fuels, thus contributing to the reduction of greenhouse gases associated with the aviation industry.

Commercialisation

Oxford University Innovation Ltd. has filed a priority patent application on the technology and welcomes discussion with companies interested in licensing it for commercial development.

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Technology Transfer from the University of Oxford

Solar-powered efficient photocatalytic ammonia production

A novel photocatalyst for a sustainable and decentralised production of ammonia under mild conditions.

The importance of ammonia

As the world population continues to grow, the challenge of producing more food with less energy becomes an important question to tackle. The current global food production heavily relies on the production of ammonia containing fertilisers, which support over 48% of the world's population.

The centralised Haber-Bosch (HB) process, considered the most important invention of last century, is still the method of choice for artificial nitrogen fixation, providing more than half of the world's ammonia.

Although this method has been critical for the development of modern agriculture, it is also extremely carbon intensive accounting for 1.8% of the global CO_2 emissions, which can be further exacerbated due to the lack of decentralised production options.

Biological nitrogen fixation allows the synthesis of ammonia under ambient conditions with the use of the enzyme nitrogenase, however it still requires a large input of chemical energy provided from adenosine triphosphate (ATP) to convert molecular nitrogen into ammonia.

Although many research studies focus on mimicking the structure and function of nitrogenase, most of the efforts have been centred solely on enzymatic processes.

Sustainable photocatalytic ammonia production

Oxford researchers have targeted the sustainability challenge of ammonia production and developed a novel nitrogenase-like photocatalyst that allows an efficient conversion of nitrogen into ammonia in aqueous and visible light conditions (e.g. solar) without the need of high temperature and pressure. In addition, the methodology is characterised by having:

- a high catalytic and quantum efficiency
- the absence of sacrificial agent such as methanol or formaldehyde

The implementation of such catalyst would facilitate and promote a renewable and local decentralisation of the production of ammonia, crucial for crop production in both developed and developing countries.

Commercialisation

Oxford University Innovation Ltd. has filed a priority patent application on the technology and welcomes discussions with companies interested in licensing it for commercial development.

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Technology Transfer from the University of Oxford

CYBERSECURITY

EDUCATION

LitHits - right book, right time, right place: fitting literature into busy lives

An Oxford Faculty of English researcher has developed an app that could help give literature a platform for the digital age.

Professor Kirsten Shepherd-Barr and Dr Alexandra Paddock, from the Faculty of English, have developed one of Oxford's first Humanities spinouts, which flips the script on the age-old problem of finding time to read: instead, LitHits helps users find great literature that actually fits the time they have available.

Guided by expert curators from the University of Oxford, LitHits serves unabridged excerpts of powerful, enduring literature direct to your mobile phone, selected for how much time you have to read and what you are in the mood for. They believe that literature and mobile phones can work together: no mindless scrolling, no shortcut 'executive summaries', just immersive reading that fits into your life.

Consumers and readers, bombarded with information and options, are increasingly seeking trusted curators to discover the new and help them find more of what they love. But LitHits does more than just recommend books; it delivers a curated experience of the book itself, that lets readers dive in and find out for themselves, sampling texts as they would try on clothes or taste food. Each LitHits excerpt is preceded by a light-touch, one or two sentence Oxford-curated introduction called "The Story so Far," giving a reader all they need in order to plunge in and enjoy the excerpt.

LitHits will also generate substantial, and vital, new data on how, what, and where people read. This data will be anonymised, preserving readers' privacy while gauging general trends and developments that are in great demand from publishers, booksellers, and digital humanities scholars.

LitHits is unique in combining human curation (in the selection of excerpts and the writing of "The Story So Far" summary) with AI/machine learning technologies. The biggest single challenge for any project trying to promote reading is the curation of suitable material for potential readers. This is largely due to the manual nature of the curation process, which is very labour intensive, costly and slow. LitHits have been developing relationships with AI specialists in the department of Computer Science at Oxford to understand how we might scale up and enhance the curation process through emerging technologies such as automatic summation natural language processing. This unique opportunity dovetails with the new Schwartzman Centre's particular focus on AI and Humanities.

In 2018, Oxford University Innovation's (OUI) University Challenge Seed Fund provided some initial funds that enabled LitHits to demonstrate the viability of an app to deliver extracts of literature that people would use and enjoy. They built a limited-functionality app to test the concept with 75 volunteer testers who gave them feedback and recommendations. Later that year, LitHits competed successfully for a second round of seed funding from UCSF and built the supporting technical platform, the curation assistant, and a minimum viable product now in testing on both Android and iOS.

In April 2019 LitHits won funding from Oxford Humanities Division's new Business Engagement Partnership Fund to explore how the app might improve the social experiences of the elderly and isolated. LitHits are poised to begin similar testing in secondary schools.

LitHits want to build a business with social impact and give something back to society and the university. Their mission is to help people fit reading into their lives; to rekindle a passion for literature; to go deeper; to satisfy curiosity about literature; or simply to help people discover more of what they love. And that's just the start. LitHits's longer-term mission is to bring great literature to those who have yet to discover it. They believe the right excerpt at the right time can open the door to a life-long love of reading.

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Technology Transfer from the University of Oxford

ELECTRONICS & PHOTONICS

Commercial opportunity in transparent conductors

A low cost, high performance alternative to ITO for displays, lighting and photovoltaics.

The invention

Researchers at the Universities of Oxford and Birmingham have worked on the optimisation of doped Zinc Oxide (ZnO) based materials. ZnO based materials have been of interest for electronic applications for many years in view of their suitable band gap, electron density and electron mobilities. Until now their exploitation has been limited by their relatively low electrical conductivity.

The latest work in Oxford has addressed the requirement to be able to deposit these materials from the solution phase, negating the need to use vacuum techniques e.g. pulsed laser deposition and sputtering. Doped ZnO thin films made with our method have shown the following benefits:

- High conductivity within an order of magnitude of ITO prepared by a solution phase deposition.
- Greater than 80% optical transparency for comparable film thicknesses.
- Lower cost as ZnO is an abundant material.
- Solution phase process avoids expensive vacuum manufacturing techniques.
- Process suited to large area coverage.
- Variable topography substrates can be accommodated.

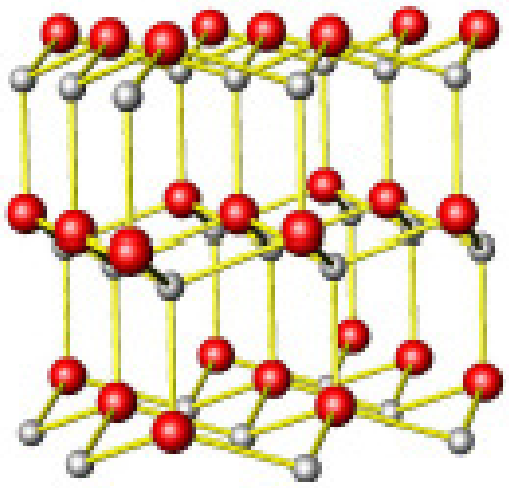
Marketing opportunity

Today, Indium Tin Oxide (ITO) is the most used transparent conductive oxide (TCO). TCOs are used in a number of areas e.g. liquid crystal displays, flat panel displays, plasma displays, touch panels, electronic inks, organic light-emitting diodes, solar cells, lighting, touch sensors, antistatic coatings and electromagnetic shielding.

Although, ITO offers an excellent combination of electrical conductivity and optical transparency, it also uses most of the world's rapidly depleting Indium resource, and hence is expensive. The cost, performance and processing convenience of these new ZnO based materials offer an opportunity to substitute ITO and also to enable a number of new applications.

Patent status

This work has been patented. Oxford University Innovation would like to talk to companies interested in developing the commercial opportunity.



ZnO structure: Zn2+ in grey, O2- in red

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Technology Transfer from the University of Oxford

Magnetic navigation

Oxford researchers have developed a method of localising mobile devices and smartphones, without the need for additional hardware.

The Oxford invention

The Oxford invention uses the spatial variation of magnetic fields to enable a mobile device to identify its location by measuring the magnitude and direction of these fields. It is possible to generate digitally coded magnetic fields using electrically powered coils, a process that can be likened to 'barcoding' the magnetic fields. With knowledge of the locations of the sources of these unique fields, the position of the device can be established within a 3D space. The coils producing the magnetic fields can be small, and could be incorporated in electrical plugs or other similar sized objects. A big advantage of this system is that once the coils are installed no additional user equipment is required, as smart phones already have inbuilt magnetometers which can be accessed with a simple app.

Existing technologies

The functionality of mobile telephones has increased dramatically over recent years and has led to the development of smartphones with many enhanced features, such as Global Positioning System (GPS) tracking for location finding, accelerometers for motion sensing and compasses in the form of magnetometers for direction finding. Such location and directional information can then be used in a variety of user functions and applications.

Limitations of GPS

Smartphones and other mobile consumer devices generally retrieve localisation data from GPS satellites. However, GPS positioning can be unreliable in some situations, particularly when the user is indoors or underground, when obtaining a satellite fix can be difficult or even impossible. This can lead to the user having little or no location information available to them, which reduces the smartphone functionality and is particularly disadvantageous when the user is in an unfamiliar environment.

Another constraint is that, in order to retrieve a location fix using GPS, a significant amount of energy is needed, and it is important to keep energy usage as low as possible in order to preserve battery life. Therefore, an alternative method may be advantageous, even in envoronments where a good GPS signal is available, if it fulfils a similar role whilst consuming less energy.

Advantages of the Oxford invention

The Oxford invention has uses in large buildings such as shopping malls or museums, underground or underwater, or wherever there is poor GPS reception. Beyond smartphones, there are also many potential uses in other portable devices.

Patent status

A patent has been applied for and Oxford University Innoavtion welcomes interest from companies interested in licensing the technology.

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Technology Transfer from the University of Oxford

Flexible transparent conductor

Available to license: A method for producing a nanomaterial-based transparent conductor

Oxford academics have developed a new material which combines market-leading optical and electrical performance with improved flexibility and an expanded range of coating options

Growing markets and new markets

The market for transparent conductors is forecast to grow from $6bn in 2012 to nearly $12bn in 2016. This spectacular growth is fuelled by the use of their materials in flat panel displays and touch screens for appliances such as tablets and smartphones. These materials also find use in thin-film photovoltaics, solid-state lighting and specialist coating applications. Opportunities for still further applications exist, however the cost, performance, accessibility and processing limitations of the current market-leading materials such as indium tin oxide (ITO) prevent their broader exploitation. For example, the brittleness of ITO makes it unsuitable for use in flexible displays.

Clear advantages

Oxford researchers have developed a method for forming a solid transparent conductor from a liquid composition to produce a new material offering a number of enhancements and user-benefits:

Truly flexible transparent conductor enables improved flexible displays and enhanced durability in existing touch screen devices.

“Paint-like” material properties mean that high precision coating techniques are not required. Traditional deposition options such as dip or spray coating can be used resulting in lower processing costs for industries such as thin-film photovoltaics.

“Thick” film capability means freestanding transparent films can be produced offering excellent electrical conductivity in all directions. In addition, using “thick” films allows a broad range of surface textures to be coated. Each of these benefits opens up new fields for the application of transparent conductors.

Matching ITO’s conductivity using cheaper source materials – ITO is expensive as indium is a rare element – means improved price/performance in existing high volume markets such as flat panel displays.

Who needs these new materials?

The reduced costs, greater flexibility and attractive processing options this technology offers will be of interest to both producers and users of all transparent conductors.

Patent protection

The underlying invention is the subject of a UK Patent application and work to develop this technology is continuing. Companies interested in progressing the commercial opportunities for this technology are invited to contact the Technology Transfer Manager.

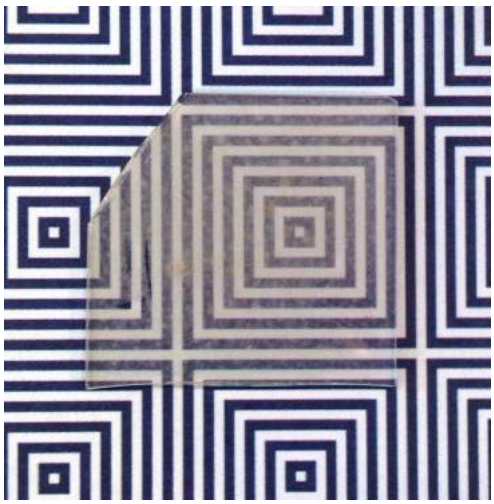

Image: Thick coatings of the new conductor deliver excellent transparency.

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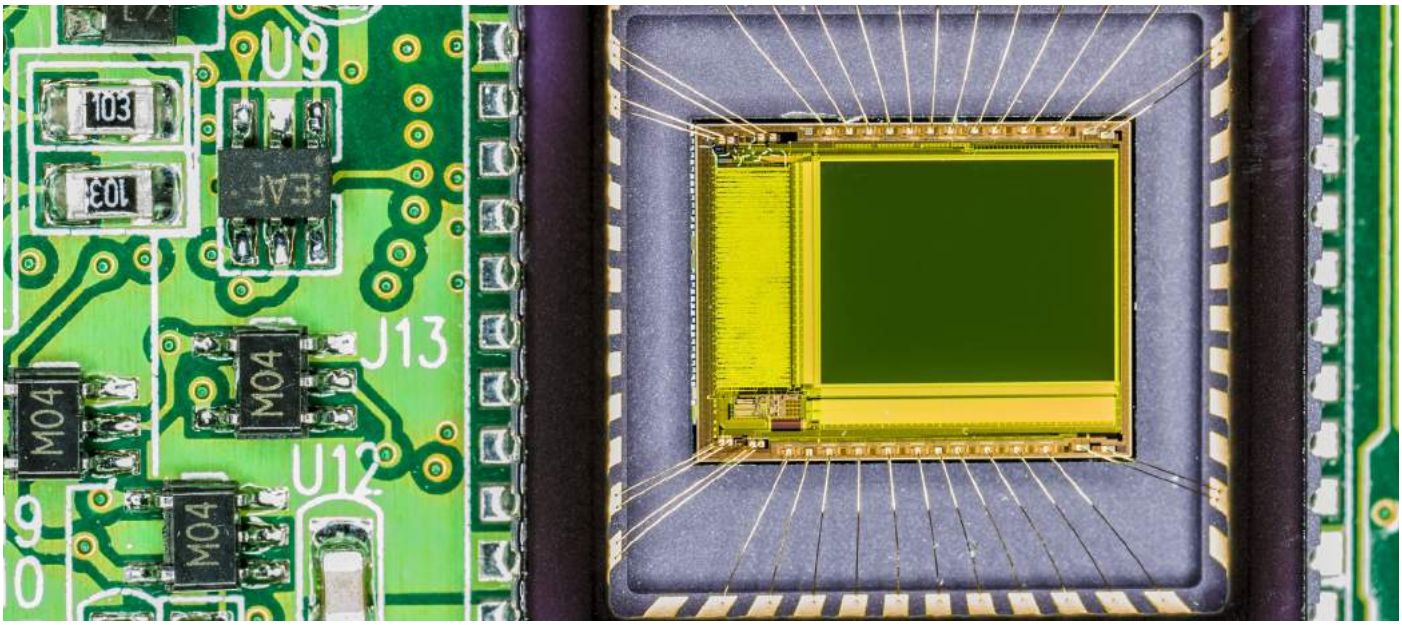
Technology Transfer from the University of Oxford

Novel pixel technique to increase performance of image sensors

Oxford researchers have developed a novel pixel technique to achieve better performance of complementary metal oxide semiconductor (CMOS) image sensors.



CMOS image sensor

Complementary metal oxide semiconductor (CMOS) image sensor technology is widely used in a number of applications such as digital cameras, video cameras, and smartphones. In recent years, CMOS image sensors have dramatically improved their performance but there is a need for further improvement on sensitivity within modern technologies.

Problem with conventional pixel design

CMOS image sensors typically include plural square-shaped pixels arranged in matrix. Each pixel includes a light sensitive area which is sensitive to incident light and an inactive area which is used to read out the amount of light falling on the light sensitive area. To improve the sensitivity, the ratio of light sensitive area to the total area of the pixel (generally defined as “fill factor”) should be maximised.

Novel pixel design to maximise fill factor

Researchers at the University of Oxford have found a novel pixel design technique that maximisies the fill factor whilst obtaining high sensitivity. The researchers removed the constraints of squared-shaped pixels and optimised the fill factor of the entire pixel matrix.

The advantage of this novel pixel design is to get a higher fill factor without increasing the pixel pitch. As a consequence, the pixels are staggered, which also has advantages from a signal processing point-of-view.

Patent protection

Oxford University Innovation has filed a priority patent covering this seeking partners to help commercialise the technology. Oxford University Innovation would like to talk to companies interested in developing commercial opportunities.

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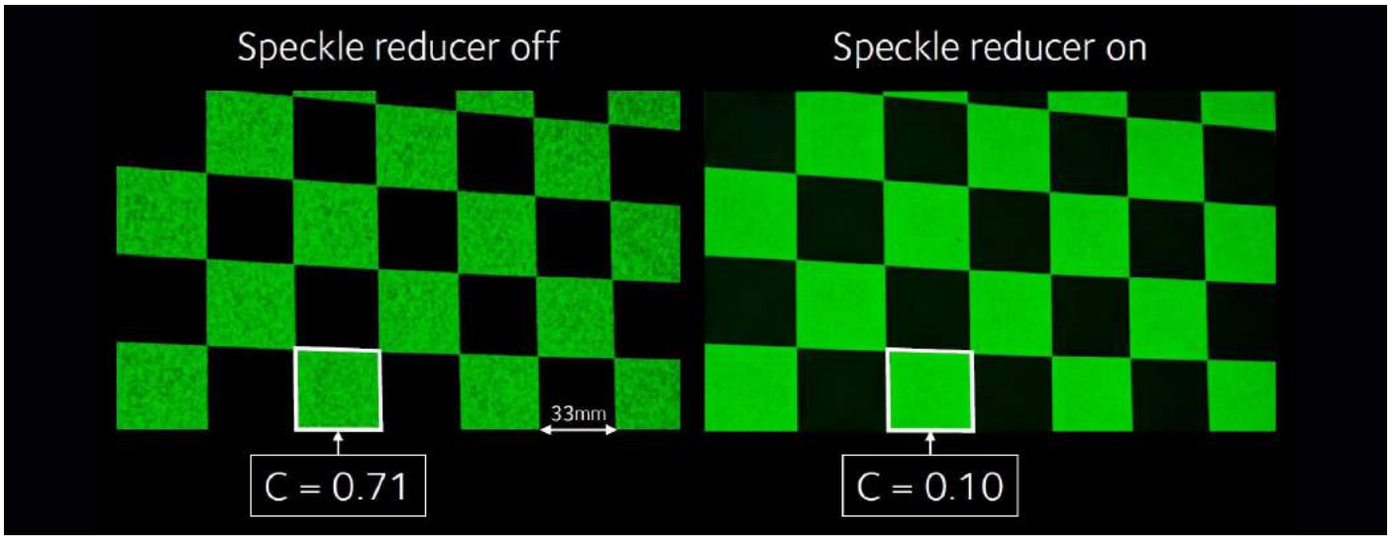
Technology Transfer from the University of Oxford

Speckle Reducer for laser imaging, projection displays and sensors

Oxford researchers have developed a new device for tackling the problem of “speckle” when using lasers for displays and imaging.



A laser is often referred to as a device that emits a beam of light through a process of amplification.

High-brightness lasers are used in the field of life science, material science, medical diagnosis, and precision engineering for high-speed, high-resolution optical imaging. However, the random scattering in imaging systems, caused by coherent lasers, is a primary obstacle for optical imaging.

However, lasers come with some drawbacks that have hindered their widespread adoption.

The problem with speckle

When a laser beam of light is shone onto a screen, the image quality produced is degraded by a coherent artifact known as speckle. When the laser light is coherent, all the waves are in phase with each other, and when you shine a laser onto a screen the light is scattered in all directions because a screen isn’t flat on the scale of the wavelength of light. This means that laser light, from all over the screen, reaches your eye having travelled a range of distances to get there.

As a result, we see an image that appears “speckly” (a granular pattern superimposed over the intended image), and which changes as you move and your position relative to the screen changes. To be able to use lasers to produce high quality images, this speckle pattern needs to be suppressed or removed entirely.

A better speckle reducer

There are some technologies, currently available, that address the problem. One method is to rotate or vibrate a diffuser rapidly which blurs out the speckle pattern. This comes with the costs of added bulky, moving parts and vibrations, power consumption and limited lifetime. Most methods rely on vibrating something, so what if we take the idea of a moving diffuser a step further?

Rather than make a solid diffuser plate and shake it around mechanically, a transparent device has been created that uses a liquid crystalline material with an alternating electric field to ‘vibrate’ the molecules about. The electrohydrodynamic turbulence created inside the device causes blurring of laser-light passing through it which reduces speckle without physically moving the device. The device has a simple design, low manufacturing cost and consumes very little power.

Patent protection

A patent has been filed which covers this technology. Oxford University Innovation Ltd. is interested in talking to potential partners to aid in the commercialisation of this new device.

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Technology Transfer from the University of Oxford

Novel signal cross coupling method goes “on-chip”

Researchers from the University of Oxford have developed a signal coupler with crossed transmission lines in planar circuit form, which results in a more compact device that is much easier to manufacture.

Signal couplers are very common circuit components in many applications, ranging from radio frequencies (kHz) to optical frequencies (THz). They are widely used for power distribution networks, heterodyne mixing applications, large sensor arrays and phase delay networks. Their primary function is to couple a defined amount of signal from one transmission path to the other, and hence can be used to combine or split signals.

Traditionally, a planar circuit-based signal coupler has both of its transmission paths aligned in parallel to each other. Whilst this is suitable for simple circuitry, it can be difficult to implement for large complex systems, since the flexibility in routing the transmission paths is limited by the coupler.

This is particularly important for large array networks, where it is preferable to have the ability to cross or bypass the transmission line using additional cablings, crossing waveguide couplers or optical free-space beam splitters. These methods are incompatible with standard radio to terahertz circuitries.

Powerful advances

Academics at the University of Oxford have developed a signal coupler that can be easily integrated into wider circuitry in planar circuits (e.g. printed circuit boards (PCBs)). They are easy to fabricate with standard PCB technology, and are compact, broadband and easy to scale for applications in different frequency domains.

The inter-arm power coupling can be configured to be directional or non-directional. More importantly, the level of power coupling can be easily and reliably controlled and adjusted with simple alterations to the circuit, which makes it easier to design for large complex networks that require a large number of couplers with different power coupling levels.

More than a couple of benefits

This new signal coupler has multiple other benefits, including:

- Reduced losses compared to traditional signal couplers
- Can be scaled to work at almost any frequency, from kHz to THz
- Easy to mass produce
- Around 10x smaller than the traditional cross-guide couplers
- Coupling strength can be adjusted easily
- Coupling direction can be designed according to specific applications by simply changing features in the planar circuit design

This could have a major impact on the design of complicated circuitries that require multiple signal couplers, reducing the size of components and improving their performance.

Technology applications

The Oxford-developed signal coupler can replace the traditional, bulky cross-waveguide coupler, as well as the freestanding dielectric beam splitter in heterodyne astronomy receivers, and has applications within satellites, telecommunications and radar, and large power distribution networks such as multiple-path phase array networks.

The technology is subject to a UK patent application, and is available for license. If you would like to hear more about the technology, please contact Oxford University Innovation.

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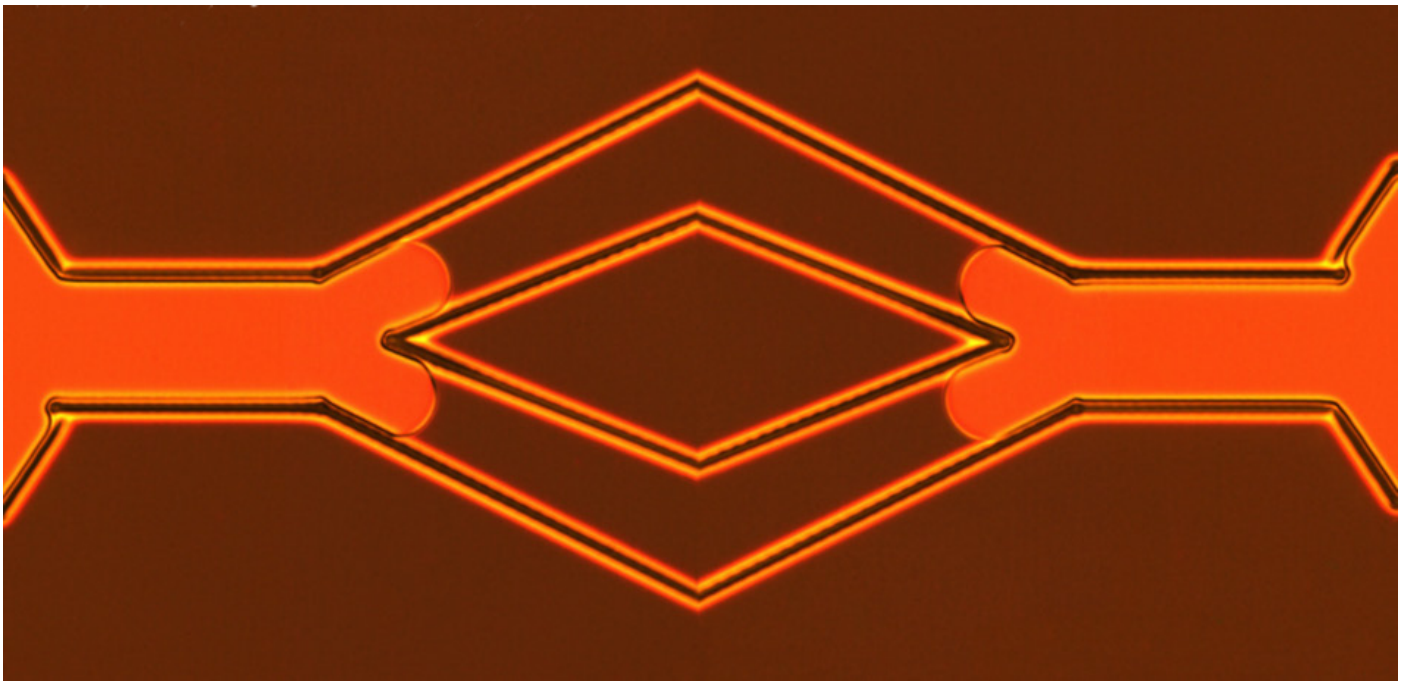
Technology Transfer from the University of Oxford

Electrical control of defects in liquid crystals

Oxford researchers have developed a method to control and accelerate the transition between high and low energy liquid crystal profiles compared to existing devices.



Liquid Crystal profiles lock-in though in-situ fabrication of polymeric structures by direct laser writing

Researchers at Oxford have developed a method to utilise direct laser writing (DLW), with in-built adaptive optics for aberration correction, for in-situ fabrication in polymerisable liquid crystalline (LC) devices. The ability to write in-situ permits the application of electric fields during fabrication that alters the macroscopic molecular configuration within the LC device.

Multidimensional polymer structures can thus be formed that mimic the LC profile at the instant of exposure to the ultrafast laser pulse in the DLW set-up. By writing at different electric field strengths, different LC states can be locked-in.

This method enables defects to be created, locked-in and then subsequently controlled with an electric field. The precise control of the defects enables new electro-optic behaviour to be discovered, fast-swithing states that are inherently unstable to be stabilised and microcargo such as microparticles to be transported from location of the device to another in a controlled way.

Applications include microfluidics-inspired devices as well as fast switching photonic devices.

Patent protection

A patent has been filed which covers this technology. Oxford University Innovation Ltd. is interested in talking to potential partners to aid in the commercialisation of this new method.

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Technology Transfer from the University of Oxford

Optical computing based on phase change materials

Researchers from the University of Oxford, the University of Münster and the University of Exeter have developed novel systems and techniques for use in optical processing and memory units based on phase change materials.

Optical computing

Our information age depends on electronic devices, which exploit the flow of electrons to transmit information. However, increasing pressure to improve the speed and storage capacity of new devices has led to the quest for different methods. In this context, optical devices represent an attractive alternative for the management of information. It has been proposed that by using photons for computation, instead of electrons, higher bandwidth devices could be developed. waveguides and electronic memories.

New optical solutions

Researchers from the University of Oxford have developed a novel array of new optical computing solutions based on previously developed optical memory and switching components using phase change materials.

These solutions include:

- Methods and devices for performing scalar, vector and matrix multiplications using optical computing components.
- A method for switching optical memories between volatile and non-volatile modes of use.
- A novel optical computing-equivalent of a digital-to-analogue converter.
- Novel techniques for reading, writing and resetting of optical memory elements.

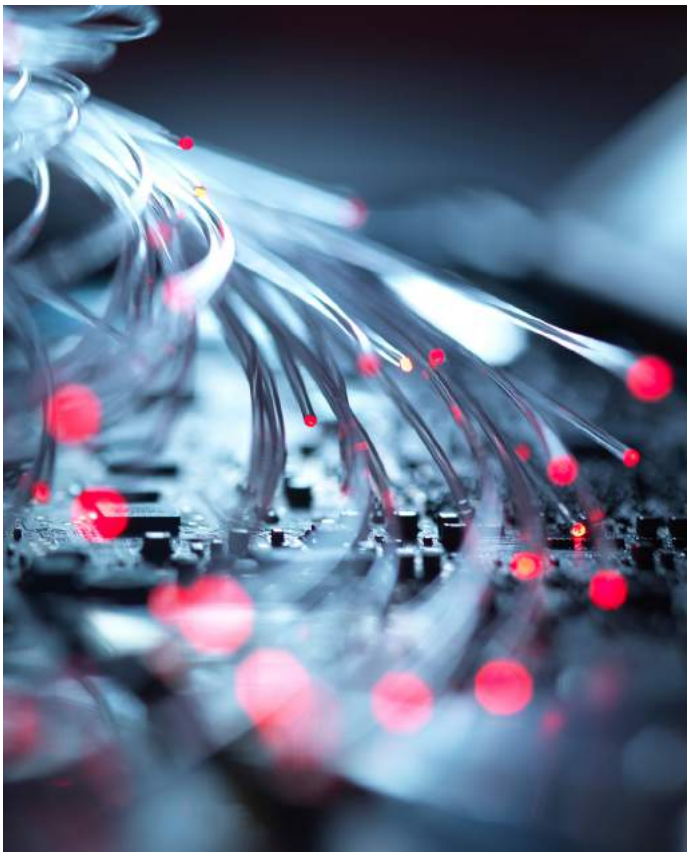
Proof-of-concept demonstrators of the new optical computing solutions have been developed and initial testing work has been completed.

The developed solutions help to pave the way towards optical memcomputing devices (devices that carry out both data processing and storage) and creating “photonic synapses” and “optical neurons”.

These devices could form integral components in next generation artificial neural networks, general processing units and machine learning and artificial intelligence systems.

Patent protection

Several patent applications concerning the technology have been filed and Oxford University Innovation is actively seeking commercial partners to help develop the technology further and take an exclusive market position in relation to it.



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Technology Transfer from the University of Oxford

Novel method for obtaining conductive films

Oxford researchers have developed a novel method for obtaining conductive CNT films with inexpensive, non-conjugated polymers.

Conductive CNT films

Conductive coatings are widely used for electromagnetic interference shielding applications, anti-static material and other opto electronic devices. The global conductive coatings market was valued at $15,120 million in 2016, and is projected to reach at $24,360 million by 2023, growing at a CAGR of 6.8% from 2017 to 2023 (Allied Market Research).

The most commonly used materials are metal nanoparticles or carbon black where transparency is not a requirement, or conductive oxides and conductive polymers when a transparent coating is required. Materials such as CNTs are projected to make a big breakthrough in the field.

The problem with cost

Generally, conductive CNT films show high conductivity and good mechanical properties, but are expensive to produce. One of the reasons is that using non covalent wrapping with expensive conjugated (semi-conducting) polymers are thought to be essential due to the poor solubility of CNTs in organic and aqueous solvents. In order to overcome this high cost, an innovative method of obtaining conductive CNT films without using the expensive conjugated polymers is highly desired.

CNT functionalisation with non-conjugated polymers

Researchers at the University of Oxford have found a novel method of obtaining semi-transparent conductive films. This has been achieved with inexpensive stable non-conjugated polymers. These films show high transparency and similar conductivities to previous conductive CNT films that use conjugated polymers.

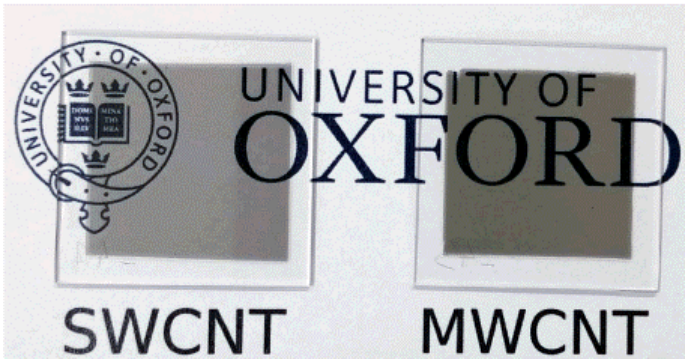
Using this method, conductive films can be directly produced from solution or sprayed onto any surface.

The main advantages of the Oxford method are:

- Similar conductivity but lower cost than previous CNT conductive films using conjugated polymer
- Better environmental stability of non-conjugated polymer than used conjugated polymer
- Can be directly sprayed onto any surface

Patent protection

A patent has been filed which covers this technology. Oxford University Innovation is interested in talking to potential partners to aid in the commercialisation of this new method.



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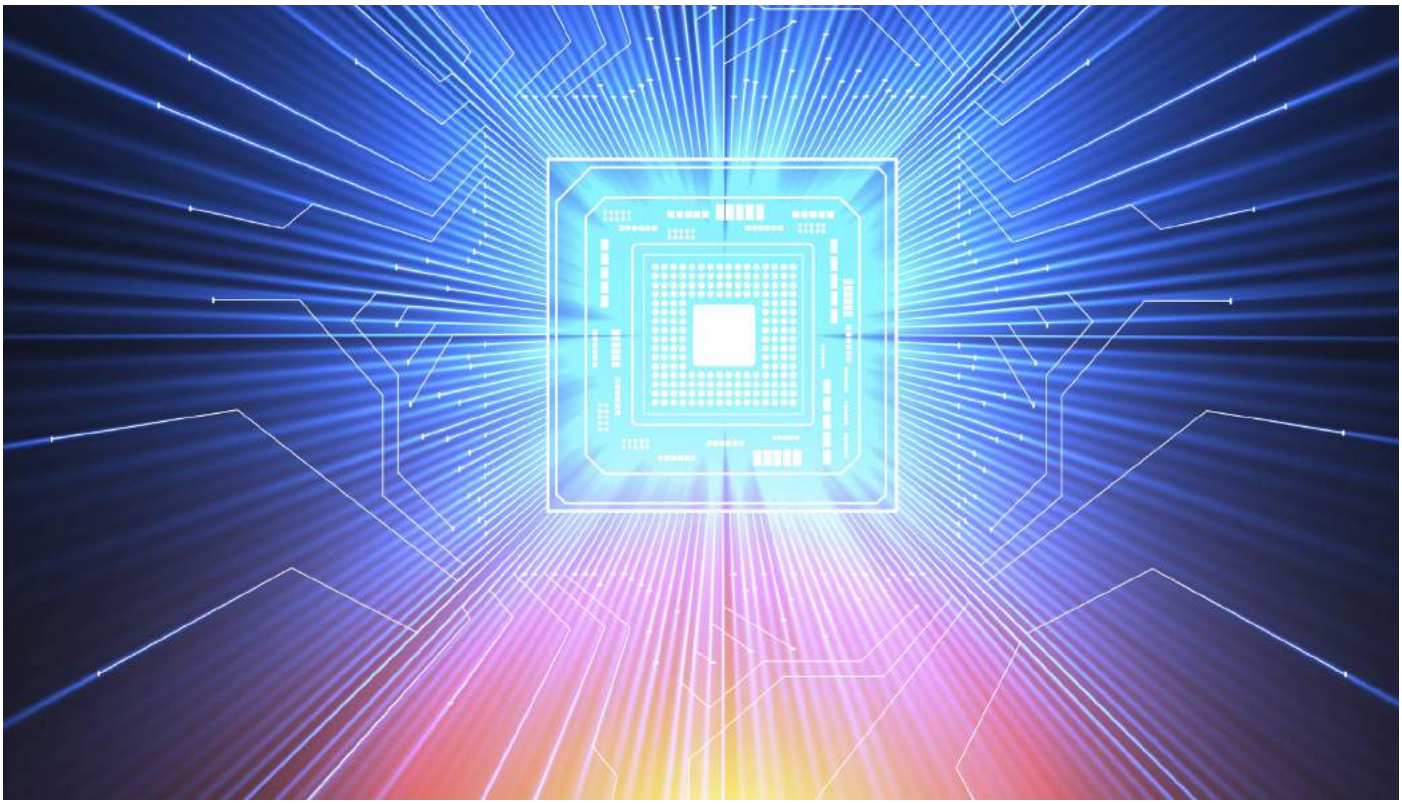
Technology Transfer from the University of Oxford

Laser writing of individual atomic defects in a crystal

Researchers at the University of Oxford have developed a way of making atomic defects in semiconductor materials that can be used to develop a new generation of quantum information technologies.



Atomic defects in wide-band gap semiconductor materials show great potential in the growing field of quantum information technologies. The manufacturing of defects have been hampered by the inability to engineer the defects in a controlled way.

Engineering materials at the scale of individual atoms has long been viewed as a holy grail of technology. With the extreme miniaturisation of modern semiconductor technology to sub- 10 nm feature sizes and the emerging promise of quantum technologies that rely inherently on the principles of quantum physics, the ability to fabricate and manipulate atomic-scale systems is becoming increasingly important.

One promising approach to quantum technologies is the use of 'colour centre' point defects in wide band gap materials that display strong optical transitions.

This allows the addressing of single atoms using optical wavelengths within the transparency window of the solid. The fabrication and engineering of colour centres is challenging, since they generally comprise compound defects containing one or more 'elements' – impurity atoms and lattice vacancies.

Oxford researchers have developed a method to write individual defect centres at selected locations with high positioning accuracy using laser processing with online fluorescence feedback. This method provides a new tool for the fabrication of engineered materials and devices for quantum technologies.

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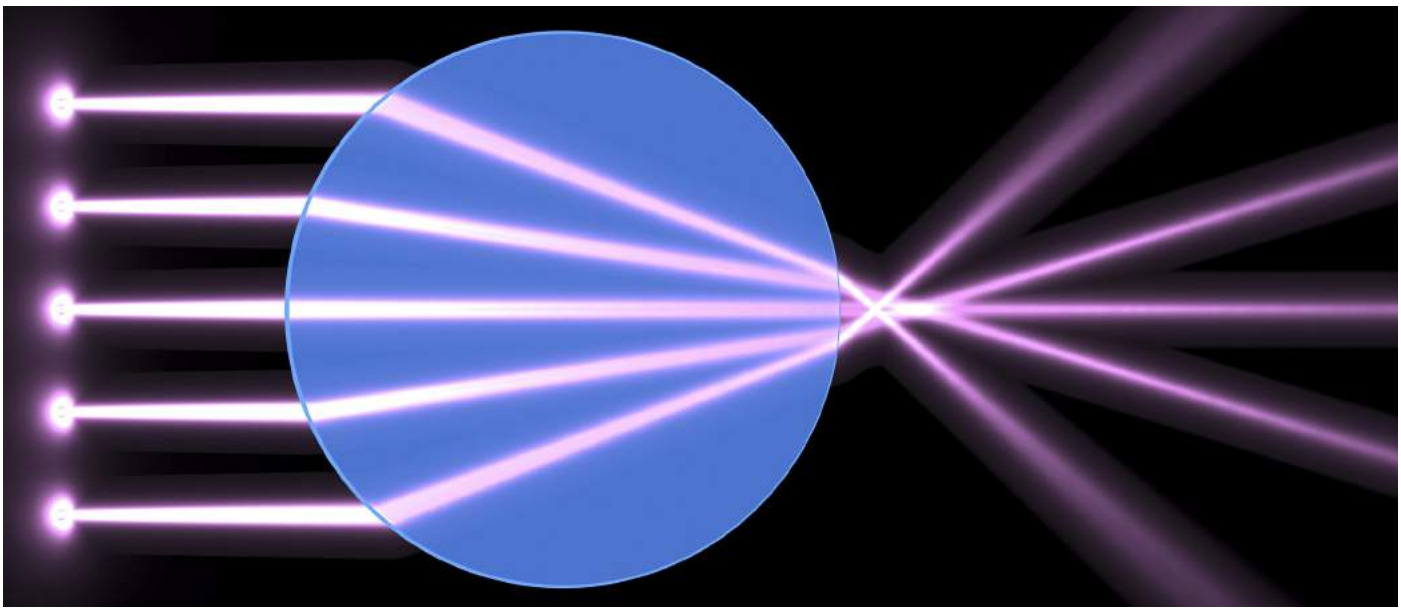
Technology Transfer from the University of Oxford

Multifunctional device for focusing light through an optical component

Oxford researchers have developed a multifunctional lens which is capable of imaging phase modulation and polarisation modulation simultaneously.



Harnessing birefringence properties in multifunctional GRIN lens based cascades

Graded Index (GRIN) lenses are affordable, flat, rigid lenses commonly used for compact imaging systems. GRIN lenses have the inherent property of radially changing birefringence, a property undesired for most applications.

Researchers at the University of Oxford have drawn previously undesirable birefringence properties of GRIN lenses to build GRIN lens cascades. GRIN lens cascades are light manipulation structures that enable novel extra functionality in commonplace GRIN lens systems, extending their range of applications.

GRIN lenses are sold widely today. Their low mass and size means optical devices using GRIN-lenses can be created in an easier, more stable, compact, low-cost way compared with conventional methods, such as using adaptive spatial light modulators or q-plates.

The GRIN based lens cascade could be applied as a multi-functional optical device which is capable of imaging, phase modulation and polarisation modulation simultaneously.

The main applications include:

- A new vector vortex beam (VVB) generator that could benefit complex light beam engineering as well as modification of the shape of laser beam focus for microscopy and super-resolution applications
- A new orbital angular momentum (OAM) generator that could benefit further microscope techniques including optical tweezing, sensing in astronomy, as well as quantum optics communication
- A new single-shot Mueller matrix measurement probe that could assist minimally invasive surgery techniques to do simultaneous scanning for detecting the boundary of, say a cancerous tumor, as a label-free indicator

Patent protection

A patent has been filed which covers this technology. Oxford University Innovation is interesting in talking to potential partners to aid in the commercialisation of these new methods.

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Technology Transfer from the University of Oxford

ENERGY & ENVIRONMENT

Smart wind generator

Researchers at the University of Oxford have developed a smart wind generator technology that is efficient, virtually silent, and offers a faster return on investment.

Conventional direct drive wind turbines are inefficient as they are optimised for a single wind speed condition. Variable speed wind turbines (<30kW) having mechanical gearboxes are expensive and require higher maintenance. Many such commercially available machines interface with mains electricity; this dramatically reduces their energy capture efficiency giving unrealistically long payoff times that make them particularly unattractive.

Oxford inventors have designed a new class of wind turbine that incorporates a patented smart electronic gearing system, which generates electricity efficiently at varying wind speeds (see figure 1).

These wind turbines are fully scalable and target domestic heating. They are cheap to manufacture and are also capable of capturing the maximum possible fraction of available wind-energy under all typical conditions. A prototype has been built and is being tested.

The Oxford wind turbines have several advantages including:

- Affordability and high efficiency
- No complicated and expensive electronics
- Silence due to absence of gearing
- Low maintenance, reliability and storm proof design

The market

The world wind energy market is growing at a rate of 20% (Frost and Sullivan, F772-14). Oxford wind turbines are aimed as an alternative, low cost water heating system to established solar water heating and other wind turbine products (domestic and industrial).

Furthermore, according to the British Wind Energy Association (BWEA), 15% of our renewable energy (3% of our electricity) will come from wind power by 2015.

Patent status

This work is the subject of a UK patent application, and OUI would like to talk to companies or investors interested in commercialising this opportunity.

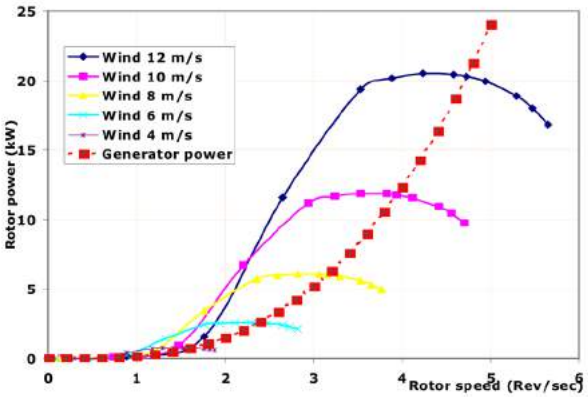

Figure 1 Oxford wind turbines tracks the optimal electrical generation for a range of wind speeds (red curve).

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Technology Transfer from the University of Oxford

Concentrating on solar

Available to license: A high concentration (>1000) solar concentrator energy system with increased ease of manufacture, storage, transport and assembly.

Scientists at the University of Oxford have developed a novel solar concentrator system that uses two simple reflective surfaces to generate high concentrations together with a stationary focus.

Concentrating solar energy

Solar energy can be harnessed to provide renewable electricity and process heating. The efficiency of these systems can be increased by focussing the solar energy using solar concentrators.

For process heating applications, temperatures of 150ºC to 400ºC or higher are typically required. In order to produce higher temperatures, high concentration factors must be achieved, requiring the use of solar concentrators that use two axis tracking. Current systems require 3D reflector designs, which are expensive to manufacture, and assemblies that are problematic to implement. This reduces the ability of currently available solar concentrators to provide a cost-effective and practical solution.

The Oxford invention

Researchers at the University of Oxford have developed an improved solar concentrator energy system complete with mounting systems which allow simple and efficient two axis tracking. The invention features:

- Single curvature reflector assemblies for ease of manufacture, transport and storage
- High concentration factors (>1000)
- Lightweight and cost-effective mounting and tracking system
- Ease of assembly, even at remote locations
- Configurations that allow the solar receiver to remain stationary

The scope of the invention is wide-ranging, encompassing any applications that involve utilising concentrated radiation from the sun. These include the direct absorption of solar radiation and the use of heat generated by solar radiation.

Readiness for market

Small scale prototypes of the solar concentrator have been built for domestic Solar Cooker applications. Field trial and performance data of the small-scale design are available to support development of industrial scale reflector configurations. Solar tracking mechanism designs are also available to licensees. The reflector configurations and solar tracking mechanisms are the subject of international patent applications.

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Technology Transfer from the University of Oxford

Oxford eco-pan revolutionises cooking efficiency

Oxford's novel cooking pan technology incorporates external fins to deliver a fast and highly efficient cooking process.

Cooking pans, as used in kitchens around the world, are generally simple vessels whose designs have not changed much over many years. Researchers at the University of Oxford have recognised however that such pans, particularly when used on gas stoves, allow a large proportion of heat energy from the heat source to dissipate into the surrounding atmosphere, rather than being used to cook food.

Efficient cookware

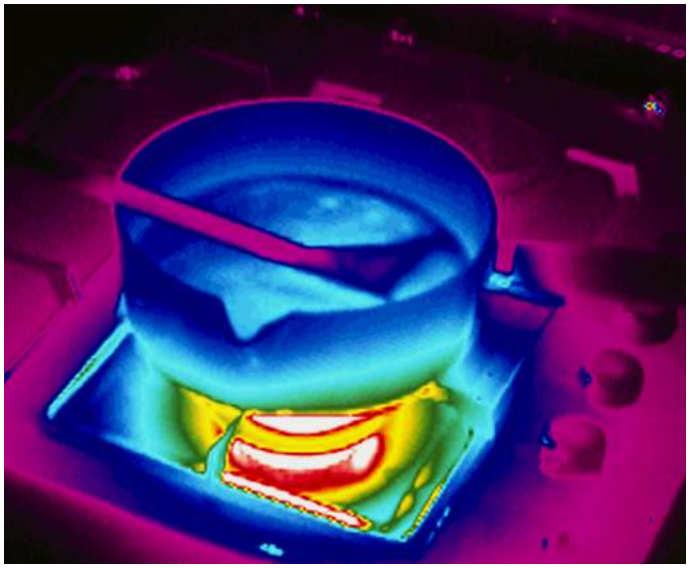
Developed in the internationally-renowned Oxford Thermofluids Institute, Oxford's novel cooking pan technology achieves higher efficiencies through use of external fins. The unique, patented, finned design channels heat from the flame across the bottom and up the sides of the pan, resulting in highly efficient, even heat distribution. By ensuring that more energy is captured by the new cooking pan, a higher proportion of energy from the heat source can contribute to heating food within the pan. In turn, this leads to a quicker and more efficient cooking process.

Oxford's cooking pan designs have arisen from a facility where world-leading solutions for jets and rockets are researched, tested and engineered. Transferring this expertise into an everyday application has led to a cooking pan design found to save up to 31% energy compared to conventional pan designs. The greatest benefit is obtained when the gas flame is largest, i.e. when the user wants the fastest cooking process possible.

The cooking pan has been the subject of two awards in recent years. In 2014, the Worshipful Company of Engineers awarded Professor Thomas Povey, the inventor of Oxford's novel cooking pan technology, their prestigious Hawley Award for "the most outstanding Engineering Innovation that delivers demonstrable benefit to the environment". The project behind Oxford's cooking pan was also a Green Apple Award winner in 2014. The Green Apple Awards is an annual campaign to recognise, reward and promote environmental best practice around the world.

Commercialisation

The Oxford cooking pan technology has been protected with patents, utility models and registered design rights in key territories worldwide. Following a successful initial launch of a range of cooking products (saucepans, frying pans and stockpots), Oxford University Innovation is now seeking commercial partners to make and sell further products incorporating the technology worldwide.



Above: Standard cooking pans do not use all the energy available to them, particularly from gas stoves.

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Technology Transfer from the University of Oxford

Sprayed graded electrodes

Oxford researches have enabled electrodes to be fabricated using spray deposition that will allow the porosity and other characteristics to be varied in a controlled fashion through the electrode thickness.

Lithium-ion batteries

The market for lithium-ion batteries (LIB) is mature and stable, with around three billion cells produced per annum for use in consumer, industrial and automotive applications. LIBs are relatively simple energy storage devices produced using a manufacturing process that is both productive and scalable. Frost and Sullivan estimated the LIB market size to be US$18bn in 2013, growing at 21 percent CAGR. Despite the market size, today's bestselling batteries use essentially the same chemistry as that invented in Oxford by Goodenough and colleagues in 1980, and the same manufacturing process.

Limitations of current LIB manufacture

Current lithium ion battery (LIB) electrodes are "monolithic" in that the electrochemically active materials that are used in powder form in the electrodes, and the residual porosity between the powder particles, are constant through the electrode thickness. Despite their known benefits, graded electrodes are not commercially available because a scalable manufacturing technology has not been developed.

Recent developments in Oxford aim to enable electrodes to be fabricated using spray deposition that will allow the porosity and other characteristics to be varied in a controlled fashion through the electrode thickness, thus facilitating both better performance of existing battery chemistries and the commercialisation of new battery chemistries.

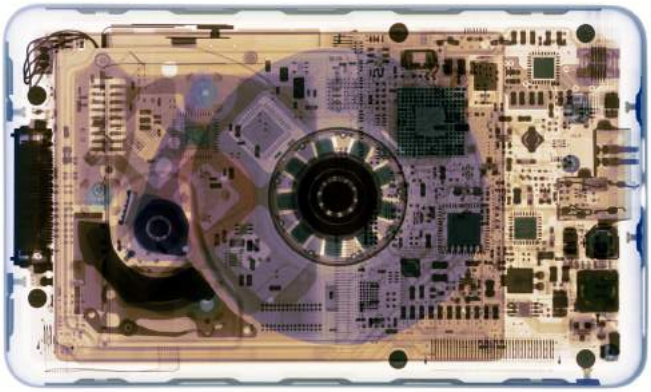
Advantages of the Oxford invention

Oxford's technology is scalable, allowing LIB manufacturers to spray electrodes from a variety of suspensions. Thin, flexible electrodes (100s nm to 10s μm) can be produced and various nanomaterials can be introduced into the electrode at any point. The spraying process allows the electrodes to be graded in different ways. Recent literature suggested that in theory, a capacity increase of up to 70 percent might be possible over conventional slurry-cast LIBs if graded particle and porosity distributions were available.

Improvements in thinness and flexibility fit well with requirements for LIBs in mobile electronics, whilst improved energy density and the possibility of using safer electrolytes suits transport applications.

Patent protection and commercial opportunities

The underlying technology is the subject of a UK Patent Application initially. Comparative performance tests against conventionally manufactured LIBs are currently being run. Oxford University Innovation would like to hear from companies interested in progressing the commercial opportunities.



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Technology Transfer from the University of Oxford

Efficient water decontamination system

Available to license: An effective water treatment to remove heavy metal ions and other toxins from contaminated water

Inexpensive removal and recovery of contaminants like heavy metals from effluent streams and ground water using polymer-surfactant flocculants that settle with gravity

Current waste water treatments

Industrial processes can result in contaminants in the effluent stream. For example, zinc, cadmium and chromium contaminations from plating processes. Present remediation techniques involve expensive and inefficient chemical precipitation and adsorption processes. Alternative treatments like ultrafiltration, reverse osmosis and ion exchange are time consuming and have significant energy requirements.

Novel materials used to pull contaminants out of solution

At the heart of this technology is a novel material that comprises a complex of polymers and surfactants that trap contaminant ions. This process is known as complexation and flocculation. Gravity then settles the flocculants, separating the contaminants from the water. The flocculants can then be treated separately to recover the contaminants in a concentrated form. The constituent polymer can also then be recycled without a deterioration of removal ability in the next cycle.

Advantages of the process

Compared with existing treatment solutions, this system has:

- an efficient removal system
- low cost implications
- reliable performance
- straight forward usage
- fast reaction times

The system is capable of removing a high percentage (95-99%) of the multivalent metal ions, such as Zn(II), Cd(II) and Cr(III), contained within dilute (10mg/L) solutions by using a small amount of polymer and surfactant. The polymers and surfactants used are commercially available, safe and inexpensive.

	Capital cost	Operational cost	Complexity of process	Performance stability	Treatment speed
Ion exchange	High	High	Medium	High	Medium
Membrane filtration	High	High	Low	High	Medium
Biosorption	Medium	Low	High	Medium	Low
Adsorption	Medium	Medium	Medium	High	Low
Chemical precipitation	Low	High	Low	High	High
Polymer-surfactant method	**Low**	**Medium**	**Low**	**High**	**High**

Table 1: Summary of dilute heavy metal treatment methods

Current status

The method has been shown to be effective on a number of heavy metal contaminants and more are currently being tested. The underlying technology is the subject of a UK patent application. Companies interested in applying this process for industrial and ground waste water treatment are invited to contact Oxford University Innovation.

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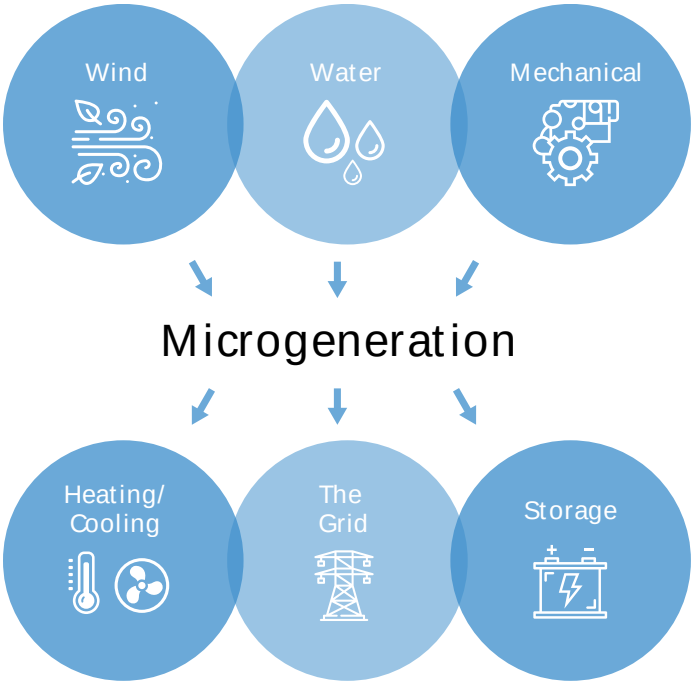
Technology Transfer from the University of Oxford

Energy microgeneration

Researchers at the University of Oxford have developed an induction motor that would replace expensive mechanical gearing in current turbine systems.



Microgeneration

Microgeneration is the small-scale generation of heat and electric power by small businesses and communities to meet their own needs as an alternative to traditional centralised grid-connected power. Examples of microgeneration vary from small scale wind turbines to ground source heat pumps.

The Oxford microgeneration system

The Oxford microgeneration system makes use of off-the-shelf induction motors with variable voltage and frequency output as the core of a highly efficient energy conversion system.

- **Cost Savings:** Significant cost reduction across all sizes, due to mass produced off the shelf components replacing and eliminating custom made small volume components
- **Proven:** 10 kW prototype has run successfully in Ireland for over 7 years.
- **Scalable:** Induction motors commercially available from kW to over 10 MW size.
- **Reliable:** Reduction of parts (no mechanical gearbox) and use of mature, mass produced components such as the induction motor leads to much improved reliability. Induction motors are known to be robust in harsh environments.
- **Low maintenance:** No mechanical gearing required.
- **Safe:** Reduced head weight improves safety of tower. Special design features for increased safety in high wind and lightning.
- **Big data:** SIM based networking and monitoring. Informed reliability.
- **Low noise:** Mechanical gearboxes are notoriously noisy – replaced with a noiseless electrical gearbox.
- **Weight reduction:** By removing mechanical gearing.

Commercialisation

This technology is subject to a patent application. Oxford University Innovation would like to speak to companies who are interested in commercialising this technology.

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Technology Transfer from the University of Oxford

Solar-powered photocatalytic production of hydrogen

Oxford researchers have developed a novel method to increase both rate and efficiencies in the production of hydrogen from photocatalytic splitting of water.

Background

As the pressures of climate change continue to grow, the reliance upon renewable energy sources that do not come from fossil fuels or generate CO_2 becomes increasingly important. Hydrogen is one source, when burned with oxygen that yields significant amounts of energy and water as a by-product. However, molecular hydrogen is very scarce and must be obtained from other sources.

A huge amount of hydrogen is contained in water, although its extraction from water is non-trivial; photocatalytic splitting of water to yield hydrogen (and oxygen) has not yet proven efficient enough for large-scale hydrogen production and efforts have been focused on the development of photocatalyst with dopants and or co-catalysts.

The invention

One material commonly used in the development of hydrolytic photocatalysts is titanium dioxide (TiO_2). Whilst this is ideal for absorbing light from the UV spectrum, the material is a poor absorber of visible light thereby limiting its use in the production of hydrogen from solar energy. Doping TiO_2 could improve visible light absorption, however low efficiencies reported precludes the use of this photocatalyst on an industrial scale.

To overcome this problem, Oxford researchers have discovered and developed a novel method to increase both rate and efficiencies in the production of hydrogen from photocatalytic splitting of water.

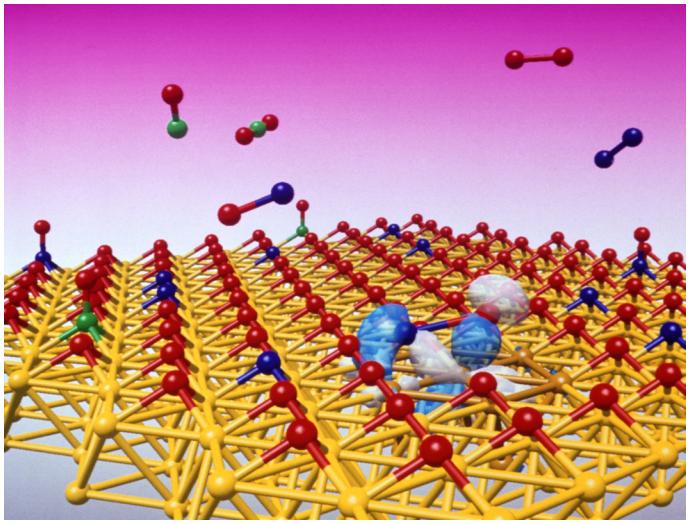
The methodology consists of irradiating a doped titanium-based photocatalyst with visible light specifically at certain temperatures and pressures, thus leading to:

- Rates that are >50x higher that of conventional methods
- Effiencies >70%

This discovery opens up the technology to industrial application with many other potential uses e.g. the recycling of CO_2 to methanol and green ammonia synthesis.

Commercialisation

Oxford University Innovation is currently seeking to license this technology for purposes of development and commercialisation. The method is the subject of a priority patent application.



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Technology Transfer from the University of Oxford

Silver electrode for electrochemical production of hydrogen

Oxford researchers have developed a new method for electrochemical production of hydrogen.

Background

As a direct consequence of the ever-increasing world population, the fossil fuel energy supplies are not sufficient to meet the energy demands of the future. The release of green-house gases and other pollutants as a result of burning such fuels negatively effects the environment on a world-wide scale, resulting in global warming and damage to human health (amongst a multitude of deleterious effects on the environment as a whole).

However, there is a push towards renewable sources of energy, such as wind, solar, and geothermal options. Another alternative is hydrogen based systems, where the combustion of hydrogen yields only water and energy. However, as most hydrogen on earth is locked up in water, sourcing molecular hydrogen for this purpose remains a bottle neck in its wide-spread use as an alternative fuel.

The technology

Hydrogen can be produced through the electrochemical splitting of water with the use of proton membrane exchanger (PEM) electrolysis. While such technique provide a sustainable solution for the production of pure hydrogen, the electrodes used in such systems often consist of platinum coated carbon supports, which due to the cost and rarity of platinum, has limited the use of PEM electrolysis in the large scale production of hydrogen fuels.

In order to address this limitation, researchers at Oxford University have developed a novel electrode support coating that replaces platinum with silver-nanoparticles.

Benefits of this technology include:

- high rate of hydrogen production compared to traditional platinum/carbon electrodes as a result of the higher applied potentials
- low-cost PEM electrolysis cathodes

Together these benefits will support further development of PEM electrolysers and increase the efficiency of large-scale hydrogen production from PEM electrolysers. Additional potential uses of the technology include the recycling of CO_2 into methanol and green ammonia synthesis.

Commercialisation

The technology subject to a UK priority patent application with opportunity for international patent protection in the future. Oxford University Innovation is seeking industrial partners interested in further development of the technology.

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Technology Transfer from the University of Oxford

Converting waste plastics back to their constituent monomers

Oxford researchers have developed an innovative process for rapidly and effectively producing high value olefins from thermoplastic polymers present in waste plastics.

Problem of plastic waste

Between 1950 and 2015, cumulative waste generation of primary and secondary (recycled) plastic waste amounted to 6300 Mt and of this approximately 800 Mt (12%) has been incinerated and 600Mt (9%) has been recycled; less than 10% of which has been recycled more than once. Around 4900 Mt — 60% of all plastics ever produced — has been discarded and is accumulating in landfill or in the natural environment. Accordingly, if current production and waste management trends continue, roughly 12,000 Mt of plastic waste will be in landfill or in the natural environment by 2050.

Processes for the conversion of waste plastics and other solid hydrocarbon materials to other useful products are known. For instance, plastic depolymerisation techniques were developed actively during the 1980s and 1990s, but none was adopted commercially as mechanical recycling methods developed rapidly.

Over the past 10 years, there has been an increase in the amount of research into the conversion of plastic into hydrocarbon fuels as oil prices have increased and waste collection and sorting methods have improved. However, the stability, ease of handling and quality of these oil products is low and further processing is required to give a fuel product.

Novel process for depolymerisation of plastic waste

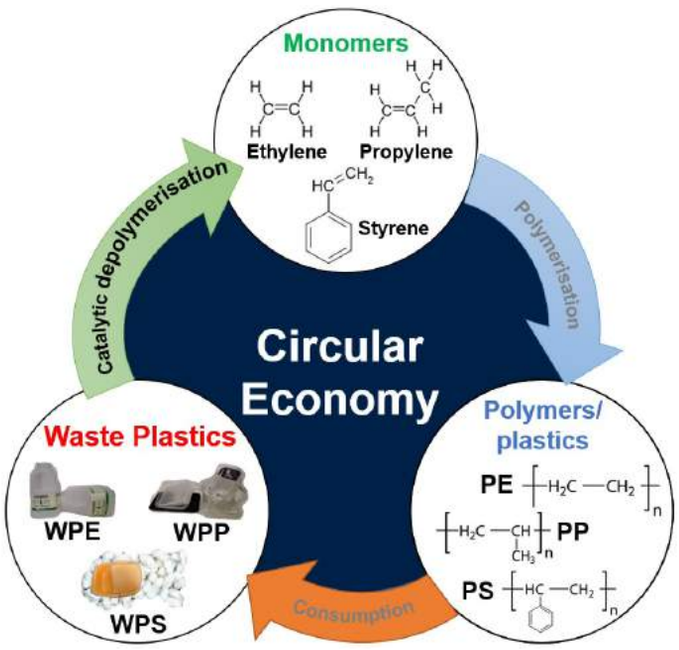
Researchers at Oxford University have developed a novel and more effective method for converting the waste plastic back into its constituent monomers with very high selectivity. The process had been tested for real-world waste and can tolerate various contaniminations such as oil and dusts etc.

The process is rapid, effective and suitable for both stationary waste disposal and on-board disposal for mobilities.

The technology opens a new erea of application in waste plastic in which the thermoplastic polymers in waste plastic could be converted back to their original monomers, thus creating a cirlular economy for the plastic industry.

Commercialisation

Oxford University Innovation Ltd. has filed a priority patent application on the technology and welcomes discussions with companies interested in licensing it for commercial development.



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Technology Transfer from the University of Oxford

Advanced fluoride-based materials in lithium-ion batteries

A new method to increase the stability of transition metal fluorides in lithium-ion batteries.

Energy storage batteries

Lithium-ion batteries have become the industry standard in numerous electrical storage devices from consumer goods such as mobile phones and laptop computers to grid-scale battery units.

Higher energy densities for such applications are always in demand to address the ever-increasing performance of portable electronics and the need for extended range with electric vehicles. Electrode materials made of transition metal fluorides provide a promising candidate for boosting the capacity of lithium ion batteries. They exhibit high theoretical energy densities that can increase capacities to three to five times those of conventional lithium ion battery products.

Whilst transition metal fluorides present a very favourable starting point for new high-capacity and low cycle batteries, there are still limitations in the implementation of this class of chemicals in lithium ion systems. The highly ionic bonding in transition metal fluorides results in low conductivities within batteries, which impacts performance.

Further, when transition metal fluorides are used as electrode materials, they often lose capacity over time due to fusing of individual particles and dissolution of the transition metal, thus impacting its stability.

To address the above challenges, large amounts of carbon and complex fabrication methods can be used with transition metal fluoride cathodes to achieve stable battery cycling behaviour. However, this reduces the practical energy density of such batteries and limits the practical charge/discharge rates that can be achieved.

High performance transition metal fluoride-based batteries

Researchers at the University of Oxford have tackled such limitations and discovered a novel method to increase the stability of transition metal fluorides in lithium ion batteries while avoiding complex fabrication methods.

The new methodology consists of the addition of an ionic liquid electrolyte to the system which allows:

- the formation of an extremely stable protective interphase layer that prevents growth over successive cycles;
- high practical charge/discharge rates; and
- a safer battery system than those based on conventional organic electrolytes.

Initial lithium ion demonstrator systems utilising a metal fluoride cathode and an ionic liquid electrolyte have been generated.

Commercialisation

A patent application directed to the technology has been filed. Oxford University Innovation is now seeking commercial partners to support further development of the technology.

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Technology Transfer from the University of Oxford

IMAGE & SPEECH PROCESSING

Maritime tracking technology

Oxford University researchers have developed a method for tracking subjects in digital image sequences in real-time for use in maritime vessel tracking and for surveillance in CCTV.

The Oxford Invention

Academics from the University of Oxford's Robotics Research Group have devised a novel technique for robust, real-time, visual tracking of previously unseen objects from a moving camera. Registration compensates for the linear motion of solid objects while segmentation allows for shape changes and perspective changes that occur when the object turns relative to the camera. On-line learning provides continual refinement of the shape of the object itself and the nature of the background.

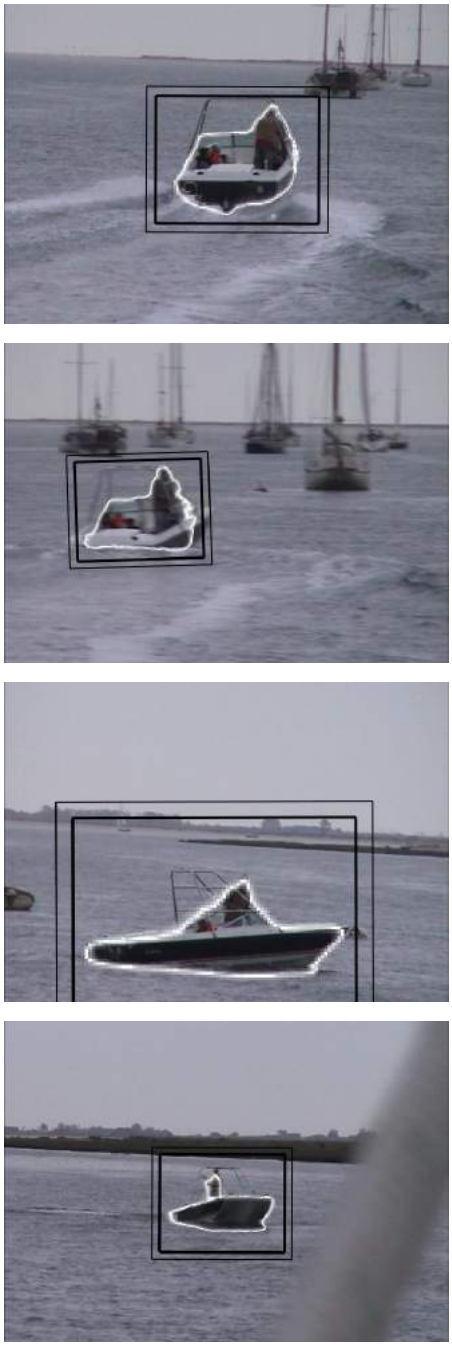
A prototype system has been tested in real time on live video footage and provides feedback to maintain the object within the frame of a pan-tilt-zoom digital video camera. The same processing software can operate on recorded sequences that demonstrate rapid and agile object motion with significant image blur, varying lighting, violent camera motion, and cluttered and changing background.

Market

Visual tracking of objects has numerous applications in surveillance (either terrestrial or maritime), military purposes and identification of organs in medical imaging applications. The technique can be used to control pan-tilt-zoom devices to stabilise a target image or for visual control of a device such as a robot to follow a target or for docking.

Status

The Oxford invention is the subject of a patent application. Oxford University Innovation would like to talk to companies interested in developing the commercial opportunity.



The images above show a speedboat undergoing a 180 degree out-of-plane rotation, illustrating shape adaptation.

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Technology Transfer from the University of Oxford

INFORMATION & COMMUNICATION TECHNOLOGIES

Non-Degenerate Travelling Wave Parametric Amplifier (TWPA)

Oxford researchers have developed an ultra-low noise microwave amplifier offering uniform gain in the operational bandwidth.

Parametric amplifier

Since their initial development in the early 20th century, parametric amplifiers have found use in low-noise radio receivers, such as those required for highly accurate radio telescopes. The principle of their operation relies on the non-linearity of the medium in which the waves are travelling to achieve amplification.

Travelling wave paramagnetic amplifier

Travelling wave paramagnetic amplifiers (TWPAs) are broadband versions of classical parametric amplifiers; however, they produce a non-uniform gain profile and have a significant zero-gain gap within their operational band.

User controlled gain profiles

Oxford researchers have made crucial modifications to a traditional TWPA to allow the user to control the gain profile.

This additional level of control ensures that uniform gain can be achieved throughout the operational bandwidth. The new amplifier also eliminates the zero-gain gap that is present in other TWPAs whilst maintaining the wide-band and high gain characteristics.

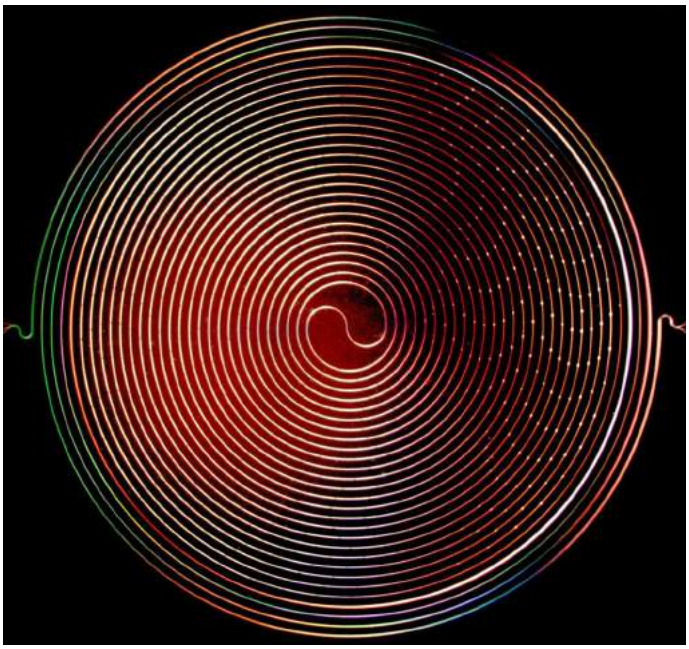
The main benefits of this technology include:

- User controlled gain profile
- Uniform gain across the operational bandwidth
- Elimination of the zero-gain gap
- Wide band and high gain amplification

This invention could be used in any situation where an ultra-low noise amplification method is needed (astronomical instruments, qubit experiments) in addition to possible uses as an ultra-low noise mixer.

Patent protection

Oxford University Innovation has filed a UK patent with the potential to be extended to international coverage and is looking for potential partners to aid in the commercialisation of the technology.



Above image: Superconducting microwave amplifier developed by researchers at the Jet Propulsion Laboratory (JPL) and the California Institute of Technology (Caltech), California, USA. The Oxford invention may be used in similar applications but represents an improvement on this type of device.

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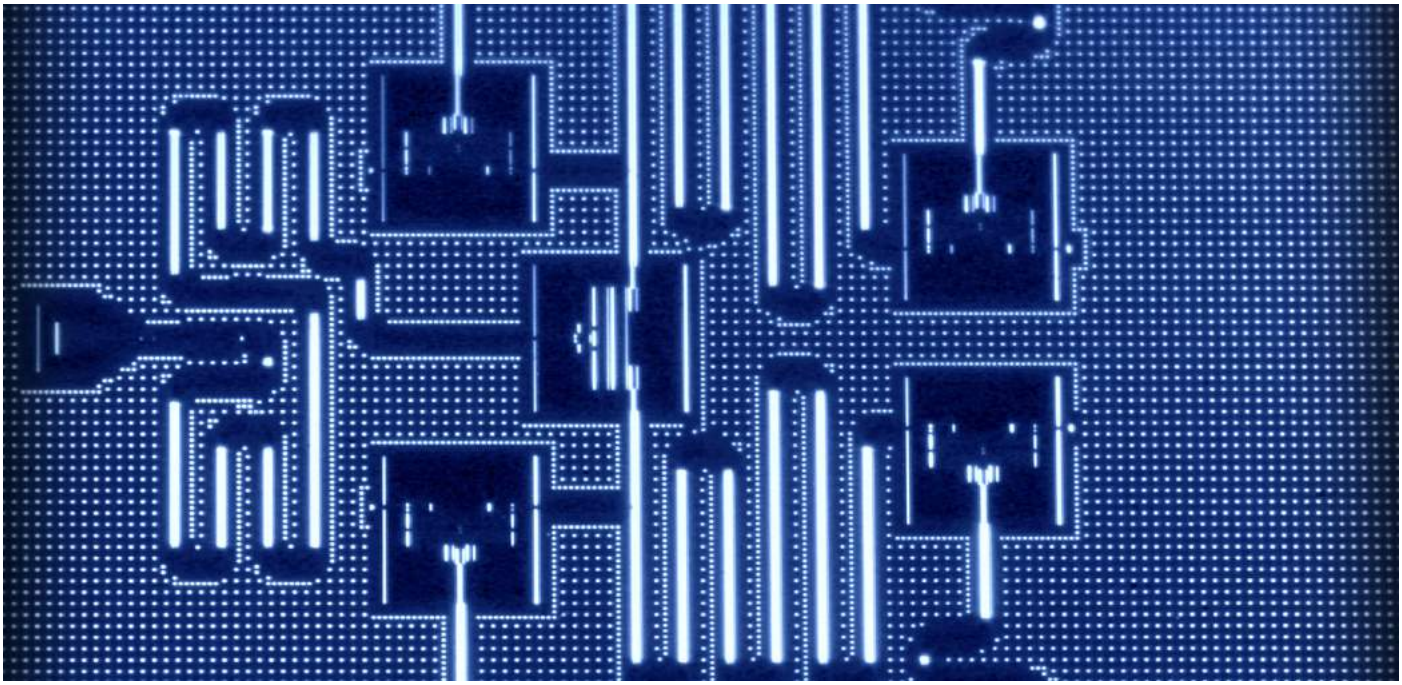
Technology Transfer from the University of Oxford

Broadband quantum limited frequency up-converter with high conversion gain

Researchers at Oxford have devised a broadband high efficiency frequency up-converter based on the nonlinear wave mixing mechanism in a travelling wave parametric device.



A frequency up-converter is a device that converts low-frequency input signal to a high-frequency output signal. Generation of signals at high frequency, with cleanly defined spectral components, high output power and low noise is important for many applications including telecommunications and signal processing. For example, such signals may be useful as a local oscillator in heterodyne receivers, for frequencies from radio waves to THz.

Based on the similar working principles of a Travelling Wave Parametric Amplifier (TWPA), researchers at Oxford have devised a broadband frequency up-converter, using nonlinear transmission medium and dispersion control elements.

The up-converter exhibits quantum-limited noise performance, which is important for extremely sensitive systems such as quantum-computing or astronomical applications. It is embodied in planar circuit form, therefore it is compact and lossless as it is comprised of superconducting materials. Where most frequency converters can only achieve low conversion efficiency of 5-20%, in this invention, more than 50% of the incoming signal is converted to the desired high-frequency component. More importantly, since this devices can operate without any biasing electronics and it is formed using superconducting material, the heat dissipation is extremely low.

Examples of application areas include astronomical experimentation, quantum computing experiments, cryogenic systems, telecommunications, signal processing and microwave engineering applications.

Patent protection

A patent has been filed which covers this technology. Oxford University Innovation is interested in talking to potential partners to aid in the commercialisation of this invention.

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Technology Transfer from the University of Oxford

INTERNATIONAL DEVELOPMENT

Smart water pumps

Oxford scientists have developed a new pump maintenance service model which significantly reduces water hand pump downtime and enables improved water access for the rural communities.

Rural water supply has been the subject of academic study and huge investment for decades. The extraction of groundwater by hand pumps is a key method by which rural communities gain access to safe and reliable water supplies. However, achieving sustainability of these supplies remains a challenge: it is estimated that one third of hand pumps in Sub-Saharan Africa are nonfunctioning.

Smart water pumps

The Oxford invention is the development of a machine learning system developed from the study of water hand pumps in Africa. By collecting and analysing data, using sensors placed in the handle of a pump, an algorithm is able to accurately assess several key factors in pump operation:

- Estimation of the groundwater at the pump,
- Predict pump failure
- Identify the user of the pump

The data output from a pump is transmitted by a standard SMS text message to inform management teams if a repair is needed or expected, thereby significantly reducing pump downtime. In two studies of over a year in length the average downtime, of 266 hand pumps, had been reduced by an order of magnitude in rural Kenya.

Oil well monitoring

Although developed for the monitoring of ground water, the methods applied are suitable for oil well monitoring and provide the opportunity for early detection of problems which could result in production losses.

Licensing opportunity

The pump monitoring algorithm has been coded into software and a patent application protecting pump monitoring system and methods has been filed. Oxford University Innovation would like to talk to parties interested in licensing this technology or their application.

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Technology Transfer from the University of Oxford

LEGAL & REGULATORY

MANUFACTURING & MATERIALS

Vacuum-deposited modification of polymer surfaces

Enabling modification of film surface properties in high yield production techniques will deliver benefits in a range of applications including organic thin film transistor manufacture.

Film features outstanding performance

Thin polymer films have a broad range of uses from packaging to electronics, automotive to building materials. Film manufacturers use multiple film layers and surface treatments to control surface energy, wetting, adhesion and a range of other parameters. In the case of creating organic thin film transistors, a problem modifying the dielectric (insulator) layer to ensure that when the semiconductor layer is disposed on top it performs well.

Methods of doing this which are “solution-based” are known but are difficult to use in large scale and at high yield, yet these requirements are fundamental to the attraction of thin film, flexible, electronics. The Oxford invention overcomes this problem by providing surface modification method which can be used within the required production environment i.e. in a reel-to-reel process under vacuum.

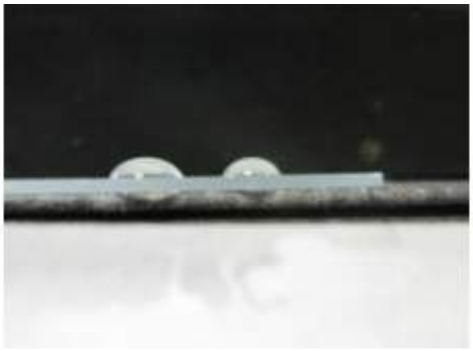
The new process offers several benefits for film processors:

- Demonstrated ability to change surface energy within a high yield production process (images illustrate how processing increases the contact angle from 60° to 90°) this has broad application across a number of fields.
- Improved transistor performance. Tests have demonstrated a factor of 3-5 times increase in hole mobility, e.g. from 0.08cm2/Vs for an untreated sample to 0.44cm2/Vs treated, with a lower threshold swing (1.0V/decade against 1.6V/decade) while maintaining the 100% production yield for these transistors.
- Reduced performance variability within a batch leading to better process capability for example compared to alternative processing techniques e.g. spin-coating.
- The Oxford invention is aimed at high yield, high speed, production processes and although motivated by the challenges of producing organic thin film transistors, the invention has broad application.

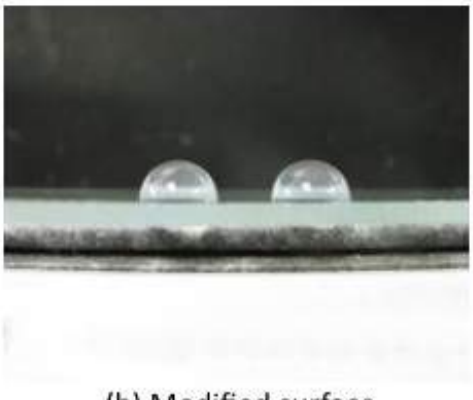
Commercial opportunities

Following successful spin coating trials, the method has been demonstrated on high yield production equipment with the substrate on a moving drum (simulating reel-to-reel behaviour). Funding is being sought to further develop the technique e.g. to understand the range of available materials and optimise processing parameters.

This project will be of interest to electronics companies and fast moving consumer goods companies, particularly those working in the field of organic thin film transistors, but also to others working in reel-to-reel film processing e.g. film converters and packaging manufacturers.



(a) Original surface



(b) Modified surface

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Technology Transfer from the University of Oxford

Rotational deformation stage for the characterisation of materials

Oxford academics have developed a ground-breaking piece of apparatus to characterise deformation of materials whilst using a scanning electron microscope.

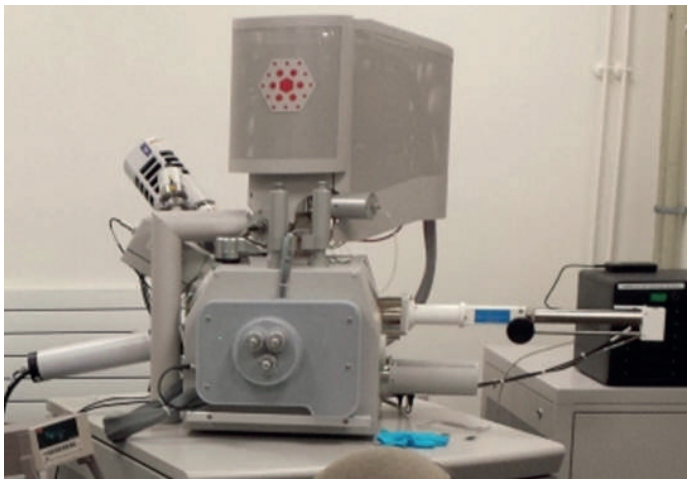
When characterising both industrial and geological materials, it is important to understand the microphysics of how they deform under the application of a force. It can be particularly useful to deform a sample whilst viewing it under a scanning electron microscope (SEM) at the same time, so that the exact mechanisms of deformation can be known.

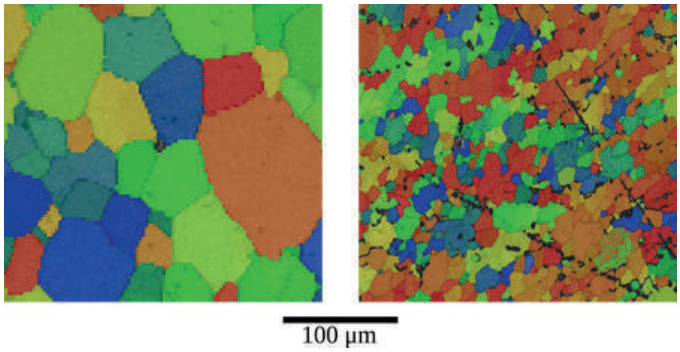
Traditional analysis

Traditional deformation stages used in SEMs deform the samples in extension. These are limited to very small deformations due to three main factors:

- The space available on the stage, this restricts the maximum elongation
- Samples in extension have a tendency to fail even after small deformations of this type

These limits on the deformation place a limit on the spectrum of material behaviour that can be investigated.





Revolutionary developments

Academics in the Earth Sciences department of the University of Oxford have developed a novel deformation stage for use on existing SEMs that allows for the deformation of the sample in a rotational geometry. By applying a torque to the centre of a specimen whilst fixing the outer edges in place, a velocity gradient is imposed along the sample surface, without the apparatus changing in dimensions.

This provides a number of benefits compared to traditional methods:

- Large deformations can be obtained in a very small space
- The surface can be imaged by a SEM during the deformation
- The apparatus is easily incorporated into existing SEMs
- The geometry is simple and compact
- The sample does not change shape, preventing sample failure at large deformations

Licensing opportunity

This deformation stage can be used for the *in situ* investigation of the mechanical properties of a wide range of materials, both industrial and geological. The technology is subject to a patent application and is available for license.

For more information about the technology and licensing opportunities, please contact Oxford University Innovation.

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Technology Transfer from the University of Oxford

Solvodynamic printing

Oxford researchers have developed a solvodynamic printing methodology capable of depositing lines of silver nanoparticles with line widths of only 30 µm from a 300 µm nozzle.

Printed electronics

Traditional printing methods have been applied to the electronics industry in order to create devices on a wide range of substrates. The ability to rapidly deposit conductive materials onto flexible substrates has fuelled a revolution in flexible electronics. Printed electronics can cover large areas with very low fabrication costs, in stark contrast to more conventional electronics.

Smaller is better

In the world of electronics, the drive to increase computational power without altering the footprint of a device means that it is necessary to decrease the size of circuitry features. In traditional electronics, this has been achieved using techniques such as photolithography; however, such techniques are often incompatible with flexible substrates. Therefore, methods to increase the definition and decrease the size of printed, conductive features are crucial.

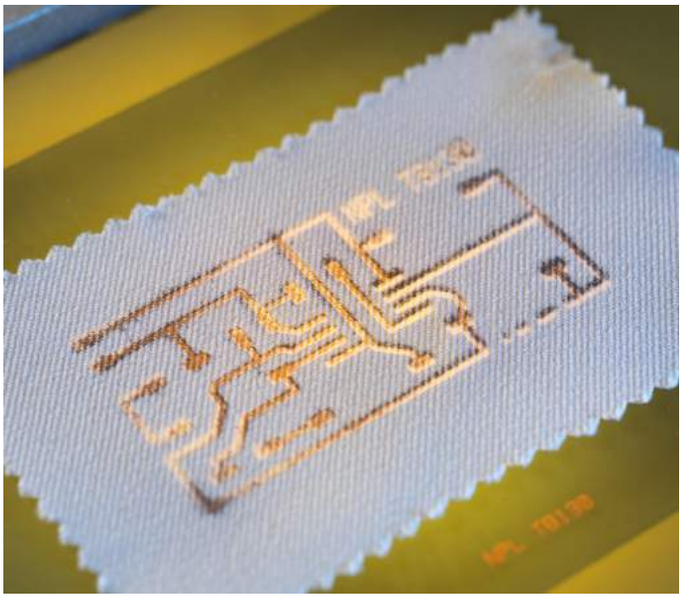
Solvents represent the solution

Researchers at the University of Oxford have developed a solvodynamic printing technique, which utilises a specific carrier solvent, which is immiscible with the ink solvent to reduce the size of printed features. The group has used this method to print lines of conductive silver nanoparticles as narrow as 30 µm from a 300µm nozzle. An added advantage of the solvodynamic method is that it can minimise the clogging printing nozzles due to the presence of a carrier solvent. We see the main advantages of this technology to be as follows:

- Narrow printed line widths (30 µm)
- May be tailored to a variety of substrates
- Prevents clogging of printer nozzles
- Can be used with a variety of printed materials

Patent protection

Oxford University Innovation has filed a UK priority patent covering this technology and are keen to talk to anyone who could aid in its commercialisation.



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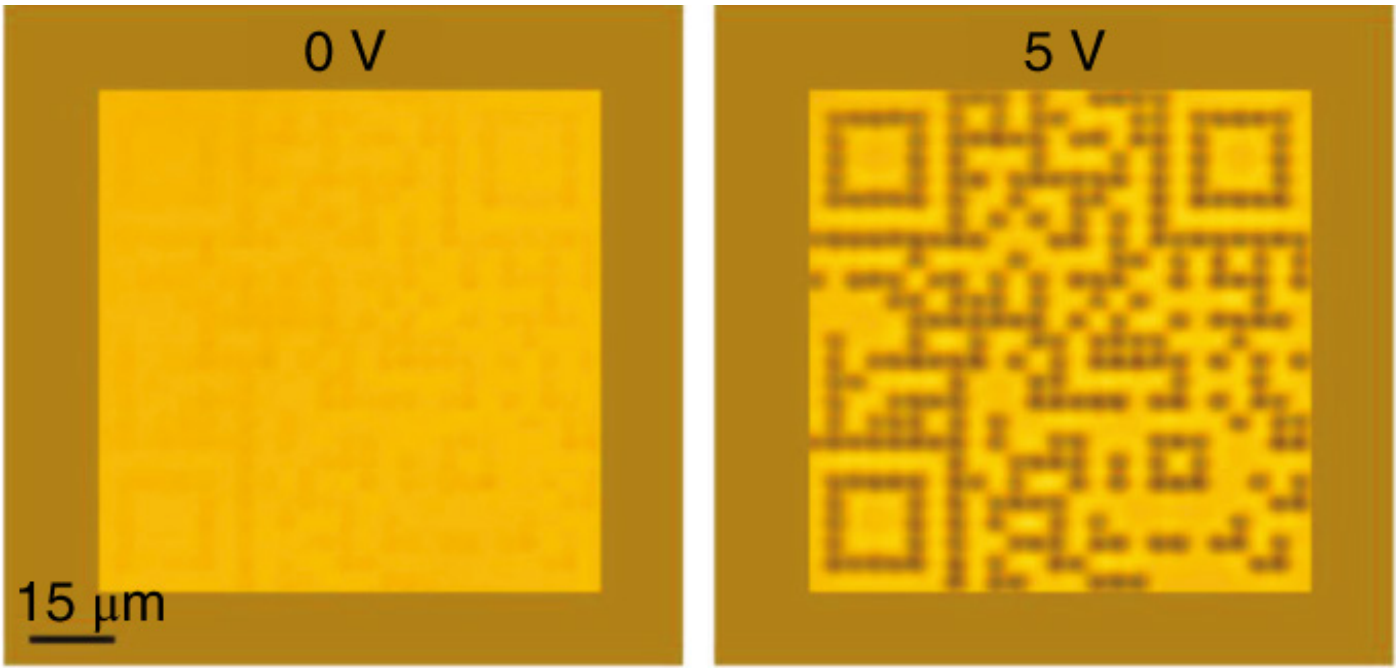
Technology Transfer from the University of Oxford

Read-on-demand features in liquid crystal devices

Oxford researchers have developed covert features that can be 3D printed into liquid crystal devices which can appear or disappear via a simple voltage application.



3D printing of high-resolution polymeric structures in LC devices using direct laser writing

Researchers at Oxford have developed a method to manufacture sophisticated micron-sized polymeric structures in liquid crystal (LC) devices using direct laser writing.

By fabricating the structures directly into a fully-assembled device, it is possible to lock-in a vast range of LC alignment profiles. Through careful matching of these refractive indices, these polymer structures can be made to appear/disappear under different voltage conditions.

This enables features such as QR codes to be hidden until the correct driving voltage conditions are applied to the device.

Examples of applications include device authentication, holography and switchable diffractive optical elements for AR/VR technologies.

Patent protection

A patent has been filed which covers this technology. Oxford University Innovation Ltd. is interesting in talking to potential partners to aid in the commercialisation of this new method.

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Technology Transfer from the University of Oxford

A new tool for characterising water permeation across films

Researchers at the University of Oxford have developed a new method to study water vapour permeation through films.

The threat of humidity

Water poses an inherent hazard to many technologies and industrial processes. A plethora of different protecting barriers or films has been devised and implemented to fit the needs of specific applications. A key example of this is in the field of optoelectronics where films are necessary to protect organic light emission diodes (OLEDs) used in mobile phone screens. It is of utmost importance to understand how water vapour permeation through these films may occur in order to improve their performance.

Finding the leaks in the current methods

Various methods are currently used to assess water vapour transmission rate (WVTR) through films but none of them present a satisfactory combination of sensitivity, accuracy, reliability and low cost. The electrical Ca test represents a promising methodology. The test relies ona metal Ca plate in contact with the film, which undergoes a change in electrical conductivity when the moisture permeates the film. Unfortunately, the preparation of samples is very cumbersome, requiring the use of a dry box and therefore is expensive to implement.

Increasing accuracy and simplicity

Academics from the University of Oxford have developed a new version of the Ca test that improves its accuracy and overall performance. The method uses a camera to record the build-up of calcium hydroxide on the Ca plate caused by the moisture that permeates across the film. Furthermore, it gives additional information about the mechanisms of permeation (macrodefects or background/nanodefects) allowing better material designs and production controls.

Sample preparation has also been simplified and the need for the use of an inert atmosphere removed.

Advantages of the Oxford technology

Other main advantages of using our technology are:

- High sensitivity
- High throughput
- Control of test environmental conditions
- Facile sample preparation

Commercialisation

This technology is under patent protection and the University is looking for investors willing to help in its development and commercialisation.

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Technology Transfer from the University of Oxford

Electrocatalytic nanoparticles Nafion® nanostructures doped with redox active species

Researchers at the University of Oxford have developed a simple synthesis route to Nafion® nanoparticles doped with redox active cationic species such as $Ru(bpy)_3^{2+}$ or methylviologen.

Redox cation doped Nafion® nanoparticles

Researchers at the University of Oxford have developed a simple synthesis route to Nafion® nanoparticles doped with redox active cationic species such as $Ru(bpy)_3^{2+}$ or methylviologen. These nanostructures display the similar facile oxidation/reduction properties as the solution phase cations. The supported catalysts are easily removed from reaction mixtures through filtration or centrifugation, thus reducing wastage. These nanoparticles could be applied to sensors, fuel cells and imaging. We believe the benefits of the redox cation doped Nafion® nanoparticles are as follows:

- Simple manufacture and recovery
- Inert and stable Nafion® support
- Incorporated cations retain their red ox reactivity
- Myriad applications due to the range of cations that can be selected for use

$Ru(bpy)_3^{2+}$ - The current face of electrocatalysis

Electrocatalysts are a subset of catalysts that operate at the surface of an electrode. Ruthenium (II) tris(2,2'-bipyridyl) ($Ru(bpy)_3^{2+}$) is a widely used electrocatalyst due to its accessible oxidation potential of 1.27 V vs SCE. The ability to electrochemically generate excited states of $Ru(bpy)_3^{2+}$ is also attractive as, upon relaxation to a ground state, such species will luminesce. The wavelength of the emitted photon is around 620nm, so will appear as red light.

In a separate application electrochemiluminescence (ECL) exploits the generation of excited species in an electrochemical reaction, which emits light upon relaxation to a lower-level state. ECL has been used in bioanalytical applications (DNA detection and Immunoassays), with $Ru(bpy)_3^{2+}$ featuring as the ECL reagent of choice. $Ru(bpy)_3^{2+}$ possesses excellent stability, a wide range of analyte tolerance and compatibility with many separation techniques. Numerous attempts have been made to immobilise $Ru(bpy)_3^{2+}$ on electrochemically inert substrates to aid with catalyst recovery and stability, however, success has been limited.

Transforming homogeneous redox chemistry into heterogeneous electrocatalysis

The developed methodology enables any homogeneous redox based chemical reaction involving cations as reagents to be transformed into an electrochemically driven catalytic process. It will transform redox solution phase chemistry by making it heterogeneous and catalytic.

Patent protection

A UK priority patent has been filed to protect this technology, and Oxford University Innovation Ltd. is looking to hear from anyone interested in helping in its commercialisation.

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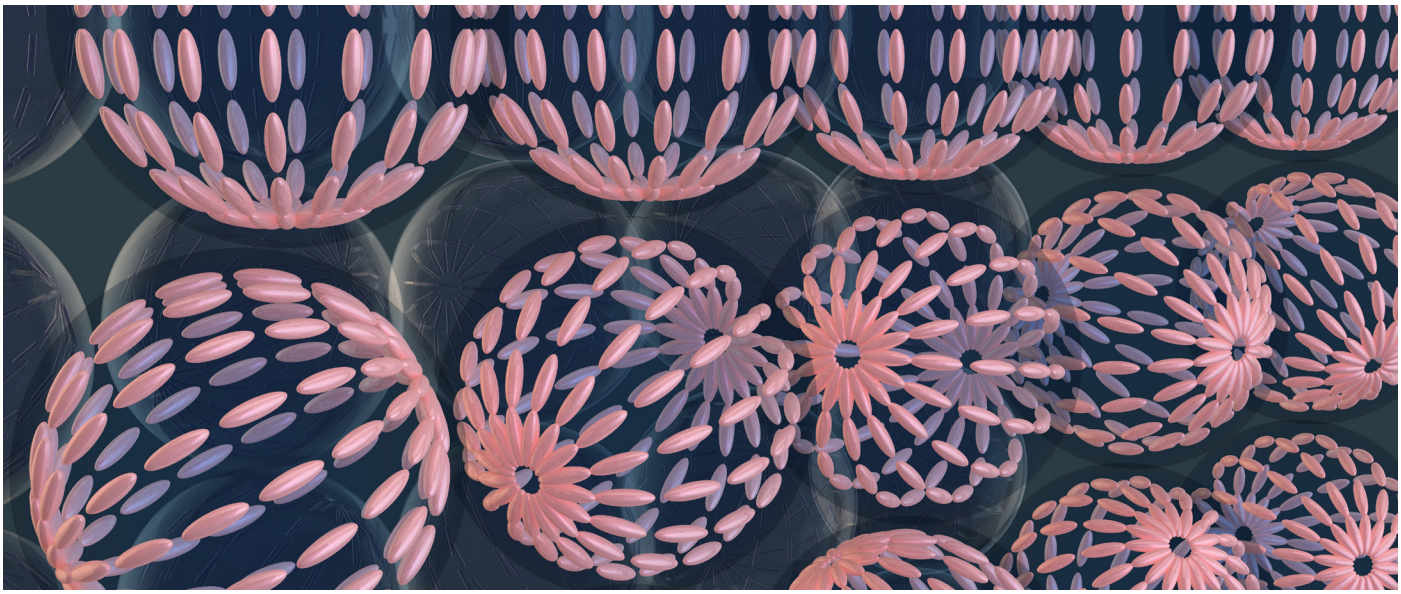
Technology Transfer from the University of Oxford

Motif printing in polymer dispersed liquid crystals

Researchers at Oxford have developed a method that uses inkjet printing technology to create designs and motifs using polymer dispersed liquid crystals.



Polymer dispersed liquid crystals

Polymer Dispersed Liquid Crystals (PDLCs) devices are a type of smart glazing or film material where liquid crystal droplets are suspended in a solid polymer matrix. When an electric field is applied to the material, the alignment of the liquid crystal director within the droplets reorients, changing the appearance of the film from translucent to transparent.

Common applications of PDLCs include smart glass used in architectural buildings, consumer electronics and automotive vehicles. PDLCs give dynamic control over the glass transparency for privacy, thermal efficiency and aesthetic purposes.

A PDLC inkjet printing method

Current fabrication methods limit the PDLC regions to large homogenous areas, consisting of a single mixture of liquid crystal, polymer binder and additional components. Therefore, typical PDLC smart window panels have uniform properties over the entire area of the panel, and the entire window pane is switched from opaque with no voltage and transparent with a voltage.

Researchers at Oxford have developed a method to produce thin-films with independent PDLC regions, fabricated from different liquid crystal formulations. The method is based on drop-on-demand inkjet printing technology, which enables easy deposition of one or more liquid crystal formulations onto a polymer binder or as a complete formulation. After printing, phase separation is induced via thermal or photopolymerisation.

The ability to create PDLC films and have PDLC regions made using different formulations allows for designs & motifs to be displayed.

The advantages and improvements of the invention:

- PDLC films can be patterned at micron-level resolution.
- PDLC regions of the film can be composed of different liquid crystal formulations, including different liquid crystals and/or dopants.
- The method is extremely efficient and scalable.
- Potential reduction in PDLC panel fabrication cost.
- Can be retrofitted to existing structures.

Patent protection

A patent has been filed which covers this technology. Oxford University Innovation Ltd. is interested in talking to potential partners to aid in the commercialisation of this new method.

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Technology Transfer from the University of Oxford

Tuneable optical coatings

Researchers at the University of Oxford have identified and used a new class of chalcogenide glass materials in optical coatings which have potential applications across a broad range of optical components.

Optical coatings, which are easy-to-manufacture multi-layered stacks of dielectric and metallic thin films, are used in a broad range of different components of devices including data storage mediums, lenses and displays.

Photonic components such as spatial light modulators can also make use of these stacks. Such optical coatings utilise the principle of thin film interference, i.e. phase driven constructive and destructive interference of light waves, to enable a multitude of optical effects.

Often thick optical coatings are required in order to achieve desired optical effects in a device. This means that the process of applying optical coatings can be material intensive. Further, such coatings are passive, meaning they lack tunability due to their static material properties, which limits their usefulness in many potential applications such as solid-state displays and smart glasses.

In recent years, the creation and manipulation of colour reflected off a surface by changing the refractive index of ultra-thin functional layers has been realised through use of phase change materials (PCMs). Optical coatings and devices can be designed with ultra-thin film structures such that white light is reflected as red, green or blue.

Having PCMs in these thin film structures means that the light reflected in the displays can be adapted and tuned on demand.

Whilst PCM's lead the way in tuneable optical coatings, such coatings often require a more complex stack arrangement and can have high optical losses associated with them, which is not ideal in many scenarios where transmission/reflection efficiency is of crucial importance.

With this in mind, researchers at the University of Oxford have identified a new class of chalcogenide glass materials, with highly tuneable properties, reduced stack complexity and applicability across a broad range of devices. This enables components to be manufactured which are thinner and exhibit lower losses than in existing devices. In addition, the optical properties can be continuously tuned, in contrast to many existing devices which are restricted to a limited number of different optical states.

Patent protection

This novel technology is the subject of a patent application. Oxford University Innovation is now seeking commercial partners to adopt the new technology and support its future development.

Image: Chalcogenide glass.

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Technology Transfer from the University of Oxford

Variable linewidth nanolithography

Researchers at Oxford have created a set of nanolithography methods to form patterns using a single scanning probe.

Nanolithography is a method used to etch, write or print onto a material surface in the range of 10^{-9} to 10^{-6} meteres or structures in the nanometre range. Over the years, several lithographic techniques have been developed for patterning in the nanoscale region. Electron-beam lithography and scanning probe nanolithography are a few techniques often used in research environments.

Scanning probe lithography is often used to form mask-less patterns typically by etching a surface using a purpose-built 'probe'. In the case of nanolithography, such probes can be configured with a sufficiently sharp tip to enable the creation of nanoscale features. However, whilst extremely small-scale patterns and features can be formed using a nanoscale tip, it can be very difficult to tune the degree of precision a scanning probe can deliver.

Often it is the case that a desired surface pattern requires different levels of precision for its various features and using a single sharp tip on a scanning probe is not optimal. Use of a single sharp tip can limit the speed and efficiency of nanolithography processes.

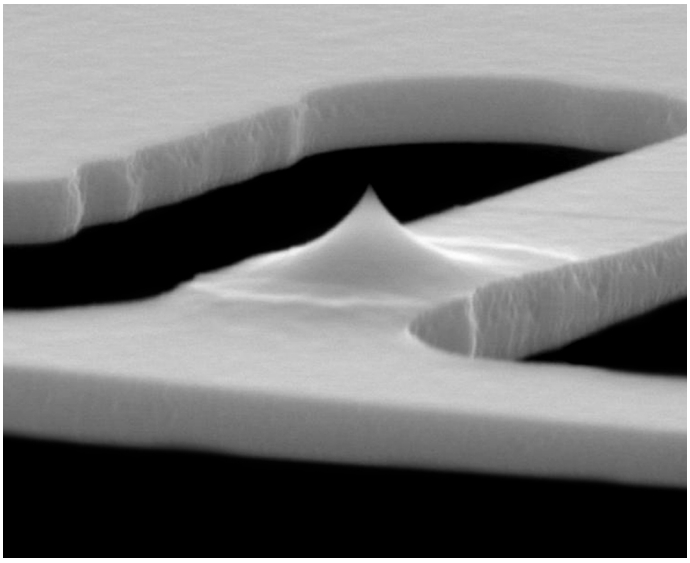
One way to address the above problem is to utilise an array of different scanning tip probes, each with a different tip sharpness. However, such a configuration would require ongoing recalibration each time a new probe is swapped in which is time consuming and prone to errors.

Researchers in the Department of Materials at Oxford have developed new nanolithography techniques to address the above-mentioned limitations with conventional methods. Through the creation of a novel scanning tip design, the researchers have created a nanolithography system in which a tuneable precision can be achieved on a surface using a single probe.

In cases where multiple passes of a probe would normally be required to create a feature on a substrate, only a single pass is required. Further, the probe design enables the scanning tips to be larger than in conventional probes and thereby reduce the rate of tip wear. So far, several scanning tip probes incorporating the new design have been fabricated and used in-house.

Patent protection

Oxford University Innovation is seeking commercial partners to further develop and sell scanning tip probes based on the new designs. A patent application directed to the new technology has been filed and so an exclusive sales channel for these new scanning probes would be possible.



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Technology Transfer from the University of Oxford

Eco-MOFs

Eco-friendly method to produce designer metal-organic frameworks for low cost sensors.

Metal-organic frameworks (MOFs) are advanced materials made from metal ions connected by organic linker molecules. MOFs can be designed from different metals and linkers to target specific end-use applications.

Commercially attractive applications are light emitting or luminescent MOFs (LMOFs) powered sensors for Volatile Organic Compounds (VOC), biomarkers and photonic devices.

Current production of MOFs is not eco-friendly. It is currently a long complex process using toxic solvents (N,N-dimethylformamide, methanol) in *harsh* high temperature and pressure environments.

Green and up-scalable production

Researchers at the University of Oxford have developed a fast method of producing large amounts MOF material. This uniquely eco-friendly method uses water as a solvent and allows processing at room temperature and pressure. The method has been applied to produce a specially designed MOF- a highly emissive silver metal based LMOF, invented and named as OX-2 by Oxford.

The resultant silver based LMOF detects changes in temperature and pressure, and functions as the electroluminescent layer of a LED device without toxic and expensive rare-earth elements.

This is a high-yield method to produce10-g of high-quality silver-based LMOFs in under an hour, using cost-effective and environmentally friendly water solutions of silver nitrate and terephthalic acid. The estimated cost is about 1000 times cheaper than commercially produced MOFs, an advantage of processing in ambient conditions and employing water as solvent.

The technology

When subjected pressure (up to 0.3 GPa) and temperature (up to 200°C), the Oxford silver based LMOF shows a dramatic decrease of the luminescence response. Its linearly reversible and reproducible thermochromic response is attractive for use in applications such as a *luminescent thermometer* and its mechanochromic response to pressure is promising for use as a luminescent *surface stress sensor*.

An Oxford MOF prototype LED device integrating OX-2 as the electroluminescent layer has been designed and fabricated (see image on the right).

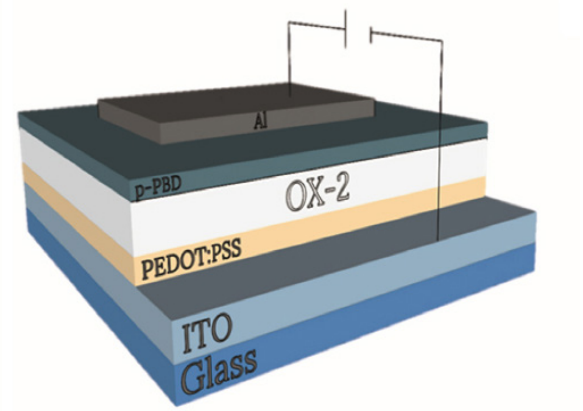
Commercial advantages of the Oxford technology:

- Eco-friendly, fast, high-yielding, cost-effective, and patent protected production methodology
- Oxford OX-2 class of silver-based LMOF gives high luminescent quantum yield (60% in powder form) with long-term stability
- Devices with OX-2 provides linear, repeatable, and reproducible thermochromic response in luminescent thermometers
- Devices with OX-2 provides luminescent response to nominal stress deformation-based sensors
- Devices with OX-2 provides electroluminescent properties fabrication of LEDs which are free of toxic and expensive rare-earth elements

Commercialisation

Oxford University Innovation Ltd. has filed a patent covering this technology and is now seeking an appropriate commercialisation partner.

Support is available to prospective commercialisation partners. Oxford researchers are advancing development of processing techniques for newly discovered target MOFs. A proof of concept programme is underway to design and develop a prototype VOC sensor suitable for industrial toxic VOC detection and diabetes diagnostics in healthcare.



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Technology Transfer from the University of Oxford

Real-time ellipsometry analysis and quality control of thin films

A quick, low-cost method to monitor dynamic changes and quality of multi-layered thin films during manufacture.

The challenge: Real-time ellipsometry analysis of complex materials

Ellipsometry is an optical technique used to characterise properties of thin films such as thickness, roughness, optical constants, composition, crystallinity, quality and concentration. In the study of mono-layered materials, these properties can be measured by fitting certain parameters, such as refractive indexes, into a model.

However, when studying complex multi-layered absorbing materials such as semiconductors, model analysis becomes challenging, computationally expensive and time consuming.

In practice, real-time analysis of multi-layered thin films is limited to determining the thickness of the sample only, followed by intensive post-production quality testing. As a result, product defects are not identified until postproduction, causing high material wastage and process inefficiency.

The market: a competitive highly concentrated industry

The ellipsometer industry is a mature market, expected to grow at a CAGR of 5.5% until 2025. Growing interest in ellipsometry due to the need to measure nanometre-scale layers in a variety of industries is envisaged to drive the demand in the global ellipsometer industry.

Scientific advances in complex nanomaterials, in fields as varied as microelectronics, biology or medicine, are calling for further sophistication in ellipsometry instrumentation in an industry with increasing levels of competition.

Our solution

Researchers at Oxford University have devised a quick, low-cost method to monitor dynamic changes and quality of multi-layered thin films during manufacture. The method enables in-situ, real-time analysis of spectroscopic ellipsometry data throughout each layer's deposition.

The invention relies on a mathematical method to analyse raw data such as amplitude ratio (ψ) and phase difference (Δ), to extract parameters of interest representative of the refractive indices (n + j k) which are a measure of the quality of the layers.

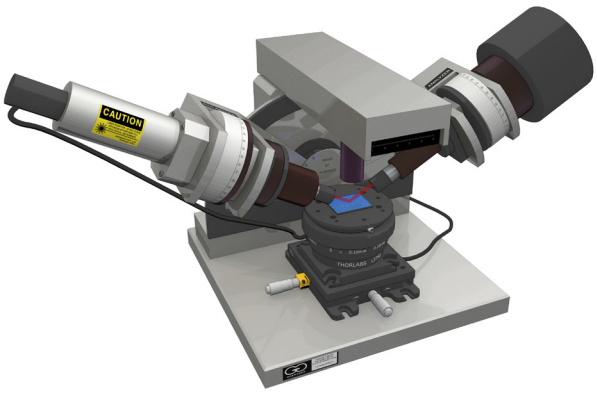
Key advantages of the invention are:

- Changes in film properties and structure can be studied real-time during layer deposition and film growth, enabling in-situ quality control
- Spectroscopic data can be studied real-time
- Defects can be detected in real-time during manufacture, reducing wastage
- Energy-saving, does not require computationally intensive modelling
- Time of analysis is reduced to milliseconds, compared to hours or even days required with computer modelling
- Highly useful for scientific research for examining quantum-level interactions

The method has applications in the analysis of a range of evolving systems such as thin film growth, surfaces, biomolecular interactions and electrochemical processes, among others.

Commercialisation

Oxford University Innovation has filed a UK patent with the potential to be extended to international coverage and is looking for potential partners to aid in the commercialisation of the technology.



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Technology Transfer from the University of Oxford

QUANTUM TECHNOLOGY

Calibrating quantum detectors

A robust method for calibrating highly sensitive photon number resolving detectors used in emerging optical applications such as quantum imaging, spectroscopy, lithography and quantum computing.

The Oxford invention

Optical detectors are used in numerous industries, from medical sciences to radiation monitors for ancient artefacts in museums. Conventional classical calibration methods use previously characterized light sources to estimate the overall efficiency of a detector. However, these approaches cannot be extended to detectors working at quantum level, as they will require light sources with extremely low powers (femtowatt) to avoid saturation and such sources are impractical. Another approach (Klyshko Scheme) that uses the statistical character of light has been proposed to solve the limitations of classical approaches but has inherent issues too.

Oxford researchers have devised a generalised and robust method for absolute efficiency estimation of photon number resolving detectors (PNRD). The figure below shows that constant efficiencies have been achieved for two PNRDs using the Oxford calibration method. The conventional Klyshko method breaks down at higher photon numbers leading to an over estimation of the detectors efficiency. The Oxford invention has several other advantages:

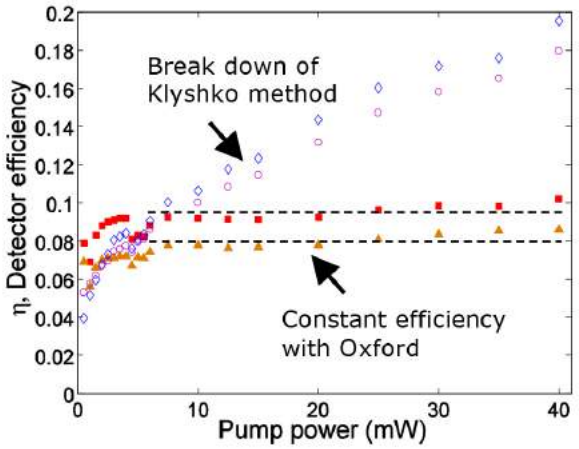
- Provides measurement redundancy
- Achieves lower absolute error
- Allows In-situ calibration
- Allows use of brighter light sources including amplified pulse pumped sources
- Can also be applied to Binary or pseudo photon-number resolving detectors

The market

Much of the revenue generated from various calibration techniques arises from the work of national laboratories throughout the world that are often the practitioners of detector standards. The Oxford invention has a wide range of applications especially where photon-number resolution is necessary for large algorithms such as emerging optical quantum information protocols.

Patent status

This Oxford invention is the subject of a patent granted in the US and Europe. Oxford University Innovation would like to talk to companies interested in commercialising this opportunity. Please contact the Project Manager to discuss this further.



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Technology Transfer from the University of Oxford

ROBOTICS & AUTONOMOUS VEHICLES

The Oxford RobotCar dataset

The Oxford Robotics Institute has compiled a unique dataset through multiple traverses of a route in central Oxford under different conditions in the Oxford RobotCar.

The challenge of long-term localisation

Autonomous vehicle research is critically dependent on vast quantities of real-world data for development, testing, and validation of algorithms prior to deployment. A number of vision-based autonomous vehicle datasets have been released, however, they do not address the main challenges of mobile autonomy.

These challenges include localisation in the same environment under significantly different conditions and mapping in the presence of structural change over time.

The Oxford RobotCar dataset

Researchers from the globally renowned Oxford Robotics Institute have collected more than 20TB images, LiDAR and GPS data by repeatedly traversing a route in central Oxford in the Oxford RobotCar. The data was collected over a period of one year and represents over 1000km of recorded driving.

The resulting unique dataset captures a large range of variation in scene appearance and structure due to:

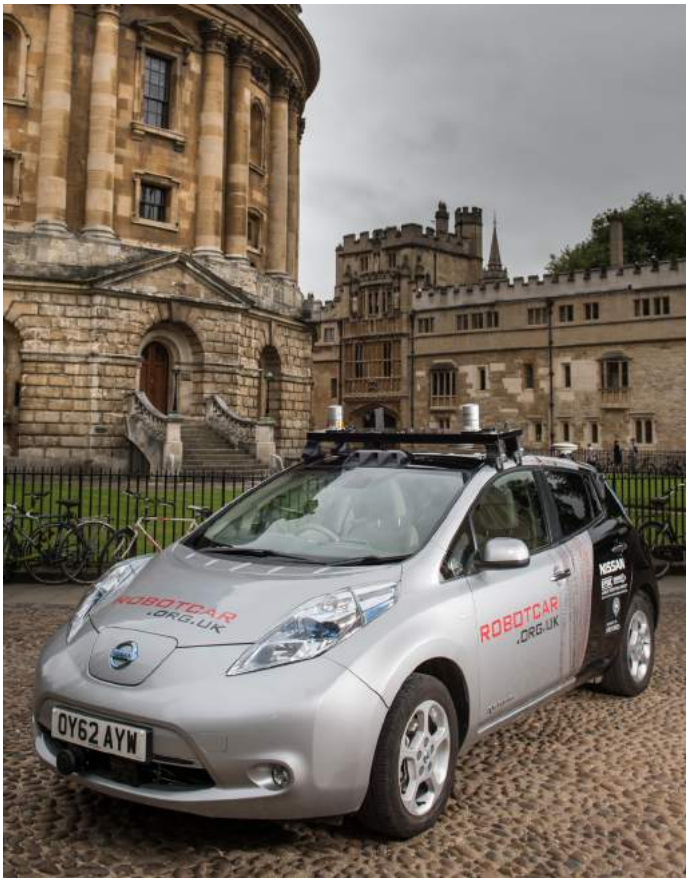
- illumination
- weather
- dynamic objects
- seasonal effects
- construction

The raw recordings from all of the available sensors are included alongside a full set of intrinsic and extrinsic sensor calibrations. MATLAB development tools are additionally included for accessing and manipulating the raw sensor data.

Commercialisation

The Oxford RobotCar dataset offers a unique opportunity for the commercial development and testing of systems capable of long-term localisation in dynamic environments. The dataset is available to license from Oxford University Innovation.

For further information on data collection and utility, please visit **http://robotcar-dataset.robots.ox.ac.uk/images/robotcar_ijrr.pdf**.



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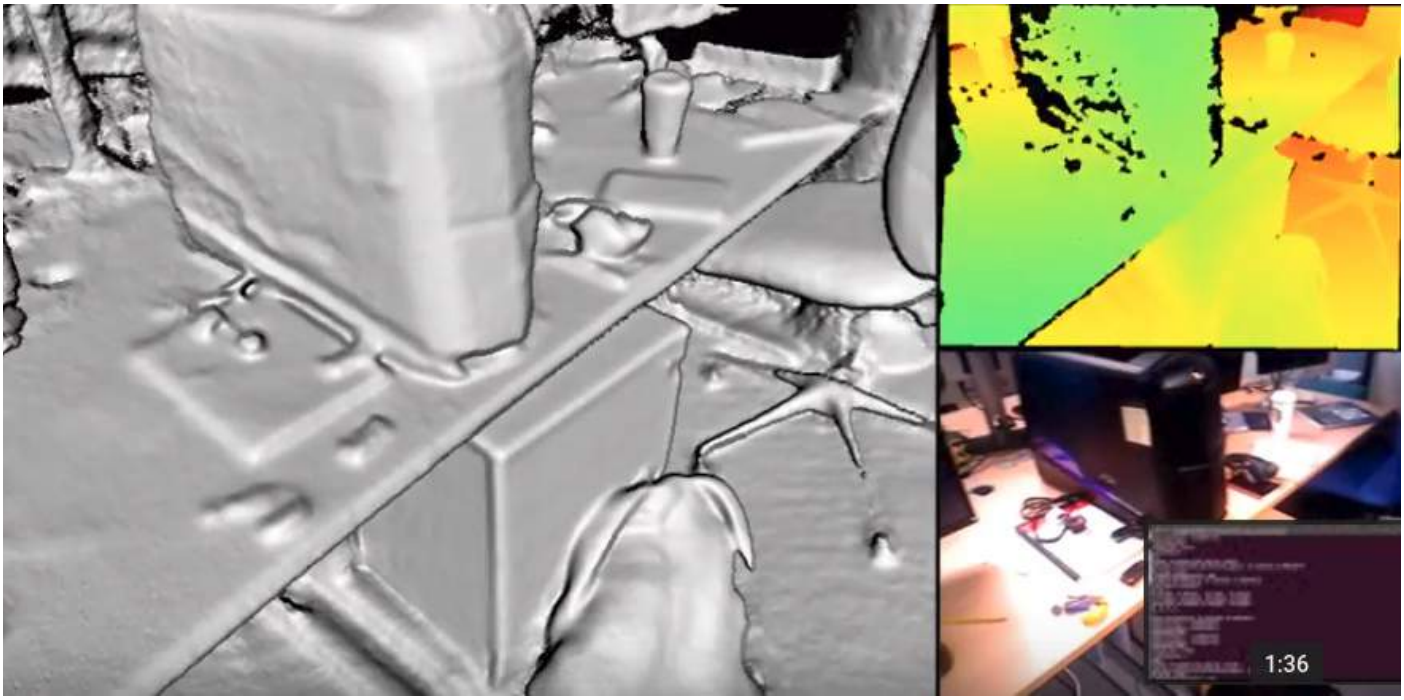
Technology Transfer from the University of Oxford

Accurate camera relocalisation with InfiniTAM

Oxford academics have developed an algorithm for estimating the pose of a 6-degree camera using a single RGB-D frame.



Above: An example of a project utilising the new camera relocaliser technology with InfiniTAM.

In the field of computer vision for robotics systems, camera pose relocalisation is one of the most important requirements for simultaneous localisation and mapping (SLAM), virtual and augmented reality (VR/AR) and navigation. Tracking camera poses or localisation is generally reliable, but from time to time the tracking can be lost and the camera pose can become unknown.

It is important to be able to “relocalise” the camera with respect to the map that has been built, rather than start the reconstruction again from the beginning. Camera pose relocalisation is also the key to reuse a pre-built 3D map by aligning current live frames with the map. In VR/AR applications, it enables multiple users to collaborate or share information with each other while exploring the same 3D environment.

Researchers at Oxford have developed an algorithm that uses a single RGB-D frame as an input to estimate the respective 6-D camera pose relative to a map built beforehand, which can be used with a SLAM or VR/AR system. Local features are selected from the RGB-D frame and then integrated into the map, which ensures the system is computationally cheap and delivers reliable matches to ensure successful relocalisation.

By using graph matching techniques, as opposed to feature matching techniques, the pairwise geometry among features can be more descriptive which further enhances relocalisation success.

www.robots.ox.ac.uk/~victor/infinitam/index.html.

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Technology Transfer from the University of Oxford

New radar robotcar dataset for autonomous vehicles

The Oxford Robotics Institute has compiled a unique dataset for scene understanding using millimetre-wave scanning radar data, for autonomous vehicle applications.

For organisations working on autonomous vehicles and navigation, datasets on which to train and develop algorithms are incredibly beneficial, particularly those which contain data about a multitude of different urban environments, seasonal variations and fluctuation in daylight.

However, it can be difficult for organisations to collect this kind of dataset themselves, especially when data from different sensors is required. In 2016, the Oxford Robotics Institute published their first dataset, the "Oxford RobotCar Dataset", which contained over 1,000km of data including monocular and stereo imagery, 2D and 3D LIDAR, and inertial and GPS data.

In 2019, an additional dataset was released: the Oxford Radar Robotcar Dataset. This includes additional data from a millimetre-wave radar and two additional 3D LIDARs.

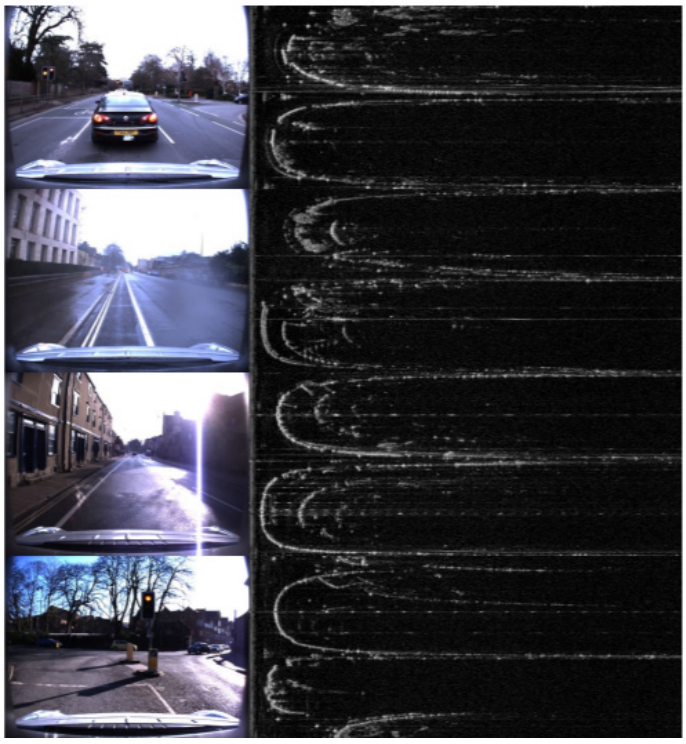
The radar used is a "Frequency-Modulated Continuous-Wave" (FMCW) class of radar, which provides a 360◦ -view of the scene and is capable of detecting targets at ranges far exceeding those of automotive 3D LIDAR. These advantages are particularly valuable to autonomous vehicles which need to see further if they are to travel safely at higher speeds or to operate in wide open spaces where there is a lack of distinct features. Moreover, these vehicles must function reliably in unstructured environments and require a sensor such as radar that thrives in all conditions – rain, snow, dust, fog, and sunlight.

Along with the raw sensor recordings from all sensors, there is provided an updated set of calibrations, ground truth trajectory for the radar sensor as well as MATLAB and Python development tools for utilising the data.

Additional information:

The Radar Robotcar dataset is presented in "The Oxford Radar RobotCar Dataset: A Radar Extension to the Oxford RobotCar Dataset" (Barnes et al., 2019).

This paper provides additional information about the sensors and their configurations used to collect the data, and the sensor layout onboard the Nissan LEAF, along with information regarding data calibration methods and data structure formats.



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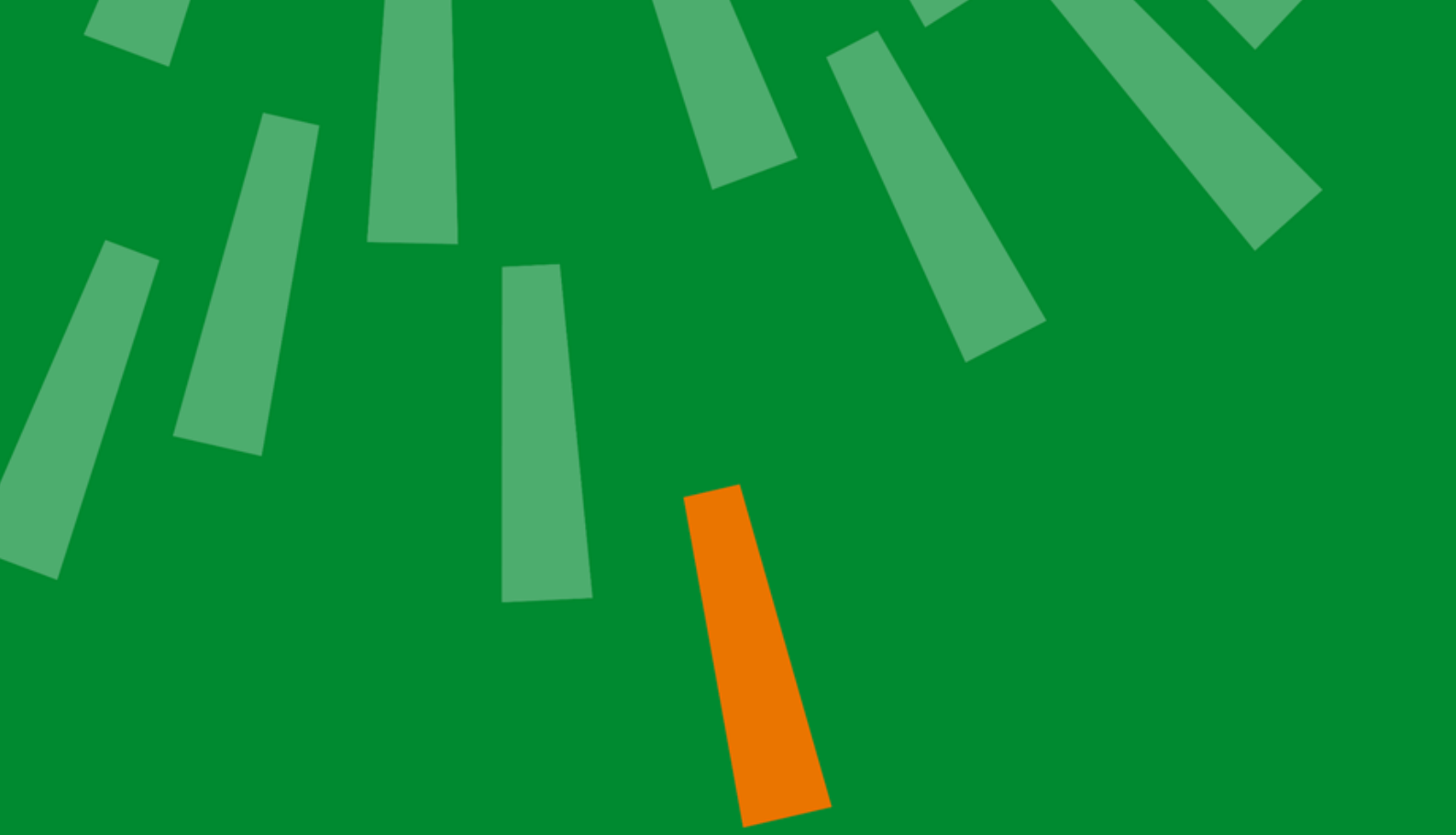
Technology Transfer from the University of Oxford



SENSORS

Sulphide sensors

Oxford researchers have developed an electrochemical sensor has been developed that measures the concentration of hydrogen sulphide (H_2S) or thiols in fluids.

Hydrogen sulphide (H_2S) is a noxious and highly toxic gas. It is formed as a by-product in numerous chemical processes and can be generated through the decomposition of organic matter (e.g. sewage effluent).

Additionally, hydrogen sulphide is present in crude oil, thereby creating a risk to workers in the petroleum industry who may be exposed to unacceptably high levels of this gas. It is therefore important in many industrial processes that monitoring procedures are in place to determine the concentrations of H_2S present in the environment.

Sulphide sensors

Figure 1 shows a schematic view of the Oxford electrochemical sensor. The sensor is exposed to the sulphide/thiol-containing fluid, which may enter the device across a permeable membrane (34). The fluid subsequently passes through two porous blocks (32 & 36), which contain an immobilised reagent that renders the sulphide/thiol-containing fluid conductive.

A potential is applied between electrodes 40 and 44, and the flow of current between electrodes 40 and 42 is measured. The current reading is then de-convoluted to provide the concentration of sulphide/thiol. Critically, immobilisation of the reagent in the electrochemical component (36) of the sensor enables miniaturisation of this technology, which leads to faster response times, lower consumption of reagents and lower unit costs.

Patent status

This technology is protected by several international patents and Oxford University Innovation would like to talk to companies interested in exploiting the above ground use of this sensing technology. Please contact the Oxford University Innovation Project Manager to discuss this further.

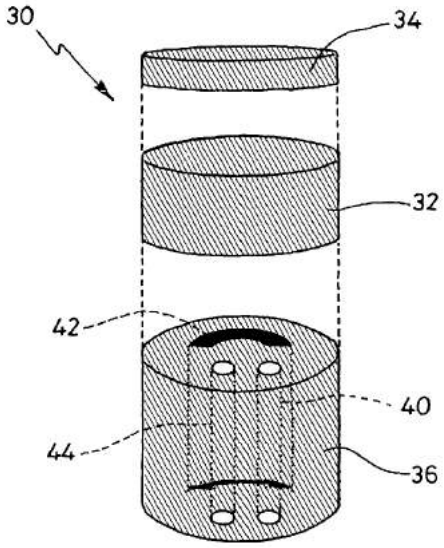


Figure 1

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Technology Transfer from the University of Oxford

Sensitive gas detectors

Oxford researchers have developed methodology based on low cost carbon based electrodes for the detection of trace quantities of toxic gases such as nitrogen dioxide and chlorine.

Marketing opportunity

The monitoring of reducible and oxidizable gases has become increasingly important as the effects of such gases upon health and the environment have been brought into the public eye. Reducible and oxidizable gases may be toxic and environmental pollutants.

The gases may be formed from burning fuel in motor vehicles, electric power plants, and other industrial, commercial, and residential sources that burn fuel. They may be present in enclosed spaces such as ice rinks from ice surface renewal machines and in kitchens or apartments from using a gas stove. Exposure to some reducible and oxidizable gases may exacerbate a pre-existing pathogenic condition in people who spend a large amount of time in such places and/or cause respiratory health problems. Consequently, continuous monitoring is required.

Known methods of gas detection include, for example, chemiluminescence, fluorometric and spectrophotometric analysis. A favoured alternative uses amperometric sensors have been found to enable low cost of components, small size, and lower power consumption than other types of sensor, and are ideal for use in portable analysis systems. Electrochemical techniques for the quantification of gases have been described but sensitive systems almost invariably employ noble metals which dramatically increase costs.

The Oxford invention

A new methodology has been developed based on low cost carbon based electrodes for the detection of trace quantities of toxic gases such as nitrogen dioxide (NO_2) and chlorine (Cl_2).

The technology has been successfully applied to the detection of low levels of chlorine and nitrogen dioxide gas but is likely to have broader application in the detection of sulphur dioxide, hydrogen, hydrazine, arsine, nitrogen monoxide, hydrocarbons including methane, oxygen, ozone, carbon monoxide, carbon dioxide, hydrogen sulphide, and carbon disulphide.

Patent status

This work is the subject of patent application, and Oxford University Innovation would like to talk to companies interested in developing the commercial opportunity that this represents. Expertise in manufacturing low cost electronic devices is particularly sought.

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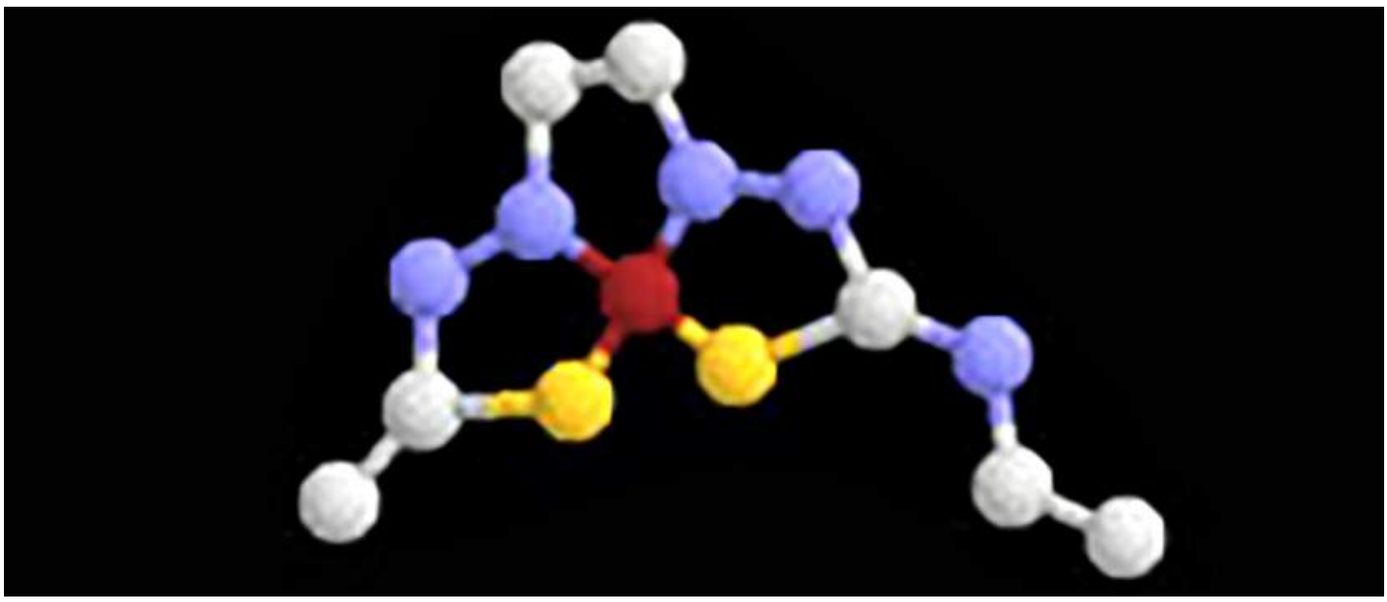
Technology Transfer from the University of Oxford

Saliva drug testing

Researchers at Oxford University have developed a hand-held device for rapid, quantitive saliva drug testing.



Early detection

The prevalence of driving while affected by drugs is rising. It has been shown that drugs are detected commonly among those involved in motor vehicle accidents, with studies reporting up to 25% of accident-involved drivers testing positive for illicit drugs with cannabis being the most common. It is apparent that drugs in combination with alcohol, and multiple drugs, present an even greater risk and it has been concluded that drug driving is a significant problem, both in terms of a general public health issue and as a specific concern for drug user.

The challenge to further progress in this area is the development of a hand held device, which will enable not only qualitative drug testing, but also quantitative testing.

A better process for collection

The Oxford Invention provides a method for creating a hand-held device for rapid, accurate, quantitative, saliva drug testing.

Unlike currently available hand-held saliva drug testing equipment, the Oxford Invention:

- Is highly sensitive
- Does not require laboratory confirmation of positive tests
- Is not pH dependent
- Provides accurate results in less than 60 seconds
- Is ideally suited for on the spot checks, for example roadside testing

Commercialisation

Oxford University Innovation Ltd. has filed a priority patent application, which covers this technology and is seeking partners to aid in its exploitation.

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Technology Transfer from the University of Oxford

Charged particle imaging

Oxford researchers have developed a variation on time-of-flight mass spectrometry (TOFMS) enabling mass-selective images of the spatial or velocity distribution of the ions at their point of formation.

Cutting-edge mass spectrometry

The advent of ultra-fast imaging sensors based on CCD and CMOS technology has expanded the capabilities of powerful techniques such as time-of-flight mass spectrometry (TOFMS). Such sensors allow large numbers of images to be recorded and stored on the nanosecond to microsecond timescale before readout at slower data rates.

Charged particle imaging

Oxford researchers have developed a variation on TOFMS which enables mass-selective images of the spatial or velocity distribution of an ion's mass-to-charge ratio at the point of formation. These techniques provide a wealth of information beyond the scope of traditional measurements.

Spatial-map imaging offers:

- the ability to develop surface imaging
- high-throughput multi-sample mass spectrometry
- an order of magnitude enhancement to speed

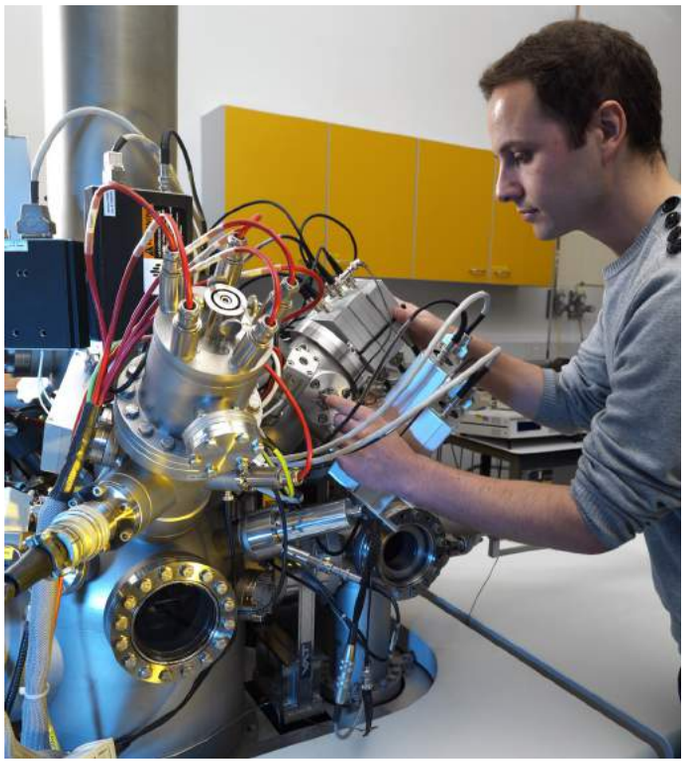
Velocity-map imaging provides:

- detailed information on molecular fragmentation processes
- structural information on the parent
- energetics and dynamics information on reaction processes

The technique provides both a standard TOFMS and images for each fragment ion. Larger molecules, such as peptides and oligonucleotides can be studied using this method.

Commercialisation

The technology is protected by a granted US patent and a European patent application. Oxford University Innovation would welcome contact from companies with an interest developing the commercial opportunity.



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Technology Transfer from the University of Oxford

Improved ToF mass spectrometry

Available to license: Improved mass resolution and ion throughput in ToF mass spectrometry

A method for improving mass resolution and ion throughput in Time-of-Flight (ToF) mass spectrometry, aimed in particular at high-end applications in drug discovery, biochemistry and proteomics

Faster, higher resolution

Time-of-flight (ToF) describes a method of mass spectrometry in which ions are accelerated by an electric field of known strength. The Oxford invention improves both the mass resolution and the data acquisition rate of ToF mass spectrometers. This simple to implement invention couples fast detectors with ToF mass spectrometry in order to improve total ion throughput and time (and correspondingly mass) resolution.

How does it work?

The invention exploits fast pixel sensors to yield a technique that will allow recording over relatively long timescales such as the ~100 micro seconds required to record a ToF mass spectrum, whilst maintaining the same high time resolution possible for the much shorter timescale of single events.

Attractive market

This invention should be of interest to companies who produce ToF mass spectrometers at the high-end of the market. We especially believe that there is an excellent fit with products aimed at the drug discovery, biochemistry and proteomics markets, where high mass resolution and high throughput for large molecular fragments is of great importance.

Doing more with current equipment

The development could be used routinely in high-end ToF mass spectrometers for achieving higher mass resolution and throughput, with a correspondingly reduced data acquisition time compared to existing state-of-the-art instruments. The invention employs a different approach from that currently used by mass spectrometer manufacturers. An order of magnitude performance advantage in terms of both mass resolution and ion throughput would be expected when employed with a commercial instrument. Implementing this invention requires a relatively low cost add-on to an existing ToF spectrometer, which could also be sold aftermarket.

Patent protection

The Oxford invention is subject to a patent granted in the US and under examination in Europe. Oxford University Innovation would like to talk to companies interested in developing this into a commercial opportunity.

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Technology Transfer from the University of Oxford

Gas detection

Available to license: Ultra-sensitive molecular gas detection

Researchers at the University of Oxford have focused on sensing technology that allows low concentration detection of a range of molecular gases

The ability to detect low concentrations of dangerous gases in the atmosphere is desirable, for example in warehouses containing chemical storage tanks or the detection of chemical agents at security posts in airports. Current high sensitivity gas sensors are often based on optical absorption or spectrometry. However, the drawback with these detectors is that they are large, expensive and can lack robustness. At the other end of the scale, electrochemical gas sensors are supplied as robust and relatively cheap, but can lack the necessary sensitivity below the parts per million threshold.

Oxford approach

Researchers from Oxford's Materials Department are developing a different method to allow ultra-sensitive detection. The method involves the creation of a 2D array of metal nanoparticles on an insulating substrate. The array is manufactured to create an insulating substrate decorated with metal nanoparticles with average spacing of just a few nanometres. This can be finely controlled by measuring the conductivity while this nanoparticle network is manufactured.

The next step is to form 'bridges' between the nanoparticles with conducting connector molecules. These connector molecules can be engineered to have a specific binding site to a particular molecular gas, which will significantly influence the electrical conductivity of the connector molecules. The number of connector molecules is again carefully controlled. As the proportion of connections is increased, the probability increases that a conducting pathway is formed. A critical point is reached when the number of connections is sufficient to provide a conducting pathway in half the random configurations and this point is called the percolation threshold.

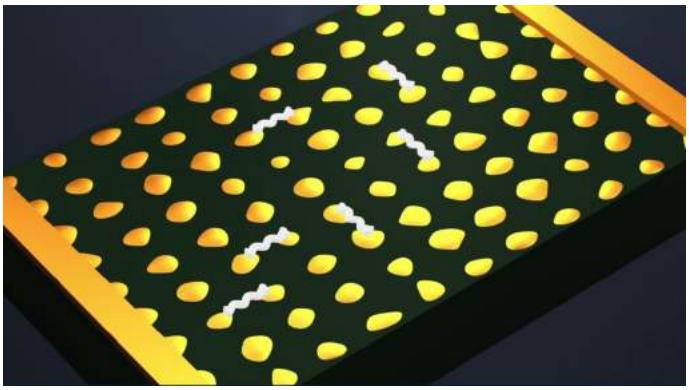
Working in the region of the percolation threshold results is the distinctive advantage of increased sensitivity. Even very low concentrations of the target gas present will disrupt the conductivity significantly.

Applications

One immediate application could be in environment monitoring of gases, with the team already showing proof of concept results for moisture and alcohol. However, two interesting applications are currently being investigated where the market needs are for ultra-sensitivity. One is explosives detection for location of landmines, the other is human breath monitoring for low concentrations of biomarkers.

Patent protection

This technology is now the subject of a patent application and Oxford University Innovation would like to discuss with interested companies the licensing of the technology.



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Technology Transfer from the University of Oxford

Ion detector

Available to license: Faster, more efficient ion detector

A fully-integrated position sensitive ion detector offering superior timing resolution with improved detection efficiency, suitable for use with low energy ions in mass spectrometry and other applications

Detecting low energy ions: a challenge

The detectors used in most high-end commercial time-of-flight mass spectrometers, as well as the position sensitive detectors used in imaging mass spectrometry, use micro-channel plates (MCPs) to convert incident ions into a measurable current. For imaging applications, the electrons produced by the MCP can either be accelerated towards a phosphor screen or detected directly e.g. using one of the new generation of CMOS-based electron detectors. Optical detection using a phosphor is currently the standard for most imaging experiments despite the decay time of the phosphor imposing a considerable limitation on the attainable time resolution in such measurements.

Competitive advantage

Researchers at the University of Oxford and the Science & Technology Facilities Council have invented a new type of ion detector which offers a number of advantages over current detectors:

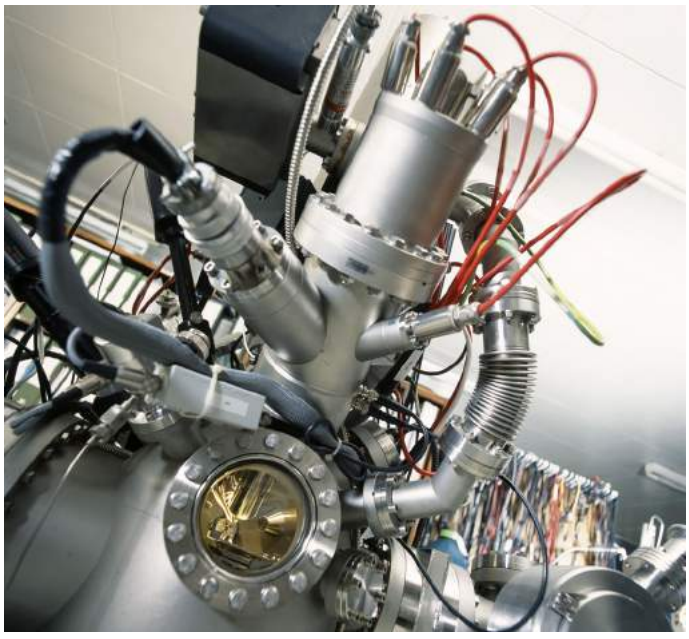
- Fully-integrated position sensitive ion detector eliminates the need for MCPs and phosphors
- Improved time resolution performance over MCP/phosphor combination already demonstrated
- Superior ion detection efficiency without the loss of spatial resolution or added complexity of comparable MCP-based approaches
- More robust detector solution which can operate at higher pressures (up to atmospheric) and without the need for a high voltage power supply

Uses for this type of detector

Low energy ion detectors are widely used in such areas as mass spectrometry, ion imaging and atom probe tomography. It is expected that this invention will be of significant interest to manufacturers in those specific fields as well as the scientific detector industry more generally.

Patent protection

The underlying technology is subject to a patent granted in the US and under examination in Europe. Companies interested in progressing the commercial opportunities are invited to contact the Technology Transfer Manager.



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Technology Transfer from the University of Oxford

Electrochemical detection of silver nanoparticles

Researchers at the University of Oxford have developed a fast and simple method to identify, quantify and characterise silver nanoparticles in a sample

Metal nanoparticles – pros and cons

Nanoparticles (NPs) have become ubiquitous, with an estimated 1600 commercial products available. However, the NPs are inevitably later released into the environment. Silver is the engineered metal NP most commonly found, with approximately 65 tonnes released into rivers globally per annum. Silver has biocidal activity on account of its disruption of the enzyme function responsible for nutrient uptake, and cellular energy production and storage processes. These powerful antibacterial properties have led to silver NPs being used in many commercial products, such as medical dressings, food preparation items and clothing (where around 50% of the NPs leach out per washing cycle!) Significantly, silver NPs cause endocrine disruption in amphibians and are toxic to many mammalian organs.

Rapid, sensitive diagnostic method

To characterise the risk posed to ecosystems by increased exposure to silver NPs, the development of detection techniques is urgently required. Oxford researchers have developed a fast and sensitive method of detecting and identifying silver NPs in a sample, which on entering the natural environment, may pose a public health risk. Their method involves assessing the presence and/or properties of the particles in a sample from electrochemical responses yielded by the particles colliding with an electrode, and allows identifying, quantifying, and characterising of particles in a sample.

Competitive advantage

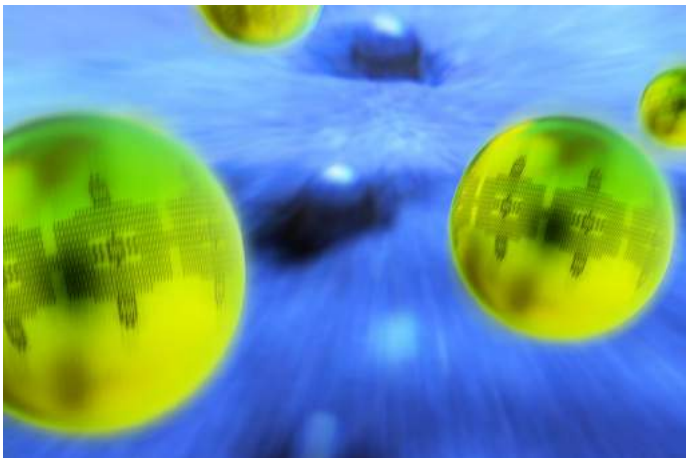
This is the first time that the direct electro-oxidation of silver NPs colliding with an electrode is both viable and quantitative, and can be used for characterisation and NP identification. The method uses low cost carbon electrodes. Additionally, electrochemical methods lend themselves to use with low cost and compact electronics, making this a method that could be widely deployed. Furthermore, the ability of the method to identify, quantify and characterise NPs provides it with excellent potential in environmental compliance monitoring and public health. Research is already underway to extend the method to the quantitative characterisation of other metal NPs, as well as mixed NP systems.

Supporting data

The Oxford researchers have published a paper describing their method in Angewandte Chemie, 2011, entitled “The electrochemical detection and characterization of silver nanoparticles in aqueous solution.”

Patent protection

The underlying technology is the subject of a UK patent application.



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Technology Transfer from the University of Oxford

Tagged nanoparticle detection

Oxford University researchers have developed electrochemical detection of tagged nanoparticles in sensing and biosensing applications.

Tagged nanoparticles

There is great interest in metallic nanoparticles (NPs) due to their unique chemical and electronic properties, arising from their large surface area to volume ratios and the separation of their electronic energy levels. Tagged (labelled) NPs are becoming increasingly important in sensing and biosensing applications.

The Oxford invention

For tagged NPs to reach their full potential in sensing applications, it is necessary to improve on methods for their detection. Oxford scientists have successfully demonstrated the use of particle coulometry to monitor the collisions of tagged NPs with an electrode.
The method allows modification of the label, and also allows detection and analysis of tagged NPs while they are in suspension. The Oxford method can be applied generally to identify tagged NPs when the labelling molecule is electroactive, and is expected to have wide application in analytical nanoscience.

Other approaches to detecting tagged nanoparticles

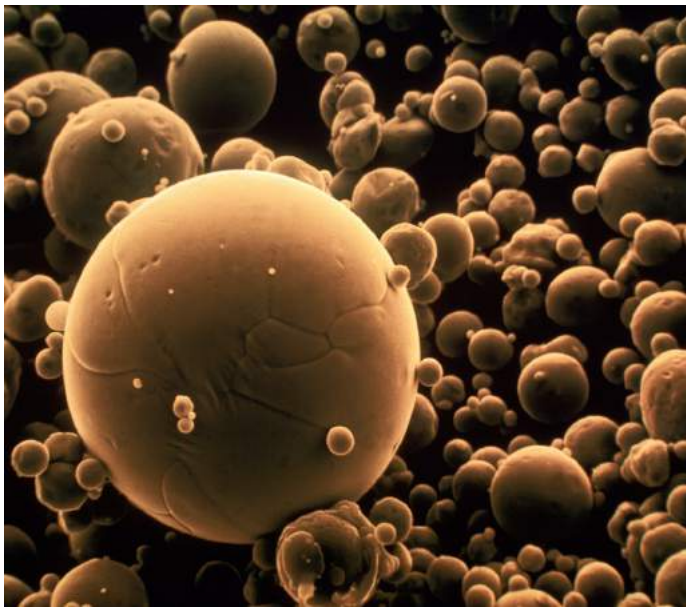
A number of approaches have previously been used for the detection of tagged NPs. Surface-sensitive spectroscopy has been used to detect tagged silver or gold NPs. Similarly, fluorescent and colour-coded tags have been used to enable rapid optical detection of target molecules. Other methods for detecting tagged NPs include ICP-MS and electrochemiluminescence. Where electrochemical methods have been used, the tagged NPs have been immobilised onto the electrode before the voltammetric or electrochemical measurement. All of these methods are inappropriate for the identification and quantification of tagged nanoparticles while they are in suspension.

Supporting data

The Oxford researchers have published details of their method in Chem. Commun., 2012, **48**, 2510–2512.

Patent protection

The technology is the subject of a UK patent application. Companies interested in progressing the commercial opportunities are invited to contact Oxford University Innovation.



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Project number: 8711

Technology Transfer from the University of Oxford

Nanoparticle detection

The low-cost, disposable electrodes can be harnessed for in-field detection and quantification of nanoparticles

The antibacterial and antiseptic effect of silver nanoparticles (Ag NPs), in combination with their cost-efficient mass production, has resulted in their use in a wide variety of consumer and medical products. The omnipresence of these nanoparticles and their corresponding release into the environment, in combination with their unknown effect on environmental systems, raises the demand for reliable and affordable techniques for their detection.

Limitations of current detection and characterisation

A number of methods including light scattering, nanoparticle tracking analysis and UV/visible measurements have been successfully used to determine the composition, concentration, size, surface charge density, adsorption and agglomeration of NPs in various systems, including real environmental samples. A limitation of these methods is that liquid samples have to be taken, transported and analysed. This carries the risk of causing changes to the sample, for example by altering the concentration or aggregation state.

Oxford developments

Oxford researchers have developed a novel approach to Ag NP detection, with potential application for long-term field studies and environmental monitoring. Their method uses specially surface-modified glassy carbon electrodes. These “sticky” electrodes are immersed into the medium of interest, the NPs are allowed to stick to the surface over a period of time, and then the amount of NPs immobilised on the electrode surface is analysed either in the field or in the laboratory.

Advantages

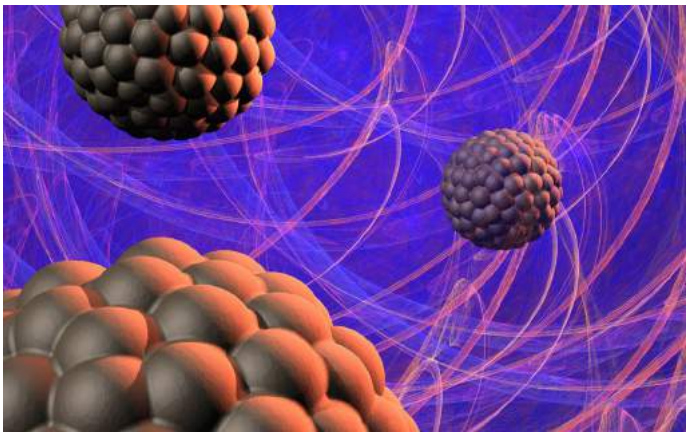
The use of sticky electrodes enables a long sampling time and thus detection of NPs even from media with low concentrations of NPs. The sample can be collected on site without an applied electric potential, i.e. under open circuit conditions. As a result, there is no need to base expensive and sensitive equipment on site. Analysis may be carried out back at the laboratory with a much reduced risk of the sample being changed by transportation. The modified carbon electrodes lend themselves to manufacture via screen printing and therefore have potential to offer a commercial partner a low cost and disposable solution.

Supporting data

The Oxford developments are described in Chemical Communications (2013), entitled “Sticky electrodes for the detection of silver nanoparticles.” Please also refer to related Project No. 7909, “Electrochemical detection of silver nanoparticles.”

Moving forward

The underlying technology is the subject of a UK patent application. Oxford University Innovation is seeking external partners to support the commercialisation of the technology.



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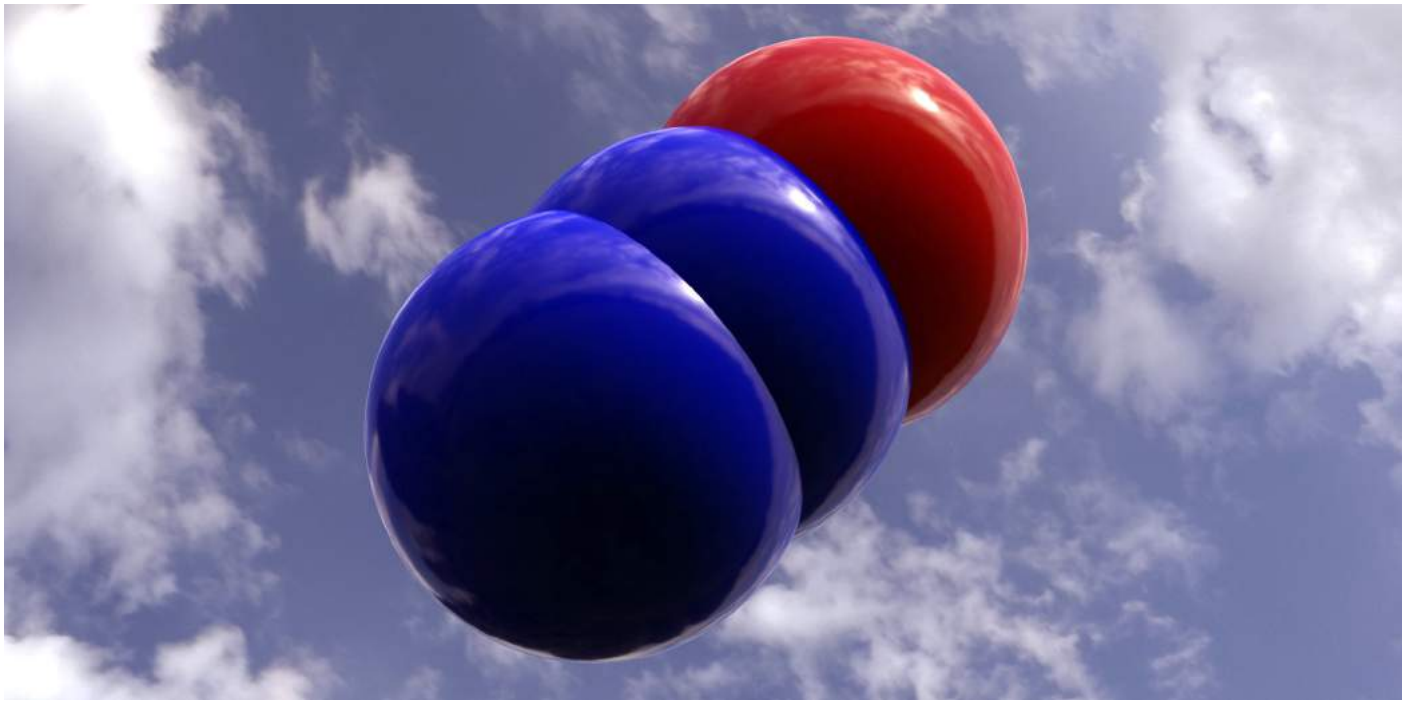
Technology Transfer from the University of Oxford

Nitrous oxide sensing

Oxford scientists have developed a system, based on ‘frustrated Lewis pair’ chemistry, which is capable of selective nitrous oxide sensing with a simple, visible colour change output.



Nitrous oxide is a powerful greenhouse gas with 300 times the heat capacity compared with carbon dioxide. Monitoring nitrous oxide, both over large areas and from industrial emissions is crucial and new technologies to address detection are needed.

The use of nitrous oxide within the healthcare industry also results in a need for monitoring the exposure to employees and patients from a health and safety perspective. Existing techniques for this are expensive and often do not provide “live” data on exposure.

New chemical entities

Oxford scientists have developed a novel class of chemicals with the ability to reversibly bind nitrous oxide, which are the first small molecules described to achieve this. The colour change resulting from nitrous oxide binding allows for simple monitoring of exposure.

Further applications

The molecules are not limited to nitrous oxide detection and several other applications have been identified or are being investigated.

- Activation of carbon-hydrogen bonds – demonstrated under mild conditions with phenylacetylene
- Hydrogenation – reversible hydrogen activation/ storage demonstrated at room temperature

Commercialisation

A patent application protecting key new chemical entities and a range of applications has been filed.

Molecules have been tested and conditions for nitrous oxide capture and release determined. Work to optimise colour change and maximise sensitivity is ongoing.

Oxford University Innovation would like to talk to companies interested in developing a sensor based on this novel class of chemicals.

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Technology Transfer from the University of Oxford

FieldSense – Next generation tactile feedback systems

Oxford researchers have developed FieldSense, a haptic feedback technology based on the precise placement of magnetic nodes.

Simulating senses

The sense of touch is critical to how we perceive the world around us. It helps us discover and classify new objects, as well as alerting us to change in the environment. Over the last 30 years, haptic technologies have sought to provide more immersive experiences by engaging our sense of touch. This has resulted in developments such as tactile electronic displays, virtual reality gaming and interactive medical devices.

Touching the limits

Current haptic technologies focus on the use of vibrational or electronic stimuli. Vibrations are neither specific nor directional meaning that they struggle to provide precise and detailed feedback. Electronic or "shock" stimuli are more precise, but depending on the magnitude of the stimulus, it could be uncomfortable or even painful for the user.

FieldSense - An attractively simple magnetic solution

Researchers at the University of Oxford have developed FieldSense, a haptic technology, which uses affordable, simple arrays of magnetic nodes to generate precise and rapid tactile feedback.

The stimuli provided by field sense can be tailored to the purpose meaning that it could bring haptic technologies into new applications, as analternative to more widely used electric stimuli.

The main advantages of the technology are as follows:

- Low cost and simple to implement
- Low power usage
- Controllable stimulus
- Pain-free feedback method

Patent Protection

The FieldSense technology is subject to a UK patent application and Oxford University Innovation Ltd. is seeking partners to aid in its commercialisation.

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Technology Transfer from the University of Oxford

Nuclear quadrupole resonance sensor for safer wireless power

Oxford researchers have developed an innovative safety solution that uses nuclear quadrupole (NQR) resonance to detect biological material within the wireless power transfer (WPT) magnetic field.

Charging ahead without wires

The global sales of electric vehicles are expected to top 1 million for the first time in 2017 (Frost & Sullivan, 2017) and with this increased demand comes a need for a more convenient and efficient method of recharging on-board batteries. Wireless charging is an attractive solution, as it reduces the amount of input required from the vehicle owner and eliminate cumbersome leads and charging stations.

Current wireless charging systems are typically based on inductive charging, where a magnetic field is generated between a coil located on the ground and one in the vehicle. Fields generated in this way generally exceed 85 kHz.

Wireless power transfer safety

There is a widely perceived danger with wireless power transfer (WPT), that humans or animals could step into the generated magnetic field while the device is in use. It is a requirement that such systems do not expose users or animals to harmful levels of electromagnetic radiation and that it adheres to guidelines set out by the International Commission on Non-ionising Radiation Protection (ICNIRP). In order to prevent this, effective “trip switches” are needed, where the power can be cut in the presence of biological material.

Nuclear quadrupole resonance

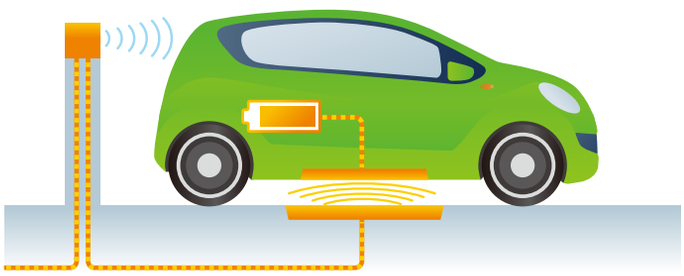
Researchers at the University of Oxford have developed a sensor, based on nuclear quadrupole resonance (NQR), capable of detecting biological material in proximity to the WPT field. The NQR system differentiates between humans or animals and can provide feedback to the WPT device to trigger a shut-down when necessary. The power can then be restored once the biological material is clear of the field.

We believe the main benefits of the Oxford solution are as follows:

- Lower cost and more reliable than current radar solutions
- Differentiation between different biological material
- Fewer false positives than other safety devices
- Easily integrated into existing WPT systems
- Allows WPT manufacturers to adhere to ICNIRP guidelines

Patent protection

A patent has been filed that covers this technology. Oxford University Innovation Ltd. is keen to talk to anyone who could aid in the commercialisation of this device.



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Technology Transfer from the University of Oxford

An ultra-sensitive photodetector based on phase change materials

Researchers at the University of Oxford have developed an ultra-sensitive and tuneable photodetector based on phase change materials.

Currently, most commercially available optical sensors that operate at room temperature in the visible to near infrared (IR) spectral range are typically based on semiconductor materials, such as silicon (Si) and indium gallium arsenide (InGaAs). Silicon is also used in image sensors used in phone and webcameras, where active pixel sensor arrays are manufactured using CMOS technology. These sensors offer high photo-sensitivity, but are expensive to manufacture, have a limited dynamic range and may be difficult to scale down in size.

In most conventional semiconductor-based optical sensors responsive to visible light near-IR light, the photo-response originates from the separation and drift of photo-excited charge carriers (photocarriers) in an electric field present between the terminals of the device. This means that the photo-response is largely determined by fixed material specific properties that govern photocarrier generation and drift, such as optical absorption and charge carrier mobility. The material specific properties also limit the dynamic range of the device, which means that typical optical devices saturate at fixed and relatively low light levels. Due to these limitations, alternative optoelectronic devices and methods of photodetection are desirable, preferably with increased adaptability to light levels.

Oxford academics have invented a new optoelectronic device that is based on phase change materials. The device is operated in a mixed mode optoelectronic configuration, which uses electrical and optical energies. The device works with an inherent negative feedback loop, where the electrical conductance of the device is modulated by the optical input flux.

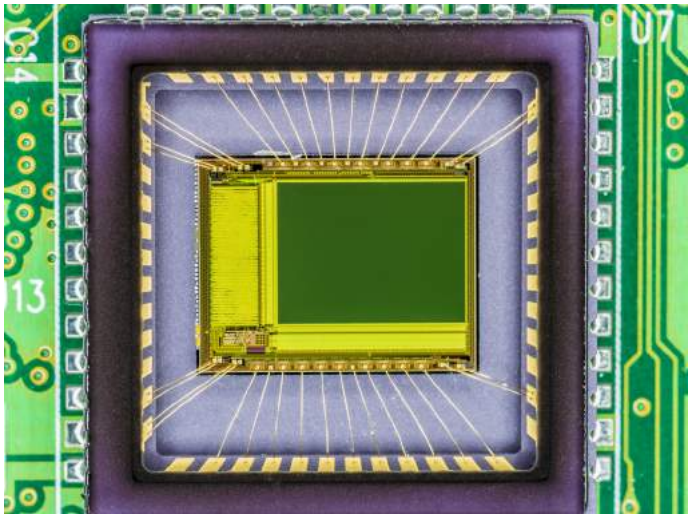
This essentially replicates the functioning of a human eye.

There are multiple benefits of the Oxford technology:

- fast
- robust
- sensitive
- wavelength selective
- energy inexpensive
- carries high signal to noise ratio
- easily scaled down

Combining these benefits allows very high device densities, which results in high spatial image resolution, an incredibly useful property for medical applications.

This technology is subject to a patent application and is now available to licence.



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Technology Transfer from the University of Oxford

An innovative sensing solution for the detection of bacteria on surfaces

Oxford academics have developed a novel sensing system providing high sensitivity for detection of bacteria or food residue on surfaces and removing the requirement for immersion of biological oxygen demand sensors into water.

Contamination detection

Contamination detection is important both on surfaces and in the monitoring of liquid waste. Imaging systems have been developed to provide such detection, particularly in the food industry where they could be used to detect food residues on surfaces or food preparation equipment following cleaning.

Despite these developments, the standard test for cleanliness still relies on swabbing a small sample region of the surface. This test does not enable detection across the entire surface and is also unreliable, depending upon a number of uncontrollable factors.

Existing biological oxygen demand (BOD) sensors, used to monitor the quality of water, require immersion in the water. However, fouling of these sensors then precludes continuous monitoring, and the sensors can only be used to sample at discrete time intervals.

Contact-less monitoring

Oxford researchers have developed novel methods for performing remote contamination detection using fluorescence.

Sensors based on this technology enable:

- reliable detection across an entire surface
- detection of bacteria on a surface and/or food residues left on a surface following cleaning
- no requirement for contact with the clean surface of interest
- monitoring of contaminants in a liquid without immersion
- continuous monitoring of waste liquids

Multiple sensor designs have been envisaged to suit various applications. Initial proof of concept work has been performed in the Department of Engineering Science.

Commercialisation

Oxford University Innovation would welcome contact from commercial entities interested in using this technology to develop sensing systems. The technology is the subject of a UK priority patent application with scope for worldwide protection.

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Technology Transfer from the University of Oxford

Soil-structure interaction sensor

Oxford researchers have developed an innovative and simple sensor capable of measuring all parameters needed to fully quantify a soil-structure interface.

The problem

Underground structures are often a key component in large-scale construction projects, including tunnels, shafts, foundations and deep excavations. These structures are exposed to contact with the surrounding soil, which is typically critical to their operation.

The normal and frictional contact stresses associated with this interaction can be monitored by installing sensors within the soil-structure interface. Existing sensors are not well suited to the harsh environments of construction monitoring, suffering from electromagnetic interference and damage through water ingress. They are also typically expensive, difficult to fabricate and unable to provide a complete assessment of interface stresses, relying on additional instrumentation to measure pore water pressure.

The solution

To surmount the limitations of existing systems, engineers at the University of Oxford have developed an innovative and simple sensor capable of measuring all parameters needed to fully quantify a soil-structure interface. This includes the normal stress and bi-directional shear stresses (and their eccentricities), alongside pore water pressure and temperature.
The device comprises a simple square structure that employs a novel mechanism of deformation to allow for measurement of pore water pressure. A machine learning approach is used with the strain sensitive transducers on the sensor structure to distinguish the complex deformations induced under the different loads. This allows a significantly lower number of strain transducers to be used, reducing sensor complexity and overall cost.

Advantages of this device include:

- More cost effective than existing sensor technologies
- Capable of measuring all stresses associated with a soil-structure interface
- Avoids the need for installation of additional instrumentation
- No damage through water ingress or electromagnetic interference
- Simplified design and straightforward manufacture compared to existing technologies

Commercialisation

Oxford University Innovation is currently seeking a licensee to help commercialise this technology. A patent protecting the invention is currently pending.

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Technology Transfer from the University of Oxford

Bespoke reference electrode for electrochemical sensors

Oxford researchers have developed a novel solid-state electrolyte-free reference electrode suitable for miniaturisation.

The use of reference electrodes

High quality reference electrodes, are essential in all electrochemical experiments embracing both amperometric and potentiometric. They are fundamental units in the many chemical sensors which rely on such electrochemical measurements including glucose sensors and fire alarms.

The stability and robustness of a reference electrodes is key for its success as they dictate the sensitivity and longevity of a sensors.

The most popular reference electrode is the silver/silver chloride electrode. This is widely used in pH meters and often the reference electrode of choice in redox potential measurements as well as in a numerous biosensors including those built on screen printed electrodes. For a stable and reproducible potential, a fixed chloride concentration is crucial and this is achieved by having a Ag/AgCl surface in contact with a solution of potassium chloride of a fixed molarity inside or bathing the electrode.

Such requirements are often problematic in applications in which the reference electrode needs to be miniaturised or when the reference electrode is used in flowing solutions. Losses of AgCl from the electrode surface are well known and are the cause of contamination, potential drift, and loss of electrode stability. Alternatives are needed to drive forward and facilitate the highly active area of (electro-) chemical sensing.

Nafion film based reference electrodes

Researchers at Oxford have addressed these limitations through a bespoke design and developed a solid state electrolyte-free reference electrode in which the two components of a redox couple are uniquely immobilised on a Nafion film supported on a metal surface.

Advantages of this novel technology include:

- Simple fabrication
- Deployable on any metal surface
- Readily miniaturised
- Avoids leaching or continuation problems
- Excellent stability and lifetime
- Disposable

In summary, the doped Nafion film based reference electrode is a robust alternative to the silver/silver chloride reference electrode. Miniaturisation would allow for applications in analytical devices at all scales, as well as in disposable sensors.

Commercialisation

Oxford University Innovation has filed a priority patent application on the technology and welcome discussion with companies interested in licensing it for commercial development.

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Technology Transfer from the University of Oxford

SOFTWARE, INTERNET OF THINGS & DATA

Real time energy and environmental monitoring using smartphone technology

Oxford researchers have developed a mobile, low cost method of measuring energy and environmental data for immediate access and visualisation via the internet using Android phones.

Competitive advantage

The use of smart-phones, for data storage and communications, enables high-resolution data collection at a fraction of the cost of commercial real time energy and environmental monitors. The phone can be configured to read a number of different meters or multichannel sensors, making the method highly versatile for a vast array of potential applications. Paired with the appropriate low cost sensing peripherals it can displace substantially more expensive sensing solutions and open up new areas of applications, for which this level of data collection has hitherto been prohibitively expensive.

Supporting data

- The research and development is supported by a 12 month EPSRC Impact Acceleration grant
- Product testing with end users is being supported by a 24 month EPSRC energy engagement project, NERC supported study and a project funded by the Technology Strategy Board
- Market analysis for commercialisation is being supported by a NERC pathfinder grant
- Kits are being tested in a number of UK commercial businesses and in 2 archaeological sites in Europe and Asia

The technology operates in 2 modes

1. Using the phone's microphone input as a 44.1 kHz digital voltmeter the device can, using cheap external electronics, read gas, electricity, fuel and water at the business meter, sub-meter or individual appliance. Other peripherals can allow measurement of temperature, moisture content, humidity and other environmental variables.
2. For more sophisticated sampling the phone can be connected to a custom built multi-channel data logger, which is capable of taking numerous independent readings in parallel. Multiple energy and environmental variables, such as temperature, humidity and light levels can thus be collected simultaneously using a single smart-phone.

Mobile phones are optimised for low power and this solution can be used as a standalone solar powered monitor for remote applications.

Energy monitoring and management

The use of this technology significantly reduces the barriers to entry for real time energy monitoring and management in commercial buildings and is relevant to a broad range of companies involved in energy in buildings and environmental monitoring generally.

Patent Protection

2 patent applications covering these methods have been filed in the UK

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Technology Transfer from the University of Oxford

Motion sickness solution for electronic device use

Researchers at the University of Oxford have developed a new algorithm which obtains real-time movement data from vehicles and reduces the effects of travel sickness by moving content on the screen accordingly.

Motion sickness

Motion sickness can occur while riding in most types of vehicle, and leads to symptoms ranging from discomfort and dizziness to nausea and vomiting in affected people. Theses effects make journeys highly uncomfortable for people who try to use their electronic portable devices while traveling.

Although some medications are available to prevent motion sickness (tablets and patches), healthcare services recommend you don't use electronic devices during journeys. Additionally, other types of products are commercialised, such as wristbands for acupressure or mild electric shocks.

However, they are only effective for a limited portion of people, who need to remember to bring them whenever they wish to use portable electronic devices while travelling. Thus, there is a big need to develop other strategies to prevent this condition and allow people to use their devices without feeling sick.

The Oxford solution

Based on this need, researchers at the University of Oxford have developed a new algorithm that can easily be implemented within an electronic device operation system without the user having to take medication etc. The algorithm takes multiple sensor inputs and moves the screen content according to the external movement of the vehicle. Settings can be personalized depending on the user's susceptibility to travel sickness and different settings can be defined, making the system suitable for most types of vehicles.

Advantages of this novel tool are:

- It can be implemented at operation system level
- It does not need to be linked to external apps
- It allows the user to customise the compensation
- It avoids motion sickness without the need for drugs or other therapies

Commercialisation

This technology is subject to a patent application. Oxford University Innovation is actively looking for partners willing to develop and implement this novel technology. If your company could be interested, please do get in touch.

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Technology Transfer from the University of Oxford

Virtual Assay drug screening software V.3.0

Oxford researchers have developed user friendly software for *in silico* drug trials in populations of human cardiac cell models.

Evidence that drug safety and efficacy testing could one day be conducted by a computer rather than on animals has led a team at the University of Oxford to develop Virtual Assay software. The Virtual Assay software has the potential to replace thousands of *in vitro* animal experiments used globally each year for this purpose. A recent evaluation study on 62 reference compounds has predicted the risk that these drugs would cause abnormal heart rhythms in patients with 89% accuracy, while similar studies conducted in animals showed ~75-85% accuracy.

Everyone is different

No two individuals respond to a drug in exactly the same way. Due to sometimes subtle variability at a physiological level, what works for one person may not work for another, even before taking into account any additional complicating factors. This is one of the most significant challenges faced by the pharmaceutical industry; clearly it is neither practical nor desirable to test a new drug on the entire population to ensure it is both safe and effective.

Drug cardiac safety

Ensuring a drug does not have potentially harmful or unexpected side-effects for the heart is a top priority, and a rigorous testing phase is required before a drug can be approved for clinical use. Even then, unforeseen problems can occur due to the large variability in patient populations, exacerbation of other pre-existing diseases or interactions with other drugs. Early detection of potential side effects is crucial, since cardiotoxicity is one of the leading causes of drug failure during development, and it also accounts for about 45% of total post-approval drug withdrawal from the market.

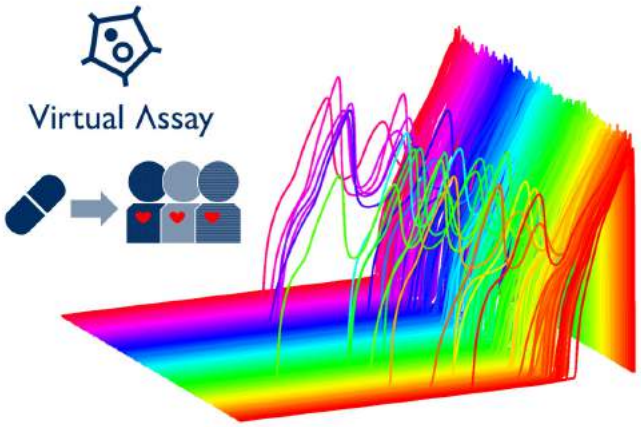
"Virtual" screening with Virtual Assay

To overcome this, *in silico* modelling is becoming increasingly important in pharmacology, for both drug efficacy and safety testing and is attracting significant attention from the commercial sector and regulatory bodies such as the US FDA, UK MHRA, and the European MRA.

Virtual Assay also makes *in silico* drug trials in populations of human models accessible by non-experts in modelling and simulations, providing a user-friendly interface and a very efficient simulation engine (1 drug trials takes about 5 minutes for 100 cells using a modern PC).

Key advantages:

- Human-based models, tightly coupled with experiments
- Populations of models to account for inter-cellular variability
- Quantitative prediction of the effects of drugs at the population level
- Mechanistic explanations into the causes of drug effects
- Consultancy services also available



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Technology Transfer from the University of Oxford

A novel mathematical method to detect stress

A mathematical model that enables accurate determination of an individual's physical or emotional state by synchronising and analysing how multiple physiological signals vary together.

Determining both physical and emotional states based on physiological signals is carried out in many fields including medicine, health, fitness and sport. The current approach typically extracts simple features such as heart rate and respiration rate over a fixed window and then trains a machine-learning classifier using these new static features.

The features extracted using this approach misses significant information about the fine-scale structure of the input paths, in particular the way in which a person breaths, how their breathing pattern changes over time, and the interactions between the changes in breathing and changes in heart rate. If improved methods were developed that utilise additional information contained in the high-frequency physiological signals, this would increase the number of cases correctly diagnosed.

Stress can have a significant impact on a person's wellbeing by contributing to heart disease through to affecting mental health. Therefore, by having an accurate detection method it will allow appropriate management at an early stage.

A new mathematical approach

Mathematicians at the University of Oxford have been able to advance the processing of multiple high-frequency physiological signals to create a more accurate and reliable output regarding an individual's state. For this technology, physiological signals are measured over a physiologically relevant time window, for example, one breath (inhale/exhale) or a heartbeat signal, rather than an arbitrary time limit.

This provides the physician with a natural window to extract meaningful features from through utilisation of some feature extraction technique such as the signature method. Using the breath as an example these features will not only contain the rate of breathing but also more fine-scale details about how that breath was breathed and how all these changes interact with other signals over the course of a breath.

These features can then be combined with feature over multiple breaths to train a machine-learning algorithm to come up with a more accurate state of an individual than the more traditional features alone.

This mathematical model can be incorporated into a device to, for example, determine stress levels, cardiac health or the presence of sleep apnoea.

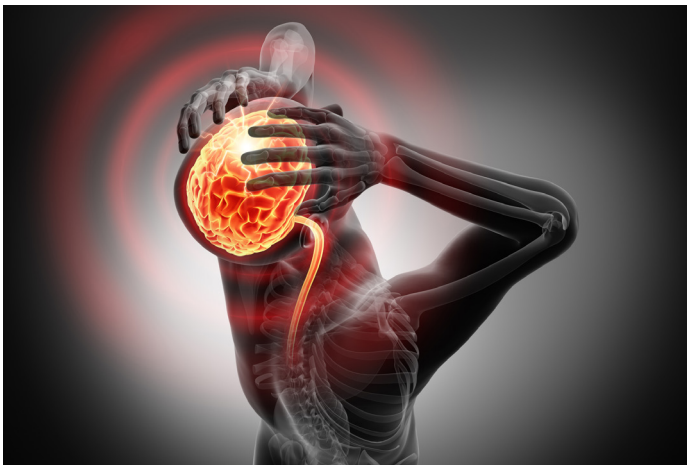
Key advantages

With this technology, the accuracy in detecting physical and emotional states can potentially be improved compared to the current system as:

- The relationship between multiple signals can now be analysed in an effective manner
- The results from several time windows e.g. multiple breaths can effectively strengthen the signal
- The use of a trained machine learning algorithm is fast, accurate and efficient

Commercialisation

Oxford University Innovation filed patent applications directed to this technology and is looking for an industrial partner to develop this opportunity further.



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