T H E   E L E C T R O N

N E W S L E T T E R   O F   T H E   I N S T I T U T I O N   O F   E L E C T R O N I C S

Issue 41: Spring 2019

ADVANCED ENGINEERING

Advanced Engineering, the UK's largest annual event for the high value manufacturing sector, celebrated its tenth anniversary in 2018 when it opened its doors at the NEC in Birmingham on 31st. October and 1st. November.

The exhibition was arranged in seven zones:

* Aero Engineering

* Composites Engineering

* Automotive Engineering

* Performance Metals Engineering

* Connected Manufacturing

* Nuclear Engineering

* UK Contract Manufacturing

The Nuclear Engineering Zone was notably new for 2018, addressing especially the potential within the nuclear civil new-build sector, and there was also an 'Innovation Gallery' that showcased a range of special products from exhibitors that were seen as being particularly innovative for their customers.

There were around 540 exhibitors and a full conference programme provided around 230 presentations on a range of general and specialist subjects. Examples included: 'Transforming Aeroacoustics and NVH using Additive Manufacturing'; 'Aerospace 4.0: Adoption of Digital Capabilities in the Aerospace Supply Chain'; 'Laser Cleaning Applications in Industries'; 'New Manufacturing Techniques for Optimised 3D Multiaxial Orthogonal Preforms'; 'Recent Advances in Human Robot Collaborative Composites Manufacturing'; 'Additive Manufacturing for High Pressure Vessels'; 'Drone Operations to support Engineering'; 'Innovating Composite Tooling through the use of Applied AI'; 'Behind the Build: NPL's Show-stopping Fighter Robot'; 'Secure Wireless Data Transmission through Composites without any Wiring Harnesses or Fibre Optics'; 'High-tech Heat Exchangers for High-tech Electronics'; 'Embedding Electronics and Sensing Functionality into Composite Materials'; and 'How the latest Integrated Line and Multi-robot Control is redefining Picking and Packing Solutions'.

In addition to the above the Advanced Engineering Show Guide included 27 specialist Editorial Features, two of which are reviewed below.

Why Engineers need Lasers

This Feature, by The Association of Industrial Laser Users, explains how the advent of the high power fibre laser has made laser applications for material processing, such as 3D printing and laser engraving considerably more cost efficient in recent years:

'Laser sources are now more compact and efficient, requiring very little maintenance. Reliability is comparable with or better than many conventional manufacturing processes. With the advent of digital manufacturing using robotic or CNC machinery, the laser is a tool which is programmable, repeatable and versatile enough to be used both for automated manufacturing in a high production environment or for stand-alone use in a smaller company or more specialised situation.'

The AILU, which hosted the Laser Manufacturing Hub at Advanced Engineering, presents the case for greater use to be made for laser material processing throughout industry:

'A focused beam of light can be moved at very high speed by mirrors and lenses to achieve very high throughput and the non-contact nature of the laser makes fixturing more straightforward. Low power units for applications like laser etching or engraving can be air-cooled for easier installation, lower running costs and higher reliability. Lasers have the repeatability to provide consistent results - for example consistent penetration welding, marking with repeatable contrast and cutting without burrs or dross.'

The Feature focuses on four specific areas:

* From 3D CAD to Component in 24 hours.

* Laser Cutting

* Etching, Engraving and Marking

* Fast Joining

'Using lasers for 3D printing (also known as Additive Manufacturing) allows near net shape manufacturing for greater material efficiency. 3D printing can enable advanced designs for lightweight construction and part count reduction. Lasers enable this technology in metals (where the melting point is high - for plastics it is more commonly a non-laser solution).

Large systems with fibre lasers for cutting of metal are now commonplace. Whether flat bed sheet metal cutting or 3D profiling, the laser allows flexibility and convenience with ease of programming a variety of parts from a single sheet of material. In recent times the fibre laser has taken over from the CO2 laser. The latest high power fibre lasers are now capable of cutting thicker materials so there is now much less reason to buy CO2 lasers except for material choice (some materials like plastics and wood can only be cut with CO2 lasers).

Laser welding often replaces TIG and MIG welding where greater automation is required. With a lack of skilled manual welders and a need to automate the welding process, laser welding has progressed to the preferred method for many applications in automotive and aerospace manufacturing. Capable of welding most metals (including copper, aluminium, titanium and nickel alloys) the laser solution is fast and has low heat input. In some cases, transparent plastics can also be joined to make hermetically sealed assemblies (for example in automotive under-bonnet electronics).'

The Association of Industrial Laser Users is based at Oxford House, 100 Ock Street, Abingdon, Oxfordshire OX14 5DH. Email: info@ailu.org.uk

The Flexible Form Electronic Future

This contribution from independent technology and innovation centre CPI highlights printable electronics as an enabling technology that is delivering new and hybrid electronic applications that incorporate the functional benefits of flexible electronics as well as the efficiency and durability of traditional electronics:

'The Internet of Things represents an evolution in which objects are capable of interacting with other objects. Printable electronics is aligned with this emerging technology through the opportunities that the printing of electronic functionality and sensing brings to applications. The printing of electronic functionality opens up a host of design opportunities and will lead to the creation of a range of future electronic applications in key market sectors, such as print and packaging, healthcare, built environment, automotive and aerospace.

Printed electronics is a complementary technology to traditional silicon-based electronics. The thin and bendable nature of printed electronics means that technology will be able to provide sensing to new geometries and design areas in the way components are made and assess in operation. Integrating electronics with flexible form factors increases the freedom for product designers to embed technology into their designs, creating the opportunity for new innovative components that are wireless, smarter, interactive, conformable, thinner, lightweight, rugged and able to blend into our surrounding environment.

Embedding sensors into materials, machines and surfaces provides the ability to assess real-time information on parameters such as strain, temperature, corrosion, pressure and humidity. Using printed electronics for sensors also means that sensing can be produced using large area roll to roll printing methods, providing the opportunity for cost-effective production methods for bespoke sensing designs.'

CPI introduces its state-of-the-art printed electronics centre in Newton Aycliffe, County Durham, which has the capacity to create rolls of thin, flexible inlays containing multiple electronic components that can be converted into labels or embedded into smart products or wearable goods:

'CPI has worked with Silent Sensors on a new product development programme to improve existing antennae designs and incorporate printed sensors into the tyre-making process and supply chain. UK-based Silent Sensors' technology tracks and manages tyre performance from the manufacturing process through to the supply chain and the road, with data collected in the cloud and presented on the driver's dashboard or as warnings to the driver on the road.

CPI has also supported the expansion of PragmatiC, a world-leader in ultra-low cost flexible electronics with the potential to enable trillions of "smart objects" that can sense and communicate with their environment. PragmatiC's unique technology platform facilitates flexible integrated circuits (flexICs) thinner than a human hair and easily embedded into any surface, thus introducing interactivity into a range of everyday items.'

CPI is based at the Neville Hamlin Building, Thomas Wright Way, Sedgefield TS21 3FG and may be contacted on 01740 625 700. Email: info@uk-cpi.com

NEW SEMICONDUCTOR TECHNOLOGIES IMPROVE EFFICIENCY OF ELECTRIC POWERTRAINS

Most power systems for electromobility use semiconductor devices built using a silicon process, but new techniques are now emerging that provide higher efficiency and so dissipate less heat, making such systems either smaller or more powerful for the same size.

In *E-Mobility Engineering* (Vol.1, No.1, October 2018) in the article 'Band Members' (p.52-56), Nick Flaherty contrasts metal oxide semiconductor field effect transistors (MOSFETs) with the more powerful insulated gate bipolar transistors (IGBTs), noting that with a bandgap of 1.1eV both are used in half and full bridge converter topologies at frequencies of up to 50kHz with efficiencies of around 85 per cent. Both of these established technologies, however, struggle with megahertz-level operation and voltages of 600-1800V that permit higher efficiency to be achieved.

In order to attain this MOSFETs and IGBTs are now being replaced with devices that use wide bandgap materials in order to increase the typical DC-DC converter efficiency from 85 per cent to 95 per cent, or else increase typical DC-AC inverter efficiency from 96 per cent to 99 per cent.

The wide bandgap materials discussed are silicon carbide (SiC) and gallium nitride (GaN):

'A 1200V planar Schottky diode built in SiC has a total capacitive charge (Qc) that is small (65nC), reducing switching losses and enabling faster operation. This has led to charger designs that are a tenth of the size and weight of those based on silicon devices and with an efficiency of 97 per cent.'

Silicon carbide is noted for its constant switching time and the fact that it does not vary with temperature, allowing for a smaller design margin for varying temperatures, making the devices suitable for the inverters in electric vehicles.

The article quotes Mario Aleo, Group Vice-president of ST Microelectronics and General Manager of its Power Transistor Division as follows:

"Major car makers and automotive Tier 1 suppliers are now committing to silicon carbide technology for future product development because of its higher aggregate efficiency compared to standard silicon in a wide range of operating scenarios."

New power conversion topologies such as totem-pole power factor correction, a design for the front end of a power system that can provide efficiencies as high as 99.2 per cent, are also enabled:

'Using silicon MOSFETs would require 14 separate devices and a highly complex controller. Using a SiC or GaN wide bandgap device, however, they can be implemented using only four transistors and a much simpler control.'

Gallium nitride, by contrast, offers even faster switching than SiC owing to higher electron mobility, but has a much lower thermal conductivity, which limits its power density. It has, however, been popular for some time in the wireless market, and new versions of the technology are being adopted in power designs:

'Lateral GaN transistors are built with horizontal rather than vertical junctions, and have improved switching characteristics over vertical silicon transistors, but are comparable to silicon super-junction MOSFETs in terms of the conduction losses per unit semiconductor

area. However, new device structures using the enhancement mode of GaN have allowed higher performance by eliminating the bulk capacitance.

650V GaN transistors built on a silicon substrate allow for higher currents and voltage breakdowns than SiC or silicon, leading to switching frequencies of more than 100 MHz. These new transistor layouts boost the high-current die performance and the yield, which are key factors for electromobility designs.

GaN technology is evolving, with the third generation of 650V devices providing greater immunity to gate noise (up from 2.1 to 4V), giving more headroom in circuit design applications.'

The article highlights research at Fraunhofer IAF, where a fully integrated monolithic converter using high-voltage AlGaN/GaN-on-Si technology has been developed:

'The integrated converter circuit is designed for a maximum voltage of plus or minus 400V and a current of 5A, and is built from four transistors and six diodes.

Packaging the die was a key consideration for the converter. If lateral components are used, the source drain and gate pads are on one side and the back of the die is used for heat dissipation.

The conventional approach of using wires to connect the die to the circuit boards restricts the overall performance of the design, so instead an embedded substrate technology from AT and S was used with the power devices embedded into the PCB material and connected from both sides.

The chips are connected directly via low-impedance copper-plated connections, or microvias, that significantly lower the inductance compared with wire bond technology. The rear of the die is also connected by means of copper-plated microvias to improve heat dissipation.'

The article quotes Fraunhofer IAF researcher Richard Reiner as follows:

"We see this mounting technology as opening up entirely new possibilities - particularly for more complex monolithic integrated GaN power circuits, as used on our multi-level converter chip. With a conventional design, we were hardly able to use and/or evaluate the power chip."

CENTRALISED CONDITION-BASED MAINTENANCE MODEL FOR ROTATING MACHINES

Vibration-based condition monitoring of rotating machines is used to identify machine faults at an early stage, but it is heavily reliant on the experience of the person involved in the fault identification process.

In *The Essential Guide to Maintenance Management*, 2018-2019, p.16-17, in the article with the above title, Jyoti Sinha and Natalia Espinoza from the University of Manchester explain how the Internet of Things (IoT) and Industry 4.0 are helping to drive change:

'Through the development of an artificial intelligence model that incorporates all relevant methods, skills, tools experience etc. in a "big data bank" gathered over a period of time, the machine learning model can identify machine faults at an early stage and propose appropriate action without involvement of any individuals and/or group within the industry. A similar example is a driverless car.

The model developed for a machine can then be adapted to other machines to create a centralised VCM model. This leads to a centralised CBM (CCBM) approach throughout the IoT application.'

The success of the CCBM is, however, completely reliant on the robustness of the developed supervised machine learning model when applying to other identical machines around the globe:

'For this study measured vibration data from different machine conditions (healthy and faulty) from a rotating rig in the Dynamics Laboratory at the University of Manchester were used. The rotating rig consists of two shafts connected by a rigid coupling and supported through four ball bearings mounted on flexible foundations. The driven shaft is connected to a three-phase electric motor through flexible coupling. The rotor has two balancing disks on the longer shaft and one balancing disk on the smaller shaft. Four accelerometers (an accelerometer per bearing pedestal at 45 degrees from the vertical axis) were used to measure the rig vibration.

The measured vibration data from the rig at two rotating speeds - 1800RPM (30Hz) and 2400RPM (40Hz) - were considered for the five rig conditions: Healthy, shaft misalignment, bearing foundation looseness, shaft bow and shaft rub. The conditions, other than the healthy condition, are machine faulty conditions which need to be identified at an early stage so that remedial maintenance can be carried out before machine failure occurs.

An artificial neural network method was used to develop the machine learning model for the identification of different faults on the rig.'

The developed machine learning model for the rig at the rotating speed of 1800RPM was blindly applied to the rig data at 2400RPM (a different operating condition) without any training at 2400RPM, and it was found that the model predicted the machine conditions correctly in two categories, 100 per cent healthy machine condition, plus, for the remaining conditions, 100 per cent machine faulty condition.

The authors concluded that 'the classification in two categories (healthy and faulty) on the blind application is useful information for plant maintenance' with the results 'very encouraging for the future development of the CCBM using IoT/Industry 4.0.'

They state:

'The possibility of Centralised Condition-based Maintenance using the concept of Internet of Things/Industry 4.0 has been explored. The Vibration-based condition monitoring (VCM) study is conducted on a laboratory -scaled rotating rig for this purpose. The knowledge-based machine learning model is developed based on a VCM approach to predict machine

defects/faults using the artificial neural network method. The blind application of the developed machine learning model shows encouraging results and provides the potential hope for the future CCBM approach based on the VCM for the commonly used rotating machines in industries around the globe.'

WIRELESS CONDITION-BASED MONITORING IN THE RAIL SECTOR

Maintenance in the railway industry has traditionally been achieved by servicing trains on a time or mileage basis, but this method does not take account of whether parts actually do need replacing, and is not entirely effective in eliminating breakdowns.

In order to improve this SKF has developed a wireless condition-based monitoring system specifically for the rail sector. Known as SKF Insight, it involves retrofitting a small sensor onto the wheelset axle-box assembly of the train in order to detect bearing damage. This picks up tiny inconsistencies in the vibration of a bearing suggesting that failure is imminent, even though it is in an environment that is awash with noise and other vibrations.

Advanced signal processing and algorithms separate the signal from the noise, ensuring that each sensor produces accurate data for further analysis.

Each of the wireless sensor nodes has an array of different sensors and is capable of taking several different measurements relating to the health of the bearing. Acceleration Enveloping, an established vibration measurement technique, is then used to provide early indication of bearing damage. A standard acceleration vibration measurement is band-pass filtered, rectified and finally enveloped.

Advanced processing and trending of the signal is then performed, which not only detects the presence of damage, but also determines which bearing component is damaged. Temperature data complements vibration data, and an automatic alarm indicates when action is needed. Experts can then check the output and produce a report which may, for example, recommend a planned replacement of a bearing.

[Reference: Pye, A., 'New Techniques moving Maintenance forward', *The Essential Guide to Maintenance Management*, 2018-2019, p.8-9].

WORLD'S FIRST NON-CONTACT MOTION AMPLIFICATION PLATFORM

RDI Technologies have launched the world's first non-contact motion amplification platform, the Iris M, which allows users to see in real-time motion that is invisible to the human eye.

It uses a patented Motion Amplification™ technique to monitor critical manufacturing operations, processes and structural components that affect plant reliability and productivity. It works by detecting subtle motion, which is amplified to a level at which it becomes visible to the naked eye. By turning every pixel in the camera into a sensor, millions of measurements are obtained in a fraction of a second without any physical connection being required to any machinery or equipment.

This technique enables users to make instant decisions about manufacturing operations based on real data. Fault types that can be visualised include:

* Piping vibration.

* Reciprocating engine and compressor motion.

* Unbalance.

* Misalignment.

* Soft foot.

* Structural looseness.

*Resonance.

*Structural cracks.

* Duct and vessel wall deflections.

* Structure stiffness and support.

* Torsional twisting, bending and flexing.

* Excessive transient loading.

* Ineffective damping.

* Vibrating screen motion analysis.

* Oscillating motion analysis.

* Cavitation, hydraulic and aerodynamic forces.

* Drive transmission faults, bells, chains, couplings and carolan shafts.

More information may be obtained from Advanced Engineering exhibitor Reliability Maintenance Solutions Limited on 01206 791 917. Email: info@motionamplification.co.uk

AUTONOMOUS MOBILE ROBOT PILOTED AT AIRBUS

An autonomous mobile robot is currently undergoing trials at the Airbus wing factory in Broughton. Developed as part of a Government-funded collaborative research project, the AMR is a computer-guided vehicle that handles and transports small aircraft components and assembly tools around the factory. It incorporates smart navigation technology that allows it to develop real-time awareness of its surroundings, and build a real-time 3D picture of the environment with laser scanners and a pair of cameras that are able to detect low-level and overhanging obstacles. A complex set of algorithms calculates and negotiates a safe route around pre-programmed positions.

NEW SOFTWARE TO EVALUATE ALTERNATIVE RADAR INTEGRATION SCENARIOS IN AUTONOMOUS VEHICLES

The packaging design of radar systems for autonomous vehicles needs to be conducted early in the vehicle development process before a prototype vehicle is available for performance testing. If engineers get the design wrong the packaging process may have to be repeated at a cost of around $1 million, not to mention delay to the launch of the vehicle.

In order to avoid these costs Autoliv, worldwide leader in automotive safety systems, has developed ANSYS HFSS electromagnetic field simulation software to evaluate alternative radar integration scenarios early in the development process. This enables prediction of how the fascia and other nearby components affect radiation patterns, enabling the design to be validated well before the prototype phase.

The article 'On the Radar' by Clive Callewaert, Principal RF Engineer for Autoliv Electronics in *Ansys Advantage* Issue 1 2018, p. 24-27, explains more:

'Radar systems use a transmitter to emit a short pulse of electromagnetic radiation. After each pulse, the transmitter is turned off and a receiver listens for signals caused by the pulse reflecting off nearby objects. Electromagnetic radiation emitted by a radar sensor may be distorted in difficult-to-predict ways by objects that the radiation must pass through. Other nearby objects may generate reflections that interfere with the receiver.

When integrating a radar sensor in a new vehicle, engineers must position the system so that the fascia and mounting bracket do not interfere with its accuracy. This means obtaining a high and relatively constant signal across the azimuth (from side to side) of the sensor while minimising wasted energy delivered to undesired directions or reflected by the bumper fascia back to the radar. The geometry of the bumper fascia is often complex because it has to meet multiple goals that include durability, safety, aesthetics and manufacturability. A slight change in sensor position can be the difference between meeting or not meeting accuracy requirements.

The simulation process begins by obtaining physical samples of the bracket and fascia materials to determine their electrical properties, which are required to run accurate electromagnetic simulations, using either waveguide or quasi-optical techniques. The measured electrical properties include the dielectric constant and loss tangent of the fascia, paint layer and bracket.

Autoliv engineers use a computer-aided design (CAD) file from the automobile's original equipment manufacturer (OEM) that contains the current geometry of the bracket, fascia and other nearby components. ANSYS SpaceClaim is used to translate and prepare the CAD for HFSS import and meshing improvement. They truncate the fascia in the simulation model to both conserve computational resources and preserve electromagnetic fidelity. Engineers have already created ANSYS HFSS models of all of the company's current radar systems.

The simulation results are post-processed in HFSS and exported into a custom MATLAB program that mimics the algorithm used by the radar sensor to evaluate radar performance including signal-to-noise ratio, field of view, bearing bias and bearing ambiguity. It allows engineers to determine, for example, the maximum distance at which the radar can detect an object with a given radar cross section at a given azimuth angle, such as an oncoming motorcycle in the next lane at a distance of 30 metres.

If predicted performance does not meet minimum requirements, geometrical countermeasures are necessary, such as relocating the radar, and then the simulation process repeats. The geometry of the fascia is also likely to change during the design process, but when changes occur Autoliv engineers obtain the new geometry, run their simulations again and, when necessary, modify their design.'

NEW 3D PRINTED IMAGER FOR UAVs

Researchers at the University of Norway have applied 3D printing to create a new low-cost hyperspectral imager for use on unmanned aerial vehicles.

Each pixel of a hyperspectral image contains information that covers the entire visible spectrum, providing data that can be used to measure such variables as ocean colour (for example to map harmful algae blooms), or to monitor crops. Traditional imagers, however, are expensive and heavy to build.

In *Unmanned Systems Technology* (April/May 2018) in the article '3D-printed Budget Imager' (p.12) Nick Flaherty describes how the new imager, which weighs under 200 grams and costs less than $700, was developed:

'The imager uses a push-broom technique with a diffraction grating and a line scanning architecture to build up a spectral image. This needed a stabilisation system so that any UAV movement would not distort the image as it was being generated.

The researchers made four prototypes with different sensors ranging from a colour CCD video camera head from Sony, a CamOne Infinity action camera head, to two monochrome industrial CMOS image sensors.

The main differences between the prototypes are the type of detectors and how they are mounted onto the grating housing.

The imager was tested with a two-axis electronic stabilising system on an octocopter, and was able to detect landscape features such as vegetation and bodies of water.

The tests showed that 3D-printing is accurate enough to produce prototype parts for optical systems. After testing, metal versions of 3D-printed parts could be ordered if desired to create imagers that would be more durable.'

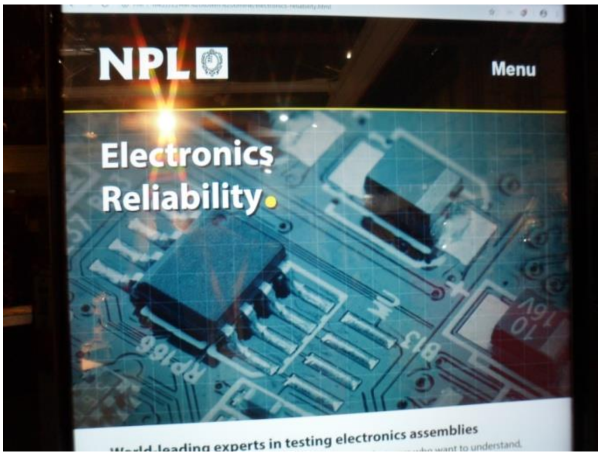
The article quotes research team leader Fred Sigernes of the University Centre in Svalbard as follows:

"Our instrument can be used very effectively on an unmanned vehicle to acquire spectral images.

Making items in metal is time-consuming and can be very expensive. However, 3D-printing with plastic is inexpensive and very effective for making even complex parts, such as the piece needed to hold the grating that disperses the light. We were able to print several versions and try them out.

Push-broom hyperspectral imagers typically require expensive orientation stabilisation, however, you can now buy inexpensive gyroscope-based, electronically stabilising systems. That made it possible for us to build our imager."

INNOVATION IN PHOTONICS: A DIODE MADE OF LIGHT



An optical version of a diode, which transmits light in one direction only, has been pioneered by The National Physical Laboratory.

In their publication *Insights beyond Measurement*, Issue 2, Spring 2018 (p.27), Principal Research Scientist Pascal Del'Haye, explains the development:

'To create an optical version of a diode we used microrings that can store extremely large amounts of light. The circulating power of the small amount of light we sent into these glass rings is comparable to the light generated by the floodlights in a whole football stadium - but confined into a device smaller than a human hair. The light intensities enable the formation of a diode via a light-with-light interaction called the Kerr effect.

Using microresonators in this way is a much smaller, lighter and more practical way of making light travel in only one direction whilst addressing a major challenge for photonics researchers - to produce diodes that don't require large, bulky magnets.

These diodes will, for the first time, open the door to cheap and efficient optical diodes on microphotonic chips, and will pave the way for novel types of integrated photonic circuits which could be used for optical computing.

They could also have significant impact on future optical telecommunication systems for more efficient use of telecom networks.'

The National Physical Laboratory was an exhibitor at Advanced Engineering and is based at Hampton Road, Teddington, Middlesex TW11 0LW.

BREAKTHROUGH IN CATHODE TECHNOLOGY

A standard cathode for a lithium-sulphur cell is typically made by mixing sulphur particles with electrically conductive carbon black, which is intended to improve its ability to carry the flow of current. Unfortunately, however, there is frequently poor electrical contact between the non-conducting sulphur particles and the electro-conductive carbon material, which can result in the sulphur separating from the cathode as the battery is cycled.

In order to address this problem Oxis Energy Limited has developed a cathode made from a mixture of particulates containing a composite of electro-active sulphur-containing material and electro-conductive carbon filled with conductive carbon filler particles dispersed in the composite structure. The electro-conductive material may be in the form of carbon nanotubes, graphene or carbon nanofibres.

In the special Advanced Engineering supplement to *Materials World*, Dr. Jennifer Unsworth, Patent Attorney for the intellectual property law firm Withers and Rogers, explains the ground-breaking technology in her article 'Feel the Buzz':

'Sulphur-containing material is first melt bonded to electro-conductive carbon. Melt bonding is a manufacturing process where the electro-conductive carbon is kneaded into a molten pool of electro-active sulphur material in a co-kneader or a twin-screw extruder. This type of appliance has not previously been used for this purpose, due to significant difficulties in maintaining rheological properties of the sulphur component above 140 degrees Centigrade.

The inventors have found that melt bonding or melt compounding facilitates better electrical contact between the constituents, which gives sulphur easier access to chemical reactions. Another advantage is that the electro-conductive carbon is well dispersed in the sulphur-based matrix, providing more efficient transfer of electricity from the current collector and an active interface for electrochemical reactions to occur.

It has been demonstrated that battery cells including cathodes that comprise, by weight, 76 per cent sulphur, 11 per cent carbon fibre nanotubes, 11 per cent carbon black and 2 per cent gelatine, lose only 20 per cent of the initial capacity after 80 charge-discharge cycles. This is a significant improvement over the existing lithium-sulphur cell systems.'

GOVERNMENT TO INVEST £86 MILLION IN NATIONAL FUSION TECHNOLOGY PLATFORM

The Government has announced that it is to provide an £86 million grant to support the building and operation of a National Fusion Technology Platform at Culham in Oxfordshire, which will enhance the UK's expertise in critical areas of fusion research as part of the Government's Industrial Strategy.

The National Fusion Technology Platform will incorporate two new centres of excellence, namely the Hydrogen-3 Advanced Technology Centre (H3AT) and the Fusion Technology Facilities Centre (FTF). The H3AT will conduct research into the processing and storage of tritium (Hydrogen 3), which will power future commercial fusion reactors, whilst FTF will conduct thermal, mechanical, hydraulic and electromagnetic tests on prototype components under the conditions experienced inside fusion reactors.

Ian Chapman, Chief Executive Officer for the UK Atomic Energy Authority, states:

"Fusion is entering the delivery era, with an increasing focus on the key technologies that will be needed for the first power stations. The National Fusion Technology Platform will help British industry to maximise growth from opportunities provided by ITER. In the longer term it means that the UK will be at the forefront of developing fusion and bringing cleaner energy to the world."

One of the key tools of the Platform will be to support UK industry to win contracts from ITER, which is currently under construction in Southern France. ITER anticipates a $20 billion capital spend with at least $1 billion on tritium-related issues.

Further Information

The UK Atomic Energy Authority was an exhibitor at Advanced Engineering and further information on this subject may be obtained from the UK Atomic Energy Authority, Culham Science Centre, Abingdon, Oxfordshire OX14 3DB. Telephone: 01235 528 822.

LAB INNOVATIONS

Co-located with Advanced Engineering was the seventh annual Lab Innovations exhibition and conference, representing the largest single gathering of laboratory manufacturers and suppliers in the UK. There were around 135 exhibitors and 42 presentations.

Key features of the exhibition included:

* The Royal Society of Chemistry Theatre.

* The Live Lab Zone (featuring quick fire demonstrations and presentations on the latest lab innovations).

* The Sustainability Lab (a new feature for 2018 showcasing environmental products and initiatives).

* The Insights and Innovation Theatre.

* The Cleanroom Hub (new for 2018 and dedicated to cleanroom solutions with specialist companies and speakers in association with Cleanroom Technology).

* The SelectScience Seal of Quality Awards (new for 2018).

* Lab News Village (new for 2018 and providing an opportunity to meet companies that had not previously exhibited at the event).

* The SLS Pavilion (a special feature dedicated to the UK's largest independent supplier of laboratory equipment, chemicals and consumables).

Presentations included 'The Digital Future of Science'; 'Burning Rubber: How Renault Formula 1 use Thermal Analysis for Advanced Composite and Adhesive Studies'; 'Small and Mighty: Rethinking Mass Spectrometry'; 'A Smart Lab Revolution is saving Energy, Money and helping Science'; 'Automated vs Manual Laboratory Washing Principles'; 'Automated Verification of the Performance and Minimum Weight of a Balance in your Laboratory without using Weights'; and 'Duetta 2 in 1 Combined Fluorescence and Absorbance Spectrometer'.

ARTIFICIAL INTELLIGENCE AIDS SCIENTIFIC RESEARCH

Every year some 2.5 million scientific articles are published (one every twelve seconds) and as a result modern researchers are struggling to keep up with the wealth of data available. In order to help alleviate some of the difficulty medical charity LifeArc partnered with science software specialists SciBite to develop a pioneering machine learning process that significantly reduces the burden of the data mining process.

The article 'May AI help you with that' in *Laboratory News* (July/August 2018), p.26-27, explains how data mining and horizon scanning have become increasingly difficult for researchers, espacially in the life science industry where innovation and progress is essential for ensuring that medicines and technologies continue to evolve to meet patient needs:

'The team at LifeArc is constantly on the lookout to gain early insights and uncover a wealth of information regarding novel technologies, new drug targets, biomarkers and rare disease connections. Analysts can spend multiple hours per day sifting through publications on PubMed, as well as publicly available grant information and a range of biotech-focused news websites in an attempt to identify articles of interest amongst the background "noise". Manually searching different sources with multiple keywords or phrases is resource intensive and means initial stages of research could only be performed at a restricted frequency and with a limited depth of review.'

A pilot study was therefore set up to:

(a) Align multiple unstructured scientific information sources including publications, news feeds and clinical trial records and create a richly annotated index of connected data.

(b) Search and analyse data to identify research findings which could inform novel drug, diagnostic and medical technology discoveries.

Semi-automated software was used that combined artificial intelligence approaches, with semantic searching and machine learning being deployed to sift through tens of millions of documents to identify genes, diseases, devices and other scientific concepts.

The article states:

'Working together with LifeArc, SciBite manually curated a library comprising tens of millions of synonyms tailored specifically to LifeArc's internal vocabularies, such as compound identities and study codes. This provided the foundation for automated pre-processing and what they call "semantic enrichment" - and it was these two things that allowed the team to attain the high quality, contextualised data necessary for machine learning to be effective.'

Neil Dunkinson, Head of Technical Sales at SciBite, is quoted as follows:

"The technology is designed to reduce the time spent mining data by up to 80 per cent, providing researchers with a subset of scientifically relevant information filtered from the vast amounts of raw data in a rapid, easy-to-interpret manner, allowing them to focus and accelerate their research. We want more and more of the hidden knowledge in scientific content to be unlocked by simple services provided by our platform, helping application developers and informatics professionals build even more intelligent systems."

The technology has been tested in the field of rare diseases, which affects around one in twenty people worldwide:

'The fact that some rare diseases share similar phenotypes with common, well-understood conditions forms the basis of an inference-led approach to understanding them. However, evidence of disease similarity is often hidden within unstructured biomedical literature. Any chance of identifying relevant links would require a time-consuming and costly review process.

The technology developed by SciBite includes a method which quantifies disease similarities identified within biomedical literature based on their phenotypes. As a first step, semantic analytics is used to extract co-occurring pairs of conditions and clinical signs from over 25 million MEDLINE abstracts. Machine learning algorithms are then used to rank these relationships and predict how scientifically significant they are, for example based on how often the diseases co-occur compared to how often they appear independently. The resulting information is subsequently used to create a knowledge graph representing the strength of connectivity between diseases based on shared phenotypes or "phenotype signatures". Where there is strong overlap in phenotype signatures, it can be hypothesised that a disease pair could share an underlying mechanistic relationship and use this to classify poorly characterised diseases.

The approach can be extended even further by including additional data sources such as gene association data and protein-protein interaction data to go beyond phenotypes and classify diseases based on richer signatures comprised of genomic, proteonic and phenotypic information.'

CMOS SENSOR TECHNOLOGY REVOLUTIONISES PARTICLE FALLOUT MONITORING IN CLEANROOM ENVIRONMENTS

Monitoring of temperature, humidity and airborne particle counts is frequently performed in cleanrooms with laser particle counters often being deployed to detect airborne particles as small as 0.5µm. Less well addressed, however, is particle fallout (PFO), which occurs when larger particles are generated and trip out of the atmosphere onto surfaces. Unlike airborne particles, these generally larger particles do not stay aloft in air currents and are therefore not picked up by conventional airborne particle sensors. This PFO is a problem, particularly in the semiconductor and optical industries.

The conventional method of monitoring PFO is through the use of witness plates where, for example, silicon wafers are left in strategic locations to collect particle fallout and then taken to a monitoring site where an optical system is used to physically count the number of particles. With this method the time between samples may be weeks or months, long after the events that have led to the PFO.

More recently instruments have been produced that measure particle deposition in real-time, but so far these have been limited to the detection of particles over 25µm in size, leaving many smaller particles undetected.

In *Cleanroom Technology* (November 2018) in the article 'Real-time Particle Fallout Monitoring: Challenges and Solutions' (p.22-23) Andrew Holland, Chief Technical Officer for XCAM, discusses how his company has applied CMOS image sensing technology to create a device that overcomes the problem by monitoring the shadows of particles being detected on CMOS image sensors.

The author states:

'The new PFO 1040 unit uses four CMOS sensors, each with an area greater than 1 square centimetre; it can provide a measurement with a high cadence, with a sampling frequency down to 1 minute, to track the accumulation of particles. In routine use, we typically use a

sampling period of around every 1 to 4 minutes, providing virtually real-time monitoring of the status of particles that have fallen onto the sensor.

At XCAM we believe that the new PFO 1040 will be a great asset to the monitoring of laboratories and clean environments, particularly where high-value sensitive processes are being conducted and will lead to improvements in quality standards in the industry.'

THE CHAMELEON AND THE CRYSTAL MAZE

This intriguing article by Danqing Wang and Teri W. Odom in the September 2018 issue of Laboratory News (p.24-25) looks at how the chameleon's ability to change colour by controlling the spacing between periodic nanocrystals in its skin has been replicated to develop a laser that is capable of changing colour in a similar way. The authors, both from Northwestern University, USA, believe that mechanically tunable lasers of this kind could enable advances in responsive optical displays, wearable photonic devices and ultra-sensitive strain sensors:

'Researchers have recently discovered that panther chameleons can change their colour by active tuning of spacings in a lattice of guanine nanocrystals on their skin. The periodic lattices function as photonic crystals - dielectric nanostructures with ordered refractive index variation - to control the light flow. Certain wavelengths of light associated with the lattice spacings can be reflected from the nanocrystals, while others are forbidden, which determines the colours we perceive in the eyes.

Chameleons manifest colour skin change from green to yellow or orange from the resting state to the excited state. At the same time, distance among guanine crystals increases to about 40 per cent, which causes shifting of selective reflectivity from short (blue, green) to long wavelengths (orange, red). Further straining the elastic skin could enable colour changes over the entire visible range. This colour change occurs within a couple of minutes and is fully reversible, and can inspire diverse applications in photonic displays, optical communications and on-chip circuits.'

Recent advances in nanofabrication have enabled unconventional material architectures to be achieved at the nanoscale, and the engineering of nanostructures can introduce new physical properties that are unavailable in conventional devices. Mechanical control of the lasing colour has subsequently been achieved by exploiting a lasing cavity based on periodic arrays of nanoparticles in a stretchable polymer matrix:

'In previous work, by switching the liquid dye solution, we had demonstrated the first real-time tunable nanolaser. Here, stretching the substrate provides an alternative way without micro-fluid channels.

Large metal nanoparticles (around 260nm in diameter) arranged in a lattice (spacing 600nm) produce high-quality cavity modes with extremely narrow resonance linewidth (less than 5nm). In cases of uneven sample surfaces and defects in the lattice sharp and intense cavity resonance is still maintained. This new lasing mechanism enables stable high cavity mode quality upon stretching of the device, distinct from current laser designs.

Significantly, stretchable nanolasing from metal nanoparticle arrays induces a wavelength shift of 31nm for a 3 per cent increase of interparticle spacing, demonstrating a sensitivity around ten times higher than those based on photonic crystals in similar geometries. This improvement is attributed to the tuning of laser colours directly by small changes in the lattice spacing, while the microscale photonic cavities are less sensitive to nanoscale structural changes.

The device also harnesses plasmons - collective oscillations of conduction electrons - on the surface of gold nanoparticles. Thanks to these plasmon resonances, light can be confined to tiny regions smaller than half its wavelength (the diffraction limit), which is typically a challenge for conventional photonic devices.'

The stretchable nanolaser is also envisaged to have possibilities in optical displays such as those used in televisions and mobile phones:

'Current electronic screens can be easily broken, while the interaction with an elastic substrate enables a flexible device robust to deformation.'

A REAL FANTASTIC VOYAGE

Many readers may remember the science fiction epic *'The Fantastic Voyage'* in which a team of medics was miniaturised and injected into a human body to perform an operation. Now, if the people are replaced with nanorobots, the theory is closer to reality than many people think.

Scientists at the Centre for Nano Science and Engineering at the Indian Institute of Science in Bangalore have managed to demonstrate controlled maneuverability of nanomotors inside living cells. The paper 'Maneuverability of Magnetic Nanomotors inside living Cells' by Pal, M. et al in *Advanced Materials*, 2018, which forms the basis of the article 'A real Fantastic Voyage' by Malay Pal in the June 2018 issue of *Laboratory News*, explains the remarkable work being undertaken by Professor Ambarish Ghosh, who is leading this fascinating project.

The author states:

'Nanomotors are extremely small devices that can be maneuvered by remotely powering them using various sources such as magnetic, acoustic or optical fields. Cellular organelles - the cytoskeletal network and a host of biomolecules - make the cytoplasm of a cell a very crowded environment. A small machine voyaging through such a milieu is, in itself, a fantastic concept.

The precise control of nanomotors inside a human cell opens up exciting opportunities for biological applications. Delivery of cargo to intracellular locations, diagnosis by sensing molecules, and probing of the intracellular environment are just some of the interesting functions that a nanomotor can perform. The controlled motion of an internal probe in a living cell gives us the ability to deliver a cargo to specific organelles. The cell can be internally probed, at specific locations, to map the physical properties.'

The application of an acoustic field can detach cells from a substrate and can also cause stress to a cell, and for this reason magnetically driven nanomotors were preferred:

'We fabricated helical nanomotors of two sizes, 2.8µ long and 400nm wide, and 2.4µ long and 250nm wide, by using a technique called glancing angle deposition (GLAD). These helical nanomotors - which are made of magnetic materials - are taken up by the cells after incubating them together for a day in a a petri dish. Post incubation, fluorescently labelled HeLa cells (a cervical cancer cell line) were imaged with a confocal microscope and a 3D reconstruction of the cell was made, wherein the motors were seen to be confined within the Z-plane of the cell.

A rotating magnetic field is generated by a triaxial Helmholz coil, built around an optical microscope, which drives the motors inside the cytoplasm, with precision. By application of magnetic fields of a magnitude as low as 80 Gauss, the motors were able to undergo rotation and net translation inside the cell. In some cases it was seen that the motors responded to the field with rotation in place with no net translation. This loss of response, though initially thought to be caused by damage to the magnetic layer, was later found to be because of their size and tendency to stick to the intracellular milieu. The smaller nanomotors were found to be more compatible with the porosity of the cytoskeletal network, and thus were more responsive in a larger number.'

Motion of nanomotors was also observed in Bovine Aortic Endothelial cells (BAEC) and Human Embryonic Kidney.

The author concludes:

'We believe that this technology could have a significant impact on medical interventions of the future. Because of the development of controlled propulsion in an intracellular environment, it is now possible to deliver payload to a predetermined site inside the cell. It has been shown previously (by Professor Ghosh's lab) that these nanomotors have the ability to trap, transport and release submicron particles with high precision and speed when integrated with plasmonics, a special kind of light matter interaction.

These tiny nanorobots, which can be maneuvered inside a living cell, hold great promise for future therapeutics. They have great potential for targeted drug delivery, as well as nano-sensing, and hence scientists are trying to use this technique as an alternative to conventional cancer treatment.'