Graphene Magazine is published by Future Markets, the world's leading publisher of market information on advanced materials and nanotechnology.
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NOTE FROM EDITOR

Graphene will provide significant benefits to a lot of industries in the coming years and it’s use is growing fast in the sporting goods and high performance sports textiles markets. Products are now available to purchase that utilize it’s thermal management capabilities, flexibility and strength. This has translated into significant performance benefits in professional sport and it’s use will continue to grow. Several of these products benefit from UK produced graphene. The industry has grown steadily in the last few years and it remains to be seen what effect Brexit will have on it’s continued development. Leading producers such as Versarein, Applied Materials and Haydale all have a large number of international collaboration agreements. We wish them and all graphene producers well in 2019.
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**SPORTING CHANCE WITH GRAPHENE**

The development of high value-added products such as smart fabrics, wearable consumer and medical devices and protective textiles has increased rapidly in the last decade. Advances in stimuli-responsive surfaces and interfaces, sensors and actuators, flexible electronics, nanocoatings and conductive nanomaterials has led to the development of a new generation of smart and adaptive electronic fibers, yarns and fabrics for application in textiles.

Graphene exhibits a unique combination of mechanical, thermal, electronic and optical properties that provide opportunities for new innovation in sports textiles.

**Sports composites**

UK-based graphene producer Versarien collaborated with Bromley Technologies Ltd to create a bronze medal winning skeleton sled for British Olympian Dominic Parsons. The X22 sleds incorporate graphene in composites to improve the structural properties while significantly reducing aerodynamic drag.

In August 2018, the company also signed an agreement with a global sports and fashion goods manufacturer. The collaboration will see both parties working on a number of projects involving the incorporation of Versarien’s proprietary Nanene few
layer graphene nano-platelets into polymer, leather, elastomer and textile structures.

In particular, the collaboration will aim to provide improved footwear and textile solutions aimed at the amateur and professional football sector. Neill Ricketts, CEO of Versarien, commented “The sports goods sector is fast moving and very open to the rapid adoption of new technologies. It is therefore a sector of significant focus for Versarien to enable a near term route to market for our high quality graphene. In entering into this collaboration with a globally renowned name in the football kit sector we are again ensuring we are developing a partnership with a leading company in its field.”


Smart sporting textiles
Versarien subsidiary Cambridge Graphene has an agreement with an unnamed Asian textiles manufacturer to supply graphene ink for smart sports apparel. The incorporation of graphene ink in fabrics, is used for conductivity and flexibility. Graphene inks can be inkjet printed directly onto fabrics to produce integrated electronic circuits that are comfortable to wear.

University of Manchester’s National Graphene Institute has produced a dress in collaboration with wearable technology company Cute Circuit. The use of graphene caused the dress to change colour according to the wearer’s breathing patterns.

The National Graphene Institute’s colour-changing graphene dress (image: Drapers).

Colmar graphene-enhanced ski jacket.

Graphene skiwear
Italian graphene producer Directa Plus has several product collaborations with textile and apparel manufacturers, incorporating the company’s Graphene Plus (G+) product:
Colmar: ski jackets and trousers. The company has 31 graphene-enhanced garments in its Ski Winter 2018/19 collection. The key benefit of incorporating G+ is that it enables the fabric to act as a filter between the body and the external environment, thereby ensuring the ideal temperature for the wearer.

Due to the thermal conductive properties of graphene, the warmth produced by the human body is preserved and distributed evenly in cold climates, yet dispersed in warm climates, and allows an even body temperature during physical activity.

Directa and Colmar developed graphene-enhanced ski outfits that the French national ski team wore in winning the 2016 FIS Alpine-Ski World Cup.

Eurojersey: Sensitive Fabrics. The collection of high quality, warp-knit technical fabrics are designed for high performance targeting the sportswear, athleisure and underwear sectors.

Oakley, in collaboration with Bioracer: G+ Graphene Aero Jersey to dissipate heat from the rider’s body. Directa Plus’ printed G+ planar thermal circuit distributes the heat generated by the body and dissipates it when needed to improve the comfort of the wearer and enable riders to use less energy to regulate their body temperature. Fabrics treated with G+ are also electrostatic and bacteriostatic. These properties contribute to moisture management and have an anti-odor effect. and, if placed on the outside of the garment, G+ reduces the friction with air and water to facilitate top sporting performance.

Deewear second-skin T-shirts and tights. D-One consists of three highly-performant technical layers: an inner layer coated in G+, an external layer of smart compress fabric and, in the advanced range, a middle layer that provides muscle articulation and postural support. The collection includes short sleeve t-shirts and leggings.

When used in fabrics, G+ technology can disperse excess body heat in warm climates and conserve body heat in cold temperatures. The fabric dries rapidly and prevents the spread of bacteria and unpleasant odours.

Graphene sports shoes

Japan-based sportswear company Descente Ltd. has produced athletic shoes using graphene. The sports shoes are sold globally through its British subsidiary, inov-8, under its G-Series brand.

Graphene has been mixed with rubber to create a sole that is 50% stronger and more durable than ordinary training shoes, according to researchers at
the UK’s University of Manchester, who worked on the development.

Laboratory tests at its National Graphene Institute have shown that the graphene-integrated rubber outsoles of these shoes are stronger, achieve more stretch, and are more resistant to wear, according to the company.

In December 2018, the company launched ROCLITE hiking boots incorporating graphene. The outsoles are 50% stronger, 50% more elastic and 50% harder wearing than the most commonly used materials.

Michael Price, inov-8 product and marketing director, said: “Working with the National Graphene Institute at The University of Manchester, we’ve been able to develop rubber outsoles that deliver the world’s toughest grip. “The hiking and outdoor footwear market has been stagnant for many years and crying out for innovation. We’ve brought a fresh approach and new ideas, launching products that will allow hikers, fast-packers and outdoor adventurers to get more miles out of their boots, no matter how gnarly the terrain.”

In recent news an international team of scientists, led by Professor Monica Craciun from the University of Exeter Engineering department, has developed a new technique using graphene to create fully electronic fibres that can be incorporated into the production of everyday clothing (https://www.nature.com/articles/s41528-018-0040-2).

Further information
The Global Market for Graphene to 2030
Published September 2018 by Future Markets, Inc. https://www.futuremarketsinc.com/graphene-market/
Graphene company **Zenyatta Ventures** has announced the closing a private placement which raised $3,000,000 Canadian dollars (~$2.2 million USD). The funds will be used for bulk sampling, environmental assessment and community engagement work on the Company’s Albany Graphite Project. The company also plans to enter an agreement with a large state-owned Chinese aerospace company. The companies to collaborate and ultimately enter into a strategic cooperation covering research, development and manufacturing in order to accelerate the industrialization and market for graphene and other Versarien 2D materials, including Hexotene, in the Chinese aerospace sector.

Water technology company **G2O** has received a £1.035 million investment in a round led by private equity firm Maven Capital Partners, and plans to sign collaborative partnerships with suppliers and enter global markets.
to expand customer reach. G2O’s graphene-based coatings technology provides highly efficient and cost-effective solutions to a broad range of filtration applications and critically can be used in conjunction with existing filtration membranes and systems. The technology has the potential to be used across multiple markets including the treatment of waste water in the oil & gas industry for oil and water separation, industrial & processed waste water treatment, domestic water filters, and desalination.

Building panels and Versarien’s Nanene will be used to develop graphene enhanced materials which will be used in structural composites. 2. Electric Vehicle applications - Versarien’s Graphinks will be used to add smart systems to a composite electric vehicle battery tray and Versarien’s Nanene will be used to improve the properties of the composite structure. The battery tray is being developed with automotive battery system manufacturers for use by global automotive OEMs.

NanoXplore has completed a private placement for total proceeds of $30,988,240 CAD (around $23.3 million USD). The Offering was conducted by a syndicate of underwriters led by National Bank Financial Inc. and including GMP Securities L.P., Paradigm Capital Inc., Echelon Wealth Partners Inc. and Beacon Securities Limited.

Haydale has secured £1 million of new working capital for the Group through a combination a new £750,000 16-month loan facility from the Development Bank of Wales (DBW) and the issue of £250,000 of new equity via a subscription with the Company.

Graphite India Ltd., the largest Indian maker of graphite electrodes used to melt scrap iron and steel, has purchased a 16% stake in US-based General Graphene Corporation for $18.6 million. General Graphene, based in Knoxville, Tennessee, has developed a proprietary technology which would allow them to produce large area, low cost graphene sheets in industrial volumes for commercial applications. Its applications include monitoring glucose, haemoglobin and cholesterol levels using bio-electric sensory devices, in which graphene offers high electrical conductivity, thinness and strength. “Graphene, with its unique properties of being the strongest, thinnest and lightest material known, is likely to open up new opportunities in high tech applications further driving efficiency and optimising costs”, said KK Bangur, chairman of Graphite India.
GRAPHENE
PRODUCT
NEWS
December 2018-January 2019
Low-cost, high volume production and ease of integration is crucial for the development of widespread application of graphene-enabled products. This month we look at new developments and breakthroughs.

**GRAPHENE PRODUCTS**

**Inov-8** has collaborated with **The University of Manchester** to create a pair of hiking boots which utilise graphene. Building on the success of its pioneering use of the material in trail running and fitness shoes last summer, Inov-8 is now bringing the technology to a market it considers to have been “starved of innovation”.

Two ROCLITE boots with graphene-enhanced rubber grip have been produced – the ROCLITE 335 and the ROCLITE 345 GTX. The former offers increased warmth on cold days, while the latter has waterproof GORE-TEX protection for hiking adventures in wet conditions. Michael Price, product and marketing director at Inov-8, said: “Working with the National Graphene Institute at The University of Manchester, we’ve been able to develop rubber outsoles that deliver the world’s toughest grip.

“The hiking and outdoor footwear market has been stagnant for many years and crying out for innovation. We’ve brought a fresh approach and new ideas, launching lightweight, fast-feel products with graphene that will allow hikers, fast-packers and outdoor adventurers.”

UK company **James Briggs Ltd** will launch a range of anti-corrosive vehicle paint primer using Applied Graphene Materials PLC materials in launch in the New Year. Extensive testing has demonstrated repeated and outstanding improvements in anti-corrosion performance for JBL’s automotive aerosol primer. The company will launch the range of graphene-enhanced anti-corrosion aerosols under their Hycote brand.

Researchers at **Monash University**, Australia, have developed graphene oxide membrane technology that can be manufactured using gravure printing, an industrial printing process. The technology will directly benefit Australian and international companies seeking energy savings and other cost advantages in water and wastewater filtration and industrial processes associated with pulp and paper, food and beverage, and pharmaceuticals. Supported by funding from the Australian government’s Co-operative Research Centre programme of...
approximately AUD 1.2 million (US$865,000) and with investment from industry partners Clean Teq Holdings and Ionic Industries, the technology is entering commercialisation phase after seven years of research and development.

India-based start-up Log 9 Materials, has developed a car, entitled Ranger that runs on air and water. The car incorporates a graphene metal-air battery that is able to increase the battery efficiency by five times at one-third the cost. The metal air batteries use a metal as anode, air (oxygen) as cathode and water as an electrolyte. A graphene rod is used in the air cathode of the batteries.

Directa Plus has signed a collaboration agreement with Ambienthesis, a Milan exchange-listed reclamation and hazardous waste disposal group. The agreement will see Directa’s C+ enhanced Grafysorber adsorbent tested as a cleaning agent for soil, groundwater and industrial waste. Testing will start at the beginning of 2019, covering various types of liquid waste using a mobile treatment plant specifically engineered for the project.

### Graphene Charge

New venture to develop technology that enhances battery energy and power density by up to 50% and offers best-in-class cycle life.

**SiNode Systems**, a U.S-based developer of silicon-graphene materials for lithium-ion batteries, and **JNC Corporation**, a Tokyo-based specialty chemical manufacturer, have formed NanoGraf Corporation—a joint venture focused on commercializing advanced materials for the Lithium-ion battery industry—with a $4.5-million investment. SiNode will be renamed **NanoGraf**.

NanoGraf’s technology aims to enhance the performance of battery materials using a proprietary graphene-wrapped silicon anode, originally invented at Northwestern University. The unique combination of silicon-based alloys and a flexible 3D graphene network reportedly helps stabilize the active material...
from Oct 17 to 19, 2018, at Makuhari Messe, in Chiba City, Chiba Prefecture, Japan, along with Ceatec Japan 2018.

It was developed in a joint research project with the research laboratory of Kazuhiko Matsumoto of the Institute of Scientific and Industrial Research, Osaka University. This time, the Advanced Technology R&D Center used a sheet-like graphene material that is made by arranging carbon atoms on a single layer. The state of electrons of graphene is different from those of other materials and semiconductors. And the new sensor uses this characteristic.

Evercloak is a University of Waterloo startup that specializes in manufacturing ultra-thin graphene and other 2-D nanomaterial films for cleantech applications. Evercloak’s low-cost advanced manufacturing platform builds ultra-thin nanomaterial membranes, enabling disruptive clean technologies that will reduce cost, energy use, and associated greenhouse gas emissions throughout the oil and gas, nuclear, energy, mining and agri-food sectors.

Haydale Graphene Industries PLC’s Taiwanese operation HTW has started to ship commercial quantities of its graphene ink for diabetes test strips. Trials have been underway for a year by the customer, but sizeable deliveries have now started as part of a 100Kg order. According to Haydale it is the first time graphene ink has been used in these quantities in this market. Trials have also started of an all-carbon sensor utilising graphene-enhanced ink that cuts out the currently used and expensive silver conductive ink tracks. The company is also partnering with Wheelsure Holdings a graphene pressure sensor. The project will begin in January 2019 and will involve production of a smart graphene pressure sensor targeting the fastener market. The sensor will integrate Haydale’s graphene sensor technology and safety product developer Wheelsure’s failsafe locking device.
Graphene composites are utilized due their exceptional mechanical and conductive properties in aerospace, automotive, packaging and electronics industries.

This month sees new developments in smartphones with graphene batteries, reducing CO2 emissions with graphene supercapacitors and oil and gas pipelines.

Armor Inc. has developed an innovative process for converting insulative, polymeric fibers into electrically conductive fibers with minimal cost and no waste products. The method leverages Garmor’s expertise of graphene-polymer interactions and has resulted in composites with single-digit graphene loadings delivering conductivity as low as high as .02 S/cm. This is ideal for wearable sensors, ESD, and other demanding applications that require integrated approaches to solving weight and measurement issues.

As part of the EU’s Graphene Flagship programme Aernnova, Grupo Antolin-Ingenieria and Airbus have incorporated graphene into the Airbus A350 horizontal tail plane. As the first part of the tail plane to contact air, the leading edge is subjected to extreme temperatures caused by compressive heating of the air ahead of the wing. Thus, it must possess excellent mechanical and thermal properties.

“Aernnova supplied the resin to Grupo Antolin-Ingenieria who added graphene directly to the resin and applied milling forces,” said Ana Reguero of Aernnova “This creates small graphene particles – an
costs and emissions over the aircraft lifetime. China-based Hainan Rubber Group has set up a research facility, which will take on graphene/natural rubber composites as its first major project. The company’s “joint laboratory for specialty natural rubber” involves a partnership with Aero Engine Corp. of the Beijing Institute of Aeronautical Materials—China’s largest aerospace materials engineering institute. In addition to the development of graphene-rubber materials, the Hainan Rubber partnership aims to build production facilities for such material as the research makes progress.

important step to get good graphene infiltration within the resin, avoiding unwanted impurities, such as solvents, which can alter the viscosity of the resin. It is important to maintain the correct viscosity of the resin to ensure the optimal outcome during the resin transfer moulding of the leading edge.” At a component level the team found that the resin with the added graphene showed increased mechanical and thermal properties, including a decreased fracture speed. By increasing the resin properties with graphene, it will be possible to make the tail edge thinner, decreasing its weight while maintaining its safety. This will provide a significant saving in fuel and therefore

**GRAPHENE PACKAGING**

Talga Resources has signed a deal with Swedish packaging giant BillerudKorsnäs to use graphene to make stronger packaging products. Graphene demonstrates excellent barrier properites in packaging applications. “BillerudKorsnäs are behind a project called the Paper Bottle project, which is a world first attempt to get a paper package that can hold carbonated drinks, which hasn’t been done before,” said Talga CEO Mark Thompson. “That obviously needs special aspects of strength and keeping the material inside the paper. So you need very good barrier coatings and graphene can play a role in things like that.”
Evercloak, is a cleantech startup that specializes in manufacturing ultra-thin graphene and other 2-D nanomaterial films for cleantech applications. The company was recently selected as a finalist in the Women in Cleantech Challenge. Allen is one of six women across Canada who will compete for a $1-million prize in the national cleantech challenge. Evercloak’s low-cost advanced manufacturing platform builds ultra-thin nanomaterial membranes, enabling disruptive clean technologies that will reduce cost, energy use, and associated greenhouse gas emissions throughout the oil and gas, nuclear, energy, mining and agri-food sectors.

SSi Energy, a division of the Northwest Territories telecommunications company SSi Micro has developed a graphene-based heat-and-power system. The “SSi Energy Solution” system captures heat waste created through the production of power and repurpose it to warm homes, water and buildings. The captured heat would be stored in thermal batteries at a central location and redistributed through a network of underground, insulated pipes. Incorporoated into the system is
a graphene supercapacitor, an energy storage unit that charges and discharges energy faster than regular batteries. “Graphene will be the next major revolution much like the industrial or the telecommunications revolution. Graphene is no less important than that,” said Jeff Philipp of SSi Energy. The benefits of graphene are many, he said. Graphene batteries function at temperatures as low as -30°C, they charge quickly, have a longer lifespan, and don’t use chemicals, which makes them easier to dispose.

Elcora Advanced Materials Corp. has been awarded a Natural Sciences and Engineering Research Council of Canada (NSERC)-ENGAGE grant with Dr. Heather Andreas, an Associate Professor in the Department of Chemistry at Dalhousie University. The project will focus on studying Elcora’s high-quality graphene as an electrode material for supercapacitors. Perforated graphene membranes could be used in next-generation filtration and gas separation applications because they can efficiently and quickly filter liquids and gases. A team of researchers in Switzerland and Korea has now developed two new processes to make such membranes with sub-100 nm pores. The highly porous perforated graphene produced by Hyung Gyu Park and colleagues of ETH Zurich and Pohang University of Science and Technology (POSTECH) could be suitable for ultrafiltration and as a 2D scaffold for making ultrathin gas-selective polymers. The researchers are working with a Swiss start-up company, HeiQ Materials AG to develop a breathable textile that repels liquids while being permeable to gases.

Clean TeQ and Ionic Industries have formed a Joint Venture to progress the commercialization of graphene-based water treatment technologies. Clean TeQ and Ionic have reportedly developed a process to manufacture high purity graphene oxide that can be applied to a membrane support to create a highly efficient graphene nanofiltration membrane (GO-Membrane). The GO-Membrane manufacturing process has been demonstrated on commercial scale industrial equipment.

Australia-based biotechnology company Circa Group has announced that UK-based University of Manchester has successfully produced graphene ink using Circa’s bio-based solvent Cyrene.

Calloway Golf has launched the ERC Soft, available in February, a golf ball that uses graphene in the outer core layer to increase the difference in compression between the outer core and the inner core to help full shots launch higher with less spin.
Graphene nanotubes are no longer merely a curiosity – they are becoming a mainstream conductive additive. This technology is helping to create new opportunities in various industries, including PVC plastisols.

**GRAPHENE NANOTUBES**

With their unique properties, graphene nanotubes (GNTs) push PVC plastisol performance higher, to fully satisfy market demand for 105 – 109 Ω/sq resistivity, to preserve a permanent and stable form even after harsh working conditions, to maintain abrasion resistance, and to demonstrate flexibility in the colouring of final products. This all is possible with just 0.25–2 wt.% of graphene nanotube concentrate, recently developed by OCSiAl.

New technology is able to eliminate the common friction points in the usage of conventional anti-static additives, such as carbon black or ammonium compounds. Application of carbon black usually affects PVC plastisol’s mechanical performance very negatively, and turns final products black, whereas ammonium compounds can become unstable over time and provide only humidity-dependent resistivity. On the top of that, processing itself is complex – carbon black influences the rheology of material and facilitates dust formation on the surface. Graphene nanotubes, which can solve all these challenges, bring vast improvements to the PVC plastisol industry.

GNTs create new business opportunities for conductive PVC plastisol manufacturers. They enjoy an overwhelming welcome in the mining industry, where assurance of safety is vital. Here are a few examples of GNTs blazing their own trail in this market. 0.4–0.5 wt.% graphene nanotube concentrate in PVC plastisol-based flexible ventilation ducting and fiberglass mesh (see image above) for mining applications enable manufacturers to obtain a resistivity of 107 Ω/sq with maintained mechanical performance. PVC plastisol-based anti-static textiles and treadmill belts mapping out graphene nanotubes extensive application in industry. Uniform, permanent, stable and humidity-independent electrical conductivity – all guaranteed by graphene nanotubes.

GNTs may have started as a “wonder-material,” but they are quickly becoming a conventional, economically viable technology for many industries. These tiny tubes are being used in a multitude of materials with increasing frequency, including PVC plastisol, polyurethane, epoxy, polyester, and acrylic polymers.
Leading global supplier of materials, Goodfellow, has collaborated with a number of major international companies to provide research materials in several industry sectors.

Case studies have now been launched on Goodfellow.com showcasing real world examples of applications where Goodfellow have provided an array of materials either from their catalogue or as a bespoke item to aid R&D projects and prototypes.

Goodfellow has also provided bespoke alloys for use by a world-leading aerospace manufacturer focused on satellites and engines. Behind some of the world’s most innovative technological developments, research and development is a key part of the company’s goal of achieving ambitious environment protection objectives. Over several years Goodfellow supplied low to medium quantities (in varying amounts of kilos) of specific types of alloys including Tungsten, Molybdenum TZM, Tantalum, Rhenium and Niobium. The materials provided have played a vital role in the development and production of the next generation of aircraft engines.

Over the coming months Goodfellow will continue to add to its portfolio of case studies to demonstrate how companies in a variety of different industry sectors can take advantage of its research materials’ expertise in order to facilitate their own industrial innovation. For more information visit – www.goodfellow.com