SMART TEXTILES & WEARABLES

At the interface of soft materials and electronics

May 2021 | Editor: Adrian Wilson

SMART FABRICS

Is this the decade for aerogels?

The aerogel technology of Aspen Aerogels, developed over the past 20 years and supported by 270 patents, has found significant applications in the fields of sustainable building materials and energy infrastructure.

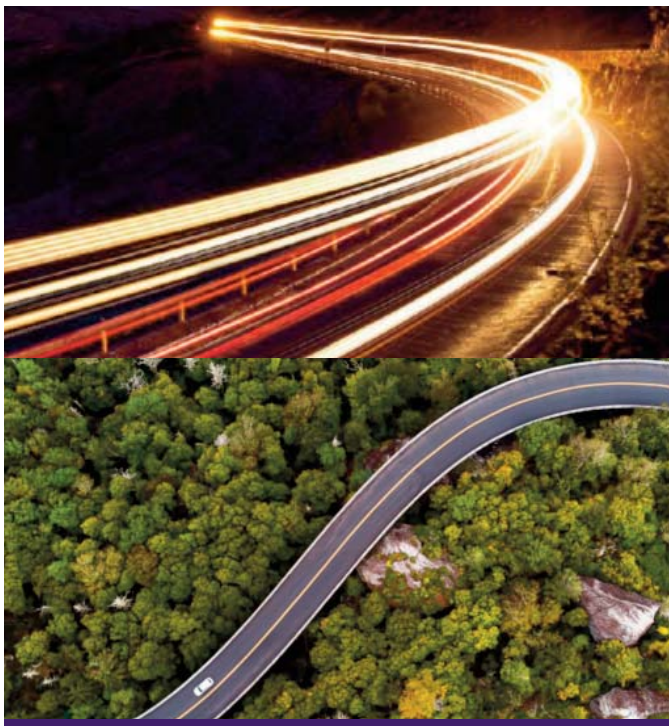
These businesses led to the company achieving record sales of US$139.4m in 2019, but Covid-19 had a significant impact on global energy infrastructure business in 2020 and sales fell to US$100.3m.

At the same time, in September 2020 Aspen secured a significant long-term contract for its PyroThin thermal barriers for electric vehicles (EVs) with a major US automotive original equipment manufacturer (OEM) and believes this is a market offering huge potential in the coming years.

Expansion

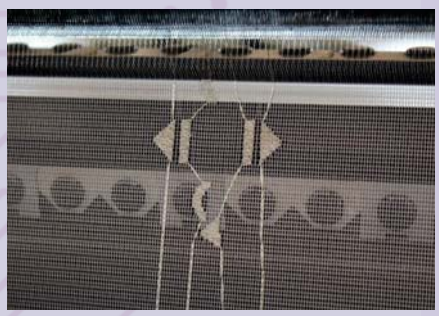
In response to this success, Aspen plans to shortly announce the location of its second manufacturing plant.

"We will need the capacity and it is important for EV players to be able to see we have the capacity," said chief executive officer Don Young, in conversation recently with Shawn Severson of Water Tower Research. "PyroThin is a unique technology addressing the universal thermal runaway problem in EV lithium-ion batteries. We also made strong progress in the development of our proprietary carbon aerogel battery materials to improve the cost and performance of lithium-ion batteries for EVs."



Aspen believes that in the years to 2030 the addressable market for EV battery thermal barriers is around US$30bn, and other battery materials for aerogels represent another US$37bn market.

Highlights this month



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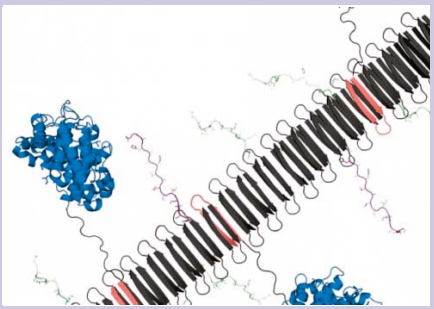

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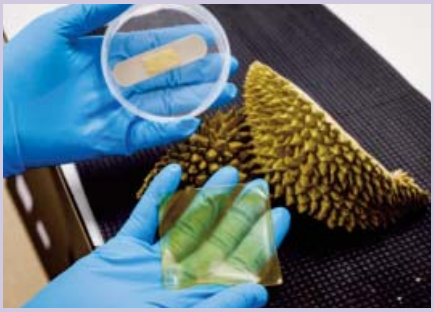

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Placed between battery cells, PyroThin thermal barriers provide precious minutes of protection from thermal runaway propagation.

Aspen believes that in the years to 2030 there is the potential for sales of US$1bn from current automotive OEM customers for PyroThin thermal barriers in an addressable market of around US$30bn, while EV battery materials represent another US$37bn market.

Insulation

In its established products, Aspen already has a US$1bn installed base in energy infrastructure products as well as a US$50m base of aerogel building materials.

Aspen's Pyrogel, Cryogel and Spaceloft aerogel blanket insulations have been widely used in the energy infrastructure, industrial and building markets for more than a decade. A patented process integrates aerogel into a fibre-batting reinforcement to create flexible, resilient and durable aerogel blankets.

As such, the company is targeting sales of US$225m in 2023, with a growth margin of around 30%.

'Puffed-up sand'

Aerogels have been in existence for more than 80 years and silica aerogel, invented in 1931 by Dr Samuel Kistler at the College of the Pacific in Stockton, California, USA, is a lightweight solid derived from gel in which the liquid component has been replaced with gas.

When the liquid is removed, what remains is "puffed-up sand" with up to 99% porosity. The result is an extremely low-density solid with several remarkable properties, most notably its effectiveness as a thermal insulator. Aerogels also have value in emerging applications such as energy storage, filtration and carbon capture.

The solids in silica aerogels are poor conductors, consisting of small, three-dimensional, intertwined clusters that comprise only 3% of the volume. Conduction through the solid is therefore low. The remaining 97% of the volume of aerogels is composed of air in extremely small nanopores. The air has little room to move, inhibiting both convection and gas-phase conduction.

These characteristics make aerogels the world's lowest density solid and most effective thermal insulator.

Markets

According to IDTechEx, the value of the aerogel market will exceed US$700m within the next decade.

This may appear modest for a unique material family that has been known for nearly a century, but after long periods of stagnation and several market failings, it would represent a notable growth from the market status in 2020.

Invented in 1931 by Dr Samuel Kistler at the College of the Pacific in California, aerogels are around 97% air in small nanopores.

There has been a significant shift in the installed capacity for silica aerogels over the past decade. Historically, this was predominantly located in North America and Europe, but there has been notable growth in China, with companies such as Nano Tech, Alison Aerogel and IBIH all establishing significant capacities.

Opportunities

The largest current end-user market for silica aerogel is the oil and gas industry, where there are still plenty of opportunities, most notably in liquefied natural gas (LNG) applications.

IDTechEx analysis expects silica aerogel products will diversify over the next 10 years. There are also many small-volume growth opportunities in municipal engineering, packaging, apparel and electronics, but the two sectors seeing the highest growth are in building and construction and EV

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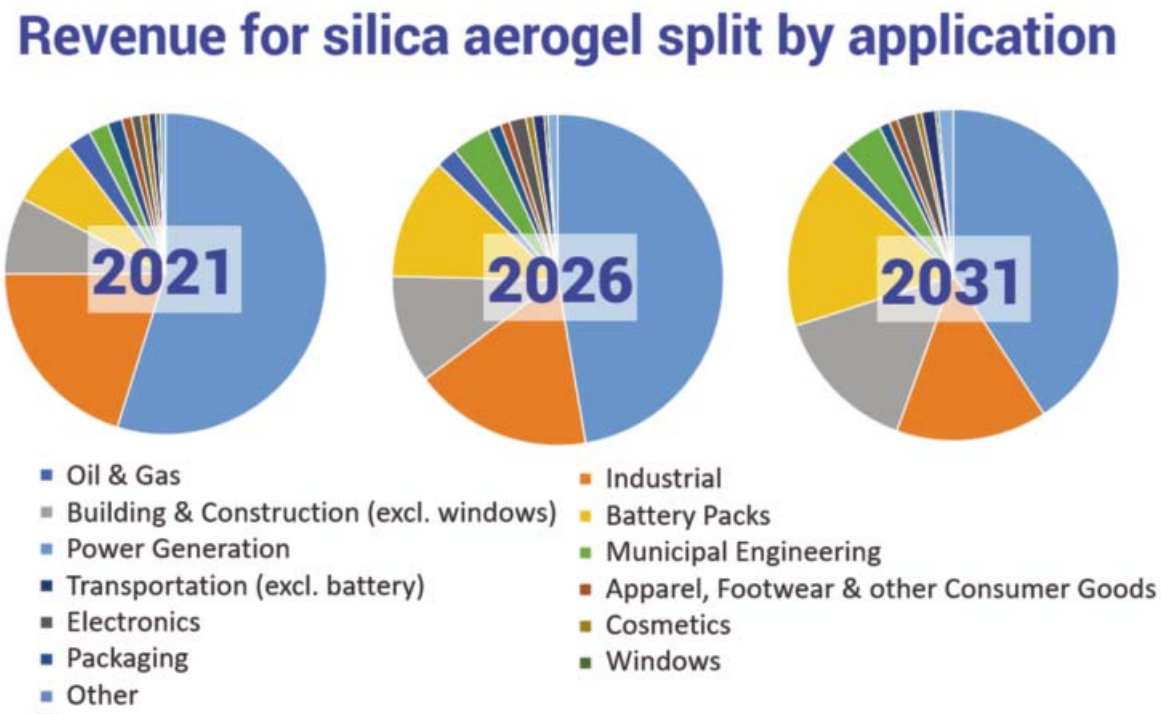

IDTechEx prediction of market shifts for aerogel materials to 2031.

battery packs. Both will be greatly influenced by changes in regulation.

Aerogel manufacturers have been trying to sell more into the building and construction market for many years. The challenge is that aerogel blankets are expensive and compete with low-cost alternatives. The success will come from regulation shifts including more energy-efficient buildings and stricter fire-safety requirements.

Disasters such as Grenfell Tower in London, UK, were caused by the insulative cladding used and have resulted in changes to regulations. Aerogel blankets can boast an A2 fire rating and when coupled with light weight, easy installation, breathability, hydrophobicity and of course the unmatched thermal insulation, market penetration will begin to be seen.

The EV market is booming and central to this is the role of lithium-ion batteries. There is still limited convergence at both the cell and pack levels, with a large variety of designs coming to market. Again, a key consideration is the thermal management.

Silica aerogel blankets have just begun to see adoption in this nascent market as a thermal runaway mitigation solution. Aerogels compete against many other solutions, but with such a large potential, even a modest market share could be highly significant.

There remains a consistent amount of research from academia and industry in the field.

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Aspen's PyroThin is a unique technology addressing the universal thermal runaway problem in EV lithium-ion batteries.

SMART FABRICS

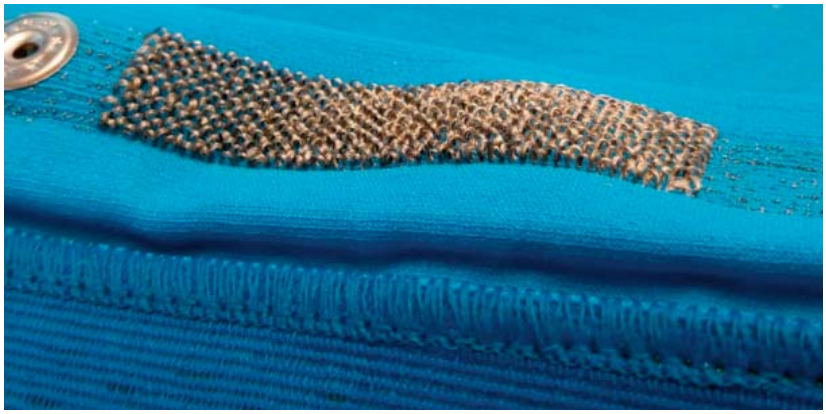
Warp knitting's simplicity for e-textiles

The benefits of the warp knitting process for the creation of electronic textiles were outlined by Tony Hoojimeijer, president of Karl Mayer North America, during a recent Techtextil North America webinar.

"When considering the e-textiles market it is clear there are a number of barriers," he said during the event, first broadcast on 25 March. "Typically, process costs are very high for such products that come onto the market, because producing e-textiles can be a pretty complex process with add-ons for the sensors always demanding multi-step processes. On the user side, washability can then be an issue, as can wearing comfort.

"The way to address this is firstly to find a suitable production process that is very volume oriented and then reduce the production steps for the different components required, to help in terms of costs. Building the functionality into the fabric, instead of adding it to the fabric later, results in more wearable and attractive garments that will lead to better and higher customer acceptance. This is what the warp knitting route offers."

Complex structures



Warp knitting, he explained, is very different to weaving in the complex structures it can create.

"The whole process works in the warp direction and all the yarns are fed from beams in parallel and then subject to all kinds of intricate movements from the bars," he said. "Loops are produced that inherently have four-way stretch, which in terms of wearability comfort is a major benefit, and it is possible to feed many different yarns into the same knitting area, in order to create applications with different characteristics. This is why warp knitting has been successful in so many fields."

The major markets for warp knits primarily based on polyester and polyamide yarns include sportswear and intimate apparel, where stretch and comfort are prerequisites. Other big markets are in shoe uppers as well as automotive headliners and many seat components. The medical field is also an area where products such as artificial blood vessels have been produced in a single pass with a warp knitting machine.

Versatility

As far as e-textiles are concerned, Karl Mayer developers have already made fabrics in which four separate electronic circuits based on conductive yarns – treated just as normal yarns – have been knitted into a fabric during single-step production.

Hoojimeijer emphasised the versatility of warp knitting in terms of accommodating many different yarns and creating unlimited structures.

In terms of productivity, he explained, fabrics that are 200 inches wide can contain 30 needles per inch operating at 3,000 rpm for 6,000 stitches in parallel.

"Complex arrangements can be fed by different bars in different ways for patterning e-textiles with different functional yarns at specific places, as is typical in athletic shirts, which have patterns where things are tighter or looser, with defined areas of compression," he said. "String bars can place specific, conductive yarn patterns in spots throughout the fabric, which can combine to create very intricate patterns and this is all done on the fly."

Demonstrator products produced by Karl Mayer include a remote control sleeve with a sensitive surface for controlling a small robot (pictured) and a knitted wireless mobile phone charger. At the ITMA 2019 textile machinery exhibition in Barcelona, Spain, a sports shirt for measuring heart rate, temperature and humidity with textile sensors was showcased.

"We have already tested many conductive yarns during development work, and we have a wide range of machines on which to explore potential applications," Hoojimeijer concluded. "If specific yarns are too thick or rigid they may be unsuitable, and for specific applications modifications of a machine's feeding devices or tension controls may be necessary, but this is a versatile route to successful mass production for many new e-textile products."

As the world's largest manufacturer of warp knitting machines, Karl Mayer has recently added an established range of flat knitting technologies with the acquisition of Stoll and is active in applications development to help its customers develop new products, with

research and development centres in Germany, Italy and Japan, as well as the US.

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SMART FABRICS

New SmartX projects announced

Following the second SmartX funding call, 10 projects submitted by 21 small and medium-sized enterprises (SMEs) from 10 European countries have been awarded total grants of more than €1m to be distributed in instalments during the 12-month programme.

The 10 projects are:

- E-POT, a joint project involving BlueGriot and Imattec from France and Bamboo and Emisys from Belgium, which aims to develop smart underwear for potty training, which would help children wake up before wetting the bed. The idea is that after wearing the smart underwear for a month, the brain will get used to the wake-up call trigger;
- Asthmaware by Dutch SMEs ItoM Medical, Panton and Transfercompany, which will monitor and assess asthma by measuring shortness of breath during sleep;
- KiTT, a next-generation wearable motion tracker being developed by Footfalls & Heartbeats and Ioetec in the UK, with Revolve of Poland. KITT's advanced textile sensor monitors joint movement in real time within a breathable knee sleeve, and is aimed at the sports/fitness and physiotherapy markets;
- RVheat, proposed by ComSensus of Slovenia and Embro of Germany, intends to integrate smart textiles into the interiors of caravans and motorhomes to create a hands-free heating ecosystem;
- Close'n'cool by Knitronix and Remmy of Italy combines temperature and pressure-sensing smart fabrics sewn into a car seat or stroller cover to maximise air circulation under a child's body and prevent overheating;
- Matscale is a joint project by Herkula of Belgium and Incoretex in Germany, which are developing a high-precision textile pressure sensor technology for implementation in mattresses;
- SenseGlove Nova is being developed by Select Fashion of Germany and SenseGlove of the Netherlands. In January, SenseGlove launched its new haptic glove for industrial virtual reality training. In contrast to its previous haptic glove, which has an exoskeleton form factor, this new solution features a textile soft glove base for comfort and ease of use. It is designed to interface seamlessly with tracking, vibro-tactile feedback and force feedback functions;
- Marina Race by Spanish SME Marina Racewear incorporates biometric sensors into the underwear of racing drivers.
- Iosoftsleep 4.0 by Têxteis Penedo of Portugal aims to develop a smart heating blanket with embedded electronic components for controlling temperature. The goal is to ensure the optimal balance between thermal insulation, breathability, flexibility and lightness;
- Sensomuscle from Spain's Austral is a solution focused on muscle recovery and designed with athletes in mind.

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NANOFIBRES

Teijin claims recycled nanofibre first

Tokyo, Japan-headquartered Teijin Frontier has developed technology to mass produce a new version of its Nanofront ultra-fine polyester, which it believes is the world's first nanofibre to be made from recycled polyester raw materials.

Key to the development are new polymer control and spinning techniques for the company's proprietary "sea-island" composite fibre processing technology, which distributes two types of polymers into the fibre's sea and island parts, then dissolves and removes the sea part using an alkaline treatment, finally extracting only the island part as raw yarn.

Teijin Frontier believes this technology will enable it to produce all of its polyester fibre products with recycled raw materials in the future, including sportswear, functional clothing and industrial uniforms.

It is forecasting sales from the development of ¥300m (US$2.8m) in 2021 and ¥800m (US$7.4m) in 2025.

In recent years, the demand for Nanofront has expanded in a wide range of fields due to growing needs for materials offering high functionality, such as absorbency and grip, and comfort, including soft texture and low skin irritation.

Meanwhile, the demand for recycling raw materials is rapidly increasing, but it has been difficult to mass produce ultra-fine fibres made from recycled polyester due to the need for high-

level polymer control and spinning.

The new fibre can create highly absorbent structures since its capillarity enhances water absorption and diffusion. Its grip properties result from nano-sized irregularities on the fibre surface that create friction. In filter materials, its fine pores and high void structure also improve collectability, and in precision structures it can enhance impermeability and heat shielding.

Teijin Frontier stresses that while made from recycled polyester raw materials, the fibre maintains all conventional quality and functionality.

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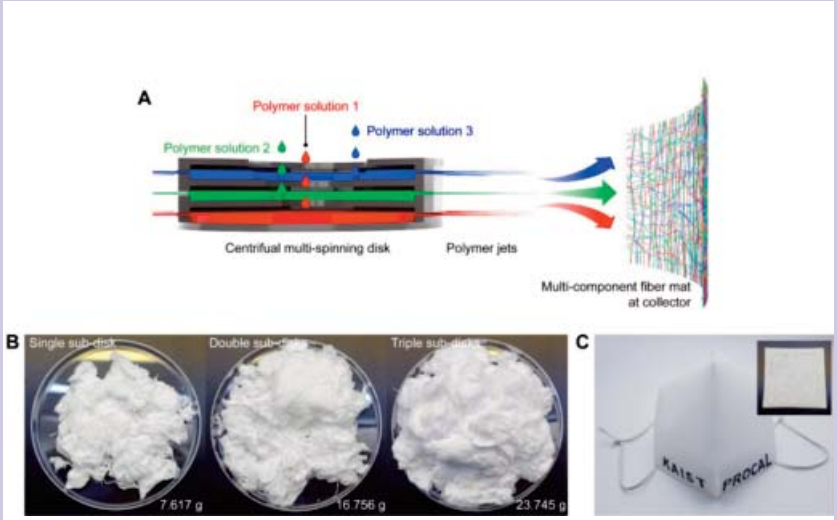
NANOFIBRES

Improved nanofibre production at KAIST

Centrifugal multispinning, a new nanofibre production technique developed at the Korea Advanced Institute of Science and Technology (KAIST), is claimed to achieve up to 300 times the output of conventional electrospinning.

Electrospinning is the common process used to prepare fine and uniform polymer nanofibres, but has several drawbacks, such as the requirement of a high-voltage electric field and electrically conductive target.

Centrifugal spinning utilises centrifugal force instead of high voltage to produce polymer nanofibres and has been proposed as a safer and more cost-effective alternative to electrospinning. Achieving scale is another advantage since the technology only requires a rotating spinneret and a collector.



(A) Schematic illustration of the centrifugal multispinning polymer nanofibre production process. (B) The polymer nanofibres spun by the system. The increase in the number of sub-disks shows the proportional enhancement of the productivity. (C) Face masks and mask filters fabricated using the mass-produced nanofibres at KAIST.

However, because existing centrifugal force-based spinning technology employs only a single rotating spinneret, productivity is limited and not much higher than that of some advanced electrospinning technologies, such as multi-nozzle electrospinning and nozzleless electrospinning. This problem persists even when the size of the spinneret is increased.

In response, a research team led by Professor Do Hyun Kim from the Department of Chemical and Biomolecular Engineering at KAIST has developed a centrifugal multispinning system for mass production by sectioning a rotating spinneret into three sub-disks. The team's findings have been published in *ACS Macro Letters*.

Using this new centrifugal multispinning spinneret with three sub-disks, the researchers demonstrated the gram-scale production of various polymer nanofibres with a maximum production rate of up to 25 g per hour, which is around 300 times higher than that of a single spinneret in a conventional electrospinning system. The production rate of up to 25 g of polymer nanofibres per hour corresponds to the production rate of about 30 face mask filters per day on a laboratory-scale manufacturing system.

By integrating the mass-produced polymer nanofibres into the form of a mask filter, the researchers were able to fabricate face masks that have comparable filtration performance with the KF80 and KF94 face masks that are currently available on the Korean market. The KF80 and KF94 masks have been approved by South Korea's Ministry of Food and Drug Safety to filter out at least 80% and 94% of harmful particles, respectively.

"When our system is scaled up from laboratory scale to an industrial unit, the large-scale production of centrifugal multispun polymer nanofibres will be made possible, and the cost of polymer nanofibre-based face mask filters will also be lowered dramatically," Kim said.

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NANOFIBRES

Creating an 'antibody factory' with nanofibres

Bioengineers at Duke University of Durham, North Carolina, USA, have developed a self-assembling nanomaterial that can help limit the damage caused by inflammatory diseases by activating key cells in the immune system.

In mouse models of psoriasis, the nanofibre-based drug mitigated damaging inflammation as effectively as a gold-standard therapy.

According to the researchers, one of the hallmarks of inflammatory diseases is the overproduction of cytokines that cause inflammation, with one of the most significant being tumour necrosis factor (TNF). Currently, the best treatment for these diseases involves the use of monoclonal antibodies (mAbs), which are designed to target and destroy TNF and reduce inflammation.

Although mAbs have enabled better treatment of inflammatory diseases, the therapy is not without its drawbacks, including high cost and the need for patients to regularly inject themselves.

Antibodies

As an alternative, the researchers have been exploring how immunotherapies can help teach the immune system how to generate its own therapeutic antibodies that can specifically limit inflammation.

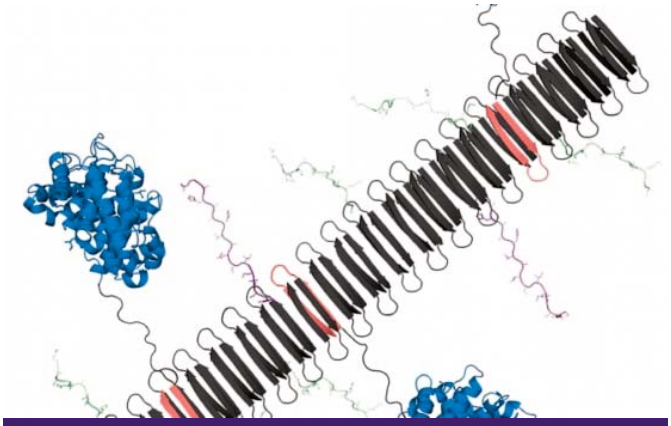
"We are essentially looking for ways to use nanomaterials to induce the body's immune system to become an anti-inflammatory antibody factory," said Professor Joel Collier, one of the lead researchers. "If these therapies are successful, patients need fewer doses of it, which would ideally improve patient compliance and tolerance. It would be a whole new way of treating inflammatory disease."

In the study, the researchers demonstrated how novel nanomaterials could assemble into long nanofibres that include a specialised protein called C3dg. These fibres were then able to activate immune system B cells to generate antibodies.

"C3dg is a protein that you would normally find in your body," said Kelly Hainline, a graduate student in the Collier laboratory. "The protein helps the innate immune system and the adaptive immune system communicate, so it can activate specific white blood cells and antibodies to clear out damaged cells and destroy antigens."

Due to the protein's ability to interface between different cells in the immune system and activate the creation of antibodies without causing inflammation, the researchers have been exploring how C3dg could be used as a vaccine adjuvant, which is a protein that can help boost the immune response to a desired target or pathogen.

In their new nanomaterial, the team extruded key fragments of the C3dg protein with components of TNF into nanofibres. The C3dg protein will trigger the B cells to create antibodies, while the TNF components will provide a blueprint of what the antibodies need to seek out and destroy.



Graphic shows the peptide nanofibre bearing complement protein C3dg (blue) and key components of the TNF protein. Image: Chelsea Fries, Duke University

"When we assembled the C3dg protein and key portions of TNF into these nanofibres, we saw that there was a strong B-cell response, which means there was an increased production of antibodies that targeted TNF," said Collier. "In standard mouse models of inflammation, mice experience a temperature change where their internal temperature will drop. But when we delivered the C3dg nanofibres, it was highly protective and the mice did not experience an inflammatory response."

Influence on response

When the team tested their nanomaterial in the psoriasis mouse model, they found that the nanofibres carrying C3dg were as effective as a mAb therapy. Further, because C3dg is normally found in the body, it was not flushed out of the system by antidrug antibodies.

After examining the psoriasis model, the team found that C3dg was not just stimulating antibody production in the B cells, it was also influencing the response of T cells.

"We observed that nanofibres that only contained the C3dg components without the TNF components still showed a therapeutic benefit to our models, which was surprising," said Hainline. "I think the most significant discovery was seeing a beneficial T-cell response that was activated by a protein you would naturally find in your body. That kind of response has been seen before with other proteins, but we have not seen any reports of people using that response with C3dg."

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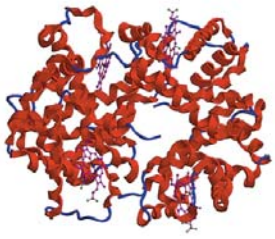


MEDICAL

Healing properties with durian's spiky thorns

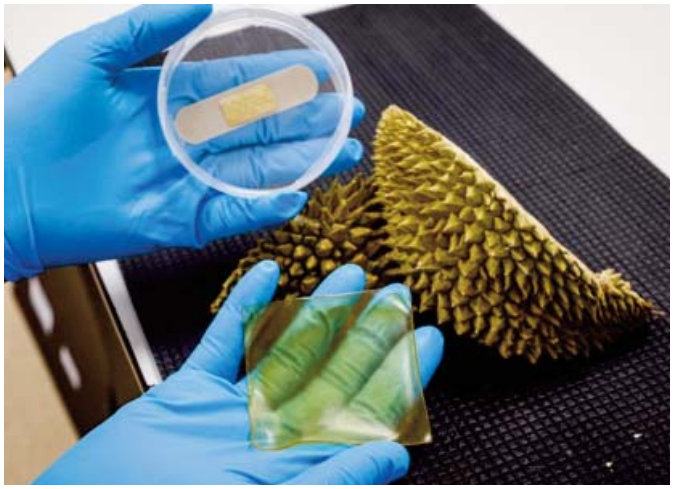
An antibacterial gel bandage has been produced from the discarded husks of the popular durian tropical fruit by food scientists from Nanyang Technological University (NTU) in Singapore.

Known as the "king of fruits" in Southeast Asia – and also as "stinky durian" since it has a highly pungent odour that has led to it being banned on public transport in certain regions – the durian has a thick husk with spiky thorns that is discarded, while the sweet flesh surrounding the seeds on the inside is considered a delicacy.

By extracting high-quality cellulose from the durian husks and combining it with glycerol – a waste by-product from the biodiesel and soap industry – NTU scientists created a soft gel, similar to silicon sheets, which can be cut into bandages of various shapes and sizes.

They then added the organic molecules produced from baker's yeast known as natural yeast phenolics, making the bandage deadly to bacteria.

Developed by the team of Professor William Chen, the director of NTU's Food Science and Technology Programme, the research was featured in *ACS Sustainable Chemistry & Engineering.*



Hydration

Conventional hydrogel patches are commonly available at pharmacies, usually used to cover wounds from surgery to minimise the formation of excessive scar tissue, resulting in a softer and flatter scar. The patch keeps the skin hydrated instead of drying up when conventional band-aid or gauze bandages are used.

Chen explained that conventional hydrogel patches on the market are made from synthetic materials, such as polymers like polymethacrylate and polyvinylpyrrolidine. Those with antimicrobial properties also use metallic compounds, such as silver or copper ions. Such synthetic materials approved for use in biomedical applications are more costly compared with the new hydrogel made from natural waste materials.

"With the growing threat of antibiotic-resistant superbugs, the world will need multiple alternative ways to prevent infections," he said. "An effective way to protect open wounds is with antimicrobial bandages that are biocompatible and safe for prolonged use by humans. This is especially important for diabetic patients suffering from chronic wounds.

"By using waste products which are currently discarded in large quantities – durian husks and glycerol – we can turn waste into a valuable biomedical resource that can enhance the speedy recovery of wounds and reduce the chance of infections."

Biodegradable

The husk comprises 60% of the durian and is usually discarded and incinerated. In Singapore, it was reported by *The Straits Times* that 14,300 tonnes of durian – an estimated 10m durians – were imported and consumed in 2017.

Being non-toxic and biodegradable, the organic gel bandage is also expected to have a smaller environmental footprint than conventional synthetic bandages.

Giving an independent comment on the innovation, Associate Professor Andrew Tan, vice faculty dean of NTU's Lee Kong Chian School of Medicine, who is an expert in metabolic disorders, said there are now existing natural and synthetic hydrogels on the market, where their usefulness in the healing of some types of wounds are well recognised.

"Hydrogel bandages are known for their non-toxicity and ability to rehydrate the wound bed and they can facilitate autolytic debridement, where the body's enzymes and natural fluids act to soften bad tissue and remove it. The innovative and unique part of Chen's current work is the upcycling of the durian rind to obtain cellulose. It is also quite unique given that the thorns of the durian can hurt, but the materials from the rind can heal."

The clinical advantage of the new hydrogel bandage is that the natural yeast phenolics embedded will help to prevent the growth of bacteria such as gram-negative *Escherichia coli* and gram-positive *Staphylococcus aureus*, and the subsequent formation of biofilms (a layer of slime that can lead to antimicrobial resistance within a bacteria colony).

As a proof of concept, the antimicrobial hydrogels were tested as a wound dressing on animal skin and showed good antimicrobial effects for up to 48 hours.

The new proof-of-concept hydrogel bandage is applied by simply laying it across the wound, just as with existing commercially available silicone gel sheets for wound dressings, the current gold standard used following cosmetic surgeries to reduce scarring.

Flexible electronics

Organic hydrogels are also useful for wearable, flexible and stretchable electronics, which Chen demonstrated in a 2019 paper published in *Scientific Reports*.

To demonstrate the use of organic hydrogels in flexible electronics, a prototype hydrogel that could conduct electrical signals was made with cellulose obtained from okara – the waste leftover from soybean pulp during the making of soy milk.

"As shown in many of our research papers, fundamental research in food science and technology carries far more interdisciplinary applications in other industries, such as healthcare, biomedical applications and speciality chemicals," Chen said.

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SMART FABRICS

Superelastic conductor on electrospun mat

A highly permeable and superelastic conductor that can be used for wearable electronic devices capable of withstanding long-time wear has been developed at Hong Kong Polytechnic University (PolyU).

The conductor is fabricated by coating or printing liquid metal onto an electrospun elastomeric fibre mat, which offers high permeability, stretchability, conductivity and electrical stability, allowing it to be employed in various applications, including health monitoring devices, soft robotics and on-skin electronics.

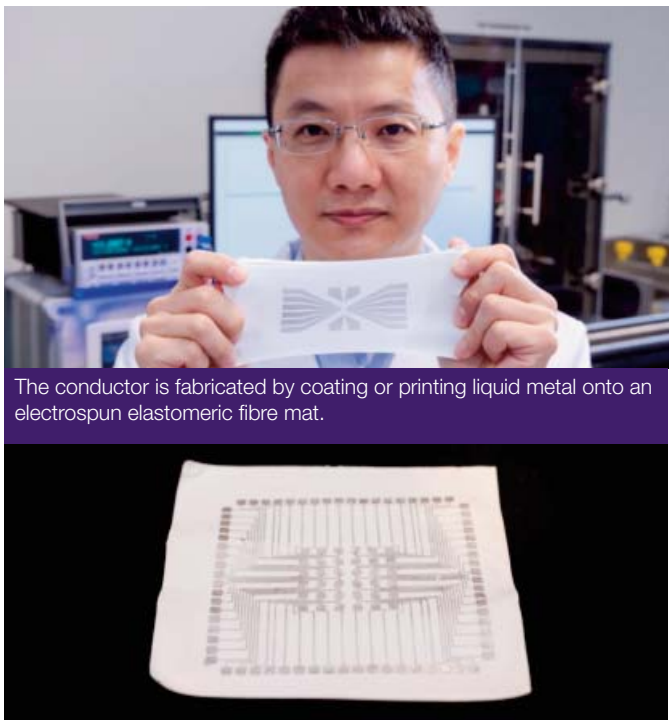
Electronic devices with high stretchability are essential in the fields of wearable electronics, on-skin electronics, soft robotics and bioelectronics. However, many stretchable electronics are fabricated with impermeable, elastic, thick films and wearing them for long periods can cause health concerns, including skin irritation and inflammation. In addition, low permeability will limit the use of multi-layered devices and hinder the development of advanced functionality in stretchable electronics.

To overcome these limitations, the research team, led by Professor Zijian Zheng of PolyU's Institute of Textiles and Clothing, have developed a new type of highly permeable superelastic conductor. The conductor enables the fabrication of biocompatible and multifunctional monolithic stretchable electronics.

The new liquid-metal fibre mat (LMFM) is fabricated by coating or printing liquid metal onto an electrospun elastomeric fibre mat followed by a mechanical activation process in which the liquid metal self-organises into a laterally porous and vertically buckled film hanging among the fibres.

The LMFM possesses excellent permeability, retaining super-elasticity and ultra-high conductivity in tensile testing. In addition, it shows excellent biocompatibility when directly applied to the human skin.

"We selected eutectic gallium-indium alloy – EGaIn – a type of liquid metal commonly used in soft electronics such as



The conductor is fabricated by coating or printing liquid metal onto an electrospun elastomeric fibre mat.

flexible printed circuit boards, as the conductive component for printing on the stretchable polystyrene-block-butadiene-block-styrene mat, a material that is usually used for rubber products like gloves or balloons as an elastomer, to fabricate the LMFM," Zheng explained.

EGaIn is a metal that can be maintained in a liquid state under room temperature. It has low viscosity, high conductivity and low toxicity, and is also capable of rapidly forming a thin, solid layer of gallium oxide (Ga_2O_3) on the surface of EGaIn upon exposure to air, offering soft and stretchable features. After stretching, the oxide formed on the surface of EGaIn buckles and breaks up into holes, providing an accordion-like structure for high stretchability and conductivity through the wrinkles.

Further, the LMFM can be fabricated vertically and stacked in three layers of printed EGaIn electrical circuits on monolithic elastic mats, with one layer acting as an electrocardiography sensor, another as a sweat sensor and the final layer as an electrothermal heater. The fabricated three-layer sample, with a total thickness of 1 mm, performs well while maintaining high permeability. It implies that the stacked architecture of the LMFM can provide excellent wearing comfort and multifunctionality.

In summary, LMFM is a new type of stretchable conductor that is easily made by coating or printing liquid metal onto an elastic electrospun fibre mat. With a simple pre-stretch process, it can offer high permeability as well as conductivity. LMFM is also able to be stacked in multiple layers while maintaining high permeability. This permeable and stretchable conductor can be adopted as a user-friendly platform needed to fabricate monolithic stretchable electronics that provide high integration density, multifunctionality and long-time wearability.

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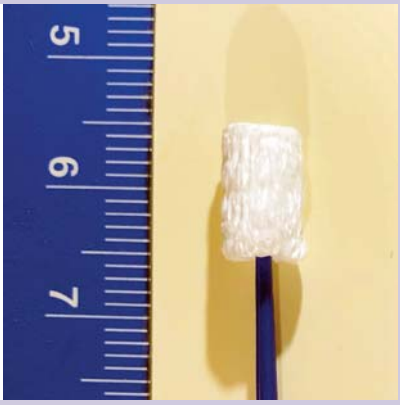
NANOFIBRES

Ultra-absorptive nanofibre swabs improve sensitivity



An ultra-absorptive nanofibre swab could reduce the number of false-negative Covid-19 tests by improving sample collection and test sensitivity.

Researchers at the University of Nebraska Medical Center in Omaha, Nebraska, USA, used an electrospinning technique to make 1-cm-long cylinders composed of aligned nanofibre layers, which they coated with a thin layer of gelatin and bonded to plastic swab sticks.

In laboratory tests, the porous nanofibre cylinders absorbed and released more proteins, cells, bacteria, DNA and viruses from liquids and surfaces than the cotton or flocked swabs commonly used for testing.

The researchers made dilutions of SARS-CoV-2 virus, swabbed the liquid samples and tested for viral RNA with RT-PCR. Compared with the two other types of swabs, the nanofibre swabs reduced the false-negative rate and detected SARS-CoV-2 at a 10-times lower concentration. The most sensitive test currently used for Covid-19 involves using a long swab to collect a specimen from deep inside a patient's nose, and then using a method called reverse transcriptase-polymerase chain reaction (RT-PCR) to detect SARS-CoV-2 RNA. But if the viral load is low, which can occur early in the course of infection, the swab might not pick up enough virus to be detectable.

"Using nanoscale fibres, we have created extremely absorptive swabs that can detect SARS-CoV-2 at very low concentrations and reduce false-negative tests," said Associate Professor Jingwei Xie of the Department of Surgery-Transplant.

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NANOFIBRES

Nanofibres the key to advanced CFRP

The University of South Alabama in Mobile, Alabama, USA, has received a US$250,000 National Science Foundation (NSF) Partners for Innovation grant to make new high-performance carbon fibre reinforced polymer (CFRP) composites available for broad commercialisation.

Conventional CFRP composites, usually in laminate form, provide an excellent weight-to-strength ratio, but mechanical, electrical and thermal weakness limits their potential compared with metals in many applications.

The new technology has demonstrated notable improvements in those properties, allowing for far better multifunctional performance that can be better tailored to the applications.

The key is a strong and highly conductive carbon nanofibre threaded through multiple arrays of carbon fibres in a zig-zag pattern along the z-direction (thickness direction) of a composite laminate panel, creating an interlocked multiscale fibre-reinforced network.

This patented technology is known as ZT-CFRP and was developed by University of South Alabama Mechanical Engineering Professor Kuang-Ting Hsiao.

"If you apply this concept, we can expect that planes, cars or sporting goods utilising ZT-CFRP will be more efficient, lower cost, simpler to design and assemble, lighter and stronger," he said. "The saved weight could be used for adding more performance or upgrading entertainment options."

The company is partnering with five major corporations for commercialisation – Hexcel, MHP Americas, Porsche Motorsport, Toray and UST Mamiya.

The NSF has long supported academic research, but its Partners for Innovation programme focuses on identifying and supporting research and technologies that have potential for accelerated commercialisation.

"The success of this technology and its commercialisation will potentially benefit all participating companies and the broader user base of composite materials," Hsiao said. "If the technology demonstrates readiness for commercialisation, the creation of start-up, licensing, joint venture and other business arrangements in various markets are all possible next steps."

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COATING

Huafeng sets new standard in 3D coating

Huafeng, headquartered in Putian, China, is introducing a new process called haptic cushion coating.

More than 300m pairs of sports shoes have now been produced by the major brands, such as Adidas, New Balance and Nike, exploiting the surface textures provided by the standard haptic coating technology developed by Huafeng.

The technology is a method of adding a huge range of surface designs to textile surfaces for both footwear and apparel. They are in thicknesses of 0.2–1.2 mm and can be in any colour combination.

Huafeng's coating process involves an additive, layer-by-layer approach based on a modified screen-printing process, and work is currently under way to fully digitise it. At present, however, the step-by-step process still ensures zero cutting waste.

The coatings are based on polyurethane chemistry exploiting a cross-linked polymer to provide strong bonding, durability, abrasion resistance and other beneficial properties. The chemistry is completely water-based with high solids content for maximum effectiveness.

"We are formulating and manufacturing our own inks to be fully in control and ensure our coatings are fully water-based and safe," said Huafeng's director of innovation and creation Thomas Schmidt. "Elaborate three-dimensional (3D) patterns are created with not only any colour combination, but graded thicknesses and modified surfaces, since we are all about touch."

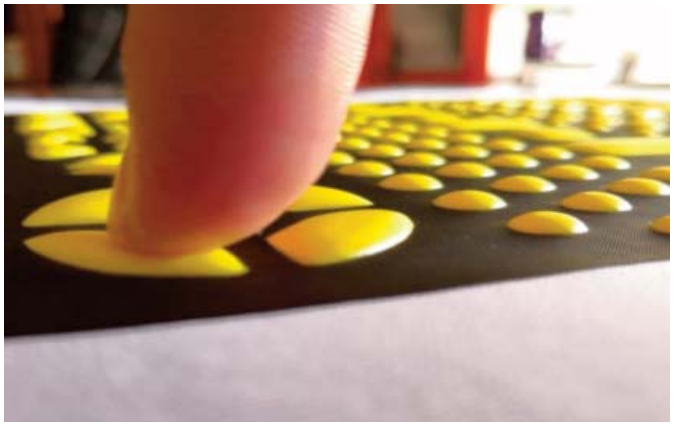
Foamed ink

The new haptic cushion coating technique is based on a new foamed ink formulation, which combined with the company's in-house one-shot printing technique now allows for the creation of surface designs that can be up to 5 mm in thickness with a smooth, round appearance, and can achieve up to 40% weight savings due to their foamed production.

Glow-in-the-dark effects have also been produced with the incorporation of fluorescent pigments.

With its Haptic Cushion Reborn concept, Huafeng has developed two approaches to recycling garments into either coarse or fine particles to be used in the coatings.

The company has accelerated its globalisation efforts during the Covid-19 pandemic, adding new offices to its network, and is also planning to open its first manufacturing plant outside its Chinese headquarters – in Vietnam.



"Our haptic coating technology has been highly successful due to its unlimited design options, high material efficiency, no cutting waste and fully water-based chemistry," Schmidt concluded. "With haptic cushion technology we are further expanding the potential for many successful and sustainable new designs."

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PROCESSING

Fibroline extends impregnation tech to yarns

Fibroline, based in Limonest, France, has developed strong expertise in the impregnation of textiles and nonwovens with its dry powder solutions.

Following a two-year research programme, an innovation team at the company has now developed and patented a new solution for yarns and composite tapes impregnation called Y-Preg.

The process remains closely linked to the use of a high-voltage alternating electric field for charging and distributing particles homogeneously into the porosities of multifilament yarns or unidirectional reinforcing fibres. Any type of binder or functional powder can be processed on the system, which uses no solvents and consumes little energy, significantly reducing the overall manufacturing environmental footprint.

"Our objectives are to assist our customers with the powder selection, powder blending and fixation parameters in order to help them identify the added value our new solution can bring to

their applications," said innovation manager Sofien Bouzouita, who is in charge of the Y-Preg business development.

Y-Preg pilot line at Fibroline's innovation centre.

A new pilot line has been installed at Fibroline's innovation centre, as well as flexible peripheral equipment to carry out semi-industrial runs with customers, prior to final technology transfer. Several partners have already attended demonstrations on this line, or via video-conferencing to overcome the constraints linked to the current pandemic.

Due to a wide range of potential new products, Fibroline decided to establish strategic co-operation agreements for each market segment, providing them with a technological advance in their field to companies driven by innovation, with the introduction of greener and unique products owing to a disruptive solution.

"The Y-Preg technology opens new business opportunities for various markets and Fibroline needs its partners' expertise to turn those ideas into successful industrial solutions," said chief executive officer Jérôme Ville. "This is the reason we decided to join forces with market leaders in their fields, to create synergies between their specific skills and our technological know-how."

Fibroline engineers are now investigating the potential of the new Y-Preg solution for impregnating medical, dental or implantable yarns with new antimicrobial, antiseptic and haemostatic additives.

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GRAPHENE

Plasma reactor for 401 Tech Bridge

The 401 Tech Bridge Advanced Materials and Technology Center, managed by the University of Rhode Island in South Kingstown, Rhode Island, USA, is installing a Haydale HT200 plasma reactor.

The HT200 incorporates Haydale's patented functionalisation technologies and will be used specifically by Graphene Composites, a nano-materials engineering company, for its newly developed antiviral GC Ink and other products.

Haydale's HT200 plasma reactor.

GC Ink has been independently tested by Brown University in Rhode Island to show effectiveness at neutralising coronavirus and influenza viruses in less than one minute.

The patent-pending virucidal and germicidal ink is being commercialised for a broad range of applications including personal protective equipment, filtration solutions and high-touch surfaces.

The technology is said to be effective because it has a dual-action mechanism – a negatively charged surface of graphene oxide traps the positively charged parts of water droplets, and the protein spikes on coronavirus and silver nanoparticles release ions that oxidise the lipid membrane protecting coronavirus RNA, thereby neutralising it.

"We are pleased to partner with Haydale and to be working with Graphene Composites as they bring the GC Ink to market," said 401 Tech Bridge executive director Christian Cowan. "We will make the Haydale equipment available to companies that are doing advanced materials research."

"It is great to see Haydale's patented functionalisation process play such a key role in the adoption of nanotechnology in response to the increased global focus on a need for viral efficacy," added Haydale chief executive officer Keith Broadbent.

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NANOFIBRES

Active purification for Jaguar Land Rover

Jaguar Land Rover has developed a cabin-air purification system that has been shown in laboratory tests to inhibit viruses and airborne bacteria by as much as 97%.

The prototype heating, ventilation and air-conditioning system uses Panasonic's Nanoe X technology to inhibit harmful bacteria and viruses and protect the cabins of future Jaguar and Land Rover models.

To provide active air purification the Nanoe X technology –

said to be 10 times more effective than its predecessor, Nanoe – uses a high voltage to create trillions of hydroxyl (OH) radicals enveloped in nano-sized water molecules. These OH radicals denature the virus and bacteria proteins, helping inhibit their growth. The OH radicals deodorise and inhibit allergens in a similar way to create a cleaner air environment for customers.

Jaguar Land Rover partnered with Perfectus Biomed, a microbiology and virology laboratory, to perform the laboratory-based sealed-chamber test designed to simulate a vehicle ventilation system in recirculation mode over a 30-minute cycle. The independent research showed that viruses and bacteria were inhibited by as much as 97%.

Panasonic's Nanoe X technology has also been tested on coronavirus (SARS-CoV-2) by Texcell, a global research organisation that specialises in viral testing and immune-profiling, and is one of the few laboratories in the world with permission to test against coronavirus.

It found more than 99.995% of the virus was inhibited during the two-hour laboratory test.

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NANOFIBRES

Inspiration for project taken from spider combs

Research and development will be a big component of the forthcoming Index 2020 nonwovens exhibition, which now takes place in Geneva, Switzerland, from 19–22 October.

In the event's latest newsletter, details are published of an intriguing project involving the exhibitor Elmarco, a supplier of nanofibre manufacturing technology.

Even comparatively straightforward processing operations such as spooling or winding are complicated when it comes to nanofibres, the company explains.

Cribellate spiders such as the feather-legged lace weaver, for example, use their calamistrum to handle and process the nanofibres they naturally produce.

Their attraction to any surface by van der Waals forces – the adhesive forces that enable geckos to stick to walls – makes handling them extremely difficult, and this is an issue that may well be hampering the wider adoption of nanofibres, however useful their many properties, especially in combination with nonwoven substrates for fields such as filtration.

Calamistrum comb

The BioCombs4Nanofibers Project takes its inspiration from the humble spider in seeking a solution to this problem.

Co-ordinated by the University of Linz in Austria, and involving universities in Czech Republic, Germany, Greece and Romania as well as Elmarco, the project aims to recreate the "calamistrum" – a comb specific to certain spiders.

Cribellate spiders such as the feather-legged lace weaver, for example, use their calamistrum to handle and process the nanofibres they naturally produce.

They make up to 40,000 sticky nanofibres in thicknesses of 10–30 nm from their cribellum – a spinning plate close to the spinnerets. To be able to handle such extremely fine nanofibres, the cribellate spiders use the calamistrum on their hindmost legs. This comb allows cribellate spiders to create a sticky capture spiral from the nanofibres for their nets – which interacts and captures the prey effectively – without sticking to the spider itself.

Why the calamistrum is non-adhesive towards these fine nanofibres is still elusive and the clarification of these properties – as well as its technical abstraction for technical nanofibre processing – is the aim of the project.

A further goal is to transfer these bionic comb structures to technical surfaces featuring anti-adhesive properties that will enable improved future tools for nanofibre handling. Similar nanostructures can also hinder the adhesion of nanofibrous protrusions of cells or micro-organisms, which may also lead to the creation of cell-repellent or antiseptic areas on medical devices and implants.

Advanced laser-induced nanostructures are currently being employed to mimic the fingerprint nanostructures of the cribellate spiders.

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DIARY OF EVENTS

June 2021

22 June – 2 July 2021
Future Fabrics Expo
London, UK
Contact: Nastassia Ramazankhani, Project Manager, The Sustainable Angle
Email: info@thesustainableangle.org
www.thesustainableangle.org/future-fabrics-expo-10

23 June 2021
Smart Materials and Devices for Electronic Textiles
Online
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https://mrs.digitellinc.com/mrs/live/601/page/2786

August 2021

5-6 August 2021
Wearable Technologies Conference 2021 USA
Online
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November 2021

3-4 November 2021
E-Textiles – 3rd International Conference on the Challenges, Opportunities, Innovations and Applications in Electronic Textiles
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MONTHLY PUBLICATIONS

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MobileTex
A monthly newsletter providing commercial news, product, and marketing and technical information of the global transport textiles industry, including the automotive, aerospace, rail and marine sectors. The publication is aimed at producers and users of fibres, yarns, fabrics and end-products used in automotive and other transportation textiles

Textiles Eastern Europe
A monthly newsletter providing commercial news, information and business opportunities of the textile and clothing industries in the emerging markets of Central and Eastern Europe and the former Soviet Union. Read by top management and global decision-makers with an interest in capitalising on and investing in the economic regeneration of this rapidly developing region

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MARKET REPORTS

Personal Protection Textiles (2nd edition)
This revised edition outlines the global market for personal protection clothing in the industrial, workwear and private sectors, and details legislation, regulations and standards for their manufacture and use

Automotive Nonwovens (3rd edition)
This updated report examines the structure of the automotive nonwovens sector, including profiles of key Tier 1 and Tier 2 players that use these rapidly developing materials

Automotive Textiles (5th edition)
This revised edition analyses the fast-moving global automotive textiles industry and describes the wide-ranging use of textile materials in vehicles

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