Often dubbed a miracle material, graphene possesses a unique combination of properties: thermal and electrical conductivity, strength, antibacterial and UV blocking. These are being put to the test in the first graphene-based textiles coming to market.

# Graphene's many gifts

One of the newest performance materials, graphene may also be the one whose time to market has been the fastest. Andre Geim and Konstantin Novoselov, scientists at the University of Manchester, first isolated the material in 2004, a breakthrough crowned by a Nobel Prize in 2010. In 2017, market research firm Future Markets has estimated that the global market for graphene will reach $250 million. Even more surprising, the first clothes integrating the substance are already available for purchase in stores thanks to premium Italian sportswear brand Colmar. The first company to launch graphene-enhanced products, it has used the innovative material in both its summer and winter collections, an indication of its cross-seasonal potential.

But graphene has much more going for it. The substance that makes up our lead pencils possesses a unique combination of properties. It has been found to be 200 times stronger than the strongest steel and is nearly transparent. It conducts heat and electricity and has antistatic and bacteriostatic properties, useful in clothing. The single atom-layer sheets of graphene, when integrated into any product or garment, will not add discernable weight.

Demand is building up, Directa Plus CEO Giulio Cesareo tells *WSA*. Based in Lomazzo, near Milan, Directa Plus has developed a manufacturing method that physically separates the graphene sheets without requiring any chemicals, as *WSA* reported in its March/April 2016 edition. It is working with several brands to develop textile applications for the high-tech material. This September, it signed a contract to supply high-performance technical textiles enhanced with its Graphene Plus (G+) technology to Alfredo Grassi, a manufacturer of workwear and uniforms for



*Former Italian ski champion Paolo De Chiesa dressed in Colmar's G+-powered skiwear.*

Colmar



*Italian compression brand Deewear has integrated new, high-performance graphene-based textiles in its ranges.*

*Deewear*

private and public organisations.

"Alfredo Grassi is one of the largest producers of workwear in Europe; the company buys 1.5 million metres of textiles every year, including many high-performance materials such as Gore-tex and G+," says Mr Cesareo, adding that in Italy alone, 280,000 people are dressed head to toe by the company, opening new options in footwear to the supplier. "This is our first significant order, representing 600,000 metres of fabric," he says. The technology Grassi has chosen is a fabric printed with a layer of G+ graphene. "Tests have demonstrated its ability to have a cooling effect on the body (by 1° or 2°C), and this is one of the reasons that motivated the contract," he points out.

Graphene's thermal conductivity allows it to dissipate heat generated by the body. Inside a winter jacket or underwear, it is said to move warmth away from hot spots to cool spots, thus increasing wearer comfort. Its antistatic effect is a useful feature for clothing made from synthetic fabrics, and bacteria will not grow on a graphene material, making it anti-odour.

## Scaling up

The production method developed by Directa Plus enables it to offer graphene in the form of inks, pastes and powders. These can then be printed on a textile substrate, or, when blended with polyurethane, used to make coatings or membranes. The membrane solution contains more graphene, says Mr Cesareo, making it more effective than print applications. The next logical step would be the development of a graphene fibre, which is in the works. Initial tests have provided "interesting results" and the company expects to make progress in the medium term. "We focus our research on developing stable, solid innovations with a supply chain that can support demand from major customers," says the Directa Plus CEO, pointing to the company's proven ability to scale up production. It delivered 3.1 tonnes of Graphene Plus materials in 2016. That is the year the company went public and acquired Osmotek, a maker of membranes, now integrated into its Directa Textile Solutions division.

Italian warp-knit specialist Eurojersey is the first textile manufacturer to integrate G+ into its




*Italian warp knitter Eurojersey is one of the first companies to develop textiles with a layer of printed graphene or a graphene -enhanced membrane in its high-stretch Sensitive Fabric range.*

*Colmar*

COPYRIGHT WTP ©

range of Sensitive branded technical fabrics, those used by Colmar. The company based near Milan is using graphene in two forms: as a membrane bonded to one or two layers of Sensitive Fabric or as a printed pattern. "The advantage of printing is that it requires lower quantities of graphene and is therefore cheaper. It also enables the graphene-enhanced fabric to be worn closer to the skin, where its thermal conductivity and antibacterial properties are most effective," says Matteo Cecchi, Eurojersey's sales director. The company plans to present new developments at the January 2018 ISPO show.

Kyorene, a company based in Shanghai, has also developed graphene-based fibres and textiles, but uses the material in its oxide form. It is integrated into polyamide, polyester or polypropylene fibres where it provides its many properties, including heat dissipation, antimicrobe, anti-dust mite and UV-blocking functions. "In addition to thermal conductivity, graphene possesses deodorant properties and offers high UV protection even in a very light and transparent fabric," says vice-general manager Romain Henricart. He furthermore claims that it may have therapeutic properties as it is a negatively charged material. This is said to have a calming and soothing effect that may also speed up muscle recovery. The materials developed by Kyorene have been tested by various institutes including ITS, CTC, TIV-SUD and are already being used by US-based workwear glove maker Armor Guys. Kyorene exhibited at Première Vision this autumn as part of its strategy to expand into new markets.

## Next generation electro-textiles

The electrical conductivity of graphene points to possible developments in electro-textiles. Working with the Graphene Institute at the University of Manchester in the UK, Francesca Rosella and Ryan Genz, the designers behind smart clothing brand CuteCircuit, created the intu Little Black Graphene Dress for the intu Trafford shopping centre earlier this year. The dress has stretch sensors that capture the wearer's breathing pattern to activate a series of LEDs. These turn from orange to green when the wearer takes a shallow breath, and from purple to turquoise, when breathing deeply.

The electrical, mechanical and optical properties of monolayer graphene could be used to make transparent textile-based electrodes for applications in wearable electronics, which is the focus of research at the Centre for Graphene Science at the University of Exeter. The centre produces its graphene by chemical vapour deposition, which deposits the nanosheets onto copper foil.

Graphwear Technologies, in the US, is working on developing a sweat-analysis patch to monitor glucose and hydration levels, but founder Saurabh Radhakrishnan also hopes to integrate the smart material into textiles.



*The intu Little Black Graphene Dress, made by CuteCircuit, on display at intu Trafford Centre in the UK.*

CuteCircuit

More surprising, or scary depending on one's viewpoint, a team of researchers at Tsinghua University in China is feeding graphene to silkworms to see if the silk they produce would be conductive. Initial results indicate that there is still much work to be done, as the researchers declared in a presentation at the American Chemical Society congress in Washington this past August.

Current applications in clothing, as seen at Directa Plus and Kyorene, tend to focus on the material's thermal conductivity, but electrical applications are in the works at these companies as well. Expectations are high regarding the miracle material and all eyes in the industry are on its potential to power the next generation of smart clothing and wearables.

COPYRIGHT