Illustration of a graphene molecule.

Inkjet Opportunity in Smart Textiles

Where technology and garments converge

What's Smart About Textiles?

The term "smart textiles" currently lacks a common definition. Functional textiles, particularly those that respond to thermal or other environmental stimuli, are often considered to be smart textiles. Such textiles actually fall into the "passive textiles" category, and the smart nature of these fabrics is often displayed by color or form change.

There is an emerging consensus that smart textiles should be defined as those that are "active" or "intelligent," and as a result, electronic textiles are coming to the forefront. Thus, a smart textile can be defined as one that can sense its environment, respond and transfer meaningful and useful information or energy.

By necessity and design, smart textiles incorporate sensors, actuators, conductors and often a central processing unit or transformer. Various materials can be used to create smart textiles, and the necessary conductive component can either be attached to the textile, integrated into the textile, or be a part of the textile itself.

In the most basic smart textiles, for example, you will find sensor hardware attached to the textile product. The textile facilitates the wearing of the smart device and enables data to be collected. The textile itself is not inherently smart.

Growth of the smart textile market segment is likely to be facilitated by the declining average price of smart sensors globally. According to Goldman Sachs, between 2004 and 2014, the average cost of internet of things sensors dropped by more than half from $1.30 to $0.60. This trend is anticipated to continue, with prices expected to drop an additional 37% by 2020 to $0.38.

In a more advanced smart textile, sensing technology is integrated into the textile. The smart element can take the form of conductive inks printed onto the fabric or metal fibres woven or knitted into the fabric. Sensors may be attached to the textile as well; the sensors themselves may also be printed, woven or knitted depending on the sophistication of the technology being used.

Finally, a smart textile's conductive

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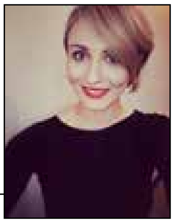
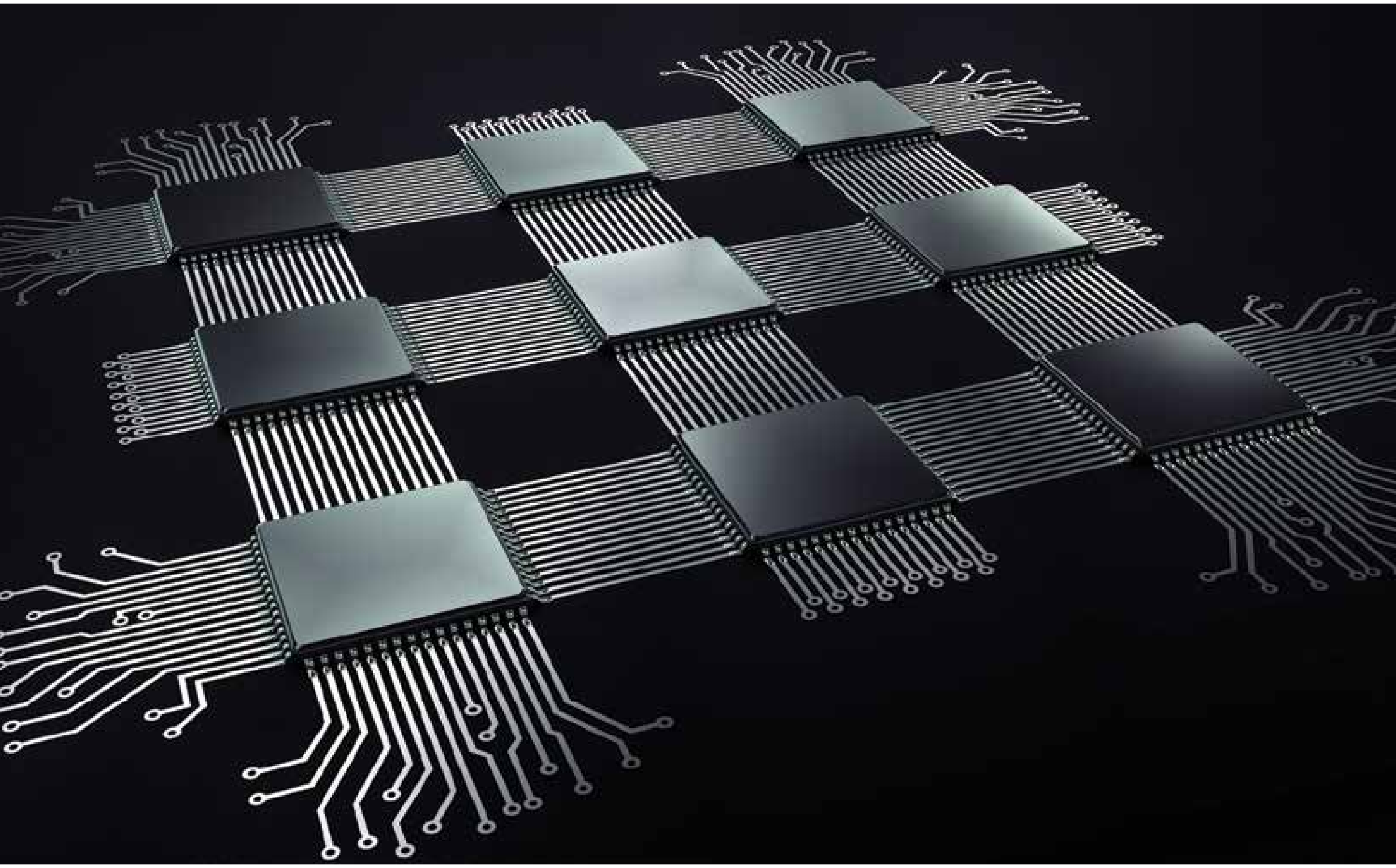


By Tansy Fall, Editor – Industry Digitalisation, World Textile Information Network (WTiN)



Stretchable electronics.

element can be a part of the textile itself. In this case, a textile or yarn's fundamental structure will have been modified — prior to extrusion of a polymer fiber, for example, or using other emerging methods — enabling the textile itself to become conductive and/or sensory.

Intelligence from research, consulting and event firm IDTechEx suggests that this most advanced category of smart textiles is growing significantly, with 38% of all players in the smart textiles sector using this technology in 2018, up 5% from the previous year. However, considering that conductive textile fiber development is still in its infancy, and these materials are often costly, there is a significant opportunity for conductive ink manufacturers, as well as for technology providers who support this application, to dominate the sector.

Conductive Inks for Smart Textiles

Smart textiles that incorporate conductive inks make up 63% of the market, according to IDTechEx. While printing with conductive inks is already the dominant technology in the smart textile space, it is equally an emerging technology in the wider textile and apparel market, providing scope for further advancement and market acquisition. Improvements in printed electronics technology and rapid circuit prototyping are enabling manufacturers to more efficiently create these smart devices, speeding up the smart textiles' development process.

A larger variety in the type of printed electronics available is also increasing adoption. For example, developments in stretchable electronics are playing a key role in improving the flexibility and comfort of electronic-embedded smart garments.

Within the stretchable electronics sector, it is the interconnects that are first to market. For this purpose, conductive inks can be printed using both inkjet and screen printing methods, and the inks themselves can be tailored for printing onto specific textile types to create an electrically active pattern.

Companies such as DuPont have already been able to create prototypes of conductive inks that are stretchable and can withstand many wash cycles. The technology is lightweight and does not hinder material comfort, which is a key end-user benefit.

Self-powering sensors can also be printed using conductive inks. These sensors are often based on piezoelectricity, and the electronic signal is generated by mechanical stress. As they do not require an additional power source, these sensors are the focus of much research exploring their sensing capabilities as well as their effectiveness as energy storage units.

Pressure is used as a source signal in materials with soft switches, which utilize a quantum tunneling composite that changes properties upon pressure. Pressure sensors are useful for creating products such as fabric keyboards and keypads. Stretch sensors are also commonly used to evaluate body and joint movements for applications in athlete training, patient rehabilitation and firefighter monitoring.

Embracing Graphene

Of the conductive inks on the market, perhaps the most promising are those that are graphene-based. Graphene, the strongest material ever tested and much discussed across industries, conducts heat and electricity efficiently, and is nearly transparent. Graphene's highly conductive nature has also allowed its reduction to graphene oxide (rGO), which is a slightly less conductive form of graphene, but can be easily printed while maintaining good conductivity. Others investing in graphene ink applications have investigated the inks that find graphene flakes dispersed in a liquid, to ensure harmonized printability and conductivity.

Although graphene ink application is still not widely seen in the market, some products are starting to emerge. UK-based Cambridge Graphene recently entered into an agreement with an unnamed Asian textiles manufacturer, for example, to supply its graphene ink for the creation of smart sports apparel. These products will enable wearers to monitor performance, health issues such as heart rate, and optimum movements.

Noting the Challenges

In her recent report, "Graphene and its Opportunities for the Textile Industry"[1], WTiN Technical Analyst and Team Leader for Material Innovation Robabeh Gharaei, Ph.D., notes that while graphene has much potential, there are still a lot of challenges to overcome.

This includes standardization, particularly around graphene quality and application. Graphene is produced through several different processes, each resulting in materials with different properties. For example, one type of graphene may be better suited to conducting heat rather than electronics. Moreover, not all graphene is created equal, and this can lead to product variation, which makes for complex supplier and buyer relationships.

Another issue is cost, which is generally high for graphene manufacturing due to its market immaturity and the need for high-quality graphene sheets in many areas. Graphene flakes, the most affordable form of graphene, can be purchased for an average of $50 - $100 per kilogram.

Safety is also a critical factor with graphene. "Like many other nanomaterials, the safety of graphene does not seem to be completely clarified, especially when it comes to inhalation and exposure to skin," said Gharaei.

The good news is that there have been studies conducted on research grade and commercial graphene-based materials — such as few-layer graphene GO and rGO — "that have shown graphene to be non-cytotoxic and non-genotoxic to human skin cells and murine lung cells, and confirmed that graphene did not harm the viability of these cells for up to 24 - 72 hours, depending on the concentration used (5 - 200 micrograms per milliliter)," Gharaei added. These studies can offer some reassurance regarding the safety of graphene.

Alternative Ink

With these challenges in mind, conductive inks made using silver are also an interesting area of development for the textile industry. While there have been many instances of silver inks coming to market, perhaps the most significant breakthrough in this area comes from a collaborative project between Austrian companies Profactor GmbH, Lenzing AG and Tiger Coatings GmbH.

Successfully completed in 2016, the iTextil project culminated in the publication of a paper on silver-based reactive inks for inkjet printing of conductive lines on textiles[2]. Nanotechnology experts spent approximately two years conducting research for the ink's development. Its primary selling point is that the ink is based only on silver as a solute, with every solid particle of silver having been removed. This makes the ink easier to jet through printheads. During printing, the solvents in the ink evaporate leaving pure silver on the material.

Though still in varying early research and development phases, these emerging technologies and solutions will continue to advance the smart textiles market, adding unique capabilities and functions to garments.

References

[1]https://www.wtin.com/article/2018/december/171218/graphene-and-its-opportunities-for-the-textile-industry-part-iii

[2]https://www.sciencedirect.com/science/article/pii/S0167931717300527

Tansy Fall is Editor — Industry Digitalisation at WTiN, a business-to-business market intelligence provider for the textile industry, with print and digital publications. Tansy is the Editor for Digital Textile magazine, which focuses on the digital textile printing sector, and IoTex magazine, which provides an insight into the complete digitalization of the textile and apparel value chain, as well as for their corresponding online platforms.

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