Disappearables, the buzzword of the day in wearable technologies, refers to the seamless integration of smart devices into everyday life. Soft, elastic, comfortable and washable, textiles are seen as one of the best ways to achieve this.

E-textiles, smarter by the day

As the fanfare surrounding activity-trackers begins to wane, attention is now shifting to what is seen as the next phase in the evolution of the Internet of Things, namely the Internet of Clothing. It is believed that users will be less inclined to discard smart clothes if their features are seamlessly embedded into the fabric of our everyday lives.

When Google presented Project Jacquard, a denim fabric that would be developed to control a smartphone (developed with Levi's), the internet giant's interest in smart clothing sent a strong signal to the textile industry that e-textiles may finally be reaching a tipping point.

"We get many calls from Silicon Valley companies," says Jan Zimmermann, head of Swiss company Forster Rohner's e-textiles business unit. "They have the algorithms, the chips, the software, the market and the marketing, the only thing they are missing is the textile." Or so they believe. Like many industry insiders *WSA* has spoken to, Mr Zimmermann says that textiles are often the last piece of the smart clothing puzzle. "This is the problem. Tech companies believe the textile element is the easy part."

Cath Rogan head of the UK-based Smart Garment People consultancy, agrees. "Smart textiles are riding on the coat-tails of Fitbit's business," she says, "but electronics and textiles remain two very different industries, and we have yet to figure out how to bridge the gap." A stronger supply chain, thanks to consolidation, as seen in the recent merger of Jabil, a supply chain

The discreet, washable smart sensor integrated into running shorts and tights by Lumo Bodytech is said to monitor cadence, stride length, ground-contact time and pelvic rotation, all sent in real-time to a smartphone app.

Lumo Bodytech

management and electronic manufacturing company, and Clothing+ of Finland, will be a plus, she also points out.

For Andreas Röpert, CEO of the ten-year old Infineon spin-off Interactive Wear AG, young designers are more tech-literate, and they will be the ones to create ever-smarter connected clothing. "There is a learning curve, in e-textiles like in any industry, which can last 20 to 35 years. The first wearable technologies having been developed in the mid-Nineties, this sector is now close to 20 years old," he says, adding that sports brands are currently working on their Fall/Winter 17/18 collections. This means 2020 is just around the corner. "I'm quite confident that we will have a real market, not just a niche market, sometime between 2020 and 2030. It will be driven by activity monitoring, self quantification and wellness," he says.

The heat is on

Before Google's e-textile project becomes a reality, biometric fitness and running clothes developed by Hexoskin, Omsignal and a handful of other companies are still struggling to bring the technology to the mainstream. "To scale up, you need to simplify," says Ms Rogan. Basic, relatively easy-to-integrate heating and lighting components would fall into this category.

Yak On, a heat-generating jacket by Korean sportswear brand Black Yak, won an ISPO 2016 award and was launched on the Korean market last year. A smartphone app controls temperature levels and the battery recharges the jacket by magnetic induction (a USB plug is also included for those using a power bank or other device). This construction not only reduces the amount of hardware in the jacket, but also makes it machine washable. "We produced 15,000 women's jackets and sold 70% of these," says Allen Choi, Black Yak's product manager. He is now working on the next generation which should have "a battery that lasts longer and a different distribution of the heating panels on the body".

Forster Rohner and Interactive Wear have developed off-the-shelf heating modules that they say are affordable and simple to use. "A heating function can help a sports brand differentiate itself from its competition," says Jan Zimmermann. Italian luxury brand Zegna was the first brand to use the modules. Displayed at TechTextil 2015, the heatable jacket came with a hanger that also served as a wireless charger. "Heating panels are a good example of a simple idea with a clear advantage," says Mr Röpert. "If the numbers go up, we can make the prices go down." Though he admits: "work needs to be done to make the components even easier to use. The advantage of the collaboration with Forster Rohner is that the production process is in place. If 10, 50 or 100,000 modules are needed, they can be manufactured."

Korean brand Black Yak's Yak On smart jacket enables wearers to control the temperature inside the jacket using a smartphone app.

Black Yak

Heating, lighting and speaker components are the three main features that Sympatex's tech division, formerly known as Tection, has focused on. The heating panels and watertight LEDs can be washed, says company manager Hervé Clerbout, who sees workwear, outdoor and cycling as key end markets for these embeddable features.

The projects that embroidery manufacturer Forster Rohner has recently been involved with include suits for Formula 1 drivers that monitor heart rate and G-force, and biometric smart clothing for first responders or elite athletes. "These projects are concrete examples of how our textile electrodes and conductive components can be used, but we would like to see applications move beyond these niche markets," says Mr Zimmermann.

Forster Rohner can manufacture various types of sensors that measure proximity, pressure, movement or stimulate the body. The latter function has been used in the Antelope electro-stimulation suit made by German tech start-up Wearable Life Science. LEDs however remain the main market for Forster Rohner, with one of its most prominent clothing applications seen at Akris, a Swiss fashion brand based in St Gallen.

The advantage of Forster Rohner's technology is that it is truly textile-based. These smart fabrics have the look and feel of a textile and can be washed like any item of clothing. They are perfectly wearable, but their performances have yet to reach the level of precision of a hardware component. "We are dealing with tolerances and deviations that are not as precise as those achieved by a rigid circuit board," says Jan Zimmermann. This means that e-textiles will not replace conventional hardware, and we won't be seeing a 'computer' shirt any time soon. "A fully textile sensor will not be as precise as a chip mounted on a textile background," he says.

Interactive Wear's current focus is to help brands build a multi-sensor network using its elastic textile cables. "With a multi-sensory network, you can get high quality data that can be fantastic for training," says Mr Röpert. Though the company is making progress, it has not yet reached the stage of industrialisation.

Textile sensors

New Zealand-based Footfalls and Heartbeats has developed fully textile sensors, with no plastic nor chips. Its main product measures relative pressure thanks to a conductive yarn and a patented knit construction, that can be made on flat-bed or circular knitting machines. "Our sensor creates a pixel-based image of relative pressure zones, showing where and how a person is sitting, for instance," says company founder Simon McMaster. Three memorandums of understanding have been signed with companies in the medical, vehicle and sports industries. The technology could be ready for market launch in 2017. "It is a very simple, and scalable application," says Mr McMaster citing pace analysis as a possible sports application. The company's next goal is to develop an absolute pressure sensor. "We have proof of concept, and in a certain set of conditions, we can get absolute pressure data, but we do not yet have a working prototype," he says. The technology is being developed in conjunction with Nottingham University and the company plans to move to the UK in 2016 to be closer to Europe, where most of its clients are located.

The silver yarns made by Noble Biomaterial are also being used to make textile sensors, part of the Scranton, Pennsylvania-based company's new Circuited division, dedicated to smart clothing. It harnesses silver's conductive properties to make e-textiles that can capture an electrical signal emitted by the body, transmit it and protect it from other signals. The technology is being used by Italian company Wav-E to make a seamless muscle stimulation suit, and it is the conductive material found in Clothing+ modules. "The advantage of our yarns is that they can be washed 200 times at high temperatures," says European manager Stephen Winnen. In addition to silver yarns, the company also metallicises fabrics. "We are seeing high momentum in this space," co-founder and chief commercial officer Joel Furey tells *WSA*.

This c fabric, presented at Itma in 2015, can generate (10W/m²) and store (10Wh/m²) energy in a fully textile matrix. It combines photovoltaic fibres, based on perovskite solar cells, and rechargeable energy-storing fibres containing a thin battery film.

Powerweave

This knitted textile-based sensor is said to detect the bioelectrical signals of active and passive skeletal muscles. It would allow ambulatory ECG and EMG. Future developments at Footfalls and Heartbeats include the ability to measure blood oxygen saturation levels and blood flow rate battery film.

Footfalls and Heartbeats

Though not technically a textile, the sensors and actuators made by Danish company Leap Technology are soft, pliant and washable. Its electroactive polymers (EAPs), first introduced in 2011, are used to make mechanical sensors, actuators, energy generators or a combination of these. The components are made of an electrical insulating layer of elastomer sandwiched between two electrodes. "This technology is often referred to as an artificial muscle, as it will change shape when voltage is applied," says Alan Poole, a Leap Technology co-founder. In clothing, it

would be used to assist or monitor movement such as a golf swing or breathing if worn on the chest. "The sensors we make are among the few that can measure slow motion with accuracy," he says. Wrist-based tracking devices are generally considered very poor at this. "Even if a person is not moving at all, Leap will measure effort and provide users with information on their internal and external proprioception system." The company's evaluation samples have been bought by sports brands. A facility located in the south of Denmark is up and running on "a medium industrial scale", says Mr Poole, explaining that this means it can produce tens of thousands, if not tens of millions.

Power-generating fibres

The next smart textile that the market may need is an energy-generating fibre to power the textile-based sensors and conductive yarns. Two research projects are making progress in this field.

Powerweave, an EU-funded project, came to a close last year with working prototypes for an energy-storing and an energy-generating photovoltaic fibre. The energy-storing fibre technology is a multi-layered yarn made with two layers of current collectors and two layers of electrodes surrounding an electrolyte core. The solar cell fibre is based on a fine perovskite film bonded to a copper core and covered with a transparent conductor layer all encased under a protective sheath, the current version measuring 150 microns in diameter. "We have made some 2,000 metres of the energy-storing fibre and about one metre of the photovoltaic fibre," says Ian Jones, principal project manager at UK-based TWI, a member of the research consortium that also includes research institutes Centexbel (Belgium) and Centi (Portugal) along with component makers Ohmatex (Denmark) and Sefar (Switzerland). "The main challenge we are facing is the adherence of the different materials," says Mr Jones, this being TWI's field of expertise. "We're looking at another three or four years before we have demonstration pieces."

The project to make a piezoelectric fibre to power textile sensors, capture signals and transmit data continues in France at the school of textile engineering ENSAIT and the European research institute for textiles, CETI. The group is working on developing a tri-component yarn that has a conductive core and sheath surrounding a nanoelectronic middle layer. This programme, called Autonotex, has recently received €4 million in regional funding with additional input from partner companies Damart (functional clothing), Eminence (underwear), Petit Bateau (children's wear), Innothéra (compression socks) and BioSerenity (maker of an epilepsy diagnostic smart shirt), the project leader.

Meeting consumer expectations

As the ecosystem to make smart clothing continues to make progress, many hurdles remain. "The reliability of the data harvested is a fundamental issue that all smart textiles have yet to resolve," says Damart's R&D manager Michel Caillibotte. Any mention of data in conjunction with a wearable device inevitably raises the question of privacy and security. Protecting the data is just one facet of the issue, as Cath Rogan points out: "Any elite athlete would be righteously concerned if his or her contract required wearing a biometric tracking device." The data collected by smart garments could be much bigger than that of the smartphone business, says Mr Röpert at Interactive Wear because people usually have one smartphone but many items of clothing.

The industry might need a new business model that would no longer be based on selling a garment but on offering a subscription-based service. "If consumers are not inspired to spend money on a smart shirt, maybe a telecom provider will offer it because it will monetise the data generated," speculates Cath Rogan. If the data produced by a smart shirt is the main source of value, it may need to be given away

Dutch fashion tech designer Marina Toeters' Gold Light Jacket is made with a patented flexible and stretchable interconnect technology developed by Imec and Holst Centre. Her goal is to seamlessly integrate smart features into everyday clothing.

Jonas Briels / by-wire.net

for free. And this is the model on which Google and Facebook have built their empires.

Finding the form and function that will meet consumer's needs and expectations also remains challenging, a matter raised by IBM Watson executive Dirk Muehlenweg at the Wearable Tech conference held at ISPO last January. During his presentation, he pointed out that 80% of companies "believe they provide an outstanding proposition to their customers, but only 8% of their customers agree". Watson is an IBM technology platform that uses natural language processing and machine learning "to reveal insights from unstructured data".

For Dutch fashion tech designer Marina Toeters, technology is not the problem. "We have the supplies, the conductive yarns, the miniaturised electronics. What we need is to make a simple product that is relevant and subtle. A garment is a very intimate, personal item. Accepting a new function can be a long, delicate process." This, she says, is the space the market is in now. The designer has been working with smart textiles for several years. She assisted Pauline van Dongen, another Dutch fashion tech designer, in developing the LED-embedded Phototrope running jacket, and is currently working with a hospital to create posture-sensing clothing for nurses and with airline company KLM.

Though certainly useful, work-related smart clothes do not have to appeal to consumers, who are free to buy a product or not. This is why sports brands are considered the true forerunners in this market (see box). Next generation smart shirts are being introduced in Japan by Goldwin and Asics, the latter working with French wearable tech start-up CityZen Sciences. After running and fitness, outdoor brands may be next in line with clothes that will monitor breathing in high altitudes. The high cost of these components makes them more suitable for premium brands, so the quality of design will be all the more critical. Exclusive consumers will want the smart functions to be integrated as discreetly as possible and closer to a disappearable than a wearable.

Positive prospects

Zeynep Demir, Shutterstock.com, Runkeeper.com

Shipments of smart clothing, for the most part fitness and running wear, are expected to represent 26 million units in 2016, surpassing other wearable devices, according to a January 2016 report by MarketResearch.com. In its latest e-textiles market survey, IDTechEX estimates that sales could reach $3 billion by 2026, up from around $100 million in 2015. Another recent report, by market intelligence firm Tractica, estimates that smart clothing and body sensor shipments will rise to 92.7 million units between now and 2021 (totalling 190 million wearables). It anticipates that body sensors will represent approximately 70% of that total market, with smart clothing accounting for about 30%. These optimistic numbers are symptomatic of the excitement associated with all smart connected devices.

Data is the new oil

The many sportswear brands that are snapping up fitness apps seems to indicate that having access to a community of users and the data it generates is more than just a trend. Since 2013, Under Armour has spent upwards of $700 million to acquire three apps, MapMyFitness, Endomondo and MyFitnessPal, thus reining in some 150 million potential users for its Health Box biometric ecosystem. In 2015, adidas bought Runtastic, with 70 million registered users, for an estimated €220 million. In March 2016 Asics Corp. purchased Runkeeper for $85 million, giving it access to a database of an estimated 33 million users. With sales slowing – or with the prospect of a permanently slow economy – sports brands may shift from selling a product to selling a subscription and using the data it collects through fitness apps, activity tracking devices and smart clothes as their primary source of income.

The 20W heating system designed for integration into clothing is a co-development by German company Interactive Wear and Swiss embroiderer Forster Rohner.

Michael Girschick / Interactive Wear AG