The smart compression sports bra by Danish women's fitness brand PureLime has a built-in heart-rate sensor co-developed with Finnish textile engineering company Clothing+.

PureLime

Progress made in miniaturised, low-energy electronics and sensors is leading to a smarter selection of electro-textiles and "energy-harvesting" accessories. Although there remains room for improvement regarding their autonomy, weight and integration into garments, this vast field of research is fuelling an increasingly data-driven athletic market.

Upgrading sportswear with electro-textiles

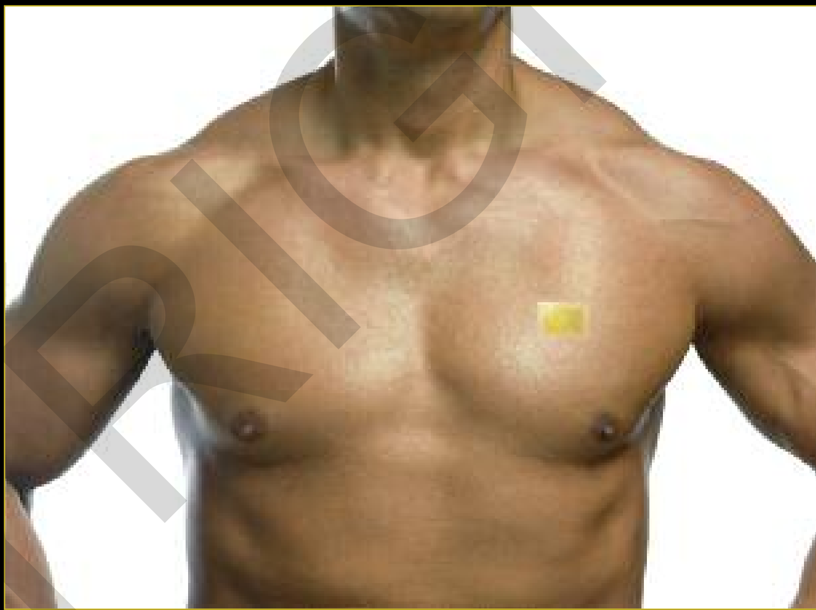
The age of mp3-equipped jackets and soft keyboards embedded into so-called smart garments, which defined much of the textile gadgetry developed in the recent past, appears to be over. We are now entering the age of sensor-equipped apparel that collects performance data used for coaching purposes by elite athletes and as motivation tools for runners and fitness fanatics.

The success of Nike+ systems and adidas miCoach has brought renewed interest to the seamless integration of electronic circuitry into textiles. But most sportstracking devices are designed to be clipped on to shoes or headbands, or worn separately as chest straps, watches or bracelets. With the exception of heart-rate monitoring (HRM) systems built into sports brassieres, this market thrives without the need to bond seamlessly with textiles.

Engineers around the world continue nonetheless to work on designing electronics that are more compatible with clothing, driven by what appears to be two key premises. The first, as stated by Amar Kendale, vice-president of strategy and market development at MC10, a Cambridge, Massachusetts-based company that works to find new applications for electronics, is that: "Electronics are poorly compatible with the human body, while textiles possess mechanical characteristics that have the potential to change the way we interact with the devices." The second, voiced by Jane McCann, Director of the Smart Clothes and Wearable Technology Research Centre at the University of Wales, Newport, is that sports enthusiasts are early adopters of new technologies. Taken together, they may explain why there have been so many attempts to integrate electronics into sports apparel.

Clothing+, a textile engineering company based in Finland (spun-off from Reima in 2002), claims to have sold 3.5 million HRM straps in 2011, and plans to sell as many in 2012. "Heart-rate monitoring is our bread and butter, 60% to 70% of all sensors on the market are Clothing+ developments," says Mikko Malmivaara, the company's product and marketing manager. Clothing+ develops its sensor-equipped accessories with taping manufacturer Bemis and silver-fibre producer Noble Biomaterials. Conductive fibres or silver-laminated fabrics transmit data and a special polymer binds the sensors to fabrics. The placement of the HRM sensor requires high precision, with a margin of error of around three millimetres, according to Mr Malmivaara, who says that it is "easy to achieve, especially with compression clothing".

Heart-rate monitors are designed to capture an electrical signal, not a mechanical pulse, as most people think, and the best spot to pick up the signal is the chest wall, says Sarah Hofmann, product manager for the Stella McCartney-adidas range. Adidas acquired Textronics, a company specialising in stretch conductive textiles (and a DuPont spin-off) in 2008, which has since become the Adidas Wearable Sports Electronics division that



MC10 has developed bendable ultra thin electronic chips and sensors that stretch by up to 200% for seamless integration into apparel. Reebok plans to introduce the concept this fall, using a system that requires wiring (not shown). MC10 is working on second generation circuitry that would transmit data wirelessly.

MC10

Glovetip, designed by French start-up Chi&Jo, is based on a pine-tree shaped tip that attaches to any glove to use smart tactile devices in cold weather. A combination of a conductive plastic with a stainless steel tip activates tactile screens, which are no longer resistive (or pressure-based), but use static electricity emitted by the skin.

Chi&Jo

designed the adidas-Stella McCartney HRM sports bra. Under Armour's E39 is another example of an HRM device integrated into a sports shirt. Danish women's fitness brand PureLime recently launched a smart sports bra using Clothing+ technology.

Clothing+ develops each product according to its client's specifications, leaving the brands to patent the system, or not. "Our reasoning is that we need to continue to invest in research and development to keep one step ahead of the game", says Mr Malmivaara. After HRM, the company is now investigating electromyography, the monitoring of muscle movement. The company is currently experimenting with leg-muscle monitoring shorts for ski jumpers and athletes who want to check that they are using their muscles symmetrically. "This information can be useful for soccer and American football players," says Mr Malmivaara.

Monitoring & statistics

The seamless integration of electronics and textiles could make a significant leap forward with the upcoming launch of what some call "electronic skin", by MC10. The Cambridge-based start-up is working with Reebok on a product to be launched later this year. Little is known about the sports brand's project other than that a smart device will be lodged in a garment.

MC10 wants to change the 'packaging' of electronics, in the words of Amar Kendale. The company's research team, whose expertise is in soft materials, has been working on creating a stretch electronic device since 2002. Instead of embedding silicon circuitry in ceramics, MC10 coats it in silicone, a biocompatible material used for implants. The technology involves ultra thin electronics encapsulated into a soft polymer creating a flexible composite material that should be virtually unnoticeable by the wearer. The silicon elements are distributed within the polymer and linked by S-shaped connectors that can stretch up to 200%. Different types of sensors, to measure heart rate, muscle activity, temperature, strain, brain activity or hydration levels can be built into the devices. A hydration patch is in development and should be ready for market in 2013, says Mr Kendale.

The Swiss research centre CESM and French high-tech company ST Microelectronics have been working on wearable monitoring devices for a number of years. ST Microelectronics is a leading producer of MEMS, or micro-electro-mechanical systems, which are small machines combining electronics with mechanics. They are used in many smart devices, including smart phones, Wii controllers, pedometers, heart-rate monitors, and are featured in Babolat's Play & Connect tennis racquet and the recently

The three-axis accelerometer in the Nike+ FuelBand measures motion and translates it into what the company calls NikeFuel. As opposed to calorie counting, dependent on gender and body type, the algorithm used by Nike is said to provide a normalised score regardless of each person's physical makeup.

Nike

presented smart football that can be used in goal-line technology. Fabio Pasolini, general manager of motion MEMS at ST Microelectronics sees MEMS as "part of a macro trend, spreading from the devices we use every day to the body itself". The company has made progress in reducing the size and energy consumption of these micro electronic machines in order to make them more human-compatible.

Like Nike+, Fuel and the adidas miCoach systems, these sensors and monitors open up the possibility of comparing one's performances with those of elite athletes or one's usual sports partners. These data-collecting systems, promoted as incentive tools to engage in a sports activity, improve training sessions, and serve as remote coaching devices, are seen as a key area of development by both ST Microelectronics and CESM.

CESM co-develops smart devices with sports brands as well as the European Space Agency. The research centre has worked on Sense Core, a multi-parameter monitoring system currently being tested by Formula 1 racers. Another item in the company's innovation pipeline is a device to measure the effect of stress on golfers' swings. Smartex, an Italian company specialising in embroidered electrodes, and Weartec, a Spanish start-up, both use devices developed by CESM.

The evolution of smart garments was discussed in depth at the annual Innovation for Extremes (Innov_ex) conference organised by the IEED Lancaster University Management School, and sponsored by Pertex. Adrian Wilson, author of 'The Future of Smart Fabrics', evoked the benefits of these devices for athletes regarding increased motivation and the possibility of competing with other athletes, but also the fact that sports brands can now collect vast amounts of data directly from their consumers.

Florence Bost, a techno-textile designer based in Paris, believes the development of electro-textiles is shifting away from major companies to tinkerers at all levels thanks to the evolution of the "maker" phenomenon. "Designers now have access to devices that were formerly the reserved domain of engineers or geeks. Ten years ago, it was difficult to work with textile-compatible electronics. Today with sites such as SparkFun, in just two clicks, anyone can start experimenting with advanced systems," she says.

The power challenge

While athletes can now immerse themselves in ever-denser layers of data and statistics, a seamless way to power these devices remains to be invented. There is much talk of flexible batteries, batteries printed on paper, piezoelectric or thermoelectric sources of energy, but as it stands now, finding a reliable and sustainable form of energy remains a challenge.

The recently revamped version of Tremont's nPower Peg harvests kinetic energy, based on the Faraday principle where a magnet moving through a coil of wire provides electricity. A user would need to walk 11 minutes to power 1 minute of talk time on a G2 call via iPhone, or 26 minutes to power 1 minute of talk time on a 3G iPhone.

Tremont

Most suppliers of MEMS and electronic sensors now focus on reducing the energy consumption of their products. "We have two options: one is to harvest energy in the environment, the other is to reduce the amount of energy required," says Amar Kendale at MC10. The company has for instance decided against using diodes, considered power-hungry functions.

Like most companies, ST Microelectronics currently uses rechargeable batteries while continuing to investigate ways of collecting energy from the environment. "We free a lot of energy in each step we take," says Fabio Pasolini. He believes self-operating or autonomous devices will be available in the next three to five years.

The need to power the growing number of electronic gadgets and instruments people use every day has inspired some companies to develop energy-harvesting accessories. For hikers, the need to charge up when off the grid is feeding a new product category in the outdoor industry. Solar energy is one possibility. But photovoltaic cells lack the flexibility that would make them appropriate for integration into textiles. Solar panels are generally applied to rigid products, such as backpacks, like the ones developed by UK-based Crosskase.

Tremont, an American company

Crosskase says its Solar pack stores enough energy to charge most devices twice, and recharges fully after 8 hours of exposure to natural light.

Crosskase

The Screeneye X visor, developed by German company O-Synce, is mounted with a digital display to project data directly to the user's field of vision. The device is powered by a UV-light harvesting film placed on top of the visor or charged via USB.

O-Synce

based in Cleveland, Ohio, has been working on another option, which is to harness the kinetic energy produced by movement. The company has recently presented an improved version of the nPower Peg, which accumulates kinetic energy by way of a magnet-equipped Faraday-cage-based device. Designed to be stored in the backpack, and forgotten, the new model features a sleeker design, measures 25 centimetres but weighs a hefty 400 grammes, not ideal for light packers. Textile companies and sports equipment manufacturers have contacted Tremont with projects to integrate the system into walking poles, ski poles or bike frames, says Jill LeMieux, at Tremont.

Dutch company Rubytec also specialises in energy-harvesting accessories for campers and hikers. The solar-powered devices and flashlights, at times equipped with a back-up wind-up mechanism, are a "cheap solution for energy-hungry devices", says Dennis van der Gronden, product manager at Rubytec. The battery that powers Columbia Sportswear's OmniHeat jacket can also be used to recharge a cell phone or camera, further evidence of the need for extra energy.

While electronics companies remain fascinated by the mechanical properties of textiles, seen as the ideal ground to house their ever smaller and less energy-hungry devices, traditional sportswear brands have yet to share their enthusiasm. Norwegian sports brand Norrona and French surfwear brand Oxbow have discontinued their mp3 and cell phone-operating technical jackets. With the new focus on data collection, smart textiles are increasingly evolving towards the field of health and wellness and moving away from gadgetry.