Chapter 7 Smart Materials for Sportswear

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Table of contents:

1. Introduction

'Smart' and 'intelligent' textiles are terms that are frequently used interchangeably. The first 'intelligent' clothing systems comprised of a power source, wiring and electronic devices being concealed within the garments construction. This was merely a meeting of two technologies, rather than a true amalgamation. Although this gave an element of convenience to the wearer through clever garment construction and ease of operation of the electronic device, it could not be seen as a true development of technology. Garments such as the Philips ICD+ jacket are examples of technologies being used in this way for the mass market and although at their launch much media interest was created, the consumer quickly lost interest in the 'novelty' value of such garments (Tuck, 2000). Since this starting point, much research has been undertaken to seamlessly merge fabrics, clothing and information technology concepts, resulting in truly 'smart' materials. The 'wearable motherboard' garment, developed primarily for use by the US military is considered one of the first 'smart' garments as it incorporated the majority of electronic components within the fabric structure and was described as '*The Wearable Motherboard™: The first generation of adaptive and responsive textiles'* (Gopalsamy et al, 1999:152).

From these beginnings, the scope for the potential use of smart and intelligent fabrics has widened. The development of smart textiles in the area of healthcare to aid the monitoring of soldiers upon injury quickly translated into a domestic healthcare setting, with products being developed to enable patients to be monitored remotely. These developments enabled products to be targeted towards the mass market, enabling consumers to monitor their own health through their clothing.

Sport has become more popular as a leisure activity and the promotion of health and well-being are high priority on government agendas (Mintel, 2013). However, research has also shown that whilst participation in sports such as cycling and athletics showed strong growth in the years leading up to the London Olympic games in 2012, this pattern is now in decline. Various reasons can be outlined for this decline in the market, one being that motivation can be a limiting factor. It is suggested that visual representations of the benefits of physical activity can be great motivators and this is an area in which smart textiles are finding a rapidly growing market. A consumer can use technologies incorporated into their clothing to not only see their progress during the activity, but also to set personal goals which can act as a strong driver to improve commitment to the sport (Mintel, 2013). It is therefore not surprising that the major sports brands such as, for example, Nike and Adidas have developed footwear and clothing housing inbuilt sensors that can be linked to wristbands and mobile phone apps to enable the wearer to track their progress during physical activities or intensive training.

The aim of this chapter is to provide an overview of current smart and intelligent textile technologies, that commences with a broad definition of smart textiles, then explores how such garments can be powered and how information can be collected and transmitted. The chapter will then further present how smart textiles can respond to the changes within the body and adapt to these to enhance comfort and performance, with specific reference to sportswear applications. A case study will be used to illustrate the applications of smart textiles in the sportswear market. Finally the chapter will go on to discuss the future for smart textiles and the limitations of the technologies.

2. The definition of smart materials

It is generally considered that the term 'smart material' refers to a material that is able to sense changes in its surroundings and react to these changes accordingly. However, Tao (2001) suggests that smart materials can be sub categorised into three divisions as follows:

- Passive smart materials can be thought of as sensory devices; that is, materials of this type can sense changes in the environment, but do not have the capabilities to react to these changes.
- Active smart materials are able to both sense external stimuli and react accordingly.
- Very smart materials are able to sense, react and adapt themselves according to the changes in their surroundings.

There has been much work on the development of smart materials in the medical industry, where major innovations have been noted in the monitoring of patients. Similarly, the military have found smart materials extremely useful in the monitoring of soldiers in combat, enabling medical aid to be targeted to those whose need is greatest (Park and Jayaraman, 2003). The major part of these developments can be used and adapted to enhance the use of smart materials in the sportswear industry.

As the potential applications of smart materials are so diverse there are many solutions offered to the issues of power supplies, conductive yarns and integrated sensors – each of which will now be discussed in turn.

a. Power supplies

A limiting factor in the development of smart textiles has been the amount of power required to allow the textile 'system' to operate. Early 'smart' garments were simply garments engineered to allow wires to be hidden within the garment structure so, for example, the wires connecting the headphones to an MP3 player could be concealed within the garment structure. Later developments, particularly in ski wear, such as jackets produced by Spyder™, used Eleksen™ 'softswitch' technology (Peratech 2013). These jackets concealed the electronics required to connect the fabric keyboard to the MP3 player, with the output via either headphones or inbuilt speaker systems within the structure of the garment collar. Another garment produced collaboratively by Phillips and Levis was the ICD+ jacket (Van Langenhove and Hertleer, 2004). This jacket allowed the wearer access to their mobile phone and MP3 player via an inbuilt microphone and hidden wires within the garment structure (Tuck, 2000). However, in all cases the issue of power was met by the battery of the MP3 player or mobile phones themselves.

As technology has developed beyond entertainment systems, the issue of power source has been a difficult one. Smart garments require a source to power integrated systems and, in some cases, to transmit the data generated by these systems.

Traditional mains power sources, from an AC/DC supply have been explored. These can easily meet the demands of the smart garment system, but require hard wiring to the power source. In a medical environment, where the patient is confined to bed this is not considered an issue. However, even in a medical context, restriction of movement causes discomfort to the wearer, which renders this method totally unsuitable for the sportswear garment.

Lithium ion batteries, such as those used in MP3 and mobile phone technologies have been successfully used in smart garments. The problem with this type of power source is the relatively limited lifespan and need for frequent recharging due to the power demands of the systems being supplied. This issue had caused researchers to try to find alternative power supplies (Lam et al, 2005).

Solar energy harvested using photovoltaic (PV) cells has been an area of much interest. Traditional materials for PV cells, such as crystalline silicon, gave hard, brittle structures that were not suitable for a garment end use. Developments in nanotechnologies have meant that materials based on silicon can be used to produce thin films or even be spun into fibres, thus incorporating the PV component into the textile substrate itself. The advantage of this sustainable power source is that it has limited impact on the environment, with the minimum of harmful by-products being produced. An additional advantage is that wearers in remote locations can still have access to this abundant source of power (Taieb, 2009). This also leads to a drawback – those locations which do not have a large amount of strong sunlight may have difficulty in charging the cells to the degree which is required to power the smart textile systems.

b. Conductive yarns

In order for smart garments to progress from those which cleverly hide wiring within the garment structure, the textile itself needed to become the ‘wiring system’. Conductive yarns appeared to offer the solution to this problem, but were not without initial problems of their own. Early work focussed on metallic fibres and yarns, such as copper, steel, nickel and silver which were known for their conductive properties. However, issues were quickly found with the flexibility of these fibres thus impacting on the drape and handle and ultimately the comfort of the textile. Additionally, cost was a prohibitive factor in the development of these fabrics not only due to the price of the raw materials themselves, but the additional costs of the excessive damage sustained by machinery during their production (Lam, 2006).

Further developments involved polymer based filament yarns. These yarns can be created by the traditional method of melt spinning, with the active conductive polymer component being added at the doping stage. Coating yarns using conductive polymers was also explored, with some success being found by coating polyethylene Dyneema® yarns with polyaniline (PANI) salts (Devaux et al 2009). Polypyrrole (Ppyr) has also been used as a successful conductive coating for polyester in fabric form thus expanding the possibilities for the development of truly integrated electronic systems (Mokhtari, 2012).

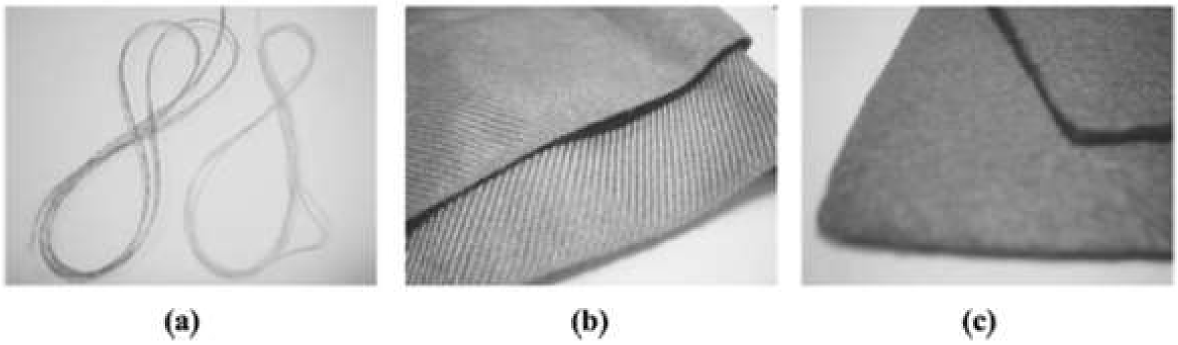

Figure 6.1 : Metal conductive fibres (a) spun metal and metal polyester blend, (b) woven spun metal yarns, (c) non woven metal fibre fabric (Lam Po Tang and Stylios, 2005, pp 120)

Another approach to integrating the electronic circuit into the textile is the use of embroidery techniques. Various researchers have explored this field and have used the yarns for embellishment as well as functionality. Researchers at Nottingham Trent University have used silver coated yarns to embroider antenna onto garments to facilitate wireless megahertz radio frequency data transmission with some success (Cork, 2013).

Another possible solution to the issue of integrated conductivity is that of conductive ink printing. This allows specific circuits to be printed as required, but there is still much development required in this field to ensure such circuits are completely effective and reliable (Moonen et al, 2012).

c. Integrated sensors

Sensors as part of a garment need to be innocuous, particularly in sportswear as to not distract the wearer from their activity, which could be detrimental to performance.

Developments in textile technology mean that the textile itself can now be considered as the sensor, rather than trying to discreetly house an external sensor within the body of the garment or textile structure.

Researchers such as Coyle et al (2009) used existing moisture wicking fabrics as a means of collecting sweat from the athlete during activity. Using a colorimetric pH indicator, an LED detector and a wireless transmitter, the researchers were able to monitor the rate of fluid loss from the body. Such a system could be useful for athletes to monitor hydration levels (which have a profound effect on performance), particularly in environments where the temperature and humidity is markedly different to that in which the athlete normally trains and competes.

Respiratory rate is considered a key indicator of performance in sports activity. Fabrics that can measure pressure strain can be used in monitoring the movement of the ribcage and therefore give an indication of respiratory rate. Piezoelectric fibres (those which generate an electrical potential when under strain) are considered the best types of fibres for this end use. Natural fibres such as silk can display these properties to some degree, but synthetic polymers such as polyvinylidene fluoride (PVDF), polyproplylene (PP) and polyethylene terephthalate (PET) can be engineered to display piezoelectric properties (Vantansever et al, 2011) Typically, these textiles need to be incorporated as a strap within the garment structure, positioned firmly around the ribcage, to give the best respiratory measurements. Additionally, piezoelectric fibres can be used to monitor the movement of the athlete during an activity. Traditionally, the movement of the athlete and their posture during training and competition is monitored by the coaching team and discussed watching post performance video footage. Smart textile monitors can be used to give real time feedback to both the athlete and the coaches enabling adjustments to posture and technique to be made whilst the athlete is undertaking activity. For example, using piezoelectric sensors in shoes has enabled feedback to be gained on walking and running gait; similarly piezoelectric wristbands have enabled tennis players to adjust their racket grip and wrist posture (Coyle et al, 2009).

Garments with integrated sensors are becoming more commonplace. Companies, such as 'Smartlife' (Smartlife, 2013) have developed a commercially available garment, the 'Smartlife healthvest®' which contains integrated sensors to monitor heart rate, respiratory rate and temperature with the potential to also provide ECG readings if required. The technology allows the user to download the information to their personal smartphone or computing device allowing personal monitoring of vital signs.

3. The influence of smart materials on sportswear performance

a. Health and performance monitoring

Health monitoring has been a key area for the development of smart textiles. Textiles placed directly against the skin and hard wired to a monitor has been a technique used for several years in the monitoring of vital signs such as heart and respiratory rates. However, more recent developments have seen advancements in wireless technologies, eliminating the need for hard wiring to an external piece of equipment and thus increasing the potential for mobility of the patient, in turn improving patient comfort and therefore as some research suggests, decreasing recovery times (Zheng et al, 2007).

These technologies are easily transferrable to the field of sportswear. Incorporating the sensors within the body of the garment and wirelessly transmitting information can provide critical information on vital signs and thus the performance of the athlete. This can provide valuable information for the athlete during the preparation phase of the competitive season and training sessions can be tailored to enhance performance, without impeding activity. Similarly, the performance of the athlete can be monitored during competition with analysis of data providing a platform with which to build a strategy for future events. However, it is critical that the sensors cannot be detected by the athlete as this could cause distraction or discomfort and ultimately cause a reduction in performance.

The limitation in this type of technology is the mode by which the wireless data is transported. Traditional wireless protocols consume large amounts of energy and thus the size of the battery to support this proved prohibitive. Recent developments in wireless protocols ANT (Stylios, 2013; Dynastream, 2013) require a much reduced amount of energy for operation and therefore enable power sources to be small enough to be incorporated into the garment and frequency of recharging reduced to an acceptable level.

b. Automatic adjustments

The definition of a true smart materials is one that is able to detect and respond to external stimulus, adapting itself accordingly. There are various types of materials that could fall into this category.

i) Shape memory

Shape memory textiles exhibit the ability to be deformed by external stimuli (usually temperature) into a temporary form and return to their original shape (Kim and Lewis, 2003). Such materials are manufactured from polymers that are heated to a specific temperature (the temperature of deformation) at which they are set into shape. The material is then allowed to cool. During use, if the material is heated to its temperature of deformation, it will then lose its set shape and thus change the properties it imparts. This process is entirely repeatable as the changes are within the morphology of the structure and not due to the degradation of the polymer (Hu, 2007).

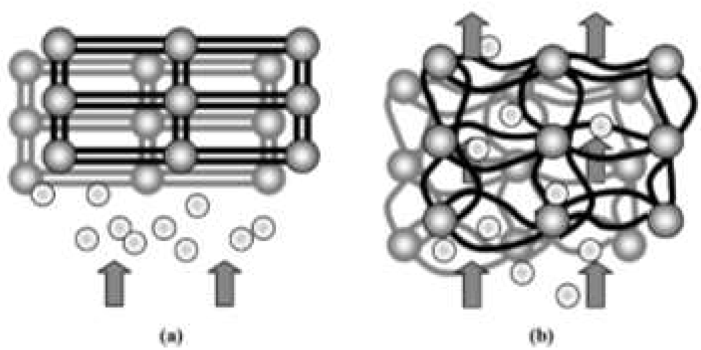

Figure 6.2 : Schematic diagram of shape memory effects (a) closed structure at low temperature and (b) open structure at high temperature

(Lam Po Tang and Stylios, 2005, pp 112)

In sportswear applications, such textiles can be useful in the thermoregulation of the body. Schoeller c-change^{TM} materials are biomimetic structures, based on the movement of the opening and closing of pine cones due to environmental conditions. The fabric structure opens as the body temperature rises allowing heat and moisture to travel away from the body, facilitating cooling. As the environment and body cool, the structure closes, thus trapping air between the garment and the body allowing thermal insulation to occur (Schoeller, 2013).

ii) Phase change

Phase change materials are those which have the ability to change state when absorbing or releasing thermal energy, thus acting as thermoregulators in fabric and garment form. Typically, these materials are based on a wax type compound encapsulated within a fibre, although this is not the only type of material and technique that can be used. Alongside paraffin waxes, compounds such as hydrated inorganic salts, linear long chain hydrocarbons and polyethylene glycols have been considered in the development of textiles with enhanced thermoregulatory properties, with techniques such as lamination and coating being explored by researchers as alternatives to fibre encapsulation.

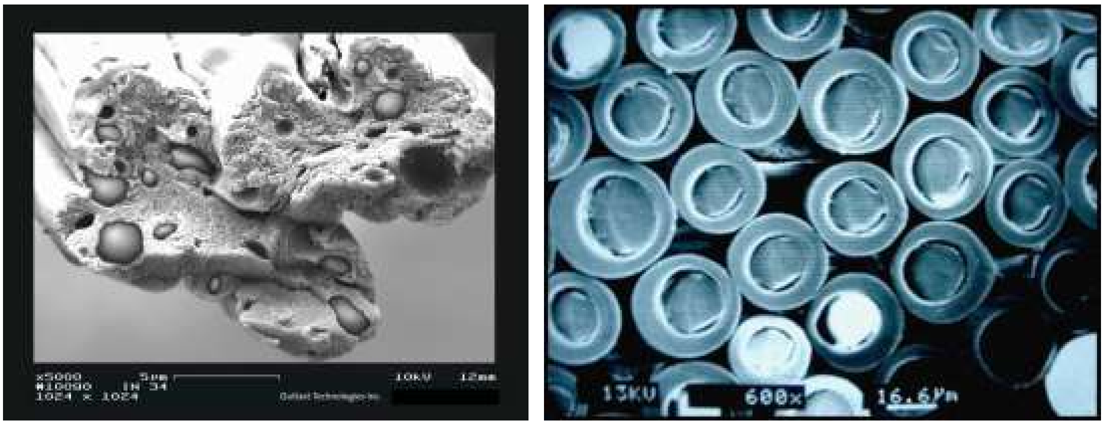

Figure 6.3: Outlast phase change material encapsulated in (i) viscose fibre and (ii) polyester fibre

Images courtesy of © Outlast Technologies LLC

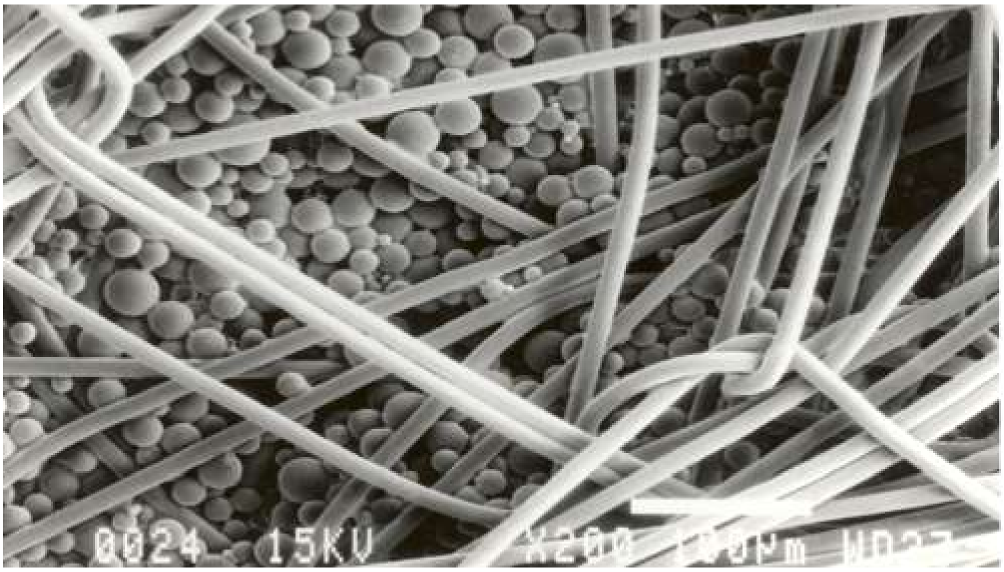

Figure 6.4: Fabric coated with Outlast phase change material

Images courtesy of © Outlast Technologies LLC

The critical factors required for a phase change material to be effective in a textile clothing application are as follows:

(i) A melting point between 15° and 30°C
(ii) A small difference between melting and solidification points
(iii) Stability to repeated melting and solidification.
(iv) Excellent thermal conductivity

Additionally, health and safety factors such as low toxicity, resistance to flammability and effects on the environment are key considerations. Ultimately, for the mass market, cost is the deciding factor (Mondal, 2007).

As body and environmental temperatures rise, the compound absorbs the thermal energy and as it does so changes state from solid to liquid, drawing heat away from the body and allowing cooling to occur. Conversley, as temperature drops, the compound emits thermal energy and it transforms from liquid to solid state, allowing heating of the surrounding area. Careful engineering of the garment is required to ensure it is the body that benefits from the movement of thermal energy and not the surrounding atmosphere (Tang and Stylios, 2005).

Currently, the amount of phase change material that can be incorporated into textile weights common in garments (approx. 150 – 400 gm^2) is such that only approximately 15 minutes of effectiveness can be achieved. However, this could be of use in sportswear applications for garments worn immediately post warm up to ensure muscles are not allowed to cool pre-activity. There has been some development using this technology in heavy weight garments such as those used in extreme sports in colder climates; gloves for snowboarding and skiing have successfully used phase change materials such as Outlast to impart thermal comfort (Outlast, 2013).

The images below show the results of experiments carried out with Outlast phase change materials incorporated into a glove. The images are taken using a infra-red camera which can track thermal emissions; red depicts areas of high thermal emission (warm areas) moving through to yellow and green as the heat gradient decreases. Blue depicts lower thermal emission (colder regions) which progresses to black as the gradient decreases further. The first image shows the hand before the test where the warm regions can clearly be identified.

Figure 6.5: The hand pre test.

Images courtesy of © Outlast Technologies LLC

The second image shows the effects of placing the hand on an ice block for five minutes whilst wearing the Outlast glove, there are still warm regions visible showing the hand being 'protected' from the cold by the phase change material.

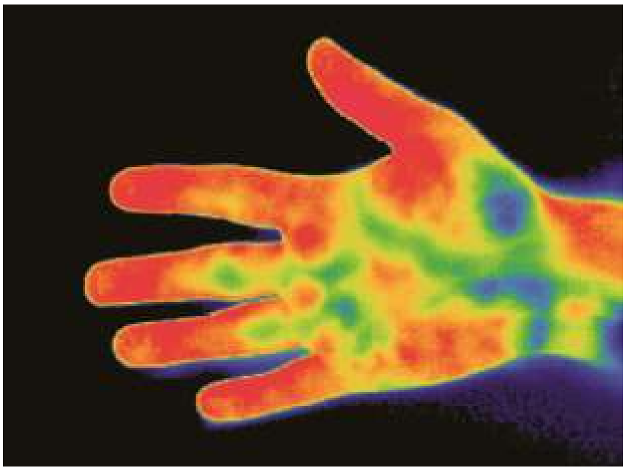

Figure 6.6: Hand placed on ice block for five minutes wearing a phase change material.

Images courtesy of © Outlast Technologies LLC

The final image shows the effects on the hand being placed on the ice block for five minutes wearing a non phase change material glove – the loss of heat can clearly be seen, which in turn could lead to wearer discomfort.

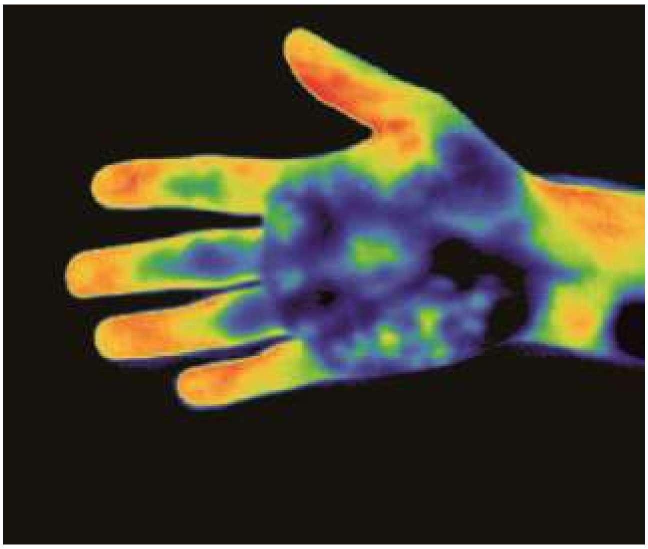

Figure 6.7: Hand placed on ice block for five minutes wearing a non pahse change material.

Images courtesy of © Outlast Technologies LLC

iii) Chromic effects

Materials experiencing a change of colour due to external stimuli are known as chromatic. The specific category of chromatic function is dependent on the stimulus as follows:

Photochromatic – colour change due to light

Electrochromic – colour change due to electrical currents

Piezochromic – colour change due to mechanical deformation

Solvachromic – colour change due to moisture

Thermochromic – colour change due to heat

Thermochromic textiles have been used to some degree in the medical industry in the monitoring of body temperature and could be used in sportswear in a similar way and aid performance monitoring. Similarly solvachromes could aid sportswear performance being used to monitor the production of perspiration and thus advise the wearer on necessary rehydration.

To date, the use of chromic textiles in apparel has been limited to a niche market in novelty fashion items.

4. Specific applications in sportswear

a. Athletics

Professional athletes require perfect conditions in both their own bodies and the external environment to perform at their optimum level (Hassan et al, 2012).

Smart textiles can offer monitoring techniques in the training environment which are non-invasive and therefore do not distract the wearer from their performance (Cho, 2010).

However, monitoring of the body's response to exercise is not in demand exclusively to professional sportspeople. Sport as a recreational activity is commonplace, with many participants having a keen interest in monitoring their performance. Many companies have recognised this 'high street demand' for such monitoring devices and several are now available for use both in the leisure and professional sportswear market. Companies such as SmartLife have developed the HealthVest[R.] The T shirt type garment is constructed from a knitted fabric base containing elastane to improve fit and comfort properties. In the front portion of the garment, ECG electrodes and a respiratory monitor are knitted into the fabric structure alongside the circuitry which is created from silver coated polyester yarns. The vest can provide real time monitoring and data output which can enable athletes to understand and adapt their performance and training regimes (SmartLife, 2013).

In a similar way, Numetrex have developed the 'Sports Bra'. The sensors and conductive components are all inherent in the garment, thus minimising any distractions that could be caused by the monitoring equipment. The information is transmitted wirelessly to a watch via a clip on transmitting device, enabling the wearer to monitor heart rate in real time. Additionally, the garments and watch accessory can be purchased in a variety of colours to cater for the fashion requirements of the wearer (Numetrex, 2013).

b. Ski wear

The sport of skiing involves periods of high activity (skiing downhill) followed by those of relative inactivity (resting at the end of the ski run, or the lift climb to the top of the slope). Ski wear therefore must be thermoregulatory - supplying the wearer with both cooling and insulating properties.

Phase change materials lend themselves perfectly to the shorter ski runs associated with recreational ski ing. Where the downhill ski runs and lift climbs are short (less than 10 – 15 minutes) enough phase change material can be incorporated into the clothing to allow effective thermoregulation to take place. Ski clothing is generally thicker than everyday wear, however, the wearer still requires clothing that is flexible enough for normal body movement, thus restricting the amount of phase change materials that can be incorporated into clothing covering the arms and legs (and torso to some degree).

Areas of the body where heat loss due to conduction is known to be greatest in cold climates are the hands and the feet. In the case of the feet less apparel flexibility is required thus the textiles used can be thicker and more phase change materials can be incorporated, increasing the length of the effectiveness of the material. A degree of manual dexterity is still required in ski ing, however, more phase change material can be incorporated in the body of the glove to improve insulation without compromising movement.

A critical factor in mountain sports is protection from the wind which can cause accelerated heat loss and hypothermia if the body is not sufficiently shielded. Coupled with this, it is essential that moisture produced by the body is allowed to escape through the garments to allow cooling when required. This moisture must be allowed to escape and not held either on the skin or within the textile structure as this can again accelerate the cooling effects of the surrounding environment. Shape memory polymers, such as those discussed in section 2b would serve a useful purpose in this case, with the structure being closed if wind chill is a threat, whilst opening up to allow moisture out if the temperature of the body began to increase.

CASE STUDY: Columbia Omni-Heat

Omni-Heat^{TM} (Columbia 2013) is another smart approach to thermoregulation, using materials that are:

- **Reflective** - a series of metallic dots printed onto the fabric reflect heat back towards the body, thus aiding thermal retention and reducing the thickness required of a traditional insulation layer (Rodie, 2010). As the body begins to heat up and humidity increases within the garment, the foil dots are activated as conductors to transmit heat away from the body, thus preventing overheating and excessive perspiration.
- **Moisture wicking** - the main fabric is a polyester / elastane blend which enables moisture wicking via the cross sectional shape of the polyester fibre.
- **Air permeable** – the main fabric structure allows the free flow of air to assist thermoregulation.

Columbia have used this technology and combined it with a ‘smart’ application in footwear. The Bugaboot^{TM} contains the technology above, plus a flexible carbon fibre heating element, powered by a lithium (mobile phone type) battery, which is charged using a mains AC adaptor (Rodie, 2010). The heating element can be operated via a push button on the side of the boot and can supply heat to the foot for up to 8 hours.

5. Future developments in smart materials

The majority of developments in smart textiles centre around the miniaturisation of the electronic components used for the monitoring of the wearer. The miniaturisation of micro chips and processors has enabled researchers, such as those at Nottingham Trent University, to incorporate chips into yarn structures. Whilst more traditional incorporation of electronics into textiles has involved a 'face' and a 'back' to the textile (the 'back' being the side of the textile on which all the componentry can be seen), the tiny micro chips work in conjunction with the yarns, which act as conductors themselves, meaning the textile structure is inherently the electronic circuit which supports the 'smart' operation (Cork, 2013).

From the perspective of truly new developments in the field of smart textiles, the use of graphene as a substrate holds great promise. Research is currently being undertaken to develop graphene as a novel electronic device. As graphene is only one atom thick it is extremely flexible and therefore could bring great leaps forward in the incorporation of electronics with textiles and garments. The U.S. Army research lab is currently exploring the options of graphene based devices as wearable electronics (Dubey et al, 2012). As was discussed earlier in the chapter, many sportswear applications of smart textiles began life as military research and this could prove to be an exciting new era for smart textiles in sportswear.

Further developments see researchers working on flexible batteries which would remove the current need for a pocket in the garment in which to house the battery power source (Kwon et al, 2012). Highly flexible batteries open exciting new possibilities in clothing design and could offer large improvements in clothing comfort, without a compromise in functionality, a critical area for consideration in sportswear.

6. Discussion

The market for smart textiles is growing, particularly in those industries, such as sportswear, in which there is a need for the wearers to be monitored and the information collected to be analysed.

The fashion industry has yet to find a real ‘use’ for such technology and smart textiles are still frequently used as novelty items. There is a danger that the fashion industry will continue to see such developments as a ‘gimmick’ using the technologies to support structures such as those with LEDs. However, designers such as Angella Mackey are keen to explore the concepts of fashion meeting function meeting technology and are creating highly functional, fashionable apparel which incorporate electronic illumination (Vega, 2013). Improvements in the flexibility of the fabrics which incorporate the componentry to enable to operation of the smart garment are also allowing designers to create garments more easily. In early developments the wiring of the components were the deciding factor in the garment design (as seen with the ICD+ jacket) which led to smart garments being heavy and bulky. Conductive yarns, componentry and sensors are now all readily available in flexible forms off the shelf, enabling lighter weight garments to be produced, which are more comfortable to wear (Ohmatex, 2013).

The apparel industry still encounters problems with power sources for smart textiles and as such is limited in the progression of the technology until a viable option is found (O'Mahoney and Braddock, 2002). Some encouragement should be taken from the mobile phone industry where much work is being done to improve battery life whilst reducing battery size. Companies such as Apple and Samsung are market leaders in the 'smart phone' arena where their products are providing an increase in functionality with no increase in battery size (Apple, 2013).

Alternative power sources should not be disregarded. Traditional rechargeable batteries which draw their charge by being plugged into the mains supply for a period of time could be replaced with more 'sustainable' alternatives. Solar power has seen great leaps forward in the last few years, with solar cells decreasing in size and, as discussed in the previous section, increasing in flexibility. The 'charge whilst you wear' concept would be appealing to consumers, who are quick to highlight their frustrations in the traditional methods of recharging batteries.

In order for the smart textile to become a reliable product for the diagnostic and medical aspects of the sports industry, improvements in wireless integrity still need to be made. There is a perception that wireless technologies are still not as reliable as their hard wired counterparts and in order for such textiles to gain credibility, absolute reliability of data transmission is critical (Hunter, 2008). Whilst this is based largely on perception rather than hard fact, wireless technologies do have room for improvement.

Finally, the environmental impact should be considered. In a world where a conscious effort is being made to reuse and recycle, is there really a place for textiles which contain added technology and what shelf life do these garments have? It could be suggested that in terms of performance sportswear, there will always be a need to monitor athletic performance be that through heart rate, blood pressure, respiratory rate or one of the other functions discussed previously in this chapter. However, as the technologies are developing at such a rate, will this mean garments can be 'upgraded' as the technology develops, or will current garments be deemed obsolete in a couple of years time – in which case does this mean the garments now will go to a landfill site, or can they be recycled? An argument could be put forward that as the garments are the sensors and are transmitting the raw data, it is the processing software that will change and as such, the garment will have a longer life than that initially thought. This issue will only be brought to light as the smart textile market widens.

7. Summary

Smart materials have an important part to play in the future of sportswear. There have been many developments since the integration of electronics into a garment in the late 1990s and although the novelty factor of this garment was quickly dismissed by the consumer, it served as a basis for innovation. Developments in military and medical applications easily translated into sportswear products. Sports performance monitoring was the first to be considered and the development of integrated sensors and piezoelectric fibres enabled professional athletes to monitor their activity in real time, recording their data for analysis and enabling training sessions to be adapted accordingly. This quickly led to mass market adaptation with products such as the Numetrex sportsbra (Numetrex, 2013).

In addition to performance monitoring, smart textiles have also been developed to enhance comfort with shape memory and phase change materials being used. These technologies have allowed apparel with exceptional thermoregulatory properties to be established which adapt in line with the wearers individual needs.

However, the concept of fashion vs function cannot be ignored. Advances in performance technologies cannot be successful without similar developments in garment design. Apparel designers are now embracing such developments and the value of the aesthetics offered by smart textile technologies such as thermo, photo and electro chromic dyes or incorporated illuminations can be seen in fashion. As these technologies are embraced by fashion, thus the ease of incorporation of performance technologies into garments is developed and the ‘gimmick’ factor is replaced by true functionality and ease of garment creation.

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