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Advancements in Wearable Smart Textiles: Transforming Health, Sports, and Beyond

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ABSTRACT:
Wearable smart textiles combine technology and fabric to create intelligent clothing capable of sensing, analyzing, and responding to stimuli. These textiles have revolutionized sports, healthcare, military, and fashion by integrating functionalities like health monitoring, temperature control, and real-time data transmission. In sports, they enhance performance through moisture management and motion tracking, while in healthcare, they enable vital sign monitoring and early disease detection. Military applications include injury detection and hazard protection, while fashion blends aesthetics with innovative features like self-cleaning and color-changing fabrics. Despite challenges like miniaturization and scalability, advancements in materials and eco-friendly processes continue to drive innovation in this transformative field.

Introduction

Wearables, initially stated as “wearable computing” can be considered as “the study or practice of inventing, designing, building, or using miniature body borne computational and sensory devices. Wearable computers may be worn under, over, or in clothing, or may also be themselves clothes

Starting from their birth back into 1960, wearables have attracted significant attention in both research and industry. Placed in between the digital and human world, wearables have the potential to transform our daily lives and interactions by enhancing our ability to sense, respond to, and adapt to our surroundings.

Wearable technology comes in various forms, including glasses, jewelry, headgear, belts, arm and wrist accessories, leg wear, and shoes. These items are evolving in both design and function, alongside innovations like skin patches and electronic textiles.There is a growing trend toward merging humans with technology, and wearables are at the forefront of this movement.

The goal of wearable computing is to seamlessly integrate electronic systems into our daily clothing. Over the next two decades, wearables will continue to develop in areas like fitness, healthcare, and automotive industries. They must be designed for comfort and ease of use, with the ability to automatically detect user activity and environmental conditions, allowing them to adapt accordingly. This could lead to clothing that serves as a "portable informative infrastructure."

The dress serves as a unique element that can accompany the wearer seamlessly, blending naturally with the human form. It acts as a universal interface that is both intuitive and unobtrusive. To achieve this, wearables must be carefully conceived, designed, and created using advanced smart textiles.

1. Smart textiles: from a simple material to a working platform.

Smart textiles are defined as textiles (in the shape of shirts, socks, shorts, belts, etc.) that can sense and react to environmental conditions or stimuli, from mechanical, thermal, magnetic, chemical, electrical, or other sources to provide functions such as health monitoring and activity tracking. They are able to sense and respond to external conditions (stimuli) in a predetermined way.

Given the diversified panorama of smart textiles, a clarification about the meaning of smart textiles are needed here. They can be classified as passive or active smart textiles: the first ones are materials to which a specific function is added by means of material, composition, construction, and/or finishing (e.g., by applying additives or coatings) (Cherenack & van Pieterson, 2012). On the contrary, active smart textiles are those capable of sensing, reacting, and adapting to the environment or stimuli and integrate actuators and sensors (Vagott & Parachuru, 2018).

The basic concept of a "wearable" textile system consists of a textile structure that senses and reacts to different stimuli from its environment. In a wide range, a smart textile system has a very simple structure thanks to which it' s possible to wear a technological apparatus with common clothes.

Wearable textile systems have been mainly designed and developed in health management and sports applications to collect data such as heart rate, sweat rate, breathing rate, muscle tension, posture status, location, and temperature. For instance, they can sense the temperature outside and consequently warm up or cool down, based on the measured temperature

In sportswear a wearable textile system promises to offer effective solutions for wearers who seek more detailed data about their fitness and performance. Smart textiles can also increase the comfort level of the user and eliminate the use of bulky equipment such as chest straps. Since athletes and major league players constantly strive to improve their performance, an opportunity of storing data for analysis by lightweight devices that can be embedded in their sportswear offers a high potential for further performance enhancement.

Close-fitting sportswear represents an ideal base for embedding sensors such as MEMS inertial modules, to accurately monitor the wearer's movements. Smart textiles allow accurate sensing by helping eliminate noise that looser-fitting garments could introduce by moving relative to the wearer's body. Sensing motion enables applications to identify areas where technique could be improved, such as running stride or arm action.

Smart Textiles

Intelligent textiles also referred as stimuli-response textiles are those which are intelligent enough to identify the stimuli from surroundings, analyze it and respond accordingly. It's not only limited to apparel and clothing sector but also play a significant role in safety, protection, fashion and convenience textile sector too

It is a composition of a sensor, processor and an actuator which coordinate with each other to sense a signal, process it and behave appropriately. Phase changing materials, shape memorymaterials, chromic materials, conductive materials and electronics incorporated textiles are some examples of intelligent textiles which are widely used in the textile industry.

1. Introduction Definitions

Emergence

Intelligent textiles are the next generation of fibres, fabrics and articles specially produced to respond in time. As the name suggests, intelligent textiles are those which are intelligent enough to identify the stimuli from the environment, analyze it and give response to them and modify accordingly by blended functionalities in that textile material by themselves.

1. Elements of Intelligent Textiles

1.1.1 Sensors- The sensors provide a nerve system to detect and send signals to textile [2], it is used to

collect the main stimuli, which can be heat, pressure, moisture or anything else from the environment.

1.1.2 Processor- This helps in processing, monitoring and analyzing signals sent by sensors to take an appropriate action as per the stimulation and some predetermined data feed into it.

1.1.3 Actuators- This is the main unit which is responsible for the response given by intelligent textile as per the signals received by the sensors and command sent by the processing unit.

2. Types of Intelligent Textiles.

2.1. Shape memory textiles

Shape memory textile is a kind of material with shape memory function introduced into textile through weaving or finishing. Under external conditions such as temperature, mechanical force, light, pH value, etc., textiles with excellent properties such as shape memory, high deformation recovery, good shock resistance and adaptability. The Italian company Corpo Nove designed a "lazy shirt". When the outside temperature is high, the sleeves of the shirt will automatically roll from the wrist to the elbow within a few seconds; when the temperature drops, the sleeves can automatically recover and can also be automatically ironed [12]. Shape memory fabrics can be developed into fashions, protective clothing and accessories with different functions, as shown in Figure 1. With the in-depth research on shape memory materials and the further improvement of textile processing technology, shape memory functional textiles will be further developed.

2.2 Color-changing textiles

Color-changing textiles refer to textiles that can display different colors with changes in external environmental conditions, such as light, temperature, pressure, etc. With its unique properties, color-changing textiles are widely used in various fields. Civilian can be used to make fashionable color-changing clothing and ever-changing decorative fabrics, military camouflage can be used in military, anti-counterfeiting field can be used as anti-counterfeiting materials, widely used in bills, certificates and trademarks.

Color-changing textiles can be obtained by the following three methods: adding color- changing fibers to the fabric; dyeing with color-changing dyes; printing with color-changing paint. Among the three methods, the research and development of color-changing fiber technology is a bit later, but its advantages are the most prominent. The fabric made of it has a good hand feel, good washing resistance, and long-lasting discoloration effect.

2.3 Smart temperature control textiles

Smart temperature control textiles mainly include three types of thermal insulation textiles, cool textiles and automatic temperature control textiles. For thermal insulation textiles, the thermal insulation materials developed at home and abroad are mainly solar thermal storage fibers and far- infrared fibers. The solar thermal storage thermal insulation fibers are used to achieve thermal insulation. The principle is that the fibers absorb visible light and infrared rays from sunlight, and then heat radiation to the human body, and finally achieve the effect of heat preservation. Compared with sunlight thermal storage fiber, far infrared fiber has better thermal insulation performance. The reason is that it absorbs the heat emitted by the human body and radiates a certain wavelength of far infrared rays to the human body to reduce the loss of heat by promoting blood circulation, thereby achieving the purpose of heat preservation. The cooling materials of cool textiles are ultraviolet and heat shielding fabrics, cool fabrics and heat-dissipating fabrics. Among them, the ultraviolet and heat shielding fabrics are mixed with fine ceramic powder in the fiber to give full

play to the advantages of ultraviolet reflection function, which can make people feel cool. Cool fabrics generally add metal oxides to polyester fabrics, and use metal oxides to reduce the possibility of clothing fading due to ultraviolet rays and light, and to ensure that the interior of the clothing is cool [13].

People who work in extremely cold environments (such as traffic police in winter) need clothes to warm them and display safety signals at the same time, which is very meaningful to them. Based on such requirements, there is a great need to develop smart textiles that(integrate thermal regulation and light-emitting functions, and use coaxial electrospinning to realize light-emitting temperature- regulated smart textiles [14].

2.4 Waterproof and moisture-permeable textiles

Waterproof and moisture-permeable textiles are also called "breathable fabrics", which are functional fabrics that integrate water-proof, moisture-permeable, windproof and warmth retention performance. This kind of fabric can not only meet the wearing needs of people during activities in harsh environments such as severe cold, rain, snow, and windy weather, but also meet the requirements of people's daily life for raincoats, etc., and has broad development prospects. It mainly includes waterproof and moisture-permeable high-density fabrics, microporous membranes, non-porous membranes and intelligent waterproof and moisture-permeable fabrics [15]. The principle of waterproof and moisture-permeable high-density fabric is that gas molecules diffuse from high concentration to low concentration through the gaps between yarns.

Microporous membrane waterproof and moisture-permeable fabrics mainly use the difference between raindrop diameter and water vapor molecular diameter to achieve the goal of waterproof and moisture-permeable. The non- porous membrane waterproof and moisture-permeable fabric uses molecular hydrophilic characteristics to increase the tension of the waterproof membrane surface to achieve the purpose of waterproofing

2.5 Self-cleaning textiles

The trend of manufacturing self-cleaning coatings is growing, which can remove inorganic and organic pollutants through two different mechanisms: rolling water droplets; photocatalysis [16]. Rolling water droplets refer to the lotus-shaped or cauliflower-shaped surface, coupled with low surface energy, will form dirty particles on the surface of the fabric, causing the water droplets to roll off and absorb dust, soil, inorganic and organic pollutants, as shown in Figure 2a, In this case, a contact angle value greater than 150° is required. Photocatalysis is the decomposition of organic dirt by light, which can be easily removed during washing,

2.6 Electronic information smart textiles

Sensatex of the United States designed and developed a smart positioning garment by installing a GPS receiver on the collar. The European Hewlett Packard laboratory has developed a positioning system smart clothing equipped with a personal area network, a global positioning system, an electronic compass and a speed monitor, which is centrally controlled by a remote control device placed on a small display on the sleeve. Children or Alzheimer's patients who wear this kind of clothing can be easily found when they accidentally get lost. Lap-land University and Finnish Reima Tutta and other institutions have developed a ski suit that uses integrated sensors including accelerometer, compass and global positioning system. If the wearer has an accident, this ski suit will be remote; the monitoring terminal sends information including the current position coordinates and physiological measurement data for timely rescue [17].

The smart emotion-sensing clothing is designed and developed by two groups of researchers from the University of Montreal and the University of London. The A windbreaker is equipped with a loudspeaker,

sensors and a body signal analyzer, which can monitor the user's body signal to determine the user's emotional changes. When feeling down, the windbreaker will play some light music to soothe the mood. This kind of clothing can help autistic patients to get out of confinement, and it can also help the elderly living alone to establish communication with their families [18]. At present, emotion-aware clothing is still in the testing stage, and more practical products are still being designed and developed.

3. Waterproof Breathable Fabric

3.1 What are Waterproof Breathable Fabric

Waterproof breathable fabrics are made for clothing that protects against weather
elements like wind and rain, while also keeping body heat. Waterproof fabric stops water from getting in or soaking through. Breathable means the fabric lets moisture escape but keeps liquid water out. High-performance fabrics are important for active sportswear, focusing on both functionality and comfort. Recently, materials that can heat or cool have gained market attention. These fabrics offer multiple functions, combining various properties for better performance.

Fabrics that allow sweat to escape while blocking outside water, like rain, are commonly used in sportswear. These water-resistant and moisture-permeable materials fall into three main types: high-density fabrics, resin-coated materials, and film-laminated materials.

Manufacturers choose these based on the needs of the final product, whether it's for casual wear, athletic gear, ski clothing, or outdoor apparel. [4]

3.2 Types of Waterproof Breathable Fabric

Densely woven water breathable fabrics:

The densely woven waterproof breathable fabrics consist of cotton or synthetic microfilament yarns with compacted weave structure. A well-known example is VENTILE, created from long staple cotton with minimal gaps between the fibers. The yarns are typically combed and woven closely together, preventing water from getting through. Oxford weave is commonly used for this purpose. When the fabric gets wet, the cotton fibers expand, which decreases the size of the pores and makes it hard for water to penetrate, even without any added water-repellent treatments. Fabrics can also be made from micro-denier synthetic yarns, which have filaments smaller than 10 microns in diameter, allowing for the creation of fabrics with very tiny pores.[4]

Laminated waterproof breathable fabrics:

Laminated waterproof breathable fabrics are created by adding membranes to textile products. These membranes are thin layers made from polymer materials. They provide strong protection against water while still letting water vapor escape. The membrane can be up to 10 microns thick.

The micro porous membranes have tiny holes on their surface smaller than a rain drops but larger than water vapour molecule. Some of the membranes are made from Polytetrafluoroethylene PTFE polymer , Polyvinylidene fluoride PVDF, etc2,3.

The hydrophilic membranes are thin films of chemically modified polyester or polyurethane. These polymers are modified by the incorporation of poly. The poly (ethylene oxide)4 constitutes the hydrophilic part of the membrane by forming amorphous region in the main polymer system. This amorphous region acts as intermolecular pores allowing water vapour molecules to pass through but preventing the penetration of liquid water due to the solid nature of the membrane. [4]

Coated waterproof breathable fabrics:

Coated fabrics with waterproof and breathable qualities have a layer of polymer material on one side.

Polyurethane is the material used for this coating.
The coatings are of two types:
1. Microporousmembranes
2. Hydrophilicmembranes.

In microporous membrane the coating contains very fine interconnected channels much smaller than finest raindrop but larger than water vapour molecules. Hydrophilic coatings is same as hydrophilic membrane but the difference between the microporous and
hydrophilic material is the former water vapour passes through the permanent
air-permeable structure whereas the later transmits vapour through mechanism involving adsorption-diffusion and de-sorption.
The desirable attributes of functional sportswear and leisurewear are as follows: [4]

- Optimum heat and moisture regulation
- Good air and water vapour permeability
- Rapid moisture absorption and conveyance capacity
- Absence of dampness
- Rapid drying to prevent catching cold
- Low water absorption of the layer of clothing just positioned to the skin
- Dimensionally stable even when wet
- Durable
- Easy care
- Lightweight
- Soft and pleasant touch

3.3 Advantages of Waterproof Breathable Fabric

3.4 Limitations of Waterproof Breathable Fabric

3.5 MOISTURE TRANSPORT MECHANISM [4]

The mechanism by which moisture is transported in textiles is similar to the wicking of a liquid in capillaries. Capillary action is determined by two fundamental properties of the capillary:

Its diameter; and Surface energy of its inside face.

The smaller the diameter or the greater the surface energy, the greater the tendency of a liquid to move up the capillary. In textile structures, the spaces between the fibres effectively form capillaries. Hence, the narrower the spaces between these fibres, the greater the ability of the textile to wick moisture. Fabric constructions, which effectively form narrow capillaries, pick up moisture easily. Such constructions include fabrics made from micro fibres, which are packed closely together. However, capillary action ceases when all parts of a garment are equally wet.
The surface energy in a textile structure is determined largely by the chemical structure of the exposed surface of the fibre, as follows. .
Hydrophilic fibres have a high surface energy. Consequently, they pick up moisture more readily than hydrophobic fibres-
Hydrophobic fibres, by contrast, have low surface energy and repel moisture.

3.5.1 FACTORS AFFECTING MOISTURE TRANSPORT [4]

There are several factors, which affect moisture transport in a fabric. The most important are:

- Fibre type;

- Cloth construction or weave;
- Weight or thickness of the material; and
- Presence of chemical treatments.

Synthetic fibres can have either hydrophilic (wetting) surfaces or hydrophobic (non- wetting) surfaces. Synthetic fabrics are generally considered to be the best choice for garments worn as a base layer. This is because they are able to provide a good combination of moisture management, softness and insulation.

While most fabrics, both natural and synthetic, have the ability to wick moisture away from the skin, not all of these are fast-drying and air permeable-two factors, which have a direct influence on cooling and perceived comfort. High-tech synthetic fabrics are lightweight, are capable of transporting moisture efficiently, and dry relatively quickly.

It is generally agreed that fabrics with moisture wicking properties can regulate body temperature, improve muscle performance and delay exhaustion. While natural fibres such as cotton may be suitable for clothing worn for low levels of activity, synthetic fabrics made of nylon or polyester are better suited for high levels of activity. They absorb much less water than cotton, but can still wick moisture rapidly through the fabric.

The main parameters for comfort and functionality are:

- Water and wind proof, breathability and comfort.
- Moisture/Sweat management
- Warmth/temperature control
- Easy-care performance
- Smart and functional design.

Polyester

Polyester has outstanding dimensional stability and offer excellent resistance to dirt, alkalis, decay, mold and most common organic solvents. Being durable, yet lightweight, polyester has elasticity and a comfortable smooth feel or “soft hand”. These are all important qualities to consumers for a wide variety outerwear and recreational applications.

Excellent heat resistance or thermal stability is also an attribute of polyester. It is the fibre used most commonly in base fabrics for active wear because of its low moisture absorption, easy care properties and low cost. Polyester is essentially hydrophobic and does not absorb moisture.

However, most polyester used in base layer clothing is chemically treated so that they are able to wick moisture. This can be done by:

- Coating the polyester with a hydrophilic finish; or
- Changing its surface chemistry to improve its wetting by moisture.

Polypropylene

Polypropylene cannot wick liquid moisture. However, moisture vapour can still be forced through polypropylene fabric by body heat. Polypropylene has the advantage of providing insulation when wet But it can melt at medium heat in home dryers.

Also, polypropylene is more oleophilic (oil absorbing) than polyester Consequently, it has a greater tendency to attract and hold oily bod) odours even more. Polypropylene is

claimed to be a proved performer in moisture management due to its hydrophobic nature and has very good thermal characteristics, keeping the wearer warm in cold weather and cold in warm weather

Silk

Because of its hollow structure, silk breathes well. It is soft strong and has natural wicking properties. However, it dries slowly and requires care in cleaning.

Wool

Not all grades of wool are appropriate for a base layer. First, since it's next to skin, it shouldn't itch. The "itch" so commonly noticed in wool garment results from the fiber ends tickling. Consequently, short fibers will cause more itch than long fibers because there will be more fiber ends touching your skin. Second, the fiber should be very fine. This allows for a fabric of high fiber density to be made, which increases strength and abrasion resistance in addition to increasing the air movement between and adjacent to pockets of dead air space in the fabric (thus, increasing warmth). Finally, fine fibers absorb less water weight per cross-sectional area, so they are more resilient than coarse fibers. The efficiency of wicking is also greater with a fine fibered fabric because more fibers (and correspondingly, more cross-sectional surface area) can be packed into a given space than an equal volume of coarse fibers.

Wool has good, natural wicking properties and will provide insulation even when wet. However, it is slow to dry. However the use of fine chlorinated merino wool is employed in Sportwool as a base layer.

Cotton

Cotton garments provide a good combination of softness and comfort. However, cotton is not recommended for use in base layer clothing because of its tendency to absorb and retain moisture. When wet, cotton garments cling to the skin. causing discomfort.

Wearing jeans on the ski slopes, for instance, will not only weigh down the skier but will also cause chilling if the jeans become wet.

The slow-to-dry and cold-when-wet characteristics of cotton make this material unsuitable in conditions in which there are high levels of moisture-either perspiration or precipitation-and where the ambient temperature is low.

Viscose Rayon

The viscose rayon is not preferred next to skin as it holds water (13 % moisture regain) in sportswear.

4. Uses of intelligent textiles

Intelligent textiles are also used for protective clothing, to safeguard against extreme hazardous environmental conditions, such as radiation and the effects of space travel, to safeguard fire-fighters against fire and heat etc. as well as these textiles also serves in health and beauty industry with their innovations, which range from drug-releasing medicated textiles, to fabric with moisturizer, perfume, cosmetics and anti-aging properties[3]. The usages of intelligent textiles in various fields are;

4.1 Sports Activities:

A production of smart socks with a foot pressure measurement technology and walking distance measurement that can be used to measure sports performance. The various electronic parts of this product can be separated in order to clean and wash the textile part of the socks. The collected data is sent wirelessly to a mobile application running into a Smartphone. With this intelligent device, the athletes can see and monitor the pressure profile of the foot sole and improve their performance. A sports person can wear intelligent bands, jackets, caps to continuously monitor the pulse rate, blood pressure, body temperature, fatigue. The necessary data can be sent to remote location where it can be analysed and may be used to improve the performance of the sports person[3].

Similar types of devices are available can be used by sky divers, swimmers or other sports persons to monitor, analyse and improve their performance.

4.2 Health sector

Intelligent wearable textile which are basically composed of various embedded sensors, actuators,

microcontrollers which not only senses, register monitor and analyze the physical and mental health of the person but it also transmit the necessary data from the patient to the medical
expert. There are diverse applications in medical sectors where these electronic or intelligent textiles are extensively used[3]. Intelligent bras are there which have the capability to detect symptoms of breast cancer at an early stage so that it can be treated and cured. For the monitoring of respiration system, heart pumping system, and other physical activity, various wireless enabled intelligent garments have been developed and still some are yet to be discovered. These are going to be very helpful for the persons who are on risk of heart attack as these wearable intelligent textiles will detect the early signs and warn the wearer and simultaneously sent the data to the person who is monitoring such a person[3]. Intelligent shirts are also developed in which the conductive fibers and various sensors are embedded which measures and monitor respiration system. The increasing demand of these wearable intelligent textiles from health care sector is going to help in developing more advance types of such intelligent textiles embedded with artificial intelligence

4.3 Military and Defence sector

Due to technological advancement in electronic sector it is now possible to develop very small sized electronics devices which can be embedded in textiles and can be used in defence sector. This will give new dimensions to military and defencesecurity[3]. In adverse environmental conditions and hazardous situations faced by soldiers, there is a need of real time information system to give protection and survivability to them. The requirements for such situations are to monitor vital signs and injuries while also monitoring environment hazards such as toxic gases[3]. The intelligent textile in military can be utilized in two ways. Firstly, Personal protective garments and individual equipment which includes battle uniforms, ballistic protection vests and helmets, chemical protection suits, belts, ropes, suspenders and field-packs. Secondly, defence systems and weapons like parachutes, shelters tent houses etc. The enhanced security to both these can be provided with intelligent textiles. If a soldier get injured during war or any other situation and he is wearing an Intelligent jackets than this information is automatically transferred to the nearby controlling and monitoring unit and necessary medical or any other help can be provided to the injured soldier. The soldier can himself monitor his pulse rate, blood pressure and other parameters through the embedded intelligent systems in the jacket. Further researches are also going on to develop such a uniform that is almost invisible and soft clothing that can become a rigid cast when a soldier break his or her leg or any other body parts.

4.4 Safety Purpose

Intelligent jackets and shirts especially for the protection of public safety personnel, namely firefighters, rescue teams, police officers are being developed with all necessary advanced safety features. They will be used in conjunction with a wireless- enabled radio system. The intelligent jacket or shirt can monitor the health and safety of public safety personnel, victims trapped in a building or underneath rubble with the ability to detect the exact location of the victims through positioning capability. It can also facilitate two- way voice and video communication. An integration of sensors and flexible light emitting displays with textile can help in designing a wearable warning signal generating jacket. This can receive and respond to stimuli from body, enabling a warning signal to be displayed and sent. The sensors in the jacket keep on monitoring the vital body parameters and if something unusual happens, same is indicated through flash of light and a wireless communication system could send a distress signal to a remote location. Textiles integrated with electronic sensor devices driven by global positioning system can detect one's exact location anytime and in any weather. Fabric area networks (FANs) make it possible with the help of

electronic devices to exchange required information, power and control signals within the user's personal space and remote locations

4.5 Fashion and Lifestyle

There are fabrics with moisture management systems that are being used for fast evaporation of sweat. Fabrics with UV protection, anti-allergic and anti-bacterial capabilities are available. There are intelligent dresses and sleep suit which emits scents depending on your mood and requirement. Intelligent fibers are being developed that can change colour and its shape as per your command. The conductive fibers could change colour on command from an electric signal that alters the reflective quality of this special fiber. Thereby increasing functions as well as fashion, Intelligent Textile with thermoregulation properties are also being developed. There are also interactive fibers which incorporates electronics that are activated by a power source.

There are wearable electronics which can be used in intelligent wearable textiles to dial mobile numbers, control music from mp3 player etc. The examples includes business suit with a mobile phone incorporated, sportswear to monitor heart rate, aerobic outfits with music players incorporated and club wear which changes colour

5. Sportswear

In the last three decades there has been a significant increase in the participation of various active sports all over the world. Healthier lifestyles are leading to the greater sports participation. Recently more numbers of sports have been invented and also many of the old sports have been again popular. The highly competitive world of sports has increased awareness among the professional sports persons, who use to demand more specific functions to be performed by sportswear in real time to increase their efficiency [1]. Design of active sportswear is still a subject of research to the academician and industrial profession. To fulfil the demand of the existing and up-coming market, the new fibre, fabrics and finishes are to be developed to satisfy specific requirement of each sport. In this context, man-made fibres have enlarged the sphere of application of these products from the simply apparel clothing to high-tech sport textiles owing to the high potential for scientific creation. The products mentioned, later performance capability, were verified in the some international games, like Olympic [2]. In the first half of 20th century sportswear was not scientifically designed due to the non-availability of speciality fibres. However, later on designing of sportswear has received scientific inputs by utilizing the knowledge synthetic polymer, fibre, fabric, finished, and smart garment design for advanced sportswear suitable for specific application [3]. In textile means for sports, „performance" has become key issues related to moisture management, temperature regulation, stretch, light weight, wind and water resistance and low frictional surface. A numbers of technological progresses have been made in the past to develop speciality polymer with micro-porous to hydrophilic characteristic, speciality fibres with different shapes and diameter, and single to multi-layer fabrics with different weave structure to improve the fabric comfort and functionality [1]. New consumers of sport textile are emerging that can be categorized into three groups, namely, (i) children, (ii) over 55-age group, and (iii) women, who are involved in aerobics and competitive sports.

Sports and Fashion

Sports are established, competitive, organized, causal, and all types of physical activities are played for the improvement of mental and physical health [1]. The clothing (gloves, T-shirts, jackets, trousers, caps, socks, shoes, etc.) and sports accessories (helmets, mouth guards, elbow/shoulder pads, Shin pads, etc.) that are required for a player/athlete have been termed sports textiles [2, 3]. Sports textiles play a vital role

in the existence and performance of athletes.

In the early 19th century, sportspersons used to wear grey linen fabric. At the end of the 19th century, dyed cotton shirts were introduced in the sports sector with different colors for team identification. With the invention of syn- thetic fibers, athlete uniforms were made from nylon, poly- ester, and spandex for better durability and elasticity. The fabric manufactured from these synthetic fibers was uncom- fortable to wear. Therefore, different research has been conducted on properties optimization regarding the mechanical and comfort properties of sports textiles [4, 5]. With the increase in outdoor and indoor sports activities, the con- sumption of textile materials in sports textiles has also increased and evolved The market for textiles related to sportswear is growing massively in the last 20 years. This market includes sports fashion wear, basic sports clothing, leisure sportswear, and footwear.The activities, related to various kinds of sports, are reported as the basics of a healthier life. The increasing trend for participation in sports leads us to invent new sports for competition with world athletes and players. That's why sportswear needs to have improved functionality so that the efficiency of the athletes can be enhanced The performance sports textiles are those in which the function- ality is enhanced, these are manufactured in low volume but have higher prices. In contrast to performance sportswear, basic sports clothing is cheaper and produced in bulk vol- ume. Leisure sports clothing is just like performance sports- wear but at cheaper prices and in bulk quantities The design of functional sportswear varies for a different types of sports and also by weather conditions, type of sport, and the physical activity required for that specific sport[20]. The development of highly functional sportswear for various kinds of sports requires immense research by industries and academic professionals. To meet the demands for sportswear, there is a need to produce new fibers, fabrics, and textile fin- ishing for the improvement of sports textile functions. In this field, the development of different man-made fibers contrib- uted a lot to converting simple sportswear into high-tech sportswear. The fashion applicability and functional perfor- mance of sportswear can be judged during international games like the Olympics [10]. The scientific development of sportswear was aided by the manufacturing of specialty fibers by which advanced and smart sports clothing can be engi- neered for suitable end applications In recent years, with the invention of innovative func- tional polymers [46, 47], fibers, yarns, fabrics, and produc- tion techniques, the design of active sportswear becomes a subject of research to fulfill the requirements of the con- sumer. The performance characteristics of the sportswear are depicted by its fiber structure, inter-fiber interaction, yarn/fabric structure, and the chemical treatment applied during its development. The invention of synthetic fibers opened a new research area for their use in active sportswear fabrics. Active sportswear engineered with functionalized fibers exhibits excellent thermal performance and moisture management properties.The properties of sportswear are directly influenced by its raw material. The correct raw material selection is a big challenge in the market for sports textiles. Different types of natural, synthetic, and special fibers are used in sports- wear according to the end product applications.

Natural fibers properties and their applications in sports textile products.

Fiber	Properties	orts textile products
Cotton	Absorbent, breathable, hypoallergic, non-toxic, comfortable, biodegradable	Used as the inner lining in sportswear.
Hemp	Absorbent, UV protective, antimicrobial, durable, comfortable, good wet strength, biodegradable	and ropes, caps

Bamboo	Absorbent, elastic, antibacterial, antifungal, natural deodorant, UV resistant, and biodegradable	Next to skin garments, knitted shirts, trousers
Wool	UV protection, antibacterial, stain resistance, antistatic, durability, and warmth	Used as an inner, mid, and outer layer for hiking, climbing, or skiing suits
Silk	Lightweight, breathable, elastic, absorbent, quick-drying, shiny appearance	Sports coats

Synthetic fibers properties and their applications in sports textile products..

Fiber	Properties	orts textile products
Polyester	Lightweight, wrinkle-free, durable, excellent elasticity, nonabsorbent, wicking properties	Shirts, trousers, jackets, gloves, socks, undergarments.
Nylon	Durable, excellent elongation, UV resistance, heat resistance, chemical resistance, mold and	Shirts, trousers, jackets, gloves, socks,
	mildew resistance, quick-drying	dergarments, tracksuits
Acrylic	Durable, excellent elastic recovery, good thermal stability, insect resistance	Shoes, shoe lining, gloves, athlete wear
Polypropylene	Low density, tough, flexible, chemical resistant, lightweight, quick- drying, and comfortable	Shirts, trousers, undergarments
Elastane	Soft, smooth, 500% stretch recovery, abrasion resistance, resistance to perspiration, body oil, and detergents	Cyclist uniform, runners, athlete uniform, undergarments, swimmers dress, body fit garments

Special fibers properties and their applications in sports textile products

Fiber	Properties	orts textile products
Hygra 20	Absorbs water 35 times its weight, is strong, dimensionally stable, antistatic	Athletic wear, skiwear, golf wear
KillatN23	Hollownylonfilament,goodwaterab sorbency,thermalinsulation,lightwe ight	Shirts,trousers,unde rgarments,shoeslini ng
Elastane	Soft, smooth, 500% stretch recovery, abrasion resistance, resistance to perspiration, body oil, and detergents.	Swimwear, activewear, floor gymnastics

Dacron	4-channel polyester fiber, high-speed perspiration evaporation, excellent wicking, quick drying time, quick moisture absorption, and transportation	Shirts, trousers, jackets, gloves, socks, undergarments

II. TECHNICAL REQUIREMENTS OF SPORT TEXTILE

The requirements for an active sportswear can be as classified in two groups, namely (i) Functional- light weight, low fluid resistance, high tenacity, strechablility, thermal regulation, UV protection, vapour permeability, and sweat absorption and release, and (ii)
Aesthetics- softness, surface texture, handle, lusture, colour, and comfort. Apart from
these general requirements, sportswear has to perform other functions activity related to a specific sport [4-5]. The required functions to be performed by the different types of sportswear are listed in Table1
Need of active sports wear
In sports, previously a conventional apparel textile technology was used. For that the player must face so many problems [1] such as:

1. Sweating – which stick the fabric with body
2. Feeling hot during run
3. Improper stretch ability
4. Extra weight of the fabric after moisture absorption
5. Give protection to body skin during fall on the ground
6. Inadequate fabric for fluid resistance for swimmer
7. Windproof, waterproof fabric for sailor
8. Light weight shoe with proper strength & air circulation
9. High tenacity & resistance to abrasion for the skiwear uniform
10. Improper gripping of the shoes during run etc.

III. CLOTHING PHYSIOLOGY AND COMFORT

Clothing physiology is the mechanism of interactions between the human body and the clothing to provide infor- mation on the physiological properties of the clothing [1].
Clothing physiology is expressed in terms of comfort, performance capability and the health of the wearer. development concept, technical characteristics, and Clothing can be considered to be physiologically appropriate, when it functions correctly during the actual use. The human body has a temperature of 37 °C and it is generally maintained under all the circumstances. During the physical activity in sport, the body temperature goes up and reversely the body gets cool down due to the removal of moisture vapour during the perspiration. To control the body temperature exceeding the comfortable value, the produced heat must simultaneously be dissipated through single or multilayer layers of the fabric. The human body can also produce half a liter to a liter perspiration per hour depending upon the sports activities is being taking place and the textile has to take care of it and it should not be impeded by the surrounding relative humidity. It is not the heat of the body, which causes prob- lems to the wearer, but the hot and humid micro-climate causes uncomfortably situation. Therefore, the moisture vapour should have engineering pathway to pass immediately from the skin to the outer surface of the clothing. Four types of clothing comforts that are essential for active sportswear are (i) thermo-physiological comfort, (ii) sensorial/tactile

comfort, (iii) mobility, and (iv) psychological comfort.

There are four types of comfort characteristics require in active sportswear for functional performance are - thermo-physiological comfort, skin sensorial comfort, ergonomics wear comfort and psychological comfort.

Thermo physiological comfort: This type of comfort is related to the thermal balance of body i.e. when the rate of loss of heat from the body equals to the rate of generation of heat by the various physiological processes. It determines the breathability and moisture management properties of fabric i.e. heat and moisture transport through the fabric.

Sensorial/Tactile comfort: This type of the comfort is related to the way that the person feels when apparel is worn next to skin rather than temperature balance. This comfort is mainly depending on the fabric surface, fabric structure and to some extent, moisture transport capacity. It is linked with skin contact sensations and is often expressed as feelings of smoothness and softness.

Mobility/Dexterity: The considerable movements of body parts occur, while doing the various physical activities in various active sports. Therefore, active sportswear must have elasticity properties (mobility) to move freely.

Psychological comfort: Psychological comfort is related to the feeling of the wearer. Psychological comfort is determined by the aesthetic properties from the point of view of style or fashion

4.3 Types of fabrics used in sportswear

A wide range of woven, knitted and nonwoven fabrics are commercially available for sportswear. These fabrics differ in their structure such as entrapped air, pore shape and size, bulk and surface properties etc. which may affect the heat and moisture transmission characteristics of the fabrics [3]. Generally, for sportswear, knitted fabrics are preferred as these fabrics have greater elasticity and stretch ability compared to woven fabrics, which provide unrestricted freedom of movement and transmission of body vapor to the next textile layer in the clothing system. With new combinations of fabrics and yarns, and with developments in fabric construction, knitted fabric appears to be the ideal base for active sportswear. Knitted garments are mainly worn next to the skin and therefore deserve attention. But the major problem in both woven and knitted fabrics is that, owing to sweat generation, the fabric tends to stick with the body of the athlete resulting in discomfort during his running. The term “sportswear” refers to any garment specially designed for use in sport activities. In order to maximize the athlete’s performance, the sportswear must be efficient, essentially, in body thermoregulation and moisture management. All these factors are dependent on the fibrous materials and structures used

4.4 Performance enhancement by sportswear

Heat stress can be reduced by suitable choice of sportswear. Differences in heat stress were reported with different types of sportswear by measuring mean skin temperature change, mean core temperature change, heart rate and total sweat loss [15]. Moisture absorption of sportswear can influence the physiological responses and exercise performance. It was reported that clothing with higher moisture absorption enhances the performance and pitching speed of baseball players. A good correlation between moisture transmission of fabric and athlete’s physiological response has been reported. A fabric with better moisture management properties increases athlete’s cardio-respiratory fitness and performance [14]. Color of sportswear can also influence the performance of player.

It has been reported that red color enhances the performance by stimuli of the testosterone dependent signal. The Compression Athletic Wear (CAW) improves the performance of players in number of active sports like jumping, power lifting and running. An athlete showed faster running speed over 10km with

lower heart rates and reduced post exercise muscle soreness when wearing CAW as compared to control. Compression garments are reported to cause reduction in metabolic energy cost of running at specific speed and improved sub maximal running economy. It has been reported that compression shorts resist fatigue due to reduced muscle oscillation during landing in sports like sprints or jump events. Enhanced performance by using CAW may be due to improved venous return and cardiac input which would reduce cardiovascular stress on athlete. Another mechanism of improved performance has been proposed which suggested that athletes run at a faster speed due to increased lactate clearance and improved leg power using CAW. Biomimetic swimwear is reported to increase the swimmer's speed with reduced net active drag force as compared to normal swimsuit

4.5 innovative Sportwear Products

some high performance fibres like Coolmax®, Thermolite and Thermocool are being offered by Advanced Fibre Technology (ADVANSA) for various sportswear applications. Coolmax® active is a high tech fibre made from specially engineered four channeled and six channeled polyester fiber which forms a transport system with an increased surface area that pulls moisture away from the skin to the outer layer of the fabric and keeps the wearer cool and dry. For active sports in cold climate, Thermolite® is very popular.

Hollow corefibrestrapinairforgreatinsulationandprovidewarmthand comfort without weight [10]. The large surface area allows the fast evaporation of perspiration and wearer stays dry 50% faster than cotton. Channeled surface has been combined with hollow core in Coolmax® all season which move moisture away from the skin when wearer is hot as well as provide warmth for added comfort in colder days. Sport wool® is a unique fabric developed for active sportswear by CSIRO Australia. It is basically a two-layer moisture management fabric with wool on the inner side and synthetic fibre on the outer side.

Another innovation of CSIRO is quick dry wool with water resistant finish on wool which dramatically reduces the drying time. Blends of wool and moisture management fibres such as Coolmax and Fine cool have been studied to produce innovative yarns with specific functionalities. It was found that fabrics with coolmax fibres show the best capillary performance with quick transport of the perspiration from skin to environment. Fine cool fabrics show higher drying rate with quick drying after wetting [5]. Wool-based fabrics show lower absorption rate but good drying capacity. Toray offered many moisture management fabrics like Stunner QD® and Field sensor®. Stunner QD® is nylon woven fabric which quickly absorbs, disperses and evaporates perspiration for quick drying. Field sensor TM® has brushed inner side which provides insulation and moisture management, thus making it suitable for winter active sportswear. Field sensor R® is ecofriendly moisture management fabric made from recycled polyester fibres which quickly absorb perspiration, carry it rapidly to fabric outer surface and disperse throughout outer surface for rapid evaporation. Fabric coating with micro-encapsulated phase changing material has been exploited by outlast. Products with Outlast technology buffer changes in humidity and temperature in microclimate and external environment.

They maintain constant body temperature by absorbing excess body heat when temperature starts rising due to heat production and releasing it when temperature falls during cooling. Inotek® fibre is innovative biomimetic [16,17]. When it absorbs moisture, it shrinks to thin structure causing microscopic air pockets to open and increase the breathability. This response is reversible and fibres come back to original dimension in dry conditions. Skin® 400 series is elastane incorporated warp knitted innovative compression athletic wear which can increase the oxygen delivery to active muscles by dynamic gradient compression. Biomimetic swimsuit Fast skin developed by Speedo® is inspired from shark skin. The denticles of shark's skin and super stretch property of fabric can enhance the performance of swimmer by

shape retention, muscle compression and reduced drag coefficient.
2.2 Commercial Classification of Sportswear
2.3 Development in Sportswear
Use of Smart Textiles / Intelligent Textiles in Sportswear

6. Use of Waterproof Breathable Fabric in Sportswear

6.2 DEVELOPMENTS IN ACTIVE SPORTSWEAR

The 1980s was a period of highly fruitful innovation in sportswear garments. Some reasonably simple microfibres and coated fabrics were developed; variants of which have met the needs of many sports garments. The innovation of new materials and garments
was so successful that in many sports the fundamental performance require- ments have been identified and largely satisfied. Nowadays, from very simple microfibres to much more complex fabrics are effectively used in active sportswear.

Sweat absorption and fast drying property

Moisture handling properties of textiles during intense physical activities have been regarded as major factor in the comfort performance. Actually the comfort perceptions of clothing are influenced by the wetness or dryness of the fabric and thermal feelings resulting from the interactions of fabric moisture and heat transfer related properties. For the garment that is worn next to skin should have :

a) good sweat absorption and sweat releasing property to the atmosphere,
b) fast drying property for getting more tactile comfort.

SPECIAL FIBRES USED

Hygra : Unitika Limited has launched Hygra,which is a sheathcore type filament yarn composed of fibre made from waterabsorbing polymer and nylon. The water-absorbing polymer has a special network structure that absorbs 35 times its own weight of water and offers quick releasing properties that the conventional water- absorbing polymer cannot do. On the other hand, nylon in the core gives tensile strength and dimensional stability. Hygra also has superior antistatic properties even under low wet conditions.The main apparel applications include sportswear like athletic wear, skiwear, golf wear etc.

Lumiac21 : Lumiace is also a product from Unitika. It is a collection of polyester filaments having different fineness (0.5 - 2.0 denier per filament) and irregular cross sections. Hygra - Lumiace combination in knitted fabric is very popular in top Japanese athletes.

Dryarn22 : Dryarn is the new fibre from Aquafil. It is a completely recyclable polypropylene microfibre. Fabric from Dryarn is very lightweight and comfortable and used in different sports. In addition it has a soft handle and a high thermo- regulatory capacity and also dries quickly. Bacteria cannot settle on smooth surface of the fibre which avoids unpleasant odour associated with decomposition of bacteria.

Killat N23 : Killat N from Kanebo Ltd is a nylon hollow filament. The hollow portion is about 33 per cent of the cross section of each filament due to which it gives good water absorbency and warmth retentive property. The manufacturing technology of Killat N is very interesting. The yarn is spun as bicomponent filament yarn with soluble polyester copolymer as the core portion and nylon as the skin portion. Then by giving alkali weight loss treatment the soluble polyester copolymer of the bicomponent filament will dissolve and a large hollow portion (exceeding 30 per cent of the cross section) will be created.

Triactor 24: Toyoba Co Ltd has developed Triactor, which is a perspiration absorbing/quick drying polyester filament as shown in fig.3. Polyester is hydrophobic and does not absorb moisture but by

changing the filaments to Y shaped cross section Toyobo has realised quick perspiration absorbency by capillary action. The hydrophobic nature and large filament surface of polyester filaments realise quick drying and refreshing properties at the same time.

Lycra25: Lycra, a truly synthetic fibre oflong chain polymer composed of at least 85% segmented polyurethane, finds wide range of end uses such as swimwear, active sportswear, floor gymnastics because of its comfort and fit2O. Adding Lycra to a fabric gives it stretch and recovery, particularly in gymnastics and swimwear where body skin flexing and stretching are inevitable. Lycra T-9026 requires still effort for the same extensibility.

Roica and Leofeel26 : Roica is a polyether type spandex made by dry spinning method and Leofeel is a soft nylon-66 yarn developed by Asahi Chemical. The combination of

Roica and Leofeel in mixed knitted tricot fabric gives a soft touch and excellent stretch. It is mainly used in swimwear.

7. CASE STUDY/BRAND

Future Perspective

A number of additional topics, such as respiratory water resistance, odorless clothes, and so on, are becoming related to sports textiles and are undergoing a few important tech- nological breakthroughs as a result of alterations, improve- ment, and continuing research. The manufacture of breathable sportswear in a variety of combinations would surely improve sportswear comfort. These characteristics are necessary for players to remain dry and confident.

Breathable textiles, along with features like UV protection, skins, and compression garments, are advancing in the realm of breathable sportswear technology, intending to improve athletic performance. Sports textiles are also per- forming more functional activities conveniently and smartly thanks to the use of smart textiles and wearable technologies.

7.1.Sustainability Issues

The expanding environmental con- cerns and their impact on the sportswear manufacturing business have prompted serious talks among all major com- panies about their goals for sustainable production and pro- curement of fabrics for sport and sportswear, as well as possible recycling solutions. With growing knowledge and education on the subject at the consumer, brand/retail, and mill levels, sustainability topics are becoming increasingly significant in the textile and clothing value chain. Polyester fiber already accounts for half of the global fiber market and is expected to continue to increase. Polyester yarn is manufactured from post-consumer recycled PET bottles, as well as fibers made from bio-polymer. IngeoTM Polylactic acid (PLA) biopolymer is already employed in a variety of athletic applications.

The bio-based LYCRA should be developed and com- mercial quantities produced for the autumn/winter 2015 and spring/summer 2016 collections to aid the corporation in achieving the goals specified in its Planet Agenda sustain- ability program, which is centered on three primary goals:

1. Minimizing its environmental footprint at its manufacturing sites by saving resources, decreasing emissions, and eliminating waste.
2. Providing competitive goods that fulfill the needs of the garment markets while using fewer resources and improving the environmental performance of all fabrics.
3. Ensuring the health and safety of our employees and communities, as well as taking part in community stewardship programs.

Most worldwide giants in the sportswear manufacturing industry, such as Adidas and Nike, have made

sustainability a strategic priority for their businesses. According to Adidas' sustainability report, "As a global leader in the athletic goods sector and a responsible company, we express our commit- ment to the implementation of sustainable business practices in both our firm and our supplier chain." We work hard to ensure that all aspects of our business, including our sup- pliers, have consistent values and that they are implemented. Our aim is clear: to raise the performance of our sites and those in our supply chain in the areas of social and environ- mental responsibility, and in this way to improve the lives of the people who manufacture our products, as well as the environment in which these products are manufactured.

Nikes's sustainability strategy is to create a portfolio of sustainable materials; materials account for around 60% of the environmental impacts of the average Nike shoe. Thus, using less or recycling more could make a big difference. Last year, for example, Nike used 7 million kg of organic cotton and included recycled polyester in more than 31 million products. Footwear and outdoor wear products from Tim- berland used 50 million post-consumer plastic bottles as recycled polyester in its footwear lines.

WL Gore has completed a project to eliminate perfluor- ooctanoic acid (PFOA) from all raw materials in the manu- facture of its waterproof functional fabrics. On January 10, 2014, GORE, inventors of the GORE-TEX® brand product technology for comfort and protection, announced that it had completed a project to eliminate PFOA from all raw materials used in the manufacturing of weatherproof func- tional fabrics. This affects all membranes and long-lasting water repellency treatments used in finished products across a wide range of categories, including mountaineering, run- ning, cycling, fashion and lifestyle garments, outdoor sports and casual wear footwear, and work wear for firefighters and police officers. GORE is one of the first firms in the industry to effectively switch its complete textile line to PFOA-free raw ingredients. The sportswear industry's outstanding per- formance is due to a high degree of innovation, strong pric- ing, and increased customer concerns about health and well- being.

8. Conclusion

In the current era of development, high-active sports textile is a very challenging field that required functionality with comfort properties. Market growth of sports textiles was increased day by day owing to the increase in sports partic- ipation and consumption of sports goods. The performance of the sports athlete is directly associated with the proper moisture management property, air permeability property, and thermal insulation properties of the garment, which was worn by the player during sports activity. The suitable selection of raw material, fiber morphology, yarn, fabric structure, type of finish, and garment pattern will provide the required functionality.

Researchers have engineered advanced polymers, fibers, yarns, and fabrics to meet cus- tomer demands and achieved the required performance characteristics. Performance characteristics of the sports- wear were also increased with the usage of highly elastic fil- aments (reduce drag forces in the garment), antibacterial finishes (reduce microbial growth due to sweating), and breathable fabrics (moisture management and temperature control). Moreover, functionalized new synthetic fibers were developed by changing the cross-section for moisture trans- portation. In the field of sports textiles, various innovative products such as polymers, fibers, yarns, fabrics, and finishes were developed with maximum comfort characteristics.

Wearable smart textiles are becoming increasingly advanced and helpful in increasing the functionality of both everyday clothing and work wear. They have applications in health management, sportswear, indus- trial work wear, temperature control, safety, and entertainment. The tech- nologies developed for wearable smart textiles are still being improved and developed. Many designs can still be streamlined to decrease

bulkiness and improve the overall integrated feel of the technology.

Textile-based smart wearables have a broad range of potential applica- tion markets such as sports, health, personal protection or entertainment. Smart clothes that reveal information on our posture, heart rate or body temperature are being developed.

Factors combined with a lack of must-have functionality which would persuade users to accept shortcomings, are mainly to blame for the fact that textile-based smart wearables are not more widely in use.

There is a related missing path to commercialization since explorations often stop at concept stage related to materials manufacturing (Barfield & Caudell, 2001). The main problems could be summarized as follow:

- Lack of miniaturization: Limited size and thickness requirements for components in wearable devices, smaller components -more design flex- ibility, ability to make technology invisible.
- Lack of Flexibility: Flexible mobiles and increasing integration into all wearables increase requirements for flexing/stretching.
- The need for materials and embedded sensors to be lighter and more flexible.

Design and developing wearable textile systems means to take into account not only functional elements (realm of engineers), but also the features needed to involve users. For instance, for sports, fitness and health purpose social acceptability will be enhanced if they enhance an individu- al's social status as well as providing the functionality needed.

By considering smart materials as a working platform that generate the end product (wearable) a set of requirements need to be met:

- Responsiveness to end-user.
- User centric ergonomic functionality: a new term – 'wearer ware' – may be needed to fill a gap in terminology.
- Ease of use.
- Wearer comfort (weight, bulkiness, flexibility, skin-friendliness).
- Ease of care & maintenance (wash-ability, repairability). Connectivity to and from the platform.
- Support for a diversity of sensors.

In order for the industry to start developing such class of products in a massive way we also need to train new professionals having a comple- mentary education that embrace knowledge from design to materials to computer science. Following this, a new curriculum is needed that should overcome the following barriers:

- Lack of Sensory experience investigation: Designers must consider the user's cognitive load, sensory and cognitive bandwidth.
- Missing of collaborative practice: Need to develop collaboration strategy between design and science, to more fully realize both the opportunities and contexts that Wearable offer (Fairburn et al., 2016).
- Material/ Technology acceptance of unknown materials, materials out of context, materials with 'bad reference'.

High active sportswear is very vast and challenging field in which required functionality can be designed by suitable choice of raw material, structure and geometry of fibres, yarns and fabrics, surface modification and garment assembly technique. During designing the sportswear fabrics, the aspects which are considered: protection/safety functions to protect wearers from adverse weather, comfort functions which gives wear comfort (thermal, sensorial and body movement comfort), exercise function to enhance

performance of athlete, and aesthetic appeal and high fashion ability. Moisture management properties like sweat absorption sweat dissipation and faster drying are primary desirable functions of high active sportswear which affect the comfort sensation of player during the game. The required functions of sportswear fabrics differ in different situations such as type of sports, environmental conditions and level of activity etc. Sportswear developed by using special type of polymer, type of fibrous material, modifying the fibre/yarn/fabric structure, lamination, finishing technology and manufacturing technology etc. The introduction of high functionality and comfort in the sportswear fabrics provide unlimited scope for sportswear fabrics

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