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A Synopsis of Smart Textiles for Sportswear

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Abstract

Engaging in sports during hot and muggy weather can lead to a variety of heat-related illnesses that can have either mild or fatal consequences. The creation and manufacture of sportswear has become increasingly important with the growth of contemporary sports, particularly in many challenging and hazardous sports. The most crucial element is the choice of fiber fabrics since it affects efficiency and performance while guaranteeing safety and physical comfort. Globally, there has been a surge in demand for smart textiles and materials in recent years. E-textiles and smart clothing can serve as a second skin to help track activity beneath the surface of the body. These days, smart textiles use sensors extensively. So, in order to become a good textile engineer, we must be knowledgeable about sensor technology and how it operates. People's changes in body composition and the environment around them can be monitored by electronic or digital sensors painted or woven into clothing. Here are several textile-based sensors that have been incorporated into clothing for a range of sports applications. It is the hope of some researchers that smart clothes will be powered by the body's natural energy. Since the sensors are integrated into the garment, they can come into close contact with the skin of the wearer and pick up a remarkably wide range of personal data. Sensors from various production-method levels are combined in one system, depending on the application area. To ensure the correct operation of the system, the textiles used for textile-based sensors must be carefully tailored to the specific application. A literature search shows that a small number of studies have been published on the development of smart clothing for monitoring, the features of textile sensors are, Longer functional life, High performance, Easy maintenance and Reliable operations. There are various sensor technologies employed in the textile sector like, Humidity and moisture monitoring, Pressure-mapping systems, Fiber-coated sensors, Printed sensors etc.

Keywords: Sensor Technology, Types of Sensors, Production Method.

Introduction

Textiles with the ability to detect and react to changes in their surroundings are known as smart textiles. A distinctive characteristic of smart clothing is the way materials are used to create intriguing features that were virtually unimaginable only a few years ago. Some of these clothing styles allow the wearer to adjust to the circumstances at hand in addition to making them aware of the bodily reactions that take place enhancing their output under those circumstances. The smart textiles fall into three categories: smart textiles that are passive, active and very smart textiles, (Koncar, 2016).

- Textiles that are passively smart can alter their characteristics in response to environmental stimuli. This category includes materials with shape memory, textiles that are hydrophobic or hydrophilic, etc.
- Sensors and actuators are incorporated into active smart textiles to link internal parameters to the message that is being transmitted. Temperature, light intensity, pollution, and other environmental signals can all be detected by them in order to determine how to respond. Afterward, they can take action using a variety of textile-based, flexible, or miniaturized actuators, such as textile displays, micro vibrating devices, light-emitting diodes (LEDs), and organic light-emitting diodes (OLED).
- Ultra smart textiles are able to sense, react and adapt their behaviour to the given circumstances.

In the textile and clothing industries, smart textiles are thought to represent a new product niche with enormous potential. Smart textiles are generally defined as textile products with added value; that is, they have the usual characteristics of textiles but also guarantee additional functions, such as appealing solutions for a variety of application domains, including medical, sports, protective apparel, and technical textiles for the automobile industry. The categories of smart textiles are based on their primary applications are medical, energy and transportation, protection, security, communication, and textile electronics (Konar, 2016).

Research on smart textiles will lead to new discoveries that advance science and provide a fresh framework for coming up with inventive ways to integrate electronics into odd settings. Among the many subfields of technical textile is sports textiles, (Cherenack & Pieterston, 2012). Smart textiles will contribute to greater social welfare and could result in significant welfare budget savings.

During international competitions such as the Olympics, sportswear’s fashionability and functionality can be evaluated. The production of specialty fibers has contributed to the scientific advancement of sportswear by enabling the engineering of sophisticated and fashionable apparel for appropriate end uses. High-activity sports include football, tennis, and athletics’ jumping, which all require a lot of physical effort to play. Sports textile performance is determined by factors such as water and wind resistance, extensibility, temperature regulation, strength with light weight, and overall moisture management capability. For a variety of end uses, sportswear typically requires distinct qualities. Among the textile and apparel industries’ leading innovators, the sportswear and sports footwear sectors have served as a springboard for numerous novel ideas and concepts in material and product design. In all sports, textile materials are used either exclusively or in conjunction with other flexible materials to create sportswear and footwear by Shisoo, (2015).

Literature Study on using of Smart Technology in Sportswear

The potential of smart textiles to communicate, transform, conduct energy, and even grow makes them potentially revolutionary fabrics.

Types of Sports

Athlete and Cycling Sports

For outdoor sports like cycling or running, performance-enhancing smart apparel should be functional, season-appropriate, and possess excellent hygiene qualities in addition to being aesthetically pleasing. Athletes sweat because they are moving around actively every minute. Sportswear made of smart textiles is created with these athletes’ needs in mind. For example, the frequently used textiles made of thermolite elicit a feeling that is dry-warm but free of strain. This technology is widely used, particularly for tights.

According to Rajut & Singh, (2017), Athletes have been linked to health problems such as asthma, cramps in their muscles during exercise, heart problems, heat strokes, and dehydration.

Overtraining by athletes who want to increase their performance in sports can be detrimental to them. have made an effort to put some of the technologies into practice in order to present the concept of a smart jersey that will aid athletes in maintaining their health, like

- Solution to respiratory problems: by attaching sensor to the anterior of the jersey, which provides significant information on respiratory flow.
- Solution to muscle strain: Rubber materials loaded with carbon are lightweight and simple to incorporate into clothing.
- In the context of wearable computing, attempts have already been made to use such sensors to detect arm gestures and body positions. This sensor can be positioned in the back, stomach, or arm regions because those areas are more likely to experience strain.
- Hydration level of body: A flexible wristband, an ultralow power microprocessor with Bluetooth, a button cell battery, and a network receiver chip are all attached to the hydration sensor.
- Body temperature regulation: The central nervous system receives signals from the internal thermal sensors, which measure the difference between the current body temperature and the target temperature continuously, instructing it to take the appropriate safety measures to reduce the rate of increase in body temperature.

Continuously observing physiological and biological alterations in athletes participating in high-risk, high-physical sports is another crucial area. Interactive electronic textiles have become available as tools to measure blood pressure, distance traveled, time spent exercising, calorie expenditure, body movement, and arm action for bettering the tennis or golf swing. Sports textiles have various applications, including the monitoring of body temperature, changes in waist circumference, time spent exercising, chemical or physical changes, and breathing rate. Textile-based piezo-resistive sensors were developed for these purposes, stated by Choudhry et al., (2020).

Recently, it has been noted that certain materials and patterns have the ability to rapidly absorb perspiration and dry the skin by removing moisture from the body. The sensor patches aid players in drying their hands more quickly, improving their grip. With the use of technological textiles, it is now possible to create materials that are more profitable and environmentally friendly than wood, while also being harder than wood and waterproof like rubber. The production of high-quality, high-performance sportswear is becoming feasible thanks to the extensive use of cutting-edge and intelligent technology in today's sports textiles, and the caliber of sports textiles is rising daily.

Breathable Sportswear – Mountaineering Sports

The standout item is the footwear; regardless of the temperature, all hikers, climbers, and hill walkers need additional robust, technical clothing. Both pros and amateurs seek out high-strength features that can be achieved with technologies made of materials with a long service life, such as those that provide flexibility and wind resistance. Cloths treated with water- and oil-repellent qualities ultimately have fewer stains because they not only keep liquids away but also loosen any soils and stains that are tenacious enough to set. It maintains the garment's shape while also preserving its breathability.

Swimsuits

Professional swimming now features some of the most cutting edge apparel available. To set records in Olympic-style swimming events, competitive swimmers wear the most advanced polyester and nylon bodysuits and trunks with improved hydrodynamic design. In fact, technical textiles are used in the creation of swimwear that is intended to improve swimmers' performance. When worn correctly, its fabrics can reduce friction on the wearer's body. These suits can reduce drag during swimming and offer compression of the abdomen, stability, and support for proper body alignment.

Gymnastics

For gymnastics, the muscular system and physical development are crucial. The body must have perfect posture when training. Because of this, technical sportswear needs to be lightweight while maintaining excellent breathability and mobility.

Sensors used in Textiles

Celikel, (2020) stated that, Sensors can translate physical quantities like pressure, strain, heat, humidity, temperature, etc. into analogue and digital electrical quantities, and they are now a crucial component of control systems. At the moment, smart textiles are systems that embed conventional sensors in textiles to measure vital parameters like movement, temperature, heart rate, respiration rate, and humidity. As of right now, real textiles are used to make the sensors in smart textiles. Motion, breath, and heart sensors have already been created with positive outcomes. However, smart textiles offer us even more potential for creating bio-potential sensors.

Conductive Materials as Sensors: Textiles with conductive qualities that alter their electrical characteristics in response to environmental influences can be employed as sensors. Typical examples include textiles equipped with stretch, pressure, and breathing sensors, among other sensors that react to deformations.

Temperature Sensors: When textile-based sensors are integrated into clothing or other fabric-based products, temperature changes can be continuously and sensitively monitored. This technology has a variety of medical and fitness applications. They are typically based on thermocouples, are already compatible with textiles, and are offered as cables. Types of temperature sensors are Thermoelectric-powered textile-based temperature sensors, Textile-based resistive temperature sensors and Fibre optic temperature sensors, (Heebo et al, 2023).

Thermal Sensors: Thermistors, for example, sense temperature variations and adjust resistance accordingly. They are also useful for measuring humidity.

Optical Sensors: light resistance, which generates a voltage output from light energy

Sound Sensors: Piezoelectric materials are able to detect sound waves and transform them into an electrical signal.

Humidity Sensors: The majority of humidity sensors rely on traditional hard materials and intricate manufacturing processes, and they are typically incompatible with flexible or inactive substrates. We create a flexible, low-resistance, CNT-based humidity sensor to get around this. To attain dependability, precision, uniformity, and longevity, the core-shell structured CNT@CPM is primed with Chit and PAMAM, culminating in an extraordinarily sensitive humidity gauge. The optimized sensor has a low hysteresis (– 0.29 to 0.30 percent RH), high sensitivity, consistent responsiveness, good linearity according to humidity rates, and an average response/recovery time of less than 20 s. Furthermore, it yields accurate humidity measurement results and is highly reliable for repeated bending (more than 15,000 times) over a long period of time (at least 1 month). They used the sensor to create smart clothing, like masks, that could use automated ventilation systems to perform multi-respiratory monitoring in real time. Its high responsiveness (less than 1.2 s) and reliable performance are indicated by multiple multi-respiratory monitoring results, making it extremely desirable for healthcare monitoring. Ultimately, these flexible sensor-paired automated ventilation systems when integrated with smart clothing can not only offer comfort but also stable, precise healthcare in any setting, (Kim et al., 2022).

Pressure Sensors: A variable capacitor is used to create textile pressure sensors. Compressible spacers made of Croslite™ are sandwiched between electrodes of conductive textiles coated in silver to create a capacitor, the capacitance of which indicates the applied pressure. Three sensors were incorporated into a snowboarding sock at strategic locations beneath the heel and ball of the

foot. Experiments conducted outdoors on a ski slope in Matterhorn Glacier Paradise (Zermatt, Switzerland) reveal that the machine learning algorithm NCC can identify turns—the fundamental activity of now boarding—with an accuracy of 84 percent based on sensor data. Furthermore, our sensor socks enable NCC to discriminate between a person standing on the ball of their foot, flat on the ground, or on their heel, as demonstrated by experiments conducted indoors. These findings imply that gait analysis or the tracking of runners' in-shoe pressure distribution could potentially make use of the socks, (Holleczek, 2010).

Strain Sensors: The creation of flexible textile-based strain sensors that are wearable and can track a variety of human motions. Strain sensors that are turboelectric are now available, along with other types such as piezoelectric, resistive, and capacitive. Although there have been advancements in raw materials, processing techniques, and structural developments for textile-based strain sensors, many problems and barriers still need to be overcome before strain sensors in fabrics can be widely used in a variety of industries, such as sports, the tech sector, universal health care, infotainment, and confidentiality, (Liza et al, 2023).

Chemical Sensors: Conductive polymers, or CPs, should be able to adapt the flexible and lightweight substrates while maintaining wearer comfort, because they have the mechanical characteristics of polymers and the electrical conductivity of semiconductors, (Galandi et al, 2021). Certain characteristics of the textile should be retained when chemical sensors are non-intrusively inserted into clothing. To be comfortable, the gadget should be light and flexible while still allowing for the normal flow of air, moisture, and heat through clothing. To be truly portable, it should also consume little power and only need a basic read-out electronics setup. Because of their rigidity and bulkiness, conventional conductor materials are unable to effectively meet these requirements.

Electrochemical Textile Sensors: Utilizing recent advancements in fiber and textile electronics, electrochemical textile sensors are being developed to create conductive yarns and fabrics that will make up the device. Typically, screen printing, dip coating, spinning, electrochemical deposition, oxidative ink-jet printing, in-situ polymerization, physical vapor deposition, and magnetron sputtering are used to apply a thin conductive film on commercial textiles. Conductive polymers and nanomaterials based on metals and carbon are the most commonly used conductive species. On the other hand, electrospinning, wet spinning, melt spinning, and floating catalyst vapor deposition can all be used to create conductive yarns.

Biosensor: These are gadgets that fuse a technological element, like an electronic sensor, with a biological element, like an enzyme or a living (or non-living) cell. Biosensors are used to measure and identify “a specific substance.” Creating biosensor-equipped apparel: in 2018, scientists applied genetically altered bacteria to a wearable, flexible material to create a running suit and shoe that would alter form based on the amount of perspiration on the wearer's body. *B. subtilis*, a harmless bacteria present in some fermented foods, was used in these prototypes. The short life cycle of microbes is undoubtedly one of the drawbacks of using them as biosensors. In an effort to solve this issue, some scientists are creating cell-free biosensors using inanimate molecular elements like protein, RNA, or DNA molecules.

Wearable technology that incorporates biosensors to track vital signs such as heart rate, perspiration, body temperature, and other health information.

Biosensors for temperature regulation: to modify body temperature in response to external factors. For instance, biosensors in a racing suit could identify sweat and trigger ventilation flaps to take moisture out of the body.

A few businesses are likewise welcoming the wearable future. Wearables can be classified into a number of categories, including Professional, Military, Personal Protection Equipment, Fitness/Performance Sportswear, and Medical/Healthcare. The smart sportswear products are,

- Arion insoles in sport shoes, is capable of measuring motion of the body. It is possible to sync the insoles and pods with the app to provide training-related data.
- Activity and sleep patterns can be tracked with Hexoskin Smart Garments. Because the body sensors can track movements to maximize the effectiveness of the workout, training is made easier.
- Polar heart rate sensor, a gentle textile strap equipped with electrodes to guarantee precise heart rate measurement.
- Qardio core ideal for those who have a higher risk of developing health issues due to genetics, a history of heart attacks or strokes, high blood pressure, high cholesterol, diabetes, or being overweight.
- The wearableX-smart yoga pant is made for guided yoga that includes vibrational response and posture monitoring.
- In Catapult sports, they use GPS to improve athletic training.
- The VITALI Smart Bra’s fabric sensors allow for the tracking of heart and respiration rates.
- Komodotec smart sleeve, used to track heart rate while work outs.

Discussion

There are more and more opportunities for creative and technological uses as the development of smart textiles with diverse “self-functioning” capabilities has opened up. Based to the concept of wearable computing, electronic devices of the future will be integrated into our regular clothes and function as intelligent personal assistants. Because regular wear can cause significant mechanical deformation of the underlying garment or substrate, wearable sensors need to retain their sensing abilities. The creation of wearable technology as a point of entry that regulates the recognition of the wearable technology’s function and is based on its inertial sensors. in order to guarantee that the wearable gadget is capable of withstanding the constraints of limited operating speed and storage capacity.

Though there are numerous barriers to the widespread use of textile-based strain sensors, including issues with accuracy and dependability, calibration, durability, interference, cost, and compatibility, scientists and engineers are working hard to find solutions and unlock the full potential of this fascinating technology.

Researchers have looked into a variety of fiber-based temperature sensors, such as thermoelectric, fiber-optical, and resistive sensors; all of these exhibit good temperature monitoring sensitivity. There are still issues to be resolved, though, like raising the sensitivity and accuracy levels, incorporating wireless communication capabilities, and creating low-cost fabrication methods. Furthermore, textile-based temperature sensors need to be robust and dependable enough to endure a range of mechanical stresses. They also need to be set up so that electronic components don’t interfere with temperature sensing. The MSR 12 medical device’s data (skin temperature and relative humidity) was compared with the microclimate temperature and humidity data collected to evaluate the functionality of the thermal monitoring system. Two distinct air conditions and two distinct physical activities have been used to test the smart T-shirt.

Although there are two types of smart textiles: electronic and adaptive, the future lies in fully textile, non-electronic solutions known as “stimuli-responsive textiles.” The palette of materials, which includes fibers, films, fabrics, and polymers, metals, and ceramics, is only constrained by the researcher’s imagination and skill. While electronic smart textiles function like circuits, stimuli-responsive textile systems rely on the characteristics of the materials. Stimulus-responsive materials can be processed directly into fibers or fabrics, or they can be applied as films, coatings, and surface treatments. Materials that respond to stimuli can take on different forms, be asymmetric, self-cleaning, self-healing, or change color. The three main, recently developed application areas of thermal comfort regulation, smart healing, and soft assistive robotics. Here, the focus is on creating a functionalized textile that can react to stimuli in predictable ways, help people or make

improvements, and improve textile qualities to offer more functions in fewer layers, (Ruckdashel et al, 2021).

Conclusion

Smart textiles are flexible materials that incorporate multifunctionalities beyond clothing through the use of proven textile techniques. The state of the art in academia is far behind commercial needs, even with recent advances. Even though there are a lot of commercial products on the market right now, many scientists are still working on novel concepts, ideas, and tangible products to meet the growing demand for smart textiles in sportswear.

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