Modern trends in smart textile technologies and applications "An analytical study"

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Abstract:

Textiles have been used in our daily life since antiquity and were mainly used to provide protection, comfort and beauty in clothing, but now textiles have changed its strategy to create new products and functions. However, recent years have seen the emergence of the so-called ‘smart textiles’, where advances in material science added intelligence to textiles and created “smart” clothes that can recognize and respond to environmental variables or stimuli from thermal, chemical, electrical and magnetic sources .Smart textiles are the integration of smart materials, such as electronics, sensors, Nanotechnology, and IT technologies, with textiles, where the remarkable growth of electronics and smart materials provided inherent potentiality in the field of textiles and for novel high-tech applications. These smart clothes are worn like conventional clothes to perform their smart functions in many situations according to the requirements of use. These textiles can be used in many militaries, safety, healthcare, protective, aerospace, and sportswear applications etc. Today, the production of smart textiles has become a reality that combines traditional textiles and clothing technology with other branches of science, such as material science, sensor and mechanical actuators technology, advanced processing technology, artificial intelligence technology, and technological sciences. With the rapid growth and advancements in textile technologies, several scientists are developing new solutions, ideas, and products with the increasing demand for smart textiles; they are positioned as the textile industry's future and are an ingrained consumer interest. This paper attempts to illustrate the recent developments and issues linked to smart fabric textiles.

Key words:

Smart fabrics, Sensors, Nanotechnology, IT technologies

الملخص:

تم استخدام المنسوجات في حياتنا اليومية منذ العصور القديمة وكانت تُستخدم بشكل أساسي لتوفير الحماية والراحة والجمال في الملابس, ولكن الآن، غيرت المنسوجات استراتيجيتها لخلق منتجات ووظائف جديدة ومع ذلك، شهدت السنوات الأخيرة ظهور ما يسمى بـ "المنسوجات الذكية" حيث أضاف التقدم في علم المواد الذكاء إلى المنسوجات وخلق ملابس "ذكية" يمكنها أن تتعرف و تتفاعل مع الظروف أو المؤثرات البيئية من مصادر حرارية ,كيميائية ,كهربية ومغناطيسية . المنسوجات الذكية هي دمج المواد الذكية، مثل الإلكترونيات وأجهزة الاستشعار وتكنولوجيا النانو وتقنيات تكنولوجيا المعلومات مع المنسوجات،

حيث جلب التقدم الرائع للمواد الذكية والإلكترونيات إمكانيات جوهرية في مجال المنسوجات وللتطبيقات المبتكرة ذات التقنية العالية. يتم ارتداء هذه الملابس الذكية مثل الملابس العادية لتؤدى وظائفها الذكية فى مواقف عديدة وفقا لمتطلبات الاستخدام.يمكن استخدام هذه المنسوجات في العديد من التطبيقات العسكرية ، والأمن, والرعاية الصحية، والحماية، والفضاء ، والملابس الرياضية وما إلى ذلك.لقد أصبح من انتاج المنسوجات الذكية اليوم واقعا يجمع بين المنسوجات التقليدية وتكنولوجيا الملابس مع فروع اخرى من العلوم مثل علوم المواد,وتكنولوجيا الحساسات والمشغلات الميكانيكية ,وتكنولوجيا المعالجة المتقدمة,وتكنولوجيا الذكاء الاصطناعى والعلوم التكنولوجية. ,ومن المتوقع أيضا أن يغير الواقع الافتراضى حياتنا فى عصر انترنت الأشياء مع الأخذ فى الاعتبار أن مجالات التطبيق المستقبلية الأوسع للمنسوجات الذكية هى الملابس الذكية و الحوسبة. مع النمو السريع والتقدم في تقنيات النسيج، يعمل العديد من العلماء على تطوير حلول وأفكار ومنتجات جديدة مع الطلب المتزايد على المنسوجات الذكية أصبحت موضع اهتمام العملاء ويتم تقديمها على أنها مستقبل صناعة النسيج. فى المستقبل ستصبح الأقمشة الالكترنية ذاتية التشغيل بشكل متزايد لتسهيل استخدام أنظمة الاستشعار المحمولة القابلة للارتداء لادارة الصحة الذاتية و رعاية المرضى عن بعد.وفي هذا السياق، تقترح هذه المراجعة إظهار التطورات والتحديات الحديثة المتعلقة بمنسوجات الأقمشة الذكية.

الكلمات المفتاحية:

الأقمشة الذكية , أجهزة الاستشعار, تكنولوجيا النانو,تكنولوجيا المعلومات

Introduction

For thousands of years, textiles have been an essential part of human life. Humans utilized textiles as clothes for protection in previous times, but their use has gradually widen. Nowadays, people wear clothing at all times, and different types of textiles may be found in almost every location. Recently, there has been a growing interest in incorporating multifunctional qualities into common materials. Fabrics, fibers, yarns, and a variety of other materials with functions have been developed for a variety of applications [1]. History has seen the development of special enhanced characteristics due to advancements in smart materials and electronics including energy storage, shape-memory materials, heat storage, and thermo-regulated fabrics. These are referred to as smart fabrics [2]. The integration of electronics and textiles in high-converging technology has enhanced the capabilities of e-textiles to create Smart E-Textiles, which bridge the difference between interaction and interconnection [50]. The term "smart textiles" refers to fabrics with innovative and technological applications that can receive and respond to external stimuli in order to adapt to changes in their environment [3]. Nanotechnology, embedded technologies, wireless communication technologies, and smart sensors can all be used to create smart textiles that can monitor activities for use in contemporary applications. Investments in Smart Textiles' Research & Development will promote their use as sustainable options, environmentally friendly to wearable technology that is lightweight and highly functional for tracking a variety of Smart Textiles application activities [50]. In today's competitive environment and desire to attract more clients, the incorporation of different user-defined specifications into traditional textile is frequently required [10]. When designing smart textiles, two factors must be considered: The choice of an appropriate smart material and integrating it into the textile structure through braiding, chemical treatments, coating, weaving, spinning, knitting, printing, stitching, or embroidery [6]. Smart textiles enable a variety of functions and uses, including security, decoration, and clothing or technical textiles [7]. Smart textile applications are widely used in healthcare, aerospace, military, computers and electronics, buildings, sports, fashion, and protective clothes [7, 8]. Some studies have demonstrated a broad variety of uses of smart fabrics. Revaiah et al. [56]

concentrated their review on smart textiles for specific military activities, such as flame retardant jackets and prolonged cold weather gear, among others. Peng et al. [57] investigated fabrics for energy and personal temperature control, emphasizing the significance of creating textiles that successfully manage the body's and environment's heat exchange. Massaroni et al. [58] researched fiber optic technology-based medical smart fabrics prompted with a rise in the patients' mobility who require constant tracking of physiological variables and the corresponding monitoring of mechanical requirements.

Due to the numerous applications in different industries, the market for smart textiles worldwide is flourishing and growing significantly [5]. According to the Research and Consulting Group for International Market Analysis, by 2028, The market is expected to reach USD 15.9 billion, according to experts [9].

Research Problem

There is hesitation when wearing smart fabrics equipped with devices with wires and electronic materials, especially when they are close to the body. Therefore, interest is increasing in developing technology in many areas of modern fiber manufacturing to be utilized in application and testing processes to transform traditional fabrics into smart fabrics that are characterized by being lightweight and equipped with wearable and comfortable wireless computers suitable for the world of fashion and other fields.

Research Aims

This study aims to illustrate the latest advancements and challenges pertaining to smart fabrics. Explaining the importance of using smart fabrics and their various applications.

Research Importance

Highlighting the use of smart fabrics and its applications.

Giving researchers the chance to conduct further studies on smart textiles, which will help spread their use.

Classification of Smart Textiles

There are three categories for smart textiles depending on their functions. They are as follows: Passive, active, and ultra-smart textiles (Figure1).

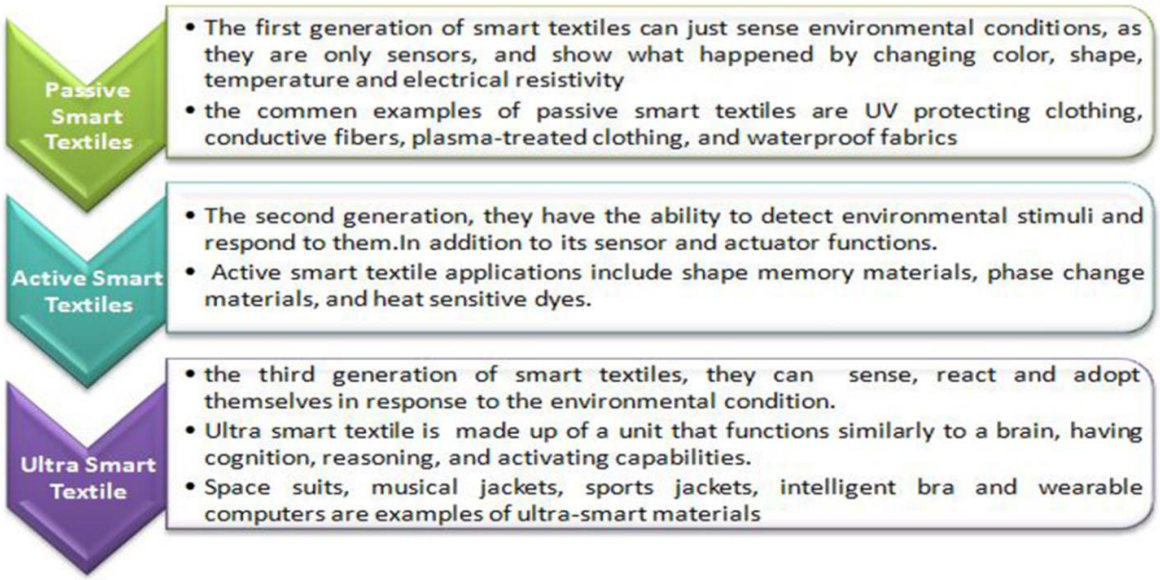

Figure 1 .Classification of smart textiles [4, 5]

Brief history of Smart Fabrics

Applications for wearable electronics (particularly wearable computing) have just recently piqued the interest of scientists, however studies into their application in belts and corsets have been conducted since the 1850s [11]. The fundamental materials required to create e-textiles, conductive threads, and fabrics have existed for more than a thousand years [12].

In 1600, conductive threads have been used since the Elizabethan period, when metallic threads, often gold and silver, were woven into clothing to add a gleaming accent. For example, many of Queen Elizabeth's dresses were embroidered with gold threads [12, 40].

In the late 19th century, electricity was first incorporated into clothes and jewelry by designers and engineers, developing a collection of lighting necklaces, hats, and costumes with sensors and actuators [41].

Body Covering, a pioneering exhibition at New York City's Museum of Contemporary Craft **in 1968**, focused on the link between technology and clothing. The show showed astronauts' space suits as well as apparel that can expand, deflate, light up, heat up, and cool itself [12].

Harry Wainwright invented the first sweatshirt **in 1985**, made of fiber optics and LEDs that projected full-color animation onto the garment's surface. Harry Wainwright created the first machine to incorporate optical fibers into fabrics **in 1995** [42].

The world's first CNC machine capable of embedding optical fibers into any flexible material, including textiles, was produced **in 1997**[12, 42]. Scientists at Department of Computer Science created the cyber jacket (Figure 2). The first prototype was created in the summer of **1997**. It comprises of a wearable mobile computer system with GPS position sensors [1].

Figure 2.Cyber jacket [1]

The first CNC machines began production **in 1998**, with the creation of animated jackets for Disney parks. [43].

Textile and fashion specialists began conducting their own research and development on smart and wearable devices **in the year 2000**, culminating in the birth of several cooperative projects between the fashion and electronics areas. The first wearable electronics clothing item on the market at the time [1].

In 2003, Wearable Motherboard from Georgia Tech (figure 3) monitored and detected bullet injuries using optical fibers and unique sensors. The data bus, which is combined with observational equipment like as an ECG, also helps the sensors get data as well. Additionally, it is capable of recording voice and temperature [1, 2, and 40].

Figure 3. Georgia Tech Wearable Motherboard [1, 2]

In 2005, Harry Wainwright and his colleague invented the first biophysical ECG jacket using optical fibers and LEDs [12, 42].

In 2006, an infrared digital display machine embedded in fabrics was demonstrated for use in military clothing [42].

In 2012, Wainwright was assigned to give a speech at the Australian textile conference, where he was asked to showcase his creations of fabrics that can be controlled by any smartphone to change color, and that have security measures to prevent theft of personal belongings [12].

In 2016, a near-field communication chip was integrated into a smart shirt that was introduced to be paired with smartphones that operate with Android system. **In 2017**, parents could track their newborn's sleep patterns with the launch of smart socks [42].

In 2018, two patent applications were filed by Nike for smart clothing: One for a self-cleaning shoes and the other for a sensor built in yoga suit. **In 2019**, for a smart shirt that monitors illness symptoms such as bronchitis and pneumonia, Samsung filed for a patent [42].

In 2020, Smart pajamas were introduced that track a user's heart rate, sleep patterns, and ability to recognize falls or trips [42].

Recently, the number of Smart clothes on the market has expanded dramatically. This is because new materials are being developed and advances in material science and electronic components are being made [1, 2, and 13].

Wearable technology is becoming much more prevalent as of today. Additionally to eyewear computing, several actuators and sensors positioned at various locations on the user's body were utilized to obtain information about a variety of different aspects, such as the wearer's present state of health or performed activity [14].

Smart Textile Materials

Smart or Functional materials are typically a component of a Smart System that can sense its environment [12].

Metals (such as silver (Ag), copper (Cu), titanium (Ti), gold (Au), and nickel (Ni)), conducting polymers (poly(3,4ethylenedioxythiophene) polystyrene sulfonate (PEDOT: PSS)), and some carbon-based materials (Graphene and carbon nanotubes) have all been employed as electrically conducting materials. The ability to communicate with the outside environment is crucial for Semiconducting or conducting functional materials, together with smart textiles, have been utilized to achieve this. A potent technique for use in smart textile development is the integration of semiconducting materials, determined by their thermal (carbon nanotubes, CNTs), mechanical (polyvinylidene difluoride (PVDF)), optical (metalorganic frameworks (MOFs), and electromagnetic activities [15].

In Figure 4, smart textile materials are presented

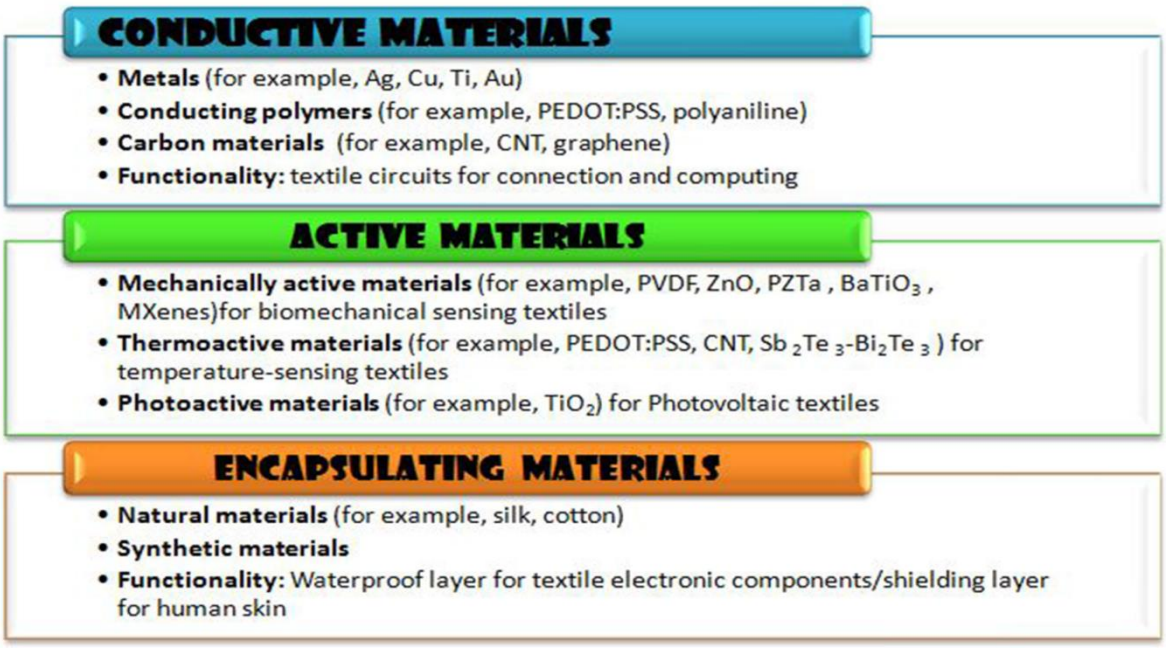

Figure 4. Smart textile materials [15]

Fabrication technologies of smart textiles

An intelligent textile has to have a sensor, an actuator (in the case of active smart fabrics) and a controlling unit (for extremely smart textiles). These components could include phase change materials, fiber optics, shape memory materials, miniaturized electronics, thermo chromic dyes, and so on. These elements are integrated into the textile structure and can be used at any level including fiber spinning, fabric production (non-woven, knitting, weaving), and finishing. It is also possible to incorporate these smart materials into the textile structure using a variety of techniques, including as chemical treatments, coatings, sewing, braiding, embroidering, and printing [4].

A number of techniques can be used to create smart fabrics, including spinning, coating, and printing. In the last few years, the majority of research has focused on developing conductive functional textile materials that might be employed in many different applications. Electrically conductive fabrics are the most portable and essential components of smart textiles. In order to create them, non-conducting fabrics are typically combined with conducting materials using a variety of application procedures, including chemical vapor deposition (CVD), coating, printing, spraying, plasma treatment, and other techniques[16].

Spinning: Continuous fibers with various diameters can be made in parallel from one or more functional materials by manipulating the initial fabrication procedure. A variety of functional materials have been spun utilizing wet, dry, melt, and electrospinning techniques to create smart textiles. Examples: Electrospinning has been used in electronic devices Wearable on textiles [15]. Coating methods are typically used to create functional layers on material surfaces [17]. Coating transforms textile materials into functional, smart, or intelligent materials that may react to events in the surroundings by earning properties such as being antibacterial, and having UV protection, electrical conductivity, and other functionalities [18]. Spray coating, dip coating, and electrochemical coating are popular coating methods for producing smart textiles because they are low-cost, convenient, and efficient. Examples:

Spray coating has been used in UV-protective clothing and water-resistant fabrics [19-21]. Printing has also been utilized to create smart textiles, particularly three-dimensional (3D) printing. Due to its ability to produce large-scale, independent, and affordable processes, this fabrication technology has already been applied in the industrial setting [22]. Previously, screen printing [23] and inkjet printing [24] were used.

Smart Textiles Development

Today's textile business must constantly adapt to changing consumer demands for new and ever-more inventive products as well as creative uses of technology. Strength and durability, surface texture and "feel," and ability to print a variety of colors and patterns have all seen notable improvements in the "conventional" textile industry' goods. Personal care aspects including antiperspirant and deodorant properties, along with flame-retardant, self-cleaning, and antimicrobial properties, are among the other developments. Development of "smart textiles," which combine intelligent nanoparticles with traditional materials, has advanced in recent years [30].

Nanotechnology is widely viewed as having immense potential in several uses around the world [32]. It is currently applied to the processing and finishing of textiles to provide functional advantages [33]. When used in textiles, nanoparticles can improve their surface properties, making them more microbicidal, waterproof, antistatic, UV-protective, color-durable, resistant

against stains, odors, and wrinkles, and thermally efficient. These nanotechnologies are used in many different applications, including geotextiles, home and household products, defense, packing, sports and recreation, and healthcare. In order to keep up with competition on the worldwide market. Major participants in nanotechnology clothes sector are introducing a new range of clothes with wearable technology. The nations examined in the study on the global market for nanotechnology clothing are Australia, Brazil, China, France, Germany, India, Indonesia, Japan, Russia, South Korea, the UK, and the United States [2]. The increased manufacturing of engineered nanoparticles and nanomaterials in the sector of textiles has resulted in a massive boom for numerous industrial sectors, thanks to metal nanoparticles. These nanomaterial-modified textiles may also find use in wound healing, drug delivery and release, air purification, cosmetics, energy harvesting and storage sensing, renewable energy generation, and electronic applications, including the creation of on-body diodes, transistors, and circuitry [51].

In order to do a variety of functions, Nanomaterial based smart devices are increasingly being integrated with textiles. Among those that have been used include graphene oxide nanoparticles, chitosan, carbon nanotube, TiO_2, Au, Ag, Pd, Cu, Si, CuO, and ZnO. [52]. Shah et al.[30] highlight various approaches for the introduction of nanoparticles into textiles and their functionalization in a review, taking into account numerous important factors like cost and environmental sustainability. Researchers are concentrating on investigating nanomaterial-based photonics over textiles in order to build very attractive, colorful, and intelligent clothing that can change color in response to diverse stimuli. Antimicrobial textiles, textiles with hydrophobicity and oleophobicity, textiles resistant to UV light, textiles with antistatic qualities, electrically conductive textiles, textiles with photonics, and textiles with color-tunable optical fibers are the most common studied topics in nanotechnology researches [30, 53].

Although there have been numerous advances in this subject, there are still constraints and hurdles that impede the industry's progress. The biggest obstacles are in the integration process, as the produced gadgets and on-body electronics frequently ruin the smoothness, comfort, and wearability of the garments [30]. In addition, the scientists take wearability and nontoxicity into account while producing supercapacitors, nanogenerators, and photoelectronic devices. [2].

Usage of smart textiles

- **Color-changing textiles**

Color-changing textiles are those that alter color in reaction to variations in the external environmental factors such as light, temperature, pressure, etc. they are extensively utilized as a result of their unique properties in many different industries. In addition to civilians using anti-counterfeit elements to manufacture fashionable color-changing clothing and continually changing decorative textiles that are widely utilized in invoices, accreditations, and trademarks, the military may use military camouflage. Fabrics that change color can be made using the following three methods: Color-changing fibers can be added to fabric, printed with color-changing paint, or dye it with color-changing dyes [54].

- **Self-cleaning textiles**

Self-cleaning coatings are gaining popularity because they use rolling water droplets and photocatalysis, two distinct mechanisms, to remove both organic and inorganic contaminants. Because of the low surface energy and lotus or cauliflower-shaped surface, rolling water

droplets create dirt on the fabric's surface, which then rolls off to absorb additional pollutants, dust, and inorganic pollutants [30].

- **Shape memory textiles**

A type of material with a shape memory property that is woven or finished into textiles is known as shape memory textile. Exceptional properties of textiles include good shock resistance, shape retention, and strong deformation recovery, and flexibility in a variety of environmental conditions, including light, temperature, mechanical force, and PH. Italian Corpo Nove Company, invented the "lazy shirt". The shirt's sleeves may recuperate naturally and even iron themselves in the winter. In high heat, they swiftly roll up from the wrist to the elbow [55].

Smart Textile Applications

- **Military/ Defense Field**

One of the primary reasons for the fast growth of smart fabrics is their usage in military projects such as extreme weather condition jackets or uniforms that change color to improve camouflage effects. In extreme environmental circumstances and dangerous situations, real-time information technology is required to maximize the protection and survival of people working in those conditions. Performance enhancements and new capabilities would be extremely beneficial in professions such as emergency response teams and the armed forces to keep an eye on vital signs and treat injuries while also keeping an eye out for environmental risks like toxic gasses. Wireless connectivity to a central unit enables medics to undertake remote triage of victims, allowing them to respond more quickly and safely [4, 12].

- **Sports Field**

In sports generally, smart devices integrated into sports apparel are able to track physiological characteristics and other functions, such as breathing, heart rate, and body temperature like the number of steps done and overall distance travelled. Smart fabrics also assist players avoid injury.

Walking shoes may be incorporated with Global Positioning System (GPS) to aid in the wearer's tracking in an emergency rescue service. Additionally, it's possible to utilize it to locate children [1].

The intelligent running shoes from Nike include a unique sensor that tracks the athlete's motions while running and communicates the data to personal iPods and other information technology gadgets. Adidas, a competing sport wear competitor, developed a running pacemaker with a built-in medical device to monitor runners' heart rates [25].

An Australian inventor created the smart bra. This bra's qualities alter in reaction to breast movement, providing more support to energetic sport ladies in action. In order to avoid excessive breast movement and consequently assist avoid breast sagging, automatically, the Smart Bra will tighten and loosen its straps or stiffen and relax its cups. The Smart Bra will be made of textiles covered with conductive polymer. The fabrics' elasticity can change in reaction to information about the amount of strain they are experiencing. At excessive movement, it will be possible for the Smart Bra to quickly tighten and loosen its straps or stiffen its cups [26].

- **Health and Medicine Field**

The system for wireless health monitoring is utilized to collect current medical data from patients and to continuously monitor muscle activity, breathing, and using an integrated textile sensor in a wirelessly capable device to provide the patient's EKG .The system contains a sensitive vest with entirely sensors made of woven fabric, a tiny electrical chip for motion sensing, and data transmission through Bluetooth [1, 12].

A children's sensory vest is designed to prevent life-threatening situations for children. Using this vest, medical professionals will be capable of keeping an ongoing eye on the functions of important organs such as lungs, skin, and heart. It can also monitor temperature of the body, this aid in the early identification of heart diseases. Sensors have been integrated into this vest so that the infant is not bothered when they are asleep [1, 12, 44].

A wearable trans-abdominal gadget called a life belt (Figure 5) is particularly helpful for monitoring pregnant women. It helps in the long-term monitoring process of both embryo and mother. It is really helpful in distant places where pregnant women lack adequate medical care. When this belt is worn by a pregnant woman, relevant information related to the mother and embryo can be sent to a computer, where a medical specialist can interpret and act accordingly. The life belt acts as an aid for the obstetrician, enabling him to monitor patients remotely and access patient medical information at any time, an automated initial the condition's diagnosis is evaluated based on the gathered and examined vital signs [1, 12]

Figure 5. Life belt [1]

- **Musical Field**

The Musical Jacket is made up of speakers that are amplified, an embroidered cloth keyboard, a fabric bus woven from conductive materials and batteries to run the apparatus, all of which are placed into a regular denim jacket, transforming it into a musical instrument that may be worn. The person wearing it can play notes, rhythms, and chords using any instrument in the Music system [27].

- **Fashion and Entertainment Field**

Designers, scientists, and engineers work together to successfully introduce smart textiles in fashion [28].They are becoming more dependent on technology, carrying MP_3 players, laptop computers, cell phones, and digital cameras [29]. Technology can also be utilized to radically alter the appearance of a textile, creating new effects such as light emitting textiles and the usage of innovative methods to make smart textile structures[12].

- **Others Applications**

Both the Hug shirt (figure 6) and the Sound Shirt (figure 7) contain sensors and actuators that can help people reduce their feeling of isolation and reunite with their family. This is achieved

by using actuators to simulate touch and emotion to a loved one who is far away, along with sensors that record the strength, length, and position of the contact [2,45]. Haptic actuation modules found in the Sound Shirt can be used for gaming and music [2, 46].

Sensoria's socks (figure 8) include 100% patented textile sensors, which are coupled with Bluetooth and improve accuracy in calculating steps, distance, velocity, altitude, and calories monitoring in the sports sector [2,47].

Figure 6. Hug Shirt [2]

Figure 7. Sound Shirt [2,46]

Additionally, sensoria smart socks have made an appearance in medical field, where they are employed in order to monitor patients remotely. Elderly patients, for example, who have a tendency to fall, can put on the socks, which identify alterations in their walking pattern and inform caretakers if there's an unexpected shift in movement. Furthermore, diabetic people keep an eye on their foot health and avoid ulcers or other problems by wearing the socks. [48].

Figure 8. Sensoria smart socks [2]

Some applications of smart textiles are summarized in Figure 9.

Figure 9. Smart Textile Applications [1, 12]

Future Challenges

Smart fabrics contribute effectively to the future of fabrics in many fields such as medical, sports, military, aerospace, fashion, entertainment, buildings and home decoration. Advances in smart wearable fabrics are not limited to healthcare and fitness monitoring, but are also leading to new emerging technological developments in virtual reality and the Internet of Things (IoT) [49]. Smart fabric technology is evolving and will most likely interact with artificial intelligence, internet of things, and human-machine interaction over the next decade, as data extracted from sensors embedded in smart fabrics can be analyzed, allowing the fabric to respond intelligently to alterations in the surroundings or in the body of the person wearing it.

Smart fabrics have been suggested for application in monitoring hospital beds, with shirts that detect pulse rate, blood pressure, oxygen intake, and other critical signs. These garments may

also be effective in monitoring stroke patients and people with serious cardiac issues, as well as those who experience falls at home or in a care center [49].

Novel textile-based implantable items (such as artificial ligaments and tendons) and other products, such as non-biodegradable polymers and biodegradable materials, are being created. Face masks and shoe covers are among the goods [2].

For the purpose of collecting, analyzing, and applying information throughout smart clothing, small microprocessors in textiles can work wonders. Garments combined with specific sensors are able to track the wearer's physiology and body position, alerting to and correcting problems or irregularities before they get out of hand [30].

Innovative sportswear, space transportation systems, and ultrasonic assembly are just a few examples of recent developments in smart textile performance [31]. The resulting wide application field may encompass, among other industries, automotive, medical, and healthcare, as well as personal protective equipment industry. The continual search for items that are lightweight and comfortable in applications for sports and fitness produce a predicted growth rate in the next years. The ability to track and evaluate physiological data, including diabetes, blood pressure, and temperature, has also increased its relevance in the medical applications industry, and it is anticipated that this application would expand more quickly than traditional ones [2].

It has been revealed that the utilization of photonic crystals, LED displays, and other technologies in smart fabrics can be used in fashion to control luminosity, colors, and holography. These garments could also integrate with sensors that measure temperature, humidity, light intensity, and movement. Flex fabric, designed by Cambridge Consultants, uses optical fiber sensors to track motions of the human body. This cloth utilizable in sports coaching as well as physiotherapy. As a result, completely functionalized clothes that can continuously monitor the wearer's health, motions, and other activities such as sports and dangers could be accomplished soon after [34].

All of these display-based applications in the future and sensor features will be operated via smartphones. When incorporating smart nanomaterials into textiles, it's important to take breathability, flexibility, and comfort into account because without them, customers won't find garments acceptable. As a result, researchers are focused on techniques for retaining these desirable characteristics while treating the textile. Cotton is always been considered the ideal selection because of its breathability, absorbency, and smoothness. However, due to its flammability, low strength, and ease of wrinkling and soiling, there is little evidence of its extensive use in fashion technology. [35]. Synthetic fibers are available that do not have these constraints, nevertheless, they lack cotton's level of comfort. As a result, researchers want to combine the useful characteristics of cotton and synthetic fibers to create nano-engineered functional textiles that make clothes comfortable [36]. In order to solve this, Guan El al. [37] are creating fabrics with micro-structured porous 3D conformation. They demonstrate how solution concentration, temperature, relative humidity, nanomaterials, flexibility, and product durability affect these factors and claim that their method of incorporating nanomaterials into textiles can produce wearable fabrics with exceptional comfort, flexibility, and functionality.

Textiles that are antibacterial, antifungal, and antiviral are extremely essential since they directly impact human health. These products are used in water purification, ventilation, personal hygiene, and air filters. Due to the COVID-19 epidemic, active sportswear has

significantly increased [38]. In short, this growth includes certain substances, agents, or nanoparticles (NPs) that coat the fabric and boost its antibacterial properties. Despite their effectiveness, synthetic chemicals and nanoparticles (NPs) lack sufficient information about their effects on the natural world. Therefore, in the future, there will need to be a greater usage of natural agents [39].

Despite technological progress, the main issue is human body comfort and safety.

Conclusions

Smart fabrics were previously unknown. Scientific efforts and continual growth in the development aspects in this sector have resulted in smart fabrics presently being touted as the future of the textile industry, and customer interest in the products has increased dramatically. Wearable e-textiles are still a nascent subject with chances to create novel products that can revolutionize how people interact with their clothes. There are numerous possible applications where smart Nano-textiles might impact our lifestyles, comfort, and become ubiquitous in this technology-driven society by allowing man to interact with his environment and space.

Abbreviations

Ag	Silver
Cu	Copper
Ti	Titanium
Au	Gold
Ni	Nickel
Pd	Palladium
Si	Silicon
CuO	Copper oxide
ZnO	Zinc oxide
TiO_2	Titanium dioxide
$BaTiO_3$	Barium titanate
PVDF	Polyvinylidene difluoride
CNTs	Carbon nanotubes
MOFs	Metalorganic frameworks
CVD	Chemical vapor deposition
UV	Ultraviolet
3D	Three-dimensional
GPS	Global Positioning Systems
NPs	Nanoparticles
IoT	Internet of Things

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