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SMART FABRICS (REVIEW)

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Abstract:

The strategy of traditional textile industry is changed during the last 20 years, to find new products and functionalities,where advances in material science added intelligence to textiles and created "smart" clothes which can sense and react to environmental conditions or stimuli. These textiles can uses in many applications military, security, personalized, healthcare, protective, outer space, and sportswear. ....etc. Production of smart textile need to cooperation between various disciplines, such as, computer science, microelectronics, polymer chemistry, material science, biotechnology,smart textile materials and their application will boom in the near future, and create a bright tomorrow for textile market on all over the world. The aim of this research is to have literature overview of these incredible, dynamic and very important objects.

Keywords: Smart textile, Technical Textiles, Interactive Fabrics,stimuli, environmental conditions.

I- Introduction:

During the last twentyyears, the traditional textile industry has changed its strategy to create new products and functionalities, amazing progress of electronics and smart materials brought huge potentiality in the field of textile technology, that are far away from conventional textile world. This has allowed the emergence of two areas: "Technical Textiles" and "Smart Textiles" or intelligent textile. **[1, 2]**

Technicaltextiles share with other branches of science like material science, structural mechanics, andsensor,actuate or technology, communication,advanced processing technology, artificial intelligence, biology etc.**[1]**Smart garments particularly suited for any physiological and physical monitoring task.**[3]** Smart materials create a bright tomorrow for textile market on all over the world.**[4]**

I.1 Definition of Smart Textiles and its Classification:

Smart fabrics have been defined as fabrics which designed andmanufactured to include technologies that provide to the user increased functionality.**[5]**They are defined also as atextile that can sense and react to environmental conditions or stimuli from mechanical, thermal, chemical, magnetic or electrical sources.**[6,7,8]** They are capable of showing asignificant change in their mechanical(such as shape, color and stiffness), thermal, optical, or electromagnetic properties, in response to the stimuli.**[9,10,11]**Smart textiles can be classified intothree categoriesbased on their functions:

1- ***Passive Smart Textile:*** The first generation of smart textiles, can only sense the environmental conditions, it is just sensors, and show what happened in it, through changing color, shape, thermal and electrical resistivity.
This textile materialcan compare by high functional textiles, as Micro fibers, hydrophobic or hydrophilic textiles, etc.**[1, 8,9]**

2- ***Active Smart Textile:*** The second generation, they can both sense and respond to the external conditions or stimuli.They are able to detect different signals from the environment such as temperature, light intensity and pollution.**[1, 8, 9]**

3- **Ultra Smart Textile:** the third generation of smart textiles, which canexecute triple functions; sense, react and adoptorreshape themselves accordingly to the environmental condition**.**They work as brain, with cognition, reasoning and activating capacities.**[1, 9]**

I.2 Difference between technical,smart or intelligent,Sustainable,and Wearable textiles:

Technical textiles are focussed on the function of textiles, rather than its aesthetic properties. So technical textiles are generally used in industrial fabrics, they are often made of micro fibres (synthetic fibres 60 times finer than human hair).**[10, 11]** They are not active and not designed to regulate themselves or use the smart material in them, and not doing any change in their properties but, they just resist or absorb energy or any stimuli from the outer environment.**[12, 13, 14]**As example of Technical textiles, garments which used for fire fighters are protective against heat and flames, due to use glass fibres in their production, also in bulletproof vests, specialty fibres such as aramid fibres are used because their high tenacity and high thermal resistance allows the vests to withstand. **[1, 9, 15]**

Smart textiles can be defined as the materials and structures which can sense the environmental conditions or stimuli. While intelligent textiles can be defined as textile structures which not only can sense but can also react and respond to environmental conditions or stimuli; These stimuli and response, could be mechanical, thermal, electric chemical, magnetic or from other source. Smart fabrics fulfil emotional and sensory needs, from health monitoring and personal security to new methods of communication and expression.**[1, 9, 16]**Smart garments particularly suited for any physiological and physical monitoring task. **[17, 18]**

Samuel think that, there is a substantive difference between the terms, ‘Smart’ and ‘Intelligent’, **[19]**but the researcher believes thatintelligent textiles are the third type of smart textiles which feel and modify their behavior based on external stimuli.

Sustainable textiles are textiles which produced in environmentally friendly way .They are made from renewable sources, and use very limited amounts of chemicals in the manufacturing process, from growing the fibre, to finishing process. They will be available for many years to come because they are produced from renewable sources, as organic cotton, which is free from chemical, and so it doesn’t harm the environment or the workers. **[15,20]**

Wearable or Electronic textiles (e-textiles) are incorporate with conductive fibers. They are not only wearable but also have local monitoring, as well as wireless communication capabilities.**[21, 22]** also, they collect information, monitor

vital statistics and report them over a wireless channel for processing, and sensors can be incorporated directly into washable and wearable clothing's.**[9, 23, 24]**This textile consist of, Input device,Data processing unit, andoutput (i.e. they contain some sort of computing technology), so provide specific functionalities that go beyond the classical functions of clothing**[25, 26, 5]**Every electronic-textile needs a power supply, electronic components and connection method to the textiles **[27, 26, 18]**,such the garments that monitor heart rate,temperature sensing jackets, able to measure the chemical composition of the body fluids, and textiles that measure pulse and immune systems. Although**[28]**Mondalthink that, they are still Smart fabrics, but just require a power source.**[16]**

I.3 How does a smart textile work?

Smart textiles can be made by blend smart materials, as conductive polymers, encapsulated phase change materials, shape memory polymers and materials, other electronic sensors and communication equipment with textile,these materials interact – according to their designed feature with the stimuli in their environment.**[9]**

I.4 Components of smart textile:

A smart material is one that shows extraordinary response when subjected to a stimulus,**[29]** It is usually a part of a 'Smart System' that has the capability to sense of environment**.[30, 21]**Newhigh-performancefiber such, (Aramids, glass fiber, pre-oxidised acrylic, Kevlar, andNanofiber),also miniaturized electronic components create usable smart clothes. TheseSmart Textiles systems consist of 6 groups: Sensors, Actuators, External communication, internal data transfer, Data processing, and Energy source. These components must all be integrated into textiles while still retaining flexible and comfortable properties for textile.**[31, 32, 33]**

The following is summary of smart materials used in smart textiles, andbrief of their applications.**[1,9]**

I.4.1 Phase changing Materials:

Recently, Fibre and textile which have automatic acclimatising properties attracting more attention,this eff ect could be achieved by using phase change material (PCM). **[1, 14]**Phase Change', is process of going from physical state to another i.e. from a solid to a liquid and vice versa, Phase change materials refer to those which have materials such as paraffin, which can change from solid to liquid state, resulting the ability of maintain a constant body heat. **[15]**

Some garments that have microcapsule of PCM (phase change material) prevent thefeeling of discomfort, because in the case of heat generation PCM absorbs the energy andmelting, while in the case of cold state,it release heat andchange to solid state. This exciting property of PCMs would be useful for the application of producing protective garments in all- kinds of weathers,it allows ofthermoregulationfor garment. PCM can be added to thepolymer solution in wet or melt spinning, or applied to the required surface of textile as acoating.

Phase change materials are highly applied in the field of textiles for different kinds of products such as apparel, underwear,bedding, socks, shoes,astronaut's suits, sportswear,and gloves, etc. **[1, 9]**

I.4.2 Shape Memory Materials

Shape memory materialsable to return to a pre-programmed shape with the right stimuli, normally as temperature, where they sense a change in temperature by making a change of crystal structure at a certain transformation temperature.**[32, 34]** There are two types of Shape memory materials(SMM):**[5]** Shape memory materials stable at two or more temperature, and shape memory materials which can change shape response to electrical stimuli. **[1, 4, 35]**

The first kind cansense a change in temperature by making a change of crystal structure at a certain transformation temperature.The crystal structure of the materials brings easier and permanent deformationat lower temperatures,but on heating, the material again returns to its initial high-temperaturestructure;mean they "remembered" their shape. They can also sense physical changes such as thermal, mechanical, or magnetic.**[36, 37]**

The second kindis the electroactive polymers which can change its shape in response to electrical stimuli.They use in abiomedical application such as artificial (tendon, cornea and bone joints), orthodontics, also in a shirt which shortens its sleeves when the temperature rises.**[1, 20]**

I.4.3 Chromic Materials

It is intelligent material which changesitscolor according to external environmental conditions; so it is also called chameleon fibers. Chromic materials are radiate, erase or just change the coloraccording to the external stimulus.Theycan classify chromic materials depending on the stimulus affecting them (electro chromic, thermochromic, Photochromic).**[23, 38]**Their applications in textile are intended for the fashion areato create fantasy designs changing its color**,** and only a few for the solar protection, alsouse in soldier's uniforms, because they made from fibres that are able to change their colour according to the external conditions as we said before, which make them perfect in camouflage effects .**[1, 9, 15]**

I.4.4 Luminescent Materials

Luminescent Materials emit light due to a stimulus. There are several types of luminescent effects:

- Electroluminescence: the external stimulus of it is electricity.
- Chemioluminescence: the external stimulus of it is a chemical reaction.
- Optic luminescence:the external stimulus of it is conduction of light.
- -Triboluminescence: the external stimulus of it is friction.
- Photoluminescence: external stimulus of it is light. There are two types of photo luminescent materials, the fluorescent and the phosphorescent,the only difference between themare the time of emission.

The difference between chromic and luminescent materials is that the first one changes colour while the second one emits light due to a stimulus. [**36, 39]**

I.4.5 Conductive materials

Conductive materials can be divided into two categories:

1) Naturally conductive fibres (Metallic fibres, Carbon fibers, Conjugated polymer fibers).
2) Treated conductive fibres (fibers that can be produced by the combination of two or more materials, such as non-conductive and conductive materials. **[40, 37]**

There are two ways to produce conductive fabrics electrical or thermal, either use metals or polymers materials. These materials have the same main properties (lightweight, durable, flexible, cost competitive, able to be crimped). **[1, 9]**

The same materials could be used for both conductivity (thermal and electric), because the two processes are similar and results from an electronic agitation/conduction. **[25, 41]**

They use high wicking finishes (ink) with a high metallic content that still retains the comfort required for clothing. With the addition of nickel, copper, silver or carbon coatings , these finishes provide many combination of physical and electrical properties for a variety of applications **[41, 28]**, or they direct use of conductive yarns, which could constitute metal such as silver, copper, etc… or conductive polymer such as polyaniline, and their derivatives **[25, 35].**

The main applications of conductive textile materials are their uses for the power supply of electronic devices in the garments, and also they could offer capability of reading the location, within a fabric **[1, 9]**

The disadvantage of this textile item is that the electrical component itself must be removed before washing, and cannot put in washing machine. **[15]**

I.4.6 Membranes

The membranes are constituted of polymers; they consist of one or more layers (until 6 layers) according to the wanted properties. They are deposited on textiles in order to add new properties onto theirs surfaces, as breathable, impermeable clothes, and to give Lotus effect. The main application of membranes is in sportswear field.**[1]**

I.4.7 Photovoltaic materials

Photovoltaic materials have the property to generate electric current by a light excitation. Organic solar cells are also very promising for textile applications but they have low efficiency, (average 5%). The main application of solar cells in textile is the electric feeding of electronic devices in them. They are using solar for charging batteries which supply energy to the proper device or recharging as in a mobile phone or Mp3 player**. [39]**

I.5 Incorporating of Smart material into Textiles:

Textile to behave smartly it must have a sensor, an actuator (for active smart textiles) and a controlling unit (for very smart textiles). These components may be phase change materials, fiber optics, shape memory materials, miniaturized electronic items, thermo chromic dyes, etc. These components form a part of the textile structure which can be incorporated into any level: fiber spinning; yarn**[42]**;fabric formation (non-woven, knitting, weaving).**[40, 43]**; or finishing. **[35]**. Also These smart materials can incorporated into the textile structure by different technologies, as embroidering **[44]**, sewing, braiding **[25]**, coating **[15]**, printing **[45]** and chemical treatments **[46, 47]**

I.6 Application of smart textile:

I.6.1 Military Field

One of the main reasons for the rapid development of smart textiles is military industry,**[24, 48]** because they are used in different projects such as extreme winter condition jackets, or uniforms that change their color to improve camouflage effects.**[12,34, 49]**

Also, there is a need for real-time information technology to increase the protection and survivability of the people who working In extreme environmental conditions, and hazardous situations, in those conditions, Improvements in performance and additional capabilities would be very important in some professions, as the defense forces and emergency response services, to monitor vital signs and ease injuries while also monitoring environment hazards such as toxic gasses, also Wireless communication with a central unit allows medics to conduct a remote triage to casualties to help them respond more rapidly and safely. **[32]**

For example, smart shirt which used in military uses, it uses optical fibersto detect bullet wounds, and special sensors that interconnect in order to monitor vital signs during combat conditions; it identifies the exact location of the physical problem or injury and transmits the information in seconds, this helps to determine who needs immediate attention.

I.6.2 medical Field

Smart fabric empowers with the Wearable devices to be continuously monitored for physiological signals during normal daily activities to the individual, Thus management and assessment of its own healthcare needs, and also can overcome the problem of clinical visits, which can a highlight into the physiological status of the patient**. [51, 52, 53]**

Smart clothing serves an important role in the remote monitoring of chronically ill patients and the elderly or those undergoing rehabilitation, special in big population groups,**[44, 43, 40]** where they can monitor the wearer's heart rate, respiration, temperature, blood pressure and a host of other vital functions, and alerting the wearer or physician if there is a problem. [20, 26]. It also promotes the concept of preventative health care. **[32]**

For example, to measure the heart rate and even an ECG, they were developed knitted structure made of stainless steel fibres because it is a very good conductor, the fibres have a good touch, it has a low toxicity to living tissue, there is no danger or little for contact allergies, and it can easily be washed without losing its properties.**[54, 55, 56]**They are used in direct contact with the skin.There are many sensors and processors used in medical textile systems, important sensors used are respiration rate, humidity, temperature,pH level estimation (to assessment of wound healing processes and in sweat monitoring) and pressure sensors. For instance, the temperature sensors are generally used to measure the body temperature. Telemedicine is one of the most important applications in smart textiles. **[57,58, 59]**

Smart textiles also, have the potential to emulate and augment the skin's sensory system by sensing external stimuli such as touch, pressure, temperature and chemical substances,for e.g. bedridden patients, pressure sensitive fabrics may aid in assessment and warning to reduce the occurrence of ulcers.**[18, 10]** Also, Every year, a lot of people all over the world undergo foot or leg amputations, due to poor blood circulation. Researchers estimate that diabetes-related amputations might be avoided by wearing smart socks with built-in pressure sensors which alert the wearer to put his feet. **[58, 60]**

I.6.3Protectivefield

Designing protective clothes requires knowledgein different field of engineering, technologies, nanotechnology, and smart textile with special properties etc. Designer who is working in a field of protective clothing is not working in a

field of artistic based on a subjective sense of harmony and beauty only, but they must respect strictly functional requirements. So, designing protective clothing means balancing between design requirements and function, protection performance, and comfort, andthe role of design is to make the technology easy to use. **[26, 61]**The types of sensors used can be varied depending on the wearer's needs, for example, a fire-fighter could have a sensor that monitors oxygen or hazardous gas levels, Other sensors monitor respiration rate and body temperature, etc.

Examples of protective clothing is Conducted Energy Clothing (CEC) which use to help security personnel and law enforcement officers; The CEC clothing is a jacket that sends electric shocks to avoid any type of physical assault, While a rubber lining in the jacket protects the wearer.**[39, 62]**

I.6.4 Sports Field

The sports sector seeking to improve athletic performance, comfort, and protection to players, many research has been developed in clothes of sports,such a breathable waterproof fabrics and moisture management textiles.

phase-change technology are used to where excess body heat is absorbed, stored and released when needed, so clothes are increasingly able to adapt dynamically to the needs of the wearer.The latest developments are integrating sensor to know of the physiological condition of the player, thus providing information about the player's physical and athletic abilities,and develop appropriate training for him accordingly.Demand for wearable sensors that can be used for kinematic analysis, vital sign monitoring and biochemical analysis is expanding rapidly, and there is a new and exciting research about involves integrating chemical sensors into textiles and its impact on sports performance. The aim of this project is to perform analysis of various constituents of sweat. **[32,63]**

I.6.5 Fashion Field

Designers, scientists and engineers collaborate In order to successfully introduce smart textiles in fashion. **[12, 52, 63]**

They are employing their creativity to use these emerging materials in new ways; they are becoming increasingly reliant on technology carrying MP3 players, laptops, mobile phones and digital cameras. These devices all contain components such as power supply, microprocessor, data transmission, they could ultimately be integrated into a common textile clothes. **[32, 64, 42]**

Technology can also be used to dramatically change the appearance of the textile, giving new effects, as Light emitting textiles, use of new ways to create smart textile structures that can release personalised scents for mood enhancements and pain release**. [32, 18]**

I.6.7 Safety and security:

Researchers put protective equipment in Smart textile to detect threats from external influences as toxic gasses. or internal (human) threats as exhaustion, or dehydration to improve the safety of the Road Transport; where they invented a comfortable, wearable technology that can detect tiredness, avoid sleep and save lives; through introducing two

different technologies in a base of hat, to measure state of mind to the drivers through either, an EEG dry sensor device, or measuring the movements. The first one, is the EEG is one of the most reliable physiological indicators to measure tiredness through a sensor on the forehead, the hardware is transmitting the brain signals to the computer to analysed it. The second is a moving sensor as Smartphone, which reacts with the movements of someone; so if the head is falling down- it is giving an alert. **[65]**

Smart clothes also have technology embedded within them, such as Global Positioning Satellite (GPS), mobile phones and digital cameras; this technology is used to determine the location of the child, thus enabling their parents to confirm that the child is safe.

I.7 Disadvantages of smart clothes:

This technologies give uncomforted sensing of the wearer, and a major challenge in wearable computing is how to interconnect this components with soft textile, and find alternatives to silicon, metal, and components which are difficult to integrate them in textile, also smart textiles must be flexible enough to be worn for long periods of time, without causing any discomfort to the wearer;we can developed this by integrate materials at the Nano scale level, as this preserves the flexible characteristics and tactile properties of clothes. **[32, 66]**

However, the disadvantage of this kind of textile is that the electrical component must be removed before washing, andit cannot be washed with an electric machine, and is so expensive. **[15]**

I.8 Future of smart clothes, and its challenges:

At present, smart textiles are one of the focus topics in the multi-disciplinary research and target a great variety of applications,smart textile is a clear priority for the future of textiles and clothing in the developed countries. **[67]**

Smart garments must not only be usable but also beautiful and attractive, aesthetics should play an important role in the design; the aesthetical function for clothes might represent a particular challenge, where research studies shown through the last 15 years that, more attractive products are also be more usable **[1, 45, 68**]. They also indicated to that design aesthetics influence on other outcome of usability tests such as user behaviour and user emotions **[45, 15]**, where in a usability test it is highly probable that the outcome are severely biased by the aesthetical refinement of the product. **[45]**

It is expected through continuous cooperation betweenuniversity research centres and manufacturers of Smart Fabric devices will yield devices ready for flight in 5-10 years**. [2]**

Although important progress has been made with regard to the development of intelligent clothes, the number of successful smart garments on the market is still rather limited (in the context of fashion and personal clothing). This might be due to the fact that the integration of electronics and computing technology into clothing represents a difficult and challenging task for designers and system developers, in addition to technological barriers, power consumption, and the high price of smart textiles as compared to conventional textiles, all of these limiting the widespread of smart textile. **[14]** .However, there are some new established companies focused on the development and commercialization of smart

textile clothing, there is the interdisciplinary collaboration between companies in fashion and electronics, and there are some companies established that sell how to integrate electronics into textiles and clothing**. [12, 25, 45]**

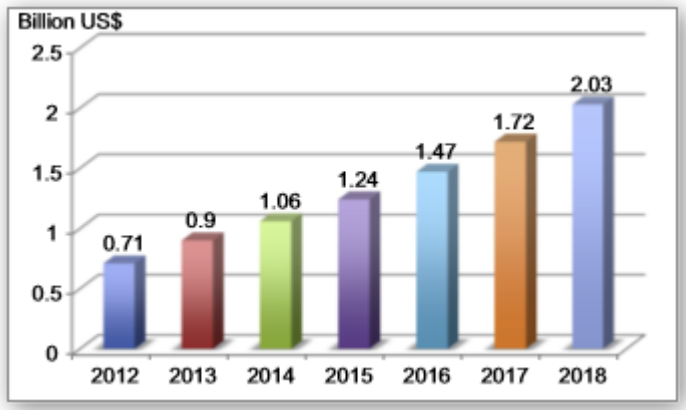

Figure (1)the global market for smart, fabrics and textiles from 2012 to 2018 in billion US dollars

At the same time, the smart textile market have experienced tremendous growth over the past few years in other sectors, such as the medical, healthcare, automotive, and sports industries, wherethese textiles offer significant potential for medical and healthcare applications and make diagnosis far more accurate and quick. The growth of the telemedicine market is also expected to have a positive impact the growth of the global market as smart textiles are equipped with sensors that record parameters and transmit them to a central unit. The market of smart textile was valued at US$1.24bn in 2015 and is estimated to reach US$3.81 bn by 2020. **[25, 45]**

Conclusion:

textiles are basically used for providing protection, comfort and beauty in apparels , But now, textiles have changed its strategy to create new, products and functionalities, Where Smart textiles, can sense and react to environmental conditions or stimuli (such, mechanical, thermal, chemical, electrical or magnetic sources). Smart textiles' 'are the integration of smart materials, as micro-electronics, sensors, Nanotechnology, and IT technologies, with textile, where the marvelous advancement of smart materials and electronics brought intrinsic potentiality in the field of textile and for innovative high-tech applications. These textiles use in many applications such as military, security, personalized healthcare, hygiene and entertainment. These clothes can give us the information we need in any particular situation and also help us to make human life healthier, more comfortable, and safer. They also need cooperation between people from various backgrounds and disciplines, such as, computer science, microelectronics, polymer chemistry, material science, biotechnology. The introduction of smart materials and computing technology in textile structures offers an opportunity to develop textiles with a new type of behavior and functionality, such able to perform computational operations.The market of smart textile was valued at US$1.24bn in 2015 and is estimated to reach US$3.81 bn by 2020.

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