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CHARACTERIZATION AND APPLICATIONS OF SMART TEXTILE TECHNOLOGY

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ABSTRACT
*Technological innovation has brought tremendous changes in the life of human with the advent of innovative scientific researches. Among these, textiles are good examples. The industrial revolution had shown a step forward on evolution which heralded the manufacturing of textiles on machineries but the advancements continued on the developments of synthetic and regenerated fibers, invention of synthetic dye stuff and new finishing process like plasma and sol gel treatments. '**Smart E-Textiles**' and '**Interactive Textiles**' emergence since past two decades had made the availability of smart technological innovative products and are ubiquitous. The geo textiles in the soil to the outer space in the expedition of the universe; from the hospitals beddings and clothing's to the entertainments; and from the personal healthcare to sportswear applications. Smart E-textiles are fabrics that have been designed and manufactured to inculcate technologies that provide the wearer with increased functionality and performance with provision of interactive interface. These textiles have multitudinous potential applications with the ability to communicate with other devices, conduct energy, transform into other materials and protect the wearer from hazards.*
KEY WORDS: *Evolution, Characterization, Application, Smart Textile Technology*

1. INTRODUCTION
"Smart E- Textiles" is a broad field of studies with products that are more than the functionality and usefulness of common fabrics but are defined as textile products such as fibers and filaments, yarns together with woven, knitted or non-woven structures that can interact with the environment and the user. The convergence of textiles and electronics (e-textiles) necessitate the development of smart materials capable of achieving a wide spectrum of functions, found in rigid and non-flexible electronic products. There are significant change in the mechanical properties (shape, color and stiffness), or their thermal, optical, or electromagnetic properties, in a handy manner in response to the stimuli.

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They are systems with different apparatuses and materials such as sensors, actuators, electronic devices together. The integration and combination of advanced tools with advanced smart materials beckon on a bright tomorrow for dynamic textile market.. Many brands have shown a lot of interest in and used e-textiles as wearable technology and Smart and e-textiles have emerged as one of the most promising materials to address one of the biggest challenges facing the world, namely, an ever increasing energy crisis. E-textiles, due to their electrical conductivity together with their flexibility, have attracted many people to engineer various types of textiles, including, lyocell, polyester, nylon and fabrics, for application in batteries, fuel cells, super capacitors and solar cells, and sensing and display inventions.Textiles represent an attractive class of substrates for realizing wearable bio-sensors. Electronic textiles, or smart textiles, describe the convergence of electronics and textiles into fabrics which are able to sense, compute, communicate and actuate. As many different electronic systems can be connected to any clothing, a wearable system becomes more versatile, and the user can change its look depending on environmental changes and individual preference. The vision of wearable computing describes future electronic systems as an integral part of our everyday clothing serving as intelligent personal assistants. Therefore, such wearable sensors must maintain their sensing capabilities under the demands of normal wear, which can impose severe mechanical deformation of the underlying garment/substrate; one promising approach to reduce the rigidity of electronic textiles and enhance its wear ability is to replace PCBs by flexible electronics. Current advances in textile technologies, new materials, nanotechnology and miniaturized electronics are making wearable systems more feasible but the final key factor for user acceptance of wearable devices is the fit comfort and it is convinced that this goal can only be achieved by addressing mechanical resistance, and durability of the materials in what is recognized to be a harsh environment for electronics: the human body and society

E-textiles are made of conductive threads and fabrics which are major materials which have been around for over 1000 years. Artisans have been wrapping fine metal foils, most often gold and silver, around fabric threads for centuries. Many of Queen Elizabeth I's gowns, were embroidered with gold-wrapped threads. The end of the 19th century welcomes the development and advent of electric appliances where people get grew accustomed to these appliances, designers, scientists and engineers began to combine electricity with clothing and jewelry—developing a series of illuminated necklaces, hats, broaches and costumes. In the collection was the work of Diana Dew,there is a line of electronic fashion, including electroluminescent party dresses and belts that could sound alarm sirens. In 1985, Harry Wainwright developed the first fully animated sweatshirt which comprises the fiber optics, LEDs, and a microprocessor to control individual frames of animation resulting in a full color cartoon on the surface of apparel.

The advancement of smart materials and electronics brought intrinsic potentiality in the field of textile technology for innovative high-tech applications, covering market segments that are far away from conventional textile world in the last few years. One of the best examples is the recent development of new sensing and intelligent cloths.

Smart and interactive textiles bring together interdisciplinary field that brings together specialists in information technology, micro systems, materials, and textiles. This to develop a new area on enabling technologies and fabrication techniques for the economical production of flexible, conformable and, optionally, large-area textile- based information systems that are expected to have unique applications for different end uses. This will be highly applied in the next generation of fibers, fabrics and articles produced from them.Many intelligent textiles are in the global market with all kinds of available opportunities that are created from their applications which include casual clothing, medical textiles, in the military, in protective and safety garments, as well as in the expedition of the space.

Textiles are world most versatile materials because of the design to which they are engineered, their conventional and emerging applications, their ease of fabrication,their flexibility, lightweight, and low cost. Electronic textiles have found their way into everyday life in the form of technological equipment within regular clothing to improve the quality of life have gone far beyond their application to civil engineering, agriculture, aircraft, sportswear, and bulletproof vests ,the rapid development of smart garments is due to their application to military purposes; however, added fashion and convenience remain only secondary to their precise end use. It is also important to note that the advent of smart textiles with various characteristics in a single material or those that produce a composite and hybrid structure using a range of new classes of materials has brought various disciplines of the engineering sciences together.. This work critically looks into Smart E- textiles as it finds

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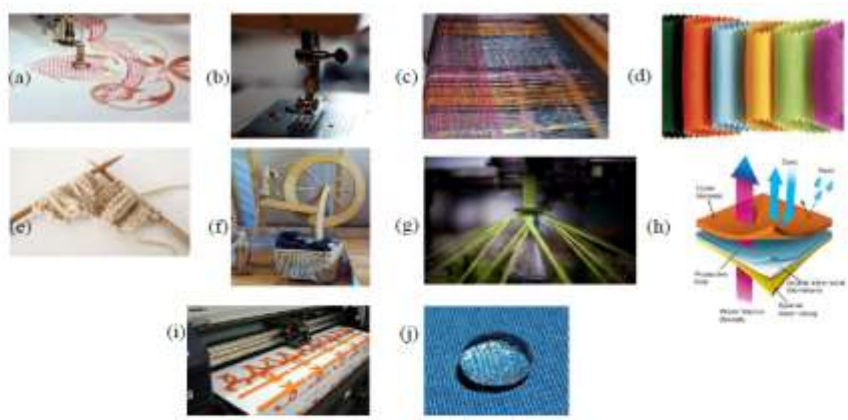
applications and has outstanding outlooks almost in every sphere of human activities due to the possession of properties of conventional textile materials and additive functional values.

2.TEXTILES/FABRIC MANUFACTURING TREATMENT

There are many types of textile or fabric some of them are group into categories as shown in figure 1.



(a) Embroidery; (**b**) sewing; (**c**) weaving; (**d**) non-woven; (**e**) knitting; (**f**) spinning; (**g**) breading; (**h**) coating/laminating; (**i**) printing and (**j**) chemical treatment.

Fig 1: Categories of textile

Source: *MatteoStoppa and Alessandro Chiolerio(2014)*

The combinations of these materials sources result into a whole range of textiles which comprise conventional cables, miniaturized electronic components, chips and special connectors. Individuals to put on comfortable textiles rather than hard, rigid boxes, first efforts have been made to use the textiles themselves for electronic functions. These smart materials are incorporated into the textile structure using different technologies perspective such as embroidering, sewing, non-woven textile, knitting weaving, spinning making, braiding, coating/laminating, printing and chemical treatments that provide specific features such as controlled hydrophobic behavior. Smart Textiles are used n the medical, sport, and artistic communities, the military and aerospace.

3. CLASSIFICATION OF SMART TEXTILES BASED ON FUNCTIONS

The various parameters that can be sensed by smart textiles are thermal, mechanical, chemical, electrical, magnetic, and optical. Hence, smart textiles can be divided into [3] four types based on their functions.

I. Sensor Based Smart Textiles (Passive)

Sensors provide a nervous system to detect signals; hence, in a passive smart material, the existence of sensors is essential. They are the first generations of smart textiles that provide additional feature in a passive mode i.e. irrespective of the change in the environment. For example, a highly insulating coat would remain insulating to the same degree irrespective of the outside temperature. Wide range of capabilities, including anti-microbial, anti-odour, anti-static, bullet proof are the other examples. They only able to sense the environment/user through sensor therefore called Sensor based smart textiles. The fabric sensors can be used for electrocardiogram (ECG), electromyography (EMG), and electroencephalography (EEG) sensing. Fabrics incorporating thermocouples can be used for sensing temperature; luminescent elements integrated in fabrics could be used for bio-photonic sensing, shape-sensitive fabrics can sense movement, and can be combined with EMG sensing to derive muscle fitness. Carbon electrodes integrated into fabrics can be used to detect specific environmental or biomedical features such as oxygen, salinity, moisture, or contaminants. Sensor based smart textiles; show up what happened on them, Such as changing color, shape, thermal and electrical resistivity. These kinds of textile materials are more or less comparable with high functional and performance textiles

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II. Actuator – Sensor Based smart Textiles (Active)

These smart textiles that has both actuators and sensors and they adapt their functionality to changing environment automatically; hence called the name **Active Smart Textiles**. The actuators act upon the detected signal either autonomously or from a central control unit together with the sensors, they are the essential element for active smart materials.Active smart textiles are shape memory, chameleonic, water-resistant and vapor permeable (hydrophilic/ nonporous), heat storage, thermo regulated, vapor absorbing, and heat evolving fabric and electrically heated suits. Active functionality could include power generation or storage, human interface elements, radio frequency (RF) functionality, or assistive technology. Power generation can be achieved through piezoelectric elements that harvest energy from motion or photovoltaic elements. Human interfaces to active systems can be roughly grouped into two categories: input devices and annunciation or display devices. Input devices can include capacitive patches that function as pushbuttons, or shape-sensitive fabrics that can record motion or flexing, pressure, and stretching or compression. Annunciation and display devices may include fabric speakers, electroluminescent yarns, or yarns that are processed to contain arrays of Organic Light Emitting Diodes (OLEDs).

III. Ultra smart textiles (Very Smart Textiles).

The ultra-smart textiles are also called Very smart textiles which can sense, react and adopt themselves to environmental conditions or stimuli (That is, Very smart materials are materials and systems which can execute triple functions; first, they are sensors which can receive stimuli from the environment; secondly they are able to give reaction based on the stimuli; thirdly they can adapt and reshape themselves accordingly to the environmental condition).A very smart or intelligent textile essentially consists of a unit, which works like the brain, with cognition, reasoning and activating capacities. The production of very smart textiles is now a reality after a successful marriage of traditional textiles and clothing technology with other branches of science like material science, structural mechanics, sensor and actuator technology, advance processing technology, communication, artificial intelligence, biology etc. New fiber and textile materials, and miniaturized electronic components make the preparation of smart textiles possible, in order to create truly usable smart clothes. These intelligent clothes are worn like ordinary clothing, providing help in various situations according to the designed applications. Materials with even higher level of intelligence develop artificial intelligence to the computers. These kinds of materials and systems are not fully achieved in the current investigation of human beings

4. MATERIALS, CONNECTIONS AND FABRICATION METHODS

The smart E-textiles can be made with series of materials using different fabrication methods.The selected materials and fabrication methods are always interconnected with the final application; hence this makes smart E-textile a multidisciplinary research field, with the need of expertise in several fields, such as textile, materials, electronics, mechanics, and computer engineering.

A. Adapted Fabrics: Smart E-Textiles Fabrication Methods

For the past few years it has been shown that traditional fabrication methods that are used to produce conventional textiles could be used in smart E-textiles production too. The developments of flexible conductive yarns with diameters that are similar to the conventional textile yarns enable the use of traditional fabrication methods to merge conductive threads with non-conductive threads. The conductive yarns incorporation processes into conventional textiles threads can be manually done by sewing conductive yarns or automatically through embroidery, weaving, knitting and breading machines. Coating non-conductive yarns with metals, galvanic substances or metallic salts can also be used to make electrical conductive yarns from pure textile threads, which also enables a Smart e-textile production. Common textile coating processes include electro plating, chemical vapor deposition, sputtering, and with a conductive polymer coating. Stamping conductive inks is also an alternative to embed conductive lines into textiles. There are several technologies that can print conductive material on textile substrates, but all of them use conductive inks with high conductive metals, such as silver (Ag), copper (Cu), and gold (Au). Below is a list of manufacturing techniques with a quality comparison of fabrication attributes.

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Table 1: Qualitative comparison of fabrication attributes.

SMART E-Textile Manufacturing Techniques	Costs of Machinery	Costs of Material	Process Complexity	Resistance to Wear
Sewing	Low	Low	Low	High
weaving	Low	High	High	High
knitting	Low	High	High	Low
Non-woven	Low	Low	Low	Low
spinning	Low	Low	Low	Low
breading	Low	Low	Low	High
coating	High	Low	Low	Low
embroidery	High	Low	High	Low
printing	High	High	Low	High

Source: Carlos Gonçalvesetal (2018).

Connecting to data acquisition systems are achievable through mechanical or electrical mechanisms. This way, textile structure platforms as woven, knitted, or nets can be used to produce smart e-textiles, avoiding attaching electronics to textile substrates.

B. Electrical Components

Smart e-textiles would not be possible without electrical components, such as electrodes, connectors, and interconnectors and when used for the acquisition of electrical biological signals such as electrocardiogram (ECG), the electrodes are the bridge between the body and the circuit. The process where there is no need of electrical signals acquisition, there is still the need of connectors and interconnectors in order to bridge the textile with the electronics.

Copper wire can be used in applications without skin contact, and silver thread can be used in applications that require direct contact with skin. The energy needed to power smart e-textile circuits is normally provided from Lithium Polymer (LiPo) batteries. The LiPo batteries are selected accordingly to a tradeoff between power autonomy and battery size. Therefore, the goal is to select the smallest LiPo battery that is able to supply the smart textile circuit power demands during a predefined amount of time. With energy harvesting solutions, it is possible to charge small LiPo batteries, keeping the e-textile energy demands during use. Someof examples of the components or connection techniques that are used in smart e-textile circuits and transducers are shown below:

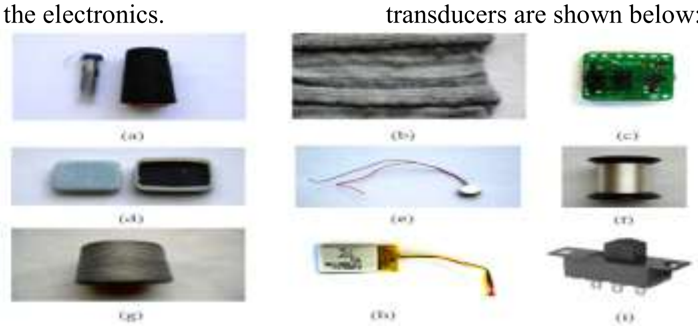

Fig2: Electronic materials and Textile used in Smart e-textiles.

Source: Carlos Gonçalvesetal (2018).

(**a**) Solder and polyester thread used into e-textiles
(**b**) E-textile capacitor
(**c**) Printed Circuit Board (PCB) for e-textiles
(**d**) Casing shell for e-textiles;
(**e**) Vibration motor
(**f**) Electrisola textile conductive wire
(**g**) Bekintex conductive thread
(**h**) Lithium-ion battery used to power e-textiles and (**i**) Slide switch used to switch On/Off e-textiles.

The two main categories of bond used for connectors and interconnects are mechanical and physical.

(i) Mechanical connections are made with snaps that are directly pressed into conduction lines, and are normally made when there is a need to detach any electrical module from the e-textile.
(ii) Physical connections include micro-welding, thermoplastic adhesion, mixed conductive polymer adhesion, joint soldering, and

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electroplating. Physical connections are made when there is a need for a permanent connection.

Smart e-textile connectors remain an open research field due to the diversity of application environments where each solution is customized and is almost unique.

C. Textile Circuitry

Textile circuitries are electrical circuits built on textile substrates. Embroidery conductive thread into textile substrates is a widely used approach and this approach is used to stitch patterns that define circuit traces, component connection pads or sensing surfaces using Computer Assisted Design (CAD) tools or FEA. The conductive patterns can also be done using inkjet-printed techniques of graphene-based conductive inks. A textile circuit is designed to have a low power consumption rate and high input impedance, which is opposite to the conventional requirement of low impedance for component interconnections. Many yarns available in the market can be used for connections and circuit elements which include silvered yarns, stainless steel thread, titanium, gold, and tin. Another technique to fabricate textile circuits is to iron a welded circuit to the textile substrate. The circuit is attached to the textile, and can be soldered like a traditional printed circuit board. Flexible conduction lines could also be made of any conductive ink and conductive polymer. Thick and thin printing processes are two production techniques that are used to print conductive inks. An example of a thick film process is silk screening, where an adhesive conductive ink is applied to the open areas of a textile mesh allowing for the ink to penetrate into the fabric. A sputtering process can also be used to produce high-resolution circuits on textile substrates. The textile substrate, kept at 150˚ C, needs to be placed in a vacuum chamber with an inert gas like argon and a shadow mask to make the circuit patterns. There are also other approaches on the use of Nano -soldering methods to produce smart e-textiles with carbon nanotubes (CNT) conductive lines. The CNTs are soldered onto the fiber surface of non-woven fabric by ultra-sonication, which brings a strong adhesion between the carbon nanotubes and the textile fibers. The CNTs do not detach when the e-textile is under vigorous mechanical stirring, or even after being washed

1. Textile Circuit Elements

Textile circuit elements are built in order to adapt to the textile substrates. Small electric components can be sewn into the conductive lines on fabrics directly or by using sockets attached to the fabric with connection resistivity that is lower than 1 Watts. Gripper snaps and textile switches can also be used so as to ensure connectivity, allowing strong connections. Electronic elements can be made out of conductive thread by sewing thread fibers in patterns, with concerted crossings, to achieve desired electrical properties. Conductive properties can be given to threads by several techniques before and after the thread manufacturing process.

Another very common technique entails the application of metal or conductive polymer coatings to the textile substrate. Laminating techniques are also used, including those that are adapted from conventional and flexible electronics. With those techniques, passive elements can be formed with conductive inks and polymers. Resistors (i.e., 2–8 W/mm), capacitors (i.e., 1 pF to 1 nF), and inductors
(i.e., 500 nH to 1μH at 10 MHz) can be made by planar printing techniques, such as screen printing or sputtering metal inks onto fabric substrates, such as cotton, polyester, silk, wool, polyacrylonite, and fiberglass fabrics. It has also been shown that resistive elements can be made by adjusting the dimension of an already coated conductive polymer fabric. In the case of transistors, the core of ametalized yarn can be used as gate, while source and drain contacts can be made by depositing metals or polymers using evaporation or soft lithography processes. Transistors can also be fabricated on strips of Kapton and be later interlaced into a textile substrate. Below is a sample of a textile electrode suitable for acquiring signals, such as biological signals in an ECG.

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Fig 3: Biological signals textile electrode for electrocardiography
Source: Carlos Gonçalvesetal (2018)

2. Fabric Smart E-textile Sensors. Resistive Pressure Sensors

These are sensors that are made up of different conductive materials in different structures using different production techniques and the variable resistive materials can be sewn, embroidered or glued to the textile substrate to measure pressure. The working principle of a resistive pressure sensor is based on an electric resistance that increases when the resistive material is stretched or compressed. According to Ohm's Law,

$$V = IR \quad \text{[i]}$$

for the same electric current, a higher resistance makes the output voltage increase.
This way, the stretch or compression can be correlated to the sensed voltage. The conductive material and production technique influence the sensitivity and sensed pressure range.

Table 2: E-Textile pressure sensors based on resistive mechanism

Production Techniques	Elements	Sensitivity	Pressure range	Size	Characteristics
Tooth structured	Conductive fabric	2.98×10^{-3} kPa^{-1}	–2000 kPa	760 mm^3	Strain in under pressure fabric
Switch tactile sensor	Plated fabric Cu, Ni	Threshold at 500 g/mm^2	70–500 g/mm^2	8 mm^2	Active sensing cells
Polyurethane foam	PPyPolyurethane	0:0007 mS/N	1–7 kN/m^2	4 cm^3	Conductance increases with compression
Conductive Rubber based	Carbon polymer	250 W/MPa	0–0.2 MPa	9 mm^2	Resistance changes with applied load
QTC-Ni based	Pressure composite	~106 W/1% compression	25% compression	Diameter = 5.5 mm	Switching behavior

Source: Carlos Gonçalves, Alexandre Ferreira da Silva,João Gomes and Ricardo Simoes(2018)

3. Capacitive Pressure Sensors

The textile capacitors are made from compliant conductive materials that are acting as conductive plates separated by dielectrics. The conductive plates can either be woven, sewn and embroidered with conductive thread/fabrics, or can be painted, printed, sputtered, or screened with conductive inks or conductive polymers.
Usually, capacitive pressure sensors are made on textiles that can be sewn, snapped, or glued to a fabric substrate and welded to other electronics or wires; the dielectrics used are typically synthetic foams, fabric

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spacers, and/or soft non-conductive polymers. Capacitive fibers can also be manufactured using techniques that are similar to those found in flexible electronics, such as a silicon fiber sputtered with metals.The capacitance of a capacitive pressure sensor depends on the following factors: (i) the area of two conductive parallel plans (ii) the conductive material and (iii) the distance between each other. Keeping the same area for the conductive plates, the capacitance will change with the distance between them. When the distance between the conductive plates decreases, the capacitance increases, and when the distance between the conductive plates increases, the capacitance decreases.

4. Optical Textile Sensors

These types of sensors were first developed in the late 70s when the photosensitivity in optical fibers was found and since then, it is incorporated into fabrics. The working principle of optical textile sensors is based on the variation of the light intensity or the amplitude that can be sensed by a fiber Bragg grating (FBG) sensor. The small glass optical fibers diameters (in the microns range) make these materials suitable for seamless textile integration with industrial processes. The optical fiber light source can be a small light emission diode (LED), and the light amplitude at the end of the optical fiber can be sensed with a small photo detector; depending on the textile movements, the light amplitude will change allowing to sense textile displacements and pressures. The optical textile sensors can be used to sense textile displacements and pressures in applications where the electrical currents cannot cross textile substrates.

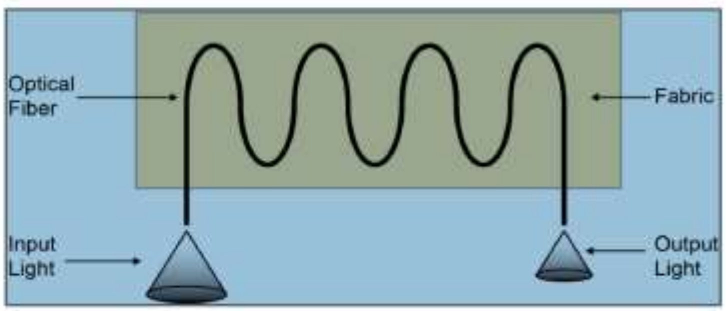

Fig 4: Optical fibers incorporated into a Fabric.
Source:Carlos Gonçalves (2018)

The schematic diagram above is a fabric with optical fibers incorporated. Stretching the elastic fabric, the light amplitude passing through the fiber increases; this therefore increases the output voltage coming out from the photo detector. There are possibilities of building several smart e-textiles that can sense temperature and humidity changes.Resistance and capacitance are the main principles behind the building of humidity textile sensors. The resistive humidity textile sensors respond to moisture variation by changing its conductivity, while the capacitive humidity textile sensors answer to water vapor by varying its dielectric constant. Polymers that are suitable for capacitive humidity sensors include polyethersulfone (PES), polysulfone (PSF), and divinylsiloxanebenzocyclobutene (BCB). Other humidity sensing devices have flexible transistors that changes conductivity with the humidity levels. Coated sensors on fabrics typically react to humidity if they are organic or carbon based. Temperature sensors harmonious with fabrics can be made on flexible substrates, such as plastics and polyimide sheets. These sensors can be later attached to fabrics or integrated into their structure. Resistance temperature detectors (RTDs) have elements, such as platinum/nichrome (NiCr) and related materials that can be coated on flexible surfaces and Kapton based plastic stripes of platinum RTDs can be woven into fabrics to manufacture a temperature sensitive textile. Thermoelectric generators can also be attached to fabrics using molding techniques and fabric connection technologies and Fiber optic sensors can also be used to sense temperature changes as well as temperature sensitive inks.

5. SOME HIGH PERFORMANCE TECHNICAL TEXTILE PROCESSES

P. Plasma Treatment

Plasma treatment as the name implies, refers to a textile surface modifying treatment which offers an improved performance textile surface without altering the properties of tear resistance, flexibility, density of the textile material.The working principles of the plasma treatment process are that when the data's are varied, the surface properties change to:

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(a) Sterilization from micro organisms
(b) Improving the dyeing and printing affinity
(c) Increasing adhesion property for the textile - Apply a fire retardant finish
(d) Apply antibacterial finishes for medical appliances and safety
(e) Influences the electrical conductivity of the surface
(f) Confer anti-crimp properties to wool
(g) De -sizing cotton surface after weaving.

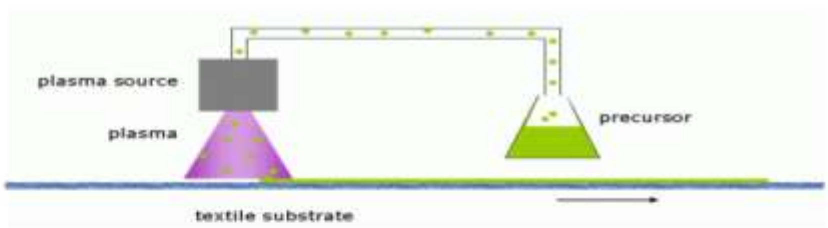

Fig 5: The principles of plasma treatment on textile surface.
Source: HenockHundeDadi (2010)

The technology of Plasma treatment gives rise to the possible applications:
i. Anti-bacterial effects
ii. Fire retardant finishes for fire protective clothing‘s.
iii. Perfume realizing fabrics applications
iv. Creating ultra-hydrophobic surfaces and the lotus effect for textile surfaces.
v. Creating ultra-hydrophilic (water-loving) fabrics for fog harvesting textiles.

Q. UV treatments

This is an electromagnetic radiation with a wavelength of 1 to 400 nm. UV- treatment technology is a technology that involves photochemical process to dry or "cure" inks, pigments, dyes, coating layers, glues, and other materials using ultraviolet light. This technology of UV-treatment has been effectively applied in graphics, wood, automotive and Tele communications since decades. This surface treatment technology is an interesting alternative to traditional water and solvent based processes. The predominant advantages to the functional and technical textile sector include: (i) Energy efficiency (ii) Production efficiency (iii) Low emission of VOC
(iv)Application on temperature sensible materials (v) Compact appliance Textiles treated with this technical method have good acceptance for medical and hygienic applications.

R. Sol gel technology for textile treatment

The word Sol is a colloidal suspension of small solid particles (10-9–10-6m) in a liquid; While Gel is a molecule of macroscopic dimensions which extends throughout the solution (polymeric network). Inorganic sol-gel layers applied for surfaces of textile are highly strong and wear resistant. Since then, there is an increasing interest in the application of the sol-gel technology for functional textile treatments.
The Important advantages of the sol gel treatment for the functional and technical textile include:

(i) Water, oil and soil repellence
(ii) Improved abrasion resistance
(iii) Antimicrobial activity
(iv) UV protection
(v) Easy care properties
(vi) Immobilization of bioactive agents and dyes
(vii) Flames retardant
(viii) Electrical conductivity

.

6. NANOTECHNOLOGY APPLICATIONS FOR FUNCTIONAL TEXTILES

Nanotechnology is a structure with a Nano size for the construction of material with enhanced properties. The application of Nano technology in the areas of functional textiles is increasing for better outcomes and most of the finishes based on Nano particles brought the highest strength, breathability and soft hand.
The Nano materials can be applied to textile by coating using various other components and different

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technology of coating. Out of the many possible applications in textile, some of which includes:

(i) Wrinkle and soil resistance
(ii) water repellence
(iii) Anti -Bacterial property
(iv) Antistatic Properties
(v) UV Protection

7. APPLICATION OF SMART TEXTILES

The following are few numerous applications of smart e-textiles:

a) Life Jacket

Life jacket is a smart textile that monitors the heart rate and blood pressure of an ill patient wearing it. The information collected by the device embedded in the jacket is transferred to a computer which can be read by medical practitioners. This life saving jacket can also be used to measure Cuff-less BP through the radial pulse waveform by arterial tonometry.

b) Military/defense

Technological advancement has led to the imputation of miniaturize electronics that can be embedded into textiles and used by civilians or special personnel, such as soldiers. The integration of electronics into military textiles could assist soldiers in achieving levels of performance and capabilities never realized before on the battlefield. Soldiers on active duty can face varying threats, often unpredictable. In extreme environmental conditions and hazardous situations there is a need for real time informationtechnology to increase the protection and survivability of the people working in those conditions. Improvements in performance and additional capabilities would be of immense assistance within professions such as the defense forces and emergency response services. The requirements for such situations are to monitor vital signs and ease injuries while also monitoring environment hazards such as toxic gases.

The applications of the e-textile in military field may be divided into two categories: (1) Personal protective clothing and individual equipment (battle dress uniforms, ballistic protection vests and helmets, chemical protection suits, belts, ropes, suspenders and field-packs) and (2) Defense system and weapons (tents, parachutes, shelters, tarpaulins and textile composites).

When a military man wears the "Smart Shirt" during war and gets injured, information on the wound and the soldier's condition would be immediately transmitted to a medical triage unit near the battlefield. This shirt can help a physician determine the extent of a soldier's injury based on the strength of his heartbeat and respiratory rate. This information lets physicians know the urgency of what to treat first.

Obviously, a lot needs to be done to develop better protective fabrics for the military personnel not only in terms of performance of individual aspects of protection but also integration of solutions into a protective system that is economical, stress free and performs optimally.

c) Health and Medicine

Health care centres are major area that has benefitted tremendously in the applications developed from the combination of smart textiles and wearable computers in the form of Telemedicine.These devices that are wearable enable physiological signals to be monitored frequently during normal daily activities. It therefore overcomes the problem of infrequent clinical visits that can only provide a brief window into the physiological status of the patient. Smart clothing serves an important role in remote monitoring of chronically ill patients or those undergoing rehabilitation and also promotes the concept of preventative healthcare. Traditionally, textiles have been regarded as an essential passive 'skin' that providesenhanced protection, comfort and appearance, whereas smart textiles have thepotential to emulate and augment the skin's sensory system by sensing externalstimuli such as proximity, touch, pressure, temperature and chemical/biologicalsubstances. For conditions such as diabetes mellitus, where the patient loses sensationin the limbs, or bedridden patients, pressure sensitive fabrics may aid in assessmentand warning to reduce the occurrence of pressure ulcers. With nanotechnologies smart textiles may provide a fully functioning haptic interface – potentially a second, more sensitive skin.

Few of such immense achievements of smart textiles in health care are shown below:

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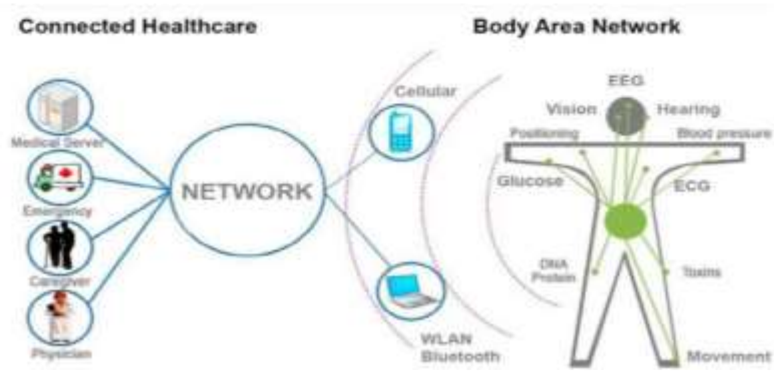

Fig 6: Applications of smart textiles and wearable computers in health care.
Source: ***Yinka-Banjo Chika etal (2017)***

d) Sport and Human Performance

The sports sector, through seeking to improve athletic performance, personal comfort and protection from the elements, has driven significant research activity within the textile industry. In sports generally, important monitoring functions such as body temperature, heart rate, breathing, and other physiological parameters such as number of steps taken and total distance travelled can be achieved using smart devices embedded on sport clothing. Smart textiles in sports also help in protection against injury of athletes. Walking shoes could be embedded with GPS (Global Positioning Systems) that helps in the tracking of its wearer in times of emergency rescues services. Most of the smart running shoes, make use of a special sensor that helps in tracking the athletes 'movements while running and sends the information to information technology tools such as a personal iPod. It helps to keep track of the athletes' running speed, total distance covered and other relevant data.

e) Networked Jacket

The network jacket aids in the tracking of location of the wearer through the use of a GPS and the map is projected into a flexible display screen on the sleeve of the jacket. It also displays the moods of the wearer via color changes and signs.

8. ELECTRONIC TABLECLOTH

The Electronic Tablecloth is an e-textile device that is used in asocial gathering where it enables users to communicate with one another through an interface with a computer via its sensor surface. Attendees at the function are able to identify themselves by entering their assigned "coaster tags" on the curly pattern, on which are embroidered the words "Place your coaster here." The coaster is in turn a capacitive coupled radio frequency identification device (RFID) tag, and is read by the tag reader in the tablecloth when the user sets it on the swirling pattern and touches the fabric electrode on top of the coaster. The computer then enters a dialog with the user through the appropriate fluorescent display and keypad. Radio frequency identification (RFID) technology is one of such pervasive technology which is now increasingly utilized in industrial logistics, supply chain management, cold chain monitoring, retailing, purchase tracking and manufacturing analysis. RFID principles show several advantages over traditional technologies like barcode and data loggers and its devices are more accurate and do not require visual contact . It provides real-time information that can help retailing and distributing officer for product delivery schedule and allows customers to identify interior information of product and services.

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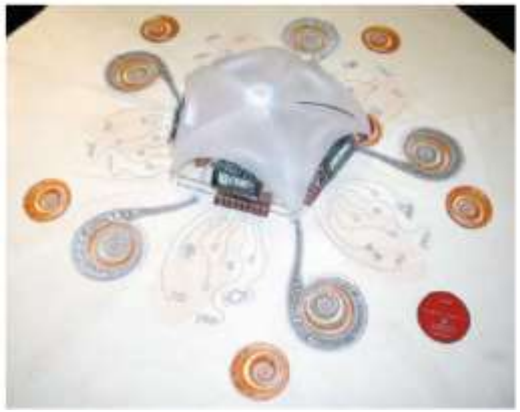

Fig 7:Sample of Electronic tablecloth.
Source: Yinka-Banjo Chika, and SalauAbiolaAdekunle(2017).

Apart from the few out of numerous applications mentioned, Smart textiles find variety of applications and possess sensing and actuating functions that can beefficiently used in different field of studies like engineering, fashion and entertainment, medicine, Sport (Smart bra,), Music industries, and defense academy etc.

9. CONCLUSION

The development of smart fabrics requires a multidisciplinary approach and technology in which knowledge of computer science and engineering, smart materials, chemistry, circuit design, and micro-electronics are fundamentally integrated with a deep understanding of textile fabrication.. Finally, the hybridization of textiles and electronics brought changes in the interactive textiles; this developing field of smart textiles could show a lot of new things in all its applications as it has its importance for medicine and healthcare, protective clothing‘s, in the casual clothing‘s and lifesaving products. The useful features that are incorporated into e-textiles bring market advantages in several areas, such as sports and healthcare; business companies already perceived the wearable e-textiles business potential and are developing e-textile products to incorporate them in their product portfolios. The wearable e-textiles are still a new field with opportunities to build innovative products that can revolutionize the way a person’s interact with their garments. There are so many potential applications where smart Nano-textiles have impact on our lifestyles ,and comfort and become ubiquitous in this technology driven world by making man to be able to interact with his environment and space.

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