



## SMART FABRICS-WEARABLE TECHNOLOGY

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### Abstract:

*Smart fabrics, generally regarded as smart Textiles are fabrics that have embedded electronics and interconnections woven into them, resulting in physical flexibility that is not achievable with other known electronic manufacturing techniques. Interconnections and components are intrinsic to the fabric therefore are not visible and less susceptible of getting tangled by surrounding objects. Smart fabrics can also more easily adapt to quick changes in the sensing and computational requirements of any specific application, this feature being useful for power management and context awareness. For electronic systems to be part of our day-to-day outfits such electronic devices need to conform to requirements as regards wear-ability, this is the vision of wearable technology. Wearable systems are characterized by their capability to automatically identify the activity and the behavioral status of their wearer as well as of the situation around them, and to use this information to adjust the systems' configuration and functionality. This write-up focused on recent developments in the field of Smart Fabrics and pays particular attention to the materials and their manufacturing techniques.*

**Keywords:** Smart fabrics; Wearable technology; Health and Medicine; Smart textiles; Sports; Fashion.

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## 1. Introduction

Textiles have been an integral part of human life for thousands of years. In the earlier ages, humans used textiles majorly as clothing for protection, but the use of textile has gradually widen. Humans now wear clothes at all times and are surrounded by textiles of various kinds in virtually all our environments. The incorporation of multifunctional values in such a common material has become an important field of interest in recent years. Fabrics, fibers yarns, and many other materials which have added functionalities have been developed for a range of applications. Textile materials and their manufacturing techniques has become an important avenue for high-tech innovations. Smart Fabrics is a research area which has its source indifferent research disciplines; chemistry, computer science and engineering, textile design and technology, material science, physics [1].

Smart Textiles refers to a wide field of studies and products that displays the functionality and usefulness of regular fabrics. Smart Textiles are textile products that are able interact with the

environment or user. They are made from fibers and filaments which are yarn together with knitted, woven or non-woven structures. The collaboration between the field textiles design and electronics is important in the fabrication of smart materials that are able to achieve a wide range of functions which can be found in non-flexible as well as rigid electronic products. Smart Textiles aims to lay a platform for increasing social welfare and will create relevant savings on welfare budget [2]. Smart textiles display a high level of intelligence and are categorized into three groups:

- Passive smart textiles: which can only use sensors to sense the environment or the user;
- Active smart textiles: which has embedded an actuator function and a sensing device and can sense and react to stimuli from the environment;
- Very/Ultra smart textiles: are smart textiles that are capable of sensing, reacting and also adapting their properties to environmental conditions.

In a passive smart material the existence of sensors is important as sensors provide a system to detect signals. Actuators acts on detected signals either from a central control unit or autonomously; together with the sensors, are the essential element for active smart materials [3]. Within the biomedical and safety communities, fabrics-based sensing has been a large field of research. These fabric sensors can be used for electroencephalography (EEG), electrocardiogram (ECG), and electromyography (EMG) sensing; fabrics with intrinsic thermocouples can be used for sensing temperature. Carbon electrodes integrated into fabrics can be used to detect specific environmental or biomedical features such as oxygen, salinity, moisture, or contaminants [4] [5].

Human interface elements, radio frequency (RF) functionality or assistive technology, power generation or storage are all active functionalities that could be embedded in smart fabric. Display or annunciation devices and input devices and are two classes of human interface elements. Input devices may comprise a shape-sensitive fabric that is capable of recording flexing or motion, pressure, and compression or stretching or capacitive patches functioning as pushbuttons while electroluminescent yarns, fabric speakers, or arrays of organic light emitting diodes (OLEDs) processed into yarns are classified as display or annunciation devices [6]. Simple elements that could simply vibrate or provide bio-feedback could be included in smart fabrics. An application of Smart Fabrics is the fabric-based antenna. These antennas are simply specific lengths conductive yarns woven or stitched into fabrics that are non-conducting [7].

Medicine and Healthcare, the military, sports, and aerospace are some of the fields in while smart fabrics have been greatly involved. This write-up pays attention unto the fabrication techniques in the manufacturing of this smart materials as well as applications or products that were or could be achieved using these techniques.

### 1.1. Review

Smart Textile is majorly based on three disciplines, which are; textile design and technology, smart materials and lastly computing science and engineering. These disciplines all come together to contribute its own part. The textile design and technology contributes with materials and fabric structures, smart materials contributes with its capability to respond to different stimuli and computing science and engineering contributes in the design of dynamic

functionalities especially in the programming of microcontrollers. An important issue in the combination between these three disciplines in the production of smart textiles is the level of integration: conventional smart technologies can be incorporated into fabrics either partly or wholly to achieve some level of smart functionalities. These two levels set the boundaries for this study. When do we or do we not have a Smart Textile? The challenge for a smart textile is that electronic components designed as at today do not possess the properties required for textile use; this is a motivation for pure textile solutions. Textile is a soft and flexible material designed to have certain properties for fashion interiors and technical application [1].

## **Research Question**

This write-up addresses these four questions:

- What is a Smart Textile?
- What is the advantage of developing Smart Textile?
- What will Smart Textile mean for future textile products?
- What new methods do we need to develop?

### **1.2. What People Were Doing**

The level of research in textile circuitry seems to be largely proprietary and unpublished. However, a number of notable work were done among which is the work of Michael Hawley at the Media Lab. He conducted an experiment, which aim to integrate electronic circuitry into fabric. This work was later abandoned by newer scientists because the appropriate techniques and materials could not be identified. Another study focuses on the production of conductive materials and processes for printing them onto fabric [8]. Researchers in this area cite the possibility of “tagging” fabrics by printing tuned L-C circuits directly onto the fabric, rather than by attaching separate, removable anti-theft tags.

Towards the end of 19th century, people were developing and getting accustomed to electric appliances, engineers as well as designers started to combine electricity with clothing and jewelry thereby developing a series of illuminated and motorized necklaces, hats, broaches and costumes [9]. For instance, in the late 1800s, young women could be employed to adorned in light-studded evening gowns from the Electric Girl Lighting Company to provide cocktail party entertainment [10]

History of smart and wearable technology can be traced back several decades. However, writers and researches identified three major periods.

### **1.3. Before the Year 2000**

Before the year 2000, which is regarded as the first period, the approach used by the researchers was in design of wearable sensors and actuators and their applications. This period was more of technology motivated period. The researchers focused on the applications of advanced electronic technologies on wearing. The resulting products were more portable rather than wearable [11]. Two notable examples during this period are;

#### 1.4. Georgia Tech Wearable Motherboard (GTWM)

The GTWM Figure 1 used optical fibers, special sensors and interconnects to monitor and detect bullet injuries. These sensors "plugged" into this motherboard using the developed Interconnection Technology. Data bus integrated with monitoring devices such as an EKG also serves to transmit information to the sensors. It could also record temperature and voice [12].



Figure 1: Georgia Tech Wearable Motherboard (GTWM)

#### 1.5. Cyber Jacket

The cyber jacket in Figure 2 was developed by Scientists at the Department of Computer Science in University of Bristol. The initial prototype was developed during the summer of 1997. It consists of a wearable mobile computer system integrated with location sensors (GPS). Cyber jacket consists of C programs interacting by means of sockets, running on a Linux kernel.



Figure 2: Cyber jacket

## 1.6. During 2000

Textile and fashion professionals began to create their own research and development on smart and wearable electronics resulting in various joint projects between fashion and electronics fields coming to existence. This period was notably important in its contribution because Prototype research on new materials for active functions of smart and interactive textiles was executed rather than their business orientation. A notable example during this period is;

## 1.7. Levi's ICD+ Jacket

This jacket in Fig3 is a collaboration of Philips Electronics and Levis fashion. In 1999 Levi Strauss and the designer Massimo Osti started to work together. The jacket is the most known outcome of their research work. Levis in cooperation with Philips Electronics began the marketing of the brand ICD+ jacket in 2000 after the research. At that time, it was the first wearable electronics garment in the market.



Figure 3: Philips and Levi's ICD+ Jacket with device pockets for Mobile Phone & MP3

## 1.8. Between 2000 and 2005

During this period the amount of Smart garments available in the market had increased tremendously. This is as a result of newly developed materials as well as advancement in electronic components and material science. Among the achievements of this era include;

- The measurement of resistance values on fabric through knitting of embedded connections;
- Electrodes and sensors are being developed using conductive textile yarns;
- Mechanical and bio physical parameters testing by applying conductive polymers began.

The above mentioned period brought great development in the field of interactive and smart textiles. An example is the Adidas's smart shoes.

The Adidas's smart shoes was launched in year 2004. It became the first smart shoe to be introduced into the market. This smart pair shoes is called "1". It is a sneaker that consists of an electric motor, a microprocessor, and sensor integrated within the material. The shoe adjusts its cushioning dependent on what surface the wearer is moving on and also how they run or walk [12].

With the aid of a 20MHz processor, the embedded sensor can read 20,000 readings in a second, and is also capable to performing 10,000 calculations in a second. A special shock absorption mechanism is incorporated in the design of the shoes for the athletes comfort.

### 1.9. Projects on Smart Textiles

Since the mid 1980's, a lot of effort and researches have been placed on smart textiles. Various groups such as European space agency, EU, NASA, as well as top fashion companies like Adidas and other industry members put funds to Research and Development for different end uses. For example, the EU has put funding project to facilitate developments of new smart and interactive textiles through FP 6 program. The 7th framework will continue in the program. The goal is to trigger strengthening, restructuring and commercial developments of products of smart textiles [12].

Table 1: Some of the research projects on smart textiles

	<b>Project name</b>	<b>Period</b>	<b>Objectives and applications</b>
1.	STELLA (Stretchable Electronics for Large Area Applications) funded by EU <a href="http://www.stella-project.eu/">http://www.stella-project.eu/</a>	1/1/06– 31/1/10	<ul style="list-style-type: none"> <li>• In healthcare</li> <li>• "Electronic skin"</li> <li>• Integrated electronic in stretchable products and parts</li> <li>• Functional and Wellness clothes</li> </ul>
2.	BIOTEX ( Bio-Sensing Textiles to Support Health Management) funded by EU <a href="http://www.biotex-eu.com/">http://www.biotex-eu.com/</a>	1/7/06-29/05/08	<ul style="list-style-type: none"> <li>• Development of sensing patches for blood and sweat,</li> <li>• Perform biochemical measurements on textile substrate and monitor body fluids</li> <li>• Optical and electrical and connection to a signal processor</li> </ul>
3.	CONTEXT (Contact less sensors for body monitoring in corporate in textiles) funded by EU <a href="http://www.context-project.org/">http://www.context-project.org/</a>	1/01/06-30/6/08	<ul style="list-style-type: none"> <li>• To measure the electrical signals of heart and muscles.</li> <li>• textiles were incorporated with contactless sensors continuous monitoring and used by untrained individuals</li> <li>• Giving information on stress</li> </ul>

			state and muscle activity.
4.	OFSETH (Optical Fiber Sensors Embedded into technical Textile for Healthcare) funded by EU <a href="http://www.ofseth.org/">http://www.ofseth.org/</a>	1/3/06-30/9/09	<ul style="list-style-type: none"> <li>• Wearable static sensors for respiratory and cardiac activity and oximetry by means of FBGs sensors and Near Infra-Red Spectrometry(NIRS)</li> <li>• Optical fibers based sensors for capabilities of wearable solutions for health monitoring are integrated.</li> <li>• Wearable mobile sensors for ambulatory healthcare monitoring and application for Sudden Infant Death Syndrome (SIDS).</li> </ul>
5.	MERMOTH: Medical Remote Monitoring of Clothes) by EU funded by EU <a href="http://www.mermoth.org/">http://www.mermoth.org/</a>	2003-2006	<ul style="list-style-type: none"> <li>• Based on a wearable comfortable garment a generic medical monitoring system Was developed,</li> <li>• Integrating smart biosensors for medical academic research and clinical drug trials</li> </ul>
6.	My Heart: Fighting Cardiovascular Disease by preventive Lifestyle & early Diagnosis) funded by EU <a href="http://www.hitech-projects.com/euprojects/myheart/">http://www.hitech-projects.com/euprojects/myheart/</a>	2007	<ul style="list-style-type: none"> <li>• Simple user interface and Interconnection with textile</li> <li>• Wireless communication and Textile sensor interface</li> <li>• On-body generic processing</li> </ul>
7	Smart drug releasing plaster by A Spanish company called Cetemmsa	2009-2010	<ul style="list-style-type: none"> <li>• Plaster patch heating software</li> <li>• Electronic system for release of the peptide capsule</li> <li>• Wireless technology for reporting to healthcare professionals</li> </ul>
8.	Project integrating antennas into parachutes by the European Space Agency	2008	<ul style="list-style-type: none"> <li>• High speed data communication</li> <li>• Transmit communication during the critical descent and landing phase of space probes and radar detectors</li> <li>• Pick up very weak signals from a space probe even small distortions</li> </ul>

## 2. Materials and Methods

### 2.1. Fabrication Techniques

Embedding electronic circuitry into textiles could be achieved in several ways; this is dependent on the choice of the substrate to be used. Some of the methods are;

- 1) The use of conductive adhesive to bond components to a substrate,
- 2) Direct soldering of surface-mount electronic components onto metallic organza,
- 3) Direct couching of thread-frame of a component's into a circuit, and
- 4) Components can also be "stapled" into a conductive stitched switch

### 2.2. Incorporating Smartness into Apparels

Integration of electronic devices into apparels during the manufacturing process is summarized in the Fig4. The microprocessors and the sensors could be integrated into the yarn directly and it would not interfere with the normal manufacturing process of the apparel. This technology is based on the encapsulated area.

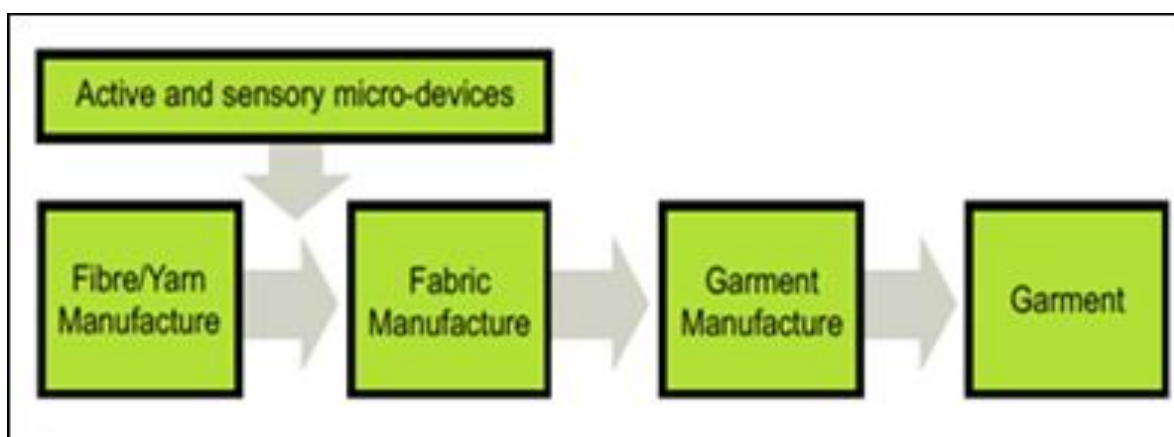


Figure 4: Steps in integrating smartness into apparel.

Mu-chip, designed by Hitachi is a chip small enough to be embedded with textile fibers. This chip is 0.4 mm x 0.4 mm x 0.15 mm. The vision of smart textiles may have LEDs, microprocessors and electroluminescent material woven together with clothing fibers to form smart textiles [9].

### 2.3. Flexible Circuit Substrates

Many methods already in use in the fabrication of circuits on flexible substrates rely on the metallization of a flexible polymer substrate that can withstand the high temperatures of conventional soldering processes. For instance, in camera designs where circuitry must fit completely into available space in small package, Kapton film is a commonly used flexible substrates, also, in portable computers and printers where a large number of connections must cross a hinge or other rotating joint, and non-planar antennas where the antenna elements must have accurate dimensions yet be shaped to fit on conical forms. However, it is to be ensured that



whenever such a substrate is used for designing a circuitry, great precaution must be taken to make sure the overall mechanical stress of the application will not be applied to the component-circuit solder joints in order to achieve the expected life-time of the product.

In this regard, traditional flexible substrates are only flexible in areas where electronic components are not integrated. This leaves a challenge on the overall mechanical properties of the substrate despite its great deal in its electrical in forming electronic interconnects.

#### **2.4. Flexible Multi-Chip Modules**

The flexible multi-chip module (FMCM) is the result of collaboration with workers at the Charles Stark Draper Laboratory to produce small, semi-flexible circuit elements that may be embedded in textile products to read sensors and report their status to a controlling host. The fabrication process of this module is similar to that developed by General Electric's MCM-E/F group.

This readout circuit is composed of a four 3 M-Chip resistors, a PIC16F84 microcontroller IC as well as a 16pF chip capacitor. The PIC16F84 microcontroller IC is the main component of this circuitry. The circuit diagram for this multi-chip module is shown in Fig5.

The RB7 and RB6 pins are where the hosts will be attached, as this forms a full-duplex RS232 (serial data link) operating at 9600 baud. The e-broidered electrodes are connected to the Trode0-Trode3 pins and the circuit is powered via the Vdd and Vmm pins.

The flexible M-chip module is measures only about 0.600 inch  $\times$  0.300 inch, and its 0.016 inch thick. It has an allowed bending radius of curvature of about 50 cm. To develop this module, the composing components were reduced to 0.006 inch by mechanical grinding and lapping of the rear face of each component.

The components were then placed on a rigid substrate, Kapton mask of 0.006 inch thick with perforations cut out to permit the chips was placed around the chips, and the components placed on the rigid substrate, then Tin and Copper interconnect was introduced through a mask.. Lastly, Kapton is used as a protective cover and attached to the top of the module, the FMCM is removed from the rigid substrate, and another Kapton cover is attached to the base, producing in a totally encapsulated element [13].

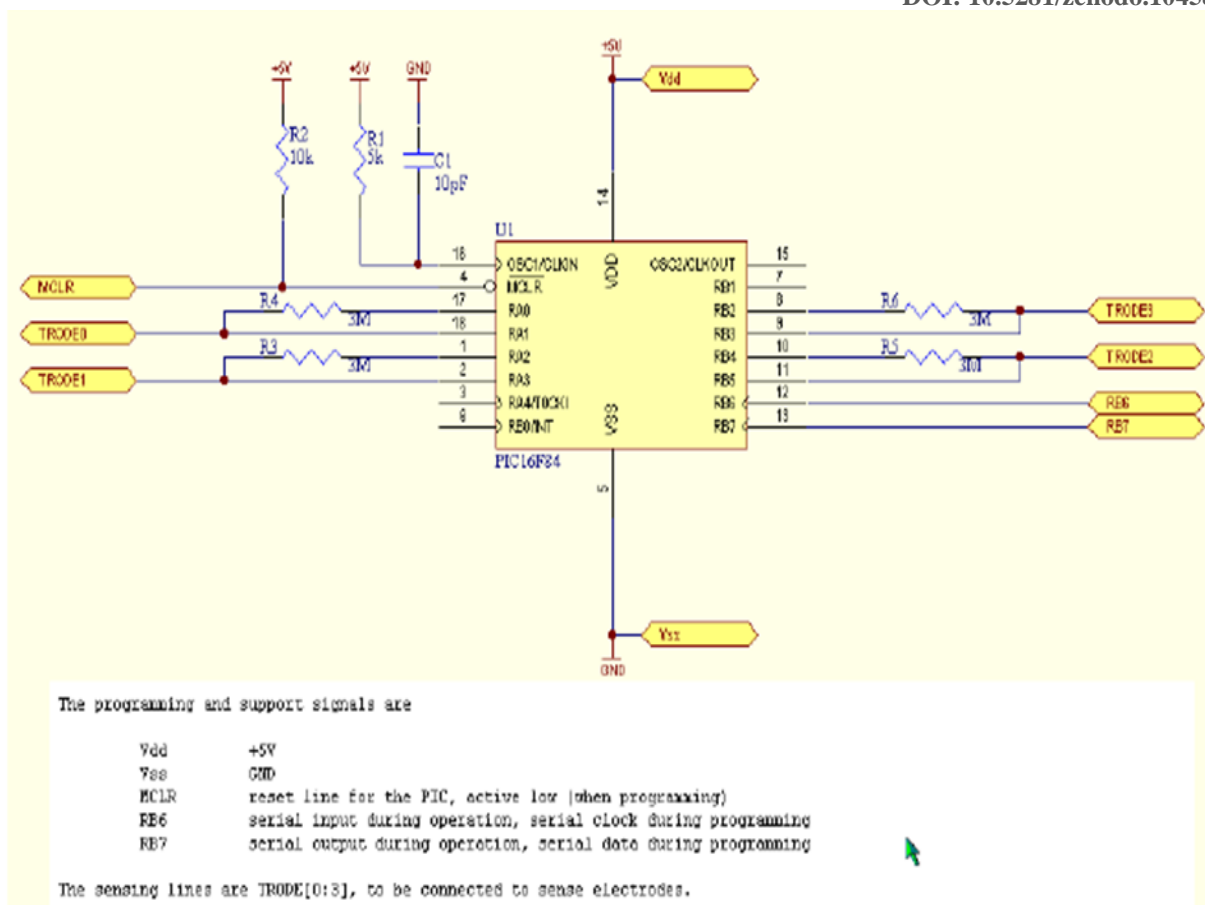


Figure 5: Schematic of the “flexible” multi-chip module.

## 2.5. Electrically Active Textiles

A lot of natural textile materials show properties that suggest their usefulness in designing electronic circuitry. There are several combinations of natural and synthetic fibers, spun with metallic fibers or wrapped or plated or conductive polymer fibers.

## 2.6. Metallic Silk Organza

Metallic silk organza in its base form is believed to have originated in India. The warp of this fabric consists of parallel silk threads. The weft of the organza is woven with a metal foil helix coated silk thread via the warp. The metallic thread is made like cloth-core telephone wire, and is highly conductive. The fiber core of the silk can withstand high temperatures and it also has high tensile strength which makes it possible for the yarn to be embroidered using an industrial machine. The conductive fibers is always kept parallel and separated at all times due to its ability to form parallelograms from the cells formed by the weave if any part of the organza is subjected to shear [13].



Figure 6: Micrograph of metallic organza

When Circuits are fabricated on organza they require protection from folding contact with themselves, which can be accomplished by coating, supporting or backing the fabric with an insulating layer which can also be cloth. In addition, circuits developed using this technique possesses various degrees of flexibility, when compared to the single degree of flexibility that conventional substrates can provide.

Fig7 shows a circuitry, built on a patch of metallic organza with PIC16C84 microcontroller as its major component. The PIC and other connecting components are soldered directly onto the fabric. This circuit controls LEDs based on the configuration of the bidirectional/O pins on the PIC. It can also sense touches along the length of the fabric. It reinforces the sense of interaction using audible feedback via a piezoelectric speaker.

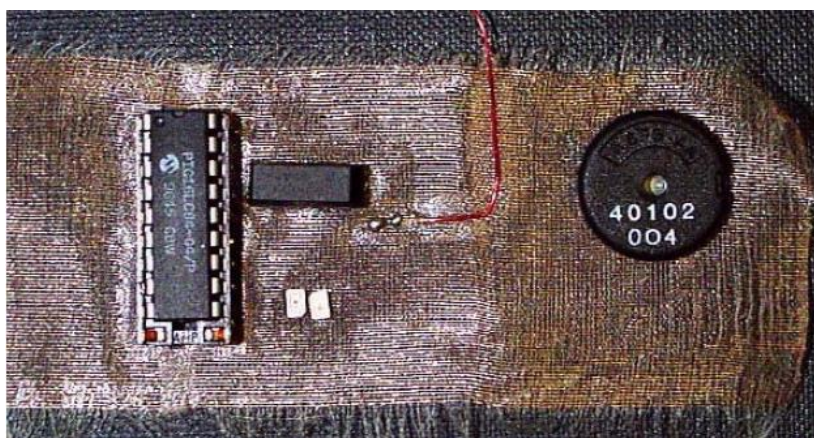


Figure 7: A fabric breadboard or "smart kerchief".

## 2.7. Conductive Fabrics

There are different ways to produce electrically conductive fabrics. A technique is to incorporate conductive yarns directly into a textile structure, for instance, through weaving. However, the incorporation of conductive yarns in a textile structure is complex and rarely a uniform process as the electrically conductive fabric has to be soft in touch or comfortable to wear rather than

rigid and hard. There are different thread types with which the conductivity can be induced. Examples are shown in Fig8:

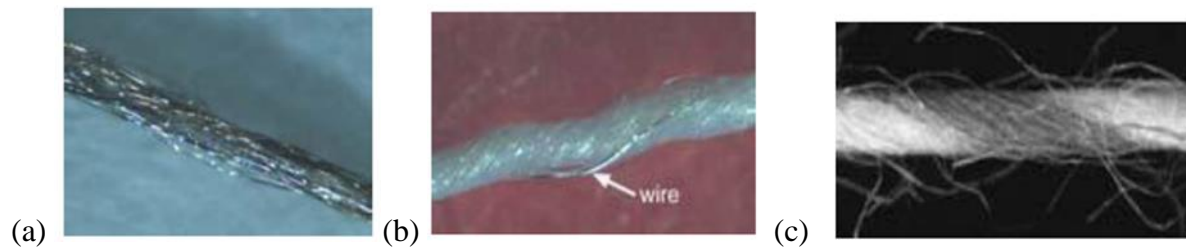


Figure 8 (a) Metal coating: There is physically/chemically coating of the polymer yarn with a thin metal layer; (b) Twisted metal wire: The twisting of metal wire around the polymer yarn; (c) Metal fibers: Metal multifilament is contained within the conductive yarn.

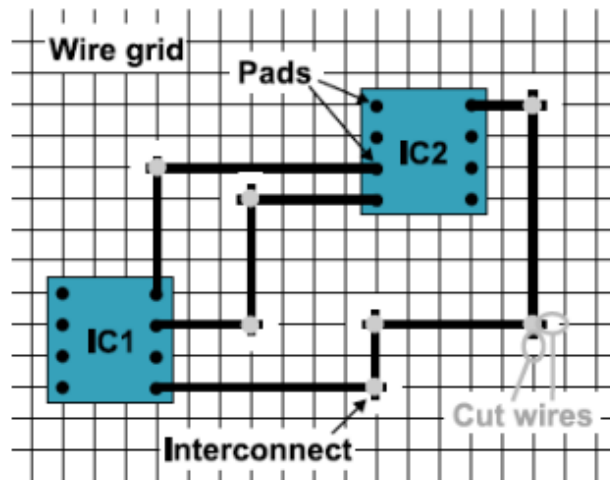


Figure 9: Approach to incorporate circuits in a textile with wire grid [13].

### 3. Results, Applications and Their Benefits

The results of researches carried out in the field of smart textiles and wearable technology has its application in many different areas of our everyday life especially in the fields of basic health and medicine, sports, as well as fashion and entertainment.

#### 3.1. Health and Medicine

Medicine is a major area which has benefitted immensely in the applications developed from the combination of smart textiles and wearable computers in the form of Telemedicine. Few of such great achievements are discussed. Fig10 shows the overview of the use of smart textiles and wearable computers in healthcare.

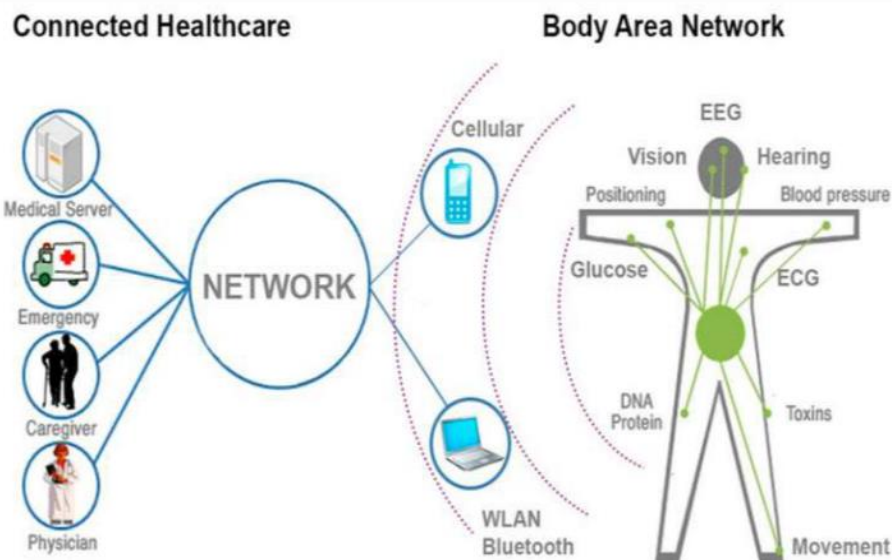


Figure 10: Smart Textiles in Healthcare.

### 3.2. Life Belt

Life belt is a trans-abdominal wearable device that is especially useful for proper monitoring of pregnant women. It aids the long-term parental monitoring process for both the fetus and the mother. This jacket is very useful in remote areas where the pregnant women lack the adequate medical care. When a pregnant woman wears this jacket, relevant information as regard the mother and the fetus can be transferred to a computer from which a medical expert can interpret and act accordingly. Life belt act as a support tool for the obstetrician, as it enables him to be able to remotely monitor patients, access patients’ medical data at any given time, evaluate automated preliminary diagnosis of their condition based on collected and analyzed vital signs, and most importantly be alerted[9].



Figure 11: Life Belts

### 3.3. Life Jacket

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



Figure 12: Life jacket

### 3.4. Wireless Health Monitoring System

The Wireless Health Monitoring System is used for acquisition of patients' current medical data and continuous monitoring of muscle activities, respiration, EKG, for the patient through the embedded textile sensor in a wireless-enabled garment. The system has a sensitized vest which includes wholly woven textile sensors, a miniaturized electronic board for motion detection, signal pre-processing, connected via Bluetooth for data transmission [9].



Figure 13a: Wireless Health Monitoring System

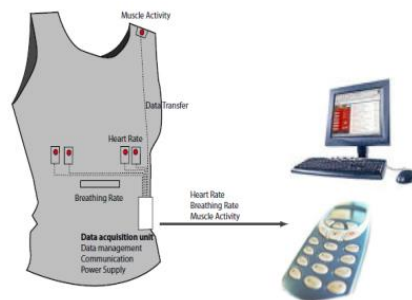


Figure 13b: Physical Structure of Wireless Health Monitoring System

### 3.5. The Sensory Baby Vest and Socks

The designer of the sensory baby vest, ITV Denkendorf, has a mission in preventing life-threatening situations and cot deaths in babies. With the use of this vest, medical experts will be able to continuously monitor functions of vital organs like the heart, skin, and lungs. It can also measure body temperature which is relevant in the early detection of the heart and circulatory

system diseases. The embedded sensors are incorporated such that the baby does not feel any discomfort while sleeping.



Figure 14: (a) Sensory Baby Socks (b) ITV's Sensory Baby Vest

### 3.6. Military/Defense Smart Armored Vest

Military forces, both in out-field and the back-end requires the need for real time information technology to increase the protection and survivability as well as their safety and effectiveness. The smart armor vest in Fig15 is a vest designed for the military to aid the military forces in the effective communication between the out-field and back-end teams as information gathered through the sensors can be transmitted wirelessly to a computer at the back-end which can be useful for the appropriate units such as the medics, forces and emergency response services to monitor important signals, signs and ease injuries.



Figure 15: Smart Armour Vests

### 3.7. Networked Jacket

This jacket (Fig16) helps in the tracking of the location of the wearer using a GPS and project the map onto a flexible display screen on the sleeve of the jacket. It also displays the moods of the wearer via color changes and signs.



Figure 16: Networked Jacket

### 3.8. Sports

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.

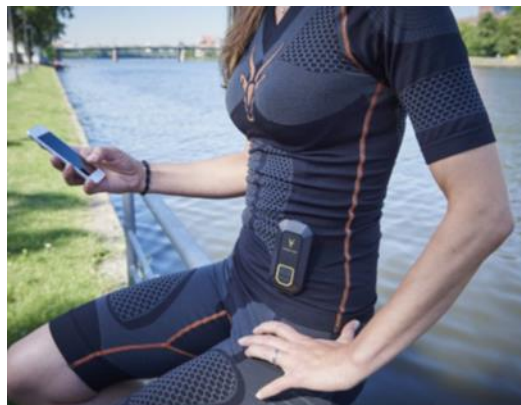


Figure 17: Muscle Activating Smart-Suit

### 3.9. Smart Sports Shoe

Walking shoes could be embedded with GPS (Global Positioning Systems) which helps in the tracking of its wearer in case of emergency rescues services. It can also help to track the whereabouts of children.

### 3.10. Smart Running Shoes from Nike and Adidas

The Nike smart running shoes, Fig.18a implements a special sensor that helps to track 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.



Adidas, a rival sport wear competitor developed the Adidas mi Coach PACER in Fig.18b which has incorporated in it a running pacer device that comprise medical tool for the measurement of athletes' heart rate while running[12].



Figure 18 (a) Nike Smart Running Shoe (b) Adidas Smart Running Shoe

### 3.11. The Smart Bra

The Smart Bra is an invention from Australia. This bra changes its properties in response to breast movement thereby providing greater support to active sport women while in action. The Smart Bra will automatically stiffen and relax its cups or tighten and loosen its straps in order to reduce excessive breast movement thereby helping to prevent sagging and breast pain[3].



Figure 19: Smart Bra

### 3.12. Fashion and Entertainment

Light emitting textiles such as in Fig.20 are beginning to find their way onto the fashion designers expo catwalks which suggest a future trend in wearable computing garment



Figure 20: Light Emitting Smart gown and shoe

### 3.13. Musical Jacket with Embroidered Keypad

The Musical Jacket in Fig.21, composes of an embroidered fabric keyboard, amplifying speakers, a MIDI sequencer/synthesizer, a fabric bus sewn from conductive organza, and batteries to power the system all integrated into an ordinary denim jacket thereby turning it into a wearable musical instrument. The wearer is able to play notes, rhythms, chords, as well as accompaniment using any instrument available in the General MIDI scheme [13].



Figure 21: Wearable MIDI Jacket

### 3.14. Electronic Tablecloth

The Electronic Tablecloth finds its use in social functions where it enables users to communicate with each other and also 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.

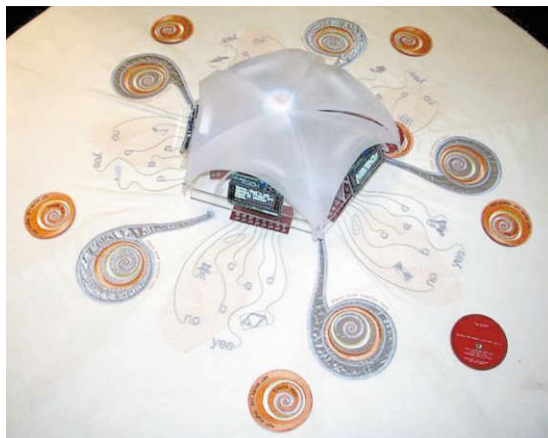


Figure 22: Electronic Tablecloth

#### 4. Conclusions & Recommendations

Before now, the field of smart textile was little known and this had made it to be only presented as an elusive product thereby limiting its use. Scientific efforts and continuous advancement in the developmental phases in this field has led to the smart fabric now being presented as the next future for textile industries and there have been tremendous increase in customers' interests in the products. As presented in this article, a lot of commercial products are now all over the markets and scientists and researchers are still pushing hard in the development of new solutions, creation of new ideas and also sophisticated products as a result of high demands of the smart fabrics in all aspects of life as discussed in this article. Grant View Research, Inc carried out a research study and came up with an estimated growth for the global market of smart textiles to reach about USD1500Million.

Wearable systems are now more feasible due to the latest advancements in the field nanotechnology, textile technologies, new materials, and miniaturized electronics but the challenge is in the level of comfort experienced by the wearer from the “wearing” of electronic devices which seem as the final key factor. However, if we address the issues of durability and mechanical resistance of the materials in this unconventional environment for electronic circuit design, I am optimistic of achieving this goal.

Finally, development of smart fabrics requires a multidisciplinary approach 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.

##### 4.1. Future Works

The advancement that we anticipate in the smart fabric field of study greatly depends on our success level in developing more interactive structures and how well we are able to combine other various relating and necessary disciplines, practices and theories in design activities of the future. An understanding of different disciplines of science and technology and also simultaneously exploring the relationships existing between them is the major challenge of developing smart fabrics. With this knowledge as well as necessary details of recent textile

designs may include, it is clearly obvious that textile designs needs to be taken to an all new level of design practice and research areas as regards both multifunctional and smart fabrics. For proper management of the ideas with these demands of science and technology, the traditional textile design space has to be subjected to changes that will make new design space a necessity. Generally, the goal in this space is divided into three; the relationship between the fabric structures and its products, the relationship between the fabric field and the other products field and lastly, the relationship between the textile design and engineering.

Some interesting products of the advancements in smart fabrics that may soon be well available in the market in the nearest future are discussed;

#### **4.2. Light Up Fabrics**

The light up fabric is a product that is coming to place our conventional household candles and reflectors. Imagine going for a stroll in the evening and you intentionally skip the candles because you have a material that can do that for you. An example of this light up fabric is the luminous Fiber Optic fabric that basically does lighting. The fabric is developed using ultra-thin optical fibers, which is woven directly onto synthetic fibers.

For that special occasion, the decor line of the light up fabric is just perfect. Although the light up fabric is tailored more for the party wears or those who rave, it is gradually being integrated into our common cloths and we can be sure to see more of such in the future in designs for sneakers, workout gears and many more.

#### **4.3. Temperature Regulating Fabric**

Outlast is a company in the field of smart textiles. Its temperature regulating fabric is capable of regulating body temperature due to the embedded heat management technology. The fabric can be used for a wide range of applications such as in the design of body armor, beddings, curtains, footwear, cushions and apparels. This material reduces spikes in body temperature that may cause sleeping disturbance, making the wearer feel just comfortable regardless of the season or the activity. It can also help to alleviate perspiration to about 70% in some instances and this makes it a welcome technology by far.

#### **4.4. Drug Releasing Material**

A breakthrough at the University of Washington sees a special material being designed to prevent women from contracting HIV. They were able to develop a fabric that is capable of releasing antiretroviral drugs in a way that is faster than previously known methods. This carefully designed fabric is a medicated electro-spun fabric. According to reports of Antimicrobial Agents and Chemotherapy published on Fierce Pharma website, the University's bioengineers used fibers similar to silk and added topical drugs that would dissolve if it is exposed to moisture, thereby releasing part of its integrated retroviral drugs quickly than topical rings or gels. Furthermore, research is ongoing to develop a tampon that would prevent HIV from sexual intercourse when inserted in the vagina.

#### 4.5. Moisturizing Textiles

Gradually, advancements in the field of smart textiles its takings us into the possibility of eradicating our usual ways of applying moisturizers and body lotions. The Juvetex Rejuvenating Fabric is designed with a permanent skin moisturizing ability. It is designed with over 20,000 micro fibers in one square inch, making the textile ultra-luxurious. It gives us a revolutionary method of hydrating without applying chemicals or creams.

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