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E-Textile: Review on Smart Wearable Fabric

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I. ABSTRACT

Smart as the word indicates that senses and respond to any changes in the surroundings. There is nothing left in this new world which is left to be made smart – from smart gadgets, smart car and now we have textiles which are smart too. Electronics Textile technology and smart fabric sensor are new features added to the common wearable clothes and also it is building advantage in the market competition. Current development in the fabric sensors is to measure force, pressure, chemicals, humidity and temperature variations and act accordingly to the body. An assortment of fine fibers and smart elements provides to control and monitor the surrounding environment.

This papers shares the recent development on this technology, most commonly used techniques and materials. Also to highlight on the key technological challenges and limitation faced in this field and on how to tackle this challenges. Despite of all these technical challenges, wearable textiles has successfully featured the sensors, actuators and other production techniques, which is used in the daily use without any bionic obstacle.

II. KEYWORDS

e-textile; smart textiles; conductive yarns; sensors; actuators.

III. INTRODUCTION

Technology which helps textiles ability to sense its surrounding nature or the outer catalyst and helps the fabrics respond to the occurrence by adapting to the nature of the conditions along with maintaining their fabric properties. These process requires smart fabrics to perform such mechanism. Using the technique of soft-computing and portable devices, these fabrics has gained tremendous demands in the recent times. Textiles are the new integrated circuits for the smart wearable. Although these wearable are not any replacement of traditional clothing and has its own market and currently does not sets any standardization of market methodology. E-textile or the smart wearable has been embedded with sense touch, strain, pressure, temperature and humidity allowance which is been made possible with the sensors of capacity, resistance and optics, which are mainly connected with the control device which passes signals and these are passed on as information. Gradually the new development is happening continuously with new dyes, new techniques and electronics, compatibility with new fibers keeping the principles same.

Usage of these textiles:

- It is mainly and broadly is used in military and medical units. These systems makes daily efficient with all the needed information on the go. This is trend of integrating our daily environment with intelligence.
- Also earlier the challenge in several fields, has now been successfully captured such as sports, art, medical, railways, automotive, aerospace, security.
- It can also be used as generating power to other portable gadgets

IV. DEFINITION

E-textile or Smart textiles is a broader study in which using the common fine fabrics and technology, an intelligent textile is produced which senses and respond to the outer stimuli and interact with the environmental or user. Primary components used for the textiles are sensors, actuators, data processors, communicators, and energy supply. Advance technology in these textiles includes fire-resistant, breathable, or ultra-strong fibers.

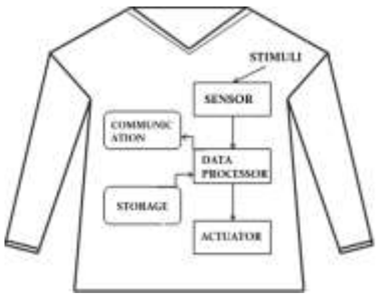
There are three classifications of these textiles based on their applications:

1. Passive Smart Textiles – that senses environmental conditions

2. Active Smart Textiles – that does both sensing and reacting to the environmental conditions

3. Very Smart Textiles – that senses, reacts and adopts the environmental conditions

V. WORKING PRINCIPLE



Materials, Connections and Fabrication Methods: Different methods are used to process these wearable textiles with several materials. Expertise required such as in field of electronics, mechanics, computer engineering, textiles etc. In this field where the fabrication methods are used along with the materials for e-textiles to make this field multidisciplinary research field. It has also been proved over the past decade, that like as conventional textile production traditional fabrication methods are also used in e-textiles production too.

Processes like embroidery, weaving, knitting, and breading machines can be used to in this conductive yarns incorporation process to conventional textiles threads. Also it can be manually done by sewing conductive yarns. To make electrical conductive yarns from pure textile threads, non-conductive yarns are coated with metals, galvanic substances or metallic salts can also be used, which also enables an e-textile production. Common textile coating processes include electroless plating , chemical vapor deposition, sputtering , and with a conductive polymer coating. 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).

Either mechanical or electrical mechanisms are used to achieve connections to data acquisition systems. This way, textile structure platforms as woven, knitted, or nets can be used to produce e-textiles, avoiding attaching electronics to textile substrate.

Electrical components, such as electrodes, connectors, and interconnectors are also required to make the wearable e-textiles production possible. When wearable e-textiles are used for the acquisition of electrical biological signals such as electrocardiogram (ECG), the electrodes are the bridge between the body and the circuit. There is still the need of connectors and interconnectors in order to bridge the textile with the electronics, when there is no need of electrical signal acquisition. The energy needed to power e-textile circuits is normally provided from Lithium Polymer (Li-Po). With ***energy harvesting solutions***, it is possible to charge small Li-Po batteries, keeping the e-textile energy demands during use.

Mechanical and physical bonds or connections are the two main bond categories for connectors and interconnects. 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. When there is a need for a permanent connection, physical connections are made. Physical connections includes micro-welding, thermoplastic adhesion, mixed conductive polymer, adhesion , joint soldering, and electroplating. Due to the diversity of application environments, e-textile connectors remain an open research field where each solution is customized and is almost unique.

Textile circuits are electrical circuits built on textile substrates. Most widely used technique is ***Embroidery of conductive thread*** into textile substrates. This technique is used to stitch patterns that define circuit traces, component connection pads or sensing surfaces using Computer Assisted Design (CAD) tools. Another technique which is also widely used to fabricate textile circuits is when a welded circuit is ironed to convert into the textile substrate. Once the circuit is attached to the textile, it can be soldered like a traditional printed circuit board. There are also some commercial printed control boards which are used for the wearable.

Table: Attribute comparison of wearable control boards.

Control Boards	Washable	Analog Pins	Digital Pins	Wireless Communication
Lilypad	Yes	Yes	Yes	No
Flora	Yes	No	Yes	No
Xadow	Yes	Yes	Yes	Yes
Square Wear	Yes	Yes	Yes	No
Igloo	Yes	Yes	Yes	No
WaRP7	No	Yes	Yes	Yes
Intel Edison	Yes	Yes	Yes	Yes

Xadow **–** When it comes to the best wearable control board, Xadow is the best control board that is available in the market due to its analog/digital pins and wireless communication. Another advantage it has is it can be washed that enables a permanent connection with a textile and textile fibers. 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. For example, silk screening is a thick film process, where an adhesive conductive ink is applied to the open areas of a textile mesh which allows ink to penetrate into the fabric.

A sputtering process is also used to produce high-resolution circuits on textile substrates. The textile substrate is kept at 150 degree celsius, and which needs to be placed in a vacuum chamber with an inert gas such as argon and a shadow mask to make the circuit patterns. There are some research projects which reports the use of Nano soldering methods for production of e-textiles with carbon nanotubes (CNT) conductive lines. The CNTs are soldered onto the fiber surface of non-woven fabric by process of ultra-sonication, which brings a strong adhesion between the carbon nanotubes and the textile fibers. The CNTs do not detach even when the e-textile is vigorously being stirred mechanically, or even after they are washed.

Electronic elements are made of conductive thread by the traditional process of sewing thread fibers in patterns, also with multiple crossings, in order to achieve desired electrical properties. By using several techniques before and after the process of thread manufacturing, conductive properties can be given to the threads to be used. Another very common technique is used for 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.

SENSORS -

Capacitive Pressure Sensors: These sensors are made on textiles that can be sewn, snapped, or glued to a fabric substrate and also can be welded to other electronics or wires. Conductive materials which acts as conductive plates are used as textile capacitors and are separated by dielectrics. The conductive plates can be woven, sewn, and embroidered with conductive thread/fabrics, or they can be painted, printed, sputtered, or screened with conductive inks, or conductive polymers. The dielectrics which are used mostly typically are synthetic foams, fabric 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 area of two conductive parallel plans, the conductive material and the distance between each other. Distance between the conductive plates will change the capacitance by keeping the same area for the conductive plates. The capacitance increases when the distance between the conductive plates decreases, the capacitance decreases and when the distance between the conductive plates increases.

Resistive Pressure Sensors: The resistive pressure sensors have a correlation between pressure and electrical resistance. These sensors can be made of different conductive materials in different structures using different production techniques. 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 = R*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.

Optical Textile Sensors: 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.

The optical textile sensors can be used to sense textile displacements and pressures in applications where the electrical currents cannot cross textile substrates.

Temperature and Humidity Sensitive Textile: There are several possibilities to build an e-textile to sense temperature and humidity changes. Resistance and capacitance are the main principles to build humidity textile sensors. The resistive humidity textile sensors answer 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 divinyl siloxane benzocyclobutene (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 compatible 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. 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. All of the conductive polymers and carbon based conductive particle polymers have a temperature dependent response. For instance, PEDOT–PSS coated fibers experience a decrease in resistance when under high temperatures. Fiber optic sensors can also be used to sense temperature changes as well as temperature sensitive inks.

Sensors definitions and classifications: Sensor is an information providing device which is mostly in the form of an electrical signal. It can sense the measured object or medium and also used to emit a signal which is related to the variations of measured quantity.

Chemical sensors are miniaturized analytical devices which can be used to deliver real time and online information at the presence of specific compounds or ions in complex samples.

Biosensors are self-contained integrated devices that are capable of providing specific quantitative or semi-quantitative analytical information using a biological recognition element (biochemical receptor) that is in direct spatial contact with transducer element.

Optical sensors or opt(r)odes, represent a group of chemical sensors in which electromagnetic (EM) radiation is used to generate the analytical signal in a transduction element. The interaction of this radiation with the sample is evaluated from the change of a particular optical parameter and is related to the concentration of the analyte. Typically, an optical chemical sensor consists of a chemical recognition phase (sensing element or receptor) coupled with a transduction element.

Mechanical sensors general definitions: The classical system for strain (and deformation) measurements is the strain gauge. Basically, it is made of thin metallic foil and the electrical insulation thin backing substrate. The gauge is attached to the object by a suitable adhesive, such as cyanoacrylate.

A metallic sheet is cut (by lithography or using the acid) to form extremely tight conductive paths in parallel making very long overall conductive path sensitive to elongations in its direction. This geometry maximizes the length of electrical circuit connecting two electrodes on a reduced surface. When the gauge is elongated in the direction of conductive path, it is deformed (lengthened) and the electrical resistance increases.

Capacitive sensors: A capacitive sensor can be an alternative solution to classical strain gauges and a measuring of their resistance changes. Its electrical capacitance varies in function of elongation. Therefore, capacitive sensors measure the electrical capacitance between two conductors deposited on the insulation substrate. The advantage of those sensors is a very high gauge factor (K) going up to 15 to 30 and in the same time the capacitive sensors are less sensitive to an electronic noise and to the temperature changes than resistive sensors.

Piezoelectric sensors: Piezoelectric materials generate an electrical field when they are mechanically excited and inversely they deform when they undergo an electrical current. This phenomenon may be explained by their crystalline structure. A large number of materials exhibit this property, and they could be classified into different families: ferroelectric oxides, quartz similar compounds, semiconductors, polymers, and ceramics. They can be found in different forms (independently on the chemical family), composites, or thin layers. The ceramic family is the most represented, and the most used material currently is PZT Led titanium zircon, for its high coefficient of piezoelectricity and its thermal stability.

VI. Application

Life belt: Life belt is a wearable smart device for trans-abdominal health monitoring that ease the parental monitoring procedures for both the mother and the fetus. This life belt is very useful for pregnant women. In remote area most of the pregnant women works during pregnancy that can occur many health problem like high blood pressure, kidney or hearth disease during multiple pregnancies. Obstetrician use a support tool call Life Belt for monitoring the patient remotely and evaluate automated preliminary diagnosis of their condition based on collected and analyzed vital signs. It can also alert the patient condition and access patient's medical data at any time.

Life jacket: Life jacket is a medical smart device wear by the patient that consequently reads their blood pressure or monitors the heart rate; It can collect the data and store in computer which can read only by the medical staff. For the paramedics a specialized camera in the form of headwear has been developed. Visual data taken by the camera can be transferred directly to medical staff at the hospital enabling them to advise instantly on appropriate treatment.

Military/defense: How smart clothing can be used to increase the safety and effectiveness are explored by the military forces all around the world. It is used for the real time information in the situation like extreme environmental conditions and hazardous situations to increase the protection and also used for survivability of the people working in those conditions. Wireless communication to a central unit allows medics to conduct remote triage of casualties to help them respond more rapidly and safely. The requirements for such situations are to monitor vital signs and ease injuries while also monitoring environment hazards such as toxic gases. . Improvements in performance and additional capabilities would be of Immense assistance within professions such as the defense forces and emergency response services.

Sportswear: Sportswear area of important smart clothing developments. In general a number of important functions can be implemented using smart devices or clothing. These include: Monitoring heart rate, breathing, body temperature and other physiological parameters; Measuring activity, for example determining the number of steps taken, the total distance travelled; Acting to actively stimulate muscles e.g. using electrical muscle stimulation; Work against activity to provide smart resistance training; Record aspects of performance, such a foot pressure or specific joint movements; Protect against injury.

Smart sports shoe: Global Positioning Systems (GPS) incorporated into walking shoes which allow the user to be tracked by mountain rescues services. They can also used to monitor the where about of young children. Gloves that contain heaters, or built in LED‟s emitting light so that a cyclist can be seen in the dark.

The sensory baby vest: The sensory baby vest is equipped with sensors that enable the constant monitoring of vital functions such as heart, lungs, skin and body temperature which can be used in the early detection and monitoring of heart and circulatory illness. It is hoped to use this vest to prevent cot death and other life-threatening situations in babies. The sensors are attached in a way that they do not pinch or disturb the baby when it is sleeping.

VII. DRAWBACK AND SOLUTIONS

1. Size of Li-Po (lithium polymer) batteries are one of the major drawbacks, which is required to fulfill power demand

One of the solution is with the use of power harvesting

2. Features like Wash ability and non-toxicity are yet to be implemented with this technology

A wearable control board known as Xadow is used which solves the purpose. It has TPU(Thermoplastic Poly Urethane) film which protects the conductive thread up to 50 washes

3. Fibres are very fragile that breaks easily due to the electric field generated, their sizes are very small between 100 to 250 mm diameter and also has risk of electrical reliability

A Technique called Macro Fibres Composites, which helps improving the fibre filling rate and increases the contact surface between fibres and electrodes. This leads to increase in its efficiency up to 50%

4. Strategies for component encapsulation and e-textile life span needs to be worked on.

Sensors and electronic components are encapsulated and attached to the fabrics. These sensors are miniaturized conventional elements along with components like micro-controllers, integrated circuit chips, resistors, capacitors and optical fibres.

5. Fabric sensor capacitors have limitations such as creep, poor resilience, signal drift and hysteresis

Robust insulating methods and compensation need to be developed to account for these issues. Capacitive fabric sensors can be built at many scales, from micro components to large sensing areas

VIII. CONCLUSIONS

Smart textiles provides a novel means to sense and ability to interact with the body of the wearer's through sensors it has the capacity to monitor according to the environment. As we can see that as on today’s date it is always focused in physical sensing according to the environment. it is always important that it cannot be compromised by the wearer's comfort and safety. Thus it has a great growth and opportunity in the stream of sports, science, exercise and many more areas.

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