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A Review Paper on "E-textiles" and its Applications

Tariq Ahmed

University Women's Polytechnic, Aligarh Muslim University, Aligarh-202002, (India)

ABSTRACT

In the field of e-textiles, innovative wears or smart and intelligent clothing new developments enables the providers to design fabric which can sense, interact and response according to the environment. E-textiles add behaviour and functionality to the fabric. The introduction to new smart materials opens up future opportunities to generate range of innovative projects related to sports wear, fashion, military, healthcare, security, safety, aerospace etc. It is not possible to integrate the computing technology into the fabric until there is development in the field of fibres and structures, miniaturization of electronic components and wireless technologies. In recent years we have seen a tremendous growth in all three departments which makes the smart clothing feasible. This paper provides the review of e textiles, describing the current status of development of e textiles by highlighting the salient applications of e textiles in different fields.

Keywords— smart fabric, e-textiles, sensors, actuators, energy scavenging

I. INTRODUCTION

Till date large and complex number of electronic devices have been developed and the first large scale fully functional digital device revealed on February 15, 1946 called ENIAC (Electronic Numerical Integrator and Computer) [1]. In recent years the advances in electronic components make it possible to merge these components with clothing defined by the term "electronic textiles" or "innovative wears". It is not simply placing the components on textiles but integration of components should be done in a seamless manner. The main focus of designers and developers of this technology to achieve practical implementations and deployment includes flexibility, miniaturization, power consumption, strength, conductivity, wearability, comfort, water resistant & washable and above all safety. Electronic textiles is the new area of research to bring various new applications in the field of medical, military or security staff and other various sectors. Many researchers have experimented and designed smart fabrics like smart shoes, smart shirts, and smart undergarments. So day by day we are getting habitual with carrying technology as technologies related with fabric such as conductive or responsive yarns are consistently getting better to deliver reliable and durable products. Electronics components have become smaller, smarter and require less power. With the existing new power efficient technologies like BLE (Bluetooth Low Energy) and 4G we are able to exchange huge volume of data with higher data rate and could remain connected all the time. This has introduced further change in the research and developments of e-textiles. But still there exists certain constraints in the smart garments success due to which yet it has not reached to the masses. The major road blocks of e-textiles are – development of proprietary products, lack of new investments, lack of collaboration with big suppliers, lack of manufacturing aid, Reliability (e.g. failure may occur due to number of washes, Battery backup technology or power requirement), wearable discomfort, and price.

II. E-TEXTILES

Electronic textiles embed the electronic components (e.g. microcontrollers, actuators, sensors) into the fabric in a seamless manner such that all the interconnected devices within a fabric can exchange signals among them. It is the fabric that has the capability to conduct electricity and could integrate electronic devices and interconnection into the garments. It uses metallic fibres (e.g. threads of silver or stainless steel) to develop e-textiles. E-textile is the new generation textile providing range of options for use in several applications and has an objective to generate smart textile products that communicate by merging smart materials and computing technologies into garments applications. Electronic textiles are different from wearable computer because it put emphasis on seamless union of smart materials and computing technologies. However, to use E textiles effectively it should offer the following characteristics [2]:

- Reliability
- Less visible to others
- Stretchable
- Water proof and easy to wash
- High conductivity in conducting threads
- High flexibility in conducting strands
- Low cost manufacturing
- Low maintenance cost
- Light weight

III. TYPES OF E-TEXTILES

E textiles can be classified differently based on component's behaviour in a smart structure, comfort and technologies types, integration of components.

3.1 *E-textiles classification based on component's function in a smart fabric* [3, 4]:

1. Passive smart materials do not have the capability to react and behave and could only recognize external stimuli. It could be sensors, conductors, resistors, capacitors etc.
2. Active smart materials hold the capability to respond the perceived external stimuli. It can sense as well as provided with the features to move or control the mechanism of the system. For example sensors and actuators
3. Dynamic smart materials are quite intelligent to restyle themselves to act in an organized manner.

3.2 *E-textiles classification based on comfort and technologies type* [5]:

1. Soft or hard supports – flexible , stretchable , comfortable fabric
2. Soft or hard components-software or hardware components

3.3 *E-textiles classification based on integration of components in a smart fabric* [6]:

1. Classical or Aesthetic electronic textiles- It is simply integration of basic or not dynamic enough electronic components like capacitors, conductors, resistors, ICs, light emitting diodes etc. into the fabric. This fabric can light up or can change color by collecting energy from inputs like vibrations, sound or heat.
2. Advance electronic textiles -it includes the integration of passive or a active smart materials straight into the underlying material i.e. fabric.

IV. COMPONENTS OF E-TEXTILES

4.1 Textile Buses, Connectors and Integration Techniques:

Textile buses are the wires that are laid down on the fabric. These buses are in the form of conductive strands or yarns. It is a vital component that defines the path to transmit/receive digital or analog signal. In recent years improved technology has supported to directly integrate conductive fibres into the substrate. These lines could be merged in the fabric at different production stages like woven, knitted or nonwoven, sewn or embroidery, spraying and printing structures or printed circuit boards (printing layers of conductive or non conductive wires). These transmission lines are also used to provide power to the fabricated electronic devices. Fibre strands may vary from very high quality metal threads covered around a non-conductive core fiber, to strands with a metal core wrapped by non-conducting threads [7]. Copper wire, Stainless-steel fibers, polymer fibers, metallic organza, silver thread, thin Kapton sheet are the examples of smart materials that have been used to produce fabric sensors[8].

To generate intelligent fabric conductive wires and electronic components must be integrated into the garments. The component integration specialization requires: coupling, pasting, soldering. Coupling involves simply joining the electronic component's wires straight to woven or nonwoven garments to join other component. Pasting technique uses conductive adhesive to integrate electronic components into flexible textile surface. Soldering is used to embed the electronic components into garments by fusing the filler material (could be an alloy) between the surfaces. Another way to fasten the electronic components into the fabric is through specially designed connectors. With the support of connectors it becomes easy to fasten or unfasten the electronic components. DigiKey Ribbon Cable Connector [9] has three traces of conductive ribbons and four crimping slots cable connector that enables circuit connection. Fabric USB connector is to provide most robust connections.

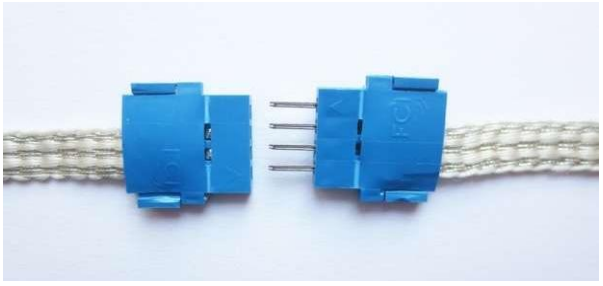

Fig. 1 DigiKey Ribbon Cable Connector [9]

Fig. 2 Fabric USB connector [8]

4.2 External Attachable Modules in E textiles

Recent research and developments in the field of mico and nano technology enables to detect physical and physiological parameters through sensors and microcontroller process this data to control various events automatically and in real time. The computing devices have become small and also integrated with sensors, radio interfaces, and wireless technologies on a single tiny board. These advances in computing and communication technologies add possibilities to implant various computing devices into our clothes. These may include microcontrollers, sensors, actuators, power source etc.

4.2.1 Processing Unit

The processing unit includes hardware and software where software provides list of instruction to provide real time dynamic functionality. The processing units generally microcontrollers, add functionality, smartness, fun, high interaction and communication level into the textiles. It brings up intelligence to the e textile. These boards are small, power efficient, programmable, and expandable through expansion slots.. There are number of micro controller units that can be embedded into the fabric like Teensy 3.1, Arduino Lilypad, Gemma, Adafruit Flora, intel Edison, Arduino Pro mini, Arduino Uno etc.

4.2.2 Sensors

Sensors are designed to measure and inform about pressure, moisture, light, heat, force or acceleration, speed, position or any other physical or environmental phenomenon. Sensors add sensing properties to the fabrics. The data signalled by a sensor integrated in a fabric could be used to do various tasks such as thermocouples to sense temperature, sensors to sense body parameters, pressure sensors, location sensors may give you the location of the user, biosensors can measure skin temperature, heart rate, EEGs, EMGs and ECGs, etc

4.2.3 Actuators

Sensors detect the signals and actuators take action upon the perceived signals. Actuators take action independently or may be supervised by the micro-controller. Actuators can show reactions to the signals that lead to change in colour or shape & may let out substances. For example chromic materials modify their optical properties due to parameters such as light, temperature, mechanical stress etc. Actuators like light emitting diodes in e textiles convert electric current into light.

4.2.4 Portable and Tiny Batteries and Ambient Power (or Energy Scavenging)

Power source is the major concern as it is required to run components fabricated into the fabric. At present there are no full proof technologies to provide power source to many electronic components that we think to implant into smart fabrics. The discrete rechargeable batteries are getting smaller and at present is the perfect solution for power back up in smart fabrics. But in a long run this alternative is not feasible so new power source technology objective is to launch new techniques that could be integrated easily into the fabric and free from frequent recharging and replacement. The key goal is to develop power generation techniques capable to convert energy available in environment into the electrical energy. The ambient power acquired energy from various external sources like solar power, kinetic energy etc. and collect it to run small devices.

Today there are number of sources for energy scavenging such as piezo electric systems, pyroelectric, thermoelectric, natural energy, light energy etc. Piezo electric effect converts the mechanical strain such as human motion, low-frequency seismic vibrations, and acoustic noise into electrical energy. Piezo electric materials can be integrated into garments to derive energy from arm and leg motions or blood pressure etc. Pyroelectric effect generates voltage with change in temperature. Thermo electric materials harvest energy from heat sources to electrical energy. The electrical energy is produced due to thermal gradient formed between two different conductors called Seebeck effect. Light energy scavenging converts sunlight or room light received through devices like photo sensors, photo diodes, or solar panels into voltage. These harvesting modules could be integrated into fabric to gather, collect and manage power requirement of small components but current technologies are at its infancy to provide the power density needed by the many components integrated into the fabric. The research and development in the near future will deliver the textiles to produce energy scavenging garments with different techniques as per user choice.

A project is proposed for energy scavenging fabric using rapid printing processes and active printed inks [10, 11]. This technique will provide cost efficient, flexible and quick method to generate energy scavenging textiles. A new technique converts mechanical energy into voltage using fiber coated with zinc oxide nano wires. Yarns spun from the fibers are capable to scavenge any form of vibration or motion for electric current [12]. Another method enables solar energy harvesting via new type of solar cells. These new generation solar cells implanted into the fabric can deliver electric current for electronic components. So the photovoltaic is the new and remarkable method to deliver the power to the devices and easy to embed in clothing. [13-15].

4.3 Communication Technologies:

Nowadays wired networks are replaced with wireless networks. A large number of wireless technologies exist that allow high bandwidth data transmission at longer distance. These technologies include GSM, WLAN, WiFi, UMTS, WiMAX, and LTE that can provide wireless communication network. For short range wireless communication Bluetooth (BLE) or infrared technology could be used. Wireless technologies provide the ability to remain connected anywhere and anytime. Sensors can also establish wireless network called Wireless Sensor Network (WSN). Wireless technologies help to communicate without wires with the devices implanted into the fabric. It supports smart fabric to communicate with other smart fabric or it may transmit/receive data to/from external remote device. A wireless network of smart fabrics can also be established to exchange data using wireless technologies.

V. APPLICATIONS OF E-TEXTILES

5.1 Health and Medical Care

Dynamic E textiles in the field of health and medicine sector help patients or doctors to monitor complex movement patterns, cardio vascular diseases (e.g. congestive heart failure, coronary artery disease, heart attack, and tachycardia) via reading change in ECG patterns, body temperature, stress levels, respiration problems (like dyspnea, sleep apnea syndrome, chronic obstructive pulmonary disease, or Asthma), pressure, noise, analysing body fluids via biochemical sensors etc. The various advances in nanotechnologies, sensors/biosensors, wireless communication technologies enables to deliver information (includes multi-parameters) of a patient wearing smart clothing straight to doctors or practitioners via wireless assistance mechanism. This would provide constant supervision to the patients. There are number of sensors used in medical to measure different parameters such as accelerometer, magnetometer, light and temperature, pressure ,flex, ECG, respiration electrodes, pulse oximeter, blood pressure and galvanic skin response, etc.

Wealthy project of EU-projects developed garment for cardiac patients to transmit physiological signals from the sensors knitted into garments to a computer or a cell phone [17].Other projects of EU are BIOTEX, OFSETH. BIOTEX uses chemical and biosensors integrated into the fabric to monitor biochemical parameters such as blood and sweat of the user [17].OFSETH focuses on optical technologies(i.e. optical sensors) to measure parameters like cardiac, respiratory rate, pulse oxymetry via Fibre Bragg Gratings sensor and near infrared spectroscopy [17]. Mamagoose pyjamas designed by Verhaerth Design and Development and the University of Brusselsin in Belgian for babies to monitor heart beat and respiration [18] .A ‘bionic glove’ is designed for paralysed hand to electrically stimulate muscles [19]. Some other common products of e-textile in medical or health area are: Life Shirt, Life Jacket, SmartMattress, SmartSheets, SmartPillow cases, Smart

Hospital Gowns, mouth guards and helmets for head injury detection [20]. Scough, New York has designed a scarf allows you to breathe pollution free air by filtering and cleaning the air. Smart T-shirt launched by Cityzen Sciences , a French company that includes components to measure heart rate, GPS location, running speed, altitude and best suited for personal health management and sports person.

5.2 Security Personnel

E textiles enhance the level of protection and survivability of the soldiers in the battle field. The future trends of e textiles shows features to provide safety against awkward weather conditions, boiweapons, supports soldiers to communicate in a secret manner. Today soldiers carry heavy loads includes items such as communication devices, weather gears and other new technology devices so e textiles has the potential to offer tiny components, light weight technologies embedded into the soldier's uniform that will ease the burden of combat soldiers. The new improved technologies enable to generate e-textiles that are chemically protective which safeguard military or security guards against hazardous chemicals and microorganism attacks, uniforms that are capable to change colors depending on the surroundings. Due to e textiles the new uniforms would be lighter and loaded with all new technologies required by soldier in a battle field. Sensatex smart shirt helps soldier if he is injured by sending wound information and soldier condition to the assistance service center [21]. The doctor may read the condition of the soldier's injury by analyzing the respiratory rate and heart rate [21].Shimmering Flower is designed with a collection of 64 fabric pixels and each pixel is uniquely addressable and slowly changes color in a controlled manner [21]. Emergency disaster personnel like fire fighters and others may wear smart textiles for their safety such as jacket attached with oxide sensor, temperature sensor, heat flux sensor, a GSP antenna, visual alarm and buzzer to declare fire fighters of emergency. Two sensors are also attached to detect in activity at the collar and also at the wrist. Accelerometers detect the user's activity [22].

5.3 Sports Wear

Smart sports wear could help athlete to record progress during workout or practice sessions. It could generate summary of your performance and allows your trainer to monitor it in real time. It may advice according to data transmitted to you or your trainer when the sportsperson is pushing him beyond limits or where you lack in your training in turn he can modify his work out.

Recently Adidas launched, ClimaChill developed by integrating titanium and aluminum into the fabric to provide cold sensations when the body temperature becomes hot. It facilitates the user to stand or workout in hot weather conditions. Under Armour E39 Electronic compression shirt featured a detachable unit called "bug". Bug gets very easily attached into the shirt. Bug can sense heart rate breathing rate, skin's surface temperature, and three dimensional running speeds and can transmit valuable data using Bluetooth technology to portable computers for monitoring by trainers. Bug gets very easily attached into the shirt [22]. Adidas Adizero F50 Soccer Shoe includes miCoach speed cell tracking device that sense progress parameters speed, maximum speed, number of sprints, distance, steps and stride rates and transmit measured performance parameters wirelessly to remote computing devices [22].

Entertainment:

Instead of carrying physical entertainment gadgets like disc players, audio MP3 system, game panels, digital cameras or video cam user can wear them. These personalized entertainment units can be integrated into the fabric that is the beauty of smart garments. Philips Research Laboratories designed a jacket fabricated with built

in microphone and headphone [23]. To play normal or virtual reality computer games number of commercial gloves fitted with sensors are available Nintendo power glove, P5 glove etc. An electronic glove in the field of music generates different musical sounds with movement of hand [24]. This can also be used to help patients to improve their fine motor skills by detecting patient's hand movements. Another application come up for party goers to wear smart garments that changes color or produce rhythmic light with the beat of the music and body movement.

5.4 Personal communication

E textiles have provided opportunities for electronic communication via dynamic electronic textiles. E-textiles embed input, output communication and processing units (such as monitors, keypad, microphones, power source, buzzers, internet connectivity) required for communication into the fabric. This will increase the mobility, flexibility and remove the need to carry hand held devices. It has wide application in personal communication and business interactions. For example workers may wear smart textiles uniform with built in electronic communication infrastructure for interacting with co-workers. This system could support e-mail, voice chat or video conferencing.

5.5 Fashion and Interior Decoration World

In fashion and interior decoration applications designers are more focused on garments decoration to receive huge attention. Luminous textiles are used in glowing textile panels or dresses for interior and fashion world. Another project uses light techniques to create light and shadow effects into the costumes. The designers have come up with highlights like LEDs integrated costumes that moves rhythmically with music, laser dresses that are deflected by laser lights, video costumes integrated with large number of LEDs to display motion pictures. The HugShirt designed by Francesca Rosella and Ryan Genz the co-founders of CuteCircuit Company. *"Embedded in the Hug Shirt there are sensors that feel the strength, duration, and location of the touch, the skin warmth and the heartbeat rate of the sender and actuators that recreate the sensation of touch, warmth and emotion of the hug to the Hug Shirt™ of the distant loved one"* [25]. Smart textiles in interior design include smart curtains and upholstery, smart carpets, smart bed sheets, smart artificial flowers, smart tablecloths, smart sofa etc. The applications of smart clothing are endless. The future trends are continuously launching advanced fabric products such as new filaments portfolio for applications that require high heat resistance, high strength, and low flame, smoke and toxicity, self-healing fabric made up of lightweight, waterproof nylon ripstop, combined with a double-sided coating best suited for mountaineers , skiers to repair minor damages to their clothing by sensing body heat, lift-assisting wearable exosuit developed as safety provider for employees who lift products, sleeping bag sleeve effective against mosquitoes, dust mites, ticks and bedbugs, capture and control volatile organic compounds like human odor, synthetic or plastic smell in the fabric, shape-shifting sofa called Lift-Bit reconfigures itself into a bed, chaise lounge, group of armchairs or a playground for kids via motion tracking sensors, fabric based portable bridge reduce challenges and appropriate for emergencies, cooling towel based on body heat control technology provides better cooling power and particularly designed for sports person to overcome effects of overheating and many more [26].

VI. CONCLUSIONS

Research and development of e-textiles enable integration of sensors, actuators and microcontrollers in a seamless manner such that user can wear or use them comfortably. It is also expected that power source or tiny

storage units could also be embedded into the fabric. In the near future dynamic textiles will encounter bumper demand due to wide application in areas such as military, sports, medical and health care, entertainment fashion, safety, etc. Due to innovative development activities the cost of smart textiles will also come down that will lead to higher demand. It is anticipated that people will wear electronic components instead of carrying them. To completely realize benefits of e textiles technologies, researchers, manufactures and service providers have to work towards adoption of these technologies by going through user requirements and performing a comprehensive analysis to make his life easy, dynamic, safe and better.

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