2. REVIEW OF LITERATURE

The review of literature pertaining to the study "**Design, Develop and Evaluate the Smart Wearable Electronic Fabric for Monitoring Healthcare**" is given under following heads:

2.1. Smart Textiles

- 2.1.1. Classification of smart textiles
  - Passive smart textiles
  - Active smart textiles
  - Ultra smart textiles
- 2.1.2. History of the smart textiles
- 2.1.3. Functions of smart textiles
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2.1. Smart Textiles

The word ‘smart textiles’ has generated high discussion in the industry and media nowadays. Smart textiles are those that are non-traditional, have interactive functionalities and have new or non-commodity applications (www.textile-future.com). Smart textiles belong to a fast evolving high tech development in the field of textiles (Hertleer and Langenhove, 2010). ‘Smart’ and ‘intelligent’ textiles are frequently used term which refers to a material that is able to sense changes (stimuli) happening in its surroundings, to react to these changes and adapt to them through integration of functionalities in the smart textile structure (Wood, 2016).

Stoppa and Chiolerio (2014) define smart textiles as textile products such as conductive fibers and filaments, yarns are together with fabric structure by weaving, knitting, embroidery or non-woven method, which are able to interact with the environment and react to them accordingly. Smart textiles or e-Textiles will serve as a means of increasing public welfare in the society. It is important to clarify the meaning of word ‘smart’ in the text smart textiles as either ‘clever’ or ‘intelligent’, as ‘fashionable’ or ‘chic’. So that the smart clothes are combination of both intelligent and fashionable clothing (Jain and Agarwal, 2005). The words ‘smart’ and ‘intelligent’ textiles are frequently used inter changeably in the textile communication industry (Wood, 2016) and are embedded in the daily objects like belt, watches and caps. The intelligent character of the textile material can be introduced at any level like in fiber level, other threads can be included to the textile material, a coating or finishing can be applied to the textile material, and even it is possible to closely connect independent appliances completely with the textile (Langenhore et al., 2007).

Smart textile represents the new generation of textiles anticipated for use in several furnishing, fashion, technical, protection and medical textile applications. It is based on three main areas: textile design and technology, smart materials and computing science and engineering. Each of these areas contribute in its own way to the whole system by textile design and technology with its materials and fabrication process, smart materials with its ability to react to different stimuli, computing science and engineering for the design of dynamic functionality and working process (Singh, 2005). The vision of the smart textile is to find interacting textile product by combining smart materials and integrated computing power into textile applications. By introducing these combination in textile structure offers on opportunity to develop textiles with a new type of behavior and functionality (Leitch, 2003).

The smart materials in our surroundings are being ‘intellectualized’ that are described as materials which are able to change its basic character according to outside stimuli or conditions (Dadhiwale, 2015). Today’s technology allows us to complete a certain function with fewer components and single material whereas, several components.

‘Smart’ or ‘functional’ materials usually form important part in the ‘smart textile system’ that are capable of sensing, reacting and responding to the environment via an active control mechanism. Smart material, occupy a ‘Technology Space’, which can be divided into different types according to its fundamental characteristics and includes the areas of sensors and actuators (Jamadar and Krasovitskii, 2016).

Smart materials with its one or more unique properties are altered significantly by external stimuli in a controlled fashion. Hence this material has built-in or intrinsic sensor(s), actuator(s) and control mechanism by which they are capable of sensing a stimulus, responding to that stimulus in a predetermined way and extent, in a appropriate time and returning to its original position as soon as the stimulus is removed (Kamila, 2013).

2.1.1. Classification of smart textiles

Weather (1998) derives that smart materials can also be classified into two categories i.e., either active or passive. Active smart materials possess the capacity to modify their geometric or material property under the application of electric, magnetic or thermal fields, therby it acquires an inherent capacity to transduce energy. Pie zoelectric materials, shape memory allays, magneto-strictive material are examples of active smart material which can be used as force transducers and actuators. On the other part, the non-active materials are called passive smart materials. Even though they are smart, they lack of the inherent capability to transduce energy. Fiber optic material is a best example for passive smart material that can act as sensors but not as actuators or transducers.

When smart materials are defined due to their function and behavior they are usually divided into passive smart materials and active smart materials (Langenhove and Hertleer, 2004). At the same time, when they are defined due to its nature and fundamental features of the ways in which each material reacts, they are divided quite differently. This kind of categorization is useful in order to present an overview of the smart materials already developed and the smart materials are classified under three categories – sensors, actuators and conducting materials that are particularly relevant to smart textile technology (Addington, et al., 2006).

- **Passive smart textiles**

The first generators of smart textiles, which provide additional feature in a passive mode that is irrespective of alteration in environment. For example, optical fiber embedded fabrics, conductive fabrics and wide range of capabilities, including anti-microbial, anti-odor, anti-static, and bullet proof. Passive smart materials can be derived as sensory devices or sensors that can only sense the environment but can't react. UV protective clothing, multilayer composite yarn and textiles, plasma treated clothing, ceramic coated textiles, conductive fibers, fabrics with optical sensors are few examples of passive smart textiles (Tao, 2001).

- **Active smart textiles**

The second generation of smart textiles has both actuators and sensors which adapt their functionality to specific agents or to changing environment automatically. Active smart materials can sense the external stimuli form the environment and also react to them accordingly; they have actuating function along with sensing device. Phase change material, shape memory, chameleonic, water resistant and vapour permeable (hydraophilic / non porous, thermo regulated, heat storage, vapor absorbing, heat evolving fabric and electrically heated suit are examples of active smart textile materials (Zhang and Tao, 2001).

- **Ultra smart textiles**

Very smart textiles are the third generation of smart textiles which can able to sense, react and having the gift to adapt themselves accordingly to the environmental conditions or stimuli. A very smart textile essentially comprises of a unit, which works like the brain, with cognition, reasoning and activating capacities. These may deal actively with life threatening situations or keeping highest level of comfort specially during extreme environmental condition. The production of ultra smart textiles is now possible by combining traditional textiles and clothing technology with other branches of science like structural mechanics, material science, sensor and actuator technology, latest communication, advanced processing technology, artificial intelligence and biology. For example, spacesuits, musical jackets, 1-wear, data wear, intelligent bra, sports jacket, baby vest, smart cloths, and wearable computer (Shyamkumar et al, 2014).

2.1.2. History of the smart textiles

Civilization has brought a tremendous change in the humans life and things are changing day by day in many fields of science and technology, which have direct impact on human being (Dadi, 2010).The basic materials needed for constructing smart textiles, conductive threads and conductive materials have been present from around over 1000 years. For example, artisans wrapped fine metal foils mostly gold and silver around fabric threads for centuries to enhance the decorative fabric. Also, many gowns of Queen Elizabeth are embroidered with gold-wrapped threads for a gleaming accent.

At the end of the 19^{th} century, the revolutionary changes took place in the development of people and made to grew accustomed to electric appliances. The designers and engineers began to do connective combination of electricity with clothing and jewellery. For example, they developed a series of illuminated and motorized necklaces, hats, broaches and costumes like light – studded evening gowns. The Museum of Contemporary Craft in New York City has done a ground breaking exhibition named body covering mainly focused on the relationship between technology and apparel. Astronaut’s space suits along with clothing were highlight in the show that could inflate and deflate light up and heat and cool itself. The designer Diana Dew exhibited collection of work has textiles such as line of electronic fashion, including electroluminent party dressed and belts that could sound alarm sirens.

2.1.3. Functions of smart textiles

Smart textiles functions in classified in five groups: sensoring, actuation, data processing, communication and energy. Sensoring achieved progress at the moment and many parameters measured are as follows:

- temperature
- acoustic: lungs, digestion, heart, joints
- biological and chemical
- pressure: blood
- bio potentials: cardiogram, encephalographs, myographs
- ultrasound: blood flow
- movement/motion: respiration
- odour: sweat
- radiation: IR, spectroscopy
- electric skin parameters
- mechanical skin parameters

Permanent monitoring for those traditional parameters are upcoming with new perspectives and well-known among these parameters are cardiogram and temperature. Data processing is the key function in smart textile and new self learning technique is required because collected data are numerous with multiple complex interrelationships and are time dependent (Langenhove, et al., 2007).

Actuation is the function that deals with actuators in smart textiles which makes response only when it is followed by an adequate reaction. The main modalities of actuation are light, sound, heating and motion. The mechanisms of actuation are mechanical, chemical, optical, thermal and electrical. Communication and energy are the second important functions that fulfill the purpose of smart textiles in effective way.

Communication covers network system and energy deals with power supply to the smart textiles (Mestrovic, et al., 2007).

2.1.4. Concept of smart textiles

The basic concept of smart textile consists of a textile structure that senses and response to different stimuli from the surrounding environment. In its simplest structure, the smart textile senses and react automatically without a controlling unit, and in its complex structure, textile sense, react and respond to a particular function with the use of a processing unit (Figure 1). The figure explains that the smart technology have the ability not only to sense and react to the changes in environment but also to activate measures to enhance the functionality (Worden, et al., 2003).

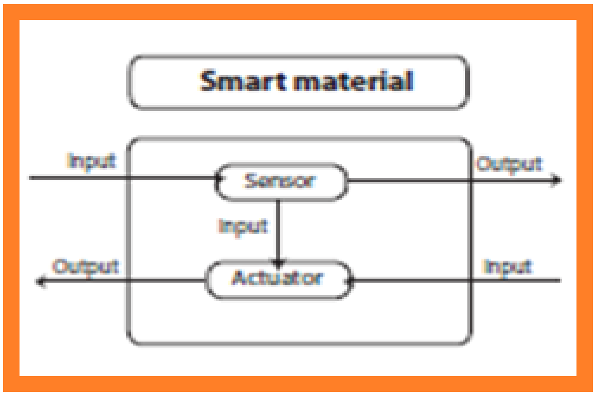

Figure.1 Structure of Smart Textiles

The mechanism of smart textiles in responding to various stimuli and changing its size, shape or color according to incorporated properties is shown in the Figure 2.

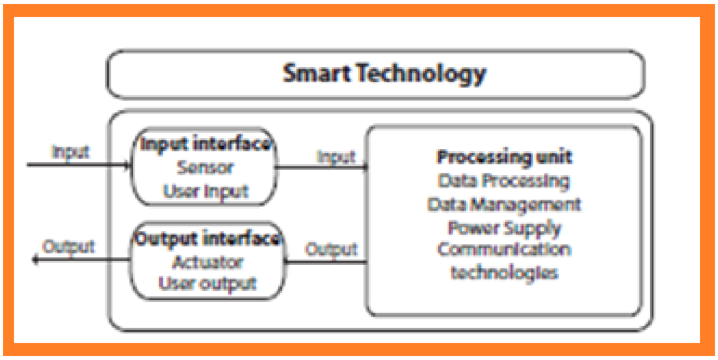

Figure.2 Mechanism of Smart Textiles

2.2. Smart Textile Technology

The integration of smart technology with textiles and clothing continues to develop academic and industrial literature. The basic function of clothing has changed from a means of covering or protecting humans to an 'instrument of augmenting human capabilities' as modern digital lifestyles demand has high ubiquities connectivity (Jeong, et al, 2010). The technology of smart textiles integrates almost all fields of applied sciences namely Fiber technology, Material science, Textile chemistry, Structural mechanics and Aviation hydraulics, Cloth manufacturing technology, Artificial intelligence and Telecommunication, Electronics and instrumentation, Molecular biology and Organic chemistry, Biotechnology, Information technology, Molecular engineering, Nanotechnology and Theory of chaos and randomizations.

These applied sciences are combined with one another to produce a fashionable textile that gives comfortable and luxurious life (Dadhiwale, (2015) Lymberis, (2003)). The vision of Smart Textile is to create textile products that interact by combining smart materials and integrated computing power into textile applications. The introduction of smart materials and computing technology in textile structures offers an opportunity to develop textiles with a new type of behavior and functionality. Besides behavior like sense, reaction and conducting electricity, the textile will be able to perform computational operations (Leitch, 2003). Smart Textile and computing technology are introducing a shift in textile, from a passive to a dynamic behavior, from textiles with static functionalities to products that exhibit dynamic functionalities. But the convergence between textile, smart materials and computing technology may not only affect textile products. It may also change the way we design and use computer artifacts. There will be another dimension in textile design, which is interactivity, but there will also be another dimension in computer artifacts, the textile structure. The shift of dimensions will affect the use, design and aesthetics of textile and computer products. New dynamic forms of behavior change the application area and the way we use textiles (Carroll, 2003).

2.3. Conducting Materials

Besides sensors and actuators, group of materials that conducts electricity are called conductors. They are usually not categorized under sensors and actuators but, due to their conducting nature they are linked with sensors and actuators to transfer data (Harlin, 2006). In general, the materials such as metallic yarns, optical fiber, yarns from conductive polymers, polymeric threads and conducting inorganic films may be integrated into the textile structure for the formation of fabric – based electrical circuits (Ghosh, et al., 2006). Clothing or fabrics constructed with conductive fibres such as carbon, gold, stainless steel, silver or copper offers great potential by facilitating the integration of 'soft' networks into fabrics thus making them 'Intelligent' and 'Smart' (Thomas, 2014).

Conductive materials are used as flexible sensors. They can take many different forms, such as fibres, incorporated into flexible skin-tight garments to measure joint motion, strain, as the resistance of the garment changes (Gibbs and Asada, 2004), polymer, yarns, fabrics, polymers, inks, coatings and stitching or embroidery (Tang and Stylios, 2005), easily made on a computer- controlled embroidery machine (Tao and Zhang, 2001a and Post and Orth, 1997).

Conductive textile materials are, strictly speaking, not intelligent. They do not react to their environment, but they make many smart textile applications possible, especially those that monitor body functions. They are widely used in smart textile applications such as sensors, communication, heating textiles and electrostatic-tic discharge clothing. Electro conductive materials are required in sensors, actuators and heating panels and the best-suited materials are highly conductive metals such as copper, silver and steel. Stainless steel and copper yarns can be made flexible, soft and durable enough to be woven or knitted, and electro conductive plastics can be created by mixing conductive polymers, electro conductive fillers such as carbon black, and metal particles (Sinclair, 2014).

The electro conductivity of these materials varies depending on stress, temperature variation, UV radiation and humidity, which can be used as a measuring parameter, (Cochrane et al., 2007). The unique property of wearable electronic communication is its mobility aspect. Wearable electronics is different from smart textile clothing whereas 'smart' means 'clever' and 'wearable computing' is called intelligent. Conductive materials are used to convert traditional textile and apparel products into wireless wearable intelligent computing devices. Conductive materials such as metallic and optical fibers, conductive and non-conductive threads, yarns, fabrics, conductive inks and coating are used to provide conductivity to create wireless textile circuitry says (Dina Meoli and Traci May-Plumlee, 2002).

2.3.1. Conductive fibers and yarns

Conductive fibers are the key element to develop smart fabrics with known electrical properties, capacitance and resistance, etc. There are two categories in conductive fibers, those that are naturally and those with created conductivity by treating and coating, etc. Metallic fibers are developed form electrically conductive metals which are very thin metal filaments, with diameters ranges from 1 to 80 microns or 0.001 to 0.080 millimeters. Metals such as copper, brass, bronze, silver, gold, aluminium, nickel, ferrous alloys, stainless steel, titanium and carbon are some of the metal fibers used currently in smart textile technology (Jain and Agarwal, 2005).

Electrically conductive fibers are produced by coating the fibers with metals, galvanic substances or metallic salts like copper sulphide and copper iodide (Lennox and Kerr, 1990). Coating process basically include electroless plating, evaporative deposition, sputtering, coating the textile with a conductive polymer (Stoppa, 2014).Advanced process of metallization polyamide fibers with silver coating was developed to get yarn strength and elasticity from polyamide and guaranteed electrical conductivity from the thin.

A conductive fibre can be defined as an electrically conductive element having the structure of a fibre. Thus, a metal nail and thick copper wire are electrically conductive but not fibres, as they are neither fine nor flexible. In contrast, for the present purposes, a fine copper wire and silver-coated polymer fibre can both be categorized as conductive fibres. Electrically conductive fibres can be used for anti-static, anti-microbial, anti-odor, shielding and other applications. In electronic textiles, the conductive elements can provide power, deliver input and output signals or act as a transducer. The electrical resistance of metals is of the order of $10^{-5}\,\Omega$ cm, whereas that of a typical insulator would be $10^{12}\,\Omega$ cm. The electrical resistance of natural fibres is governed by the humidity of the air to which they are exposed (Dias, 2015).

Optical fibres are rather stiff compared to standard textile fibres, where as Conductive fibre sensors can be manufactured without losing the general characteristic behavior of a textile. However this might not be of significant importance as footwear are made out of rather stiff materials in comparison to garments. Fibre Optic Sensors (FOS) is made out of polymeric materials. The various physical parameters usually measured with fibre optics are strain/stress, deformations, pressure, temperature, or refractive index (Cochrane et al., 2007). Rothmaier et al, (2008) have successfully developed pressure sensitive textiles based on thermoplastic silicone fibres. When pressure at a certain area of the textile is applied to the fibres they change cross section reversibly, due to their elastomeric character, and a simultaneous change in transmitted light intensity can be detected. Many papers discuss the use of optical fibres as sensors in combination with chromatic materials, where the optical fibre picks up a colour change, caused by the measured stimuli. Coyle et al, (2008) has presented a sensor for measuring sweat during exercise, using a pH sensitive dye incorporated into a fabric fluidic system. This could be very interesting to use in footwear, since the feet produce a lot of sweat. This could be used to give instant feedback to the wearer of health conditions as sweat changes ph when the body is dehydrated or before muscle fatigue.

The advantages of Fibre Optic Sensors are flexibility, stability, light weight, high temperature capacity and no heat production, insensitivity to electro-magnetic radiation and have no susceptibility to electrical discharges. (Rothmaier et al, 2008). FOS can be easily embedded in a variety of composite materials without compromising the host structures and can provide an effective ways for monitoring physical parameters with a single fiber path (Cochrane et al., 2007). With the high growth in wearable devices and electronic textiles in particular, there will be an added impetus for the development of electrically conducting pathways with properties more in line with conventional fibres and yarns. In modern times, metal wires, metal-wrapped yarns, metal-coated yarns, inherently conductive polymers and other technologies have been employed to confer electrically conductive pathways to textiles (Saddamhusen and Jamadar, 2013).

2.3.2. Conductive ink

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). Conductive inks remained fairly stable for decades, only in recent years there have been improvements, as well as innovative new inks to meet the challenges offered by printed electronics making electronic functions possible on textiles (Someya et al, 2010). Printed electronics is the term that defines the use of traditional graphic printing methods to manufacture circuits on media such as polymer films, paper, textiles, and other materials. The promise of low-cost, high-volume, high-throughput production of electronic components or devices that are lightweight, small, thin, flexible, inexpensive and disposable has spurred the recent growth in development of printed electronics technology. One of the biggest issues challenging its development was the lack of materials, particularly conductive inks that could meet the necessary electronic requirements in a thin-film (Pira, 2012).

2.4 Smart textiles applications

In the past few decades, many desk electronic appliances have been made portable because of constant miniaturization in electronics. It is reasonable to assume that, in the future, some of these portable devices will become so small and convenient to carry that they will be wearable (Tao, 2005). The Industry can be broken into four areas namely Sports, Healthcare/Medical, Fashion/Entertainment and Military/Public sector. The areas do overlap in some places, often with similar or even the same technology being repackaged for a different end-use.

2.4.1 Sports

The sports sector has historically been an early adopter of technical textiles and 'high tech' solutions, and this status has not changed for commercial smart clothes and wearable technology products too. Sportswear category can be broadly divided into training/professional sports and casual sports and each category uses different types of technology. Training and professional sportswear uses bio-physical monitoring technologies, overlapping with healthcare. Casual sportswear has been into incorporating entertainment and communication technologies into clothing (McCann and Bryson, 2009).

2.4.2 Healthcare

Wearable technology solutions for medical monitoring are widespread and are usually designed with just one thing in mind, getting the readings at very effective manner. Medical healthcare textile products have a greater emphasis for constant monitoring of biophysical data's like ECG, respiration rate, blood pressure, temperature and movement. Medical testing of these products is essential, with each country having its own set of clinical testing requirements that need to be achieved before a product can be used in a clinical environment. This is often an important factor for companies developing bio-monitoring technologies, as it can cost large amounts of money for product testing. Several companies have targeted the sports industry initially and have later moved onto the medical industry as their products have been developed further, gaining the levels of accuracy and consistency that are required for clinical use. There are two main types of healthcare products: those that are prescribed by a physician (medical healthcare) or those that are purchased by individuals who are concerned with their general heath (well-being). Examples of the latter products and developments include the Wealthy project (Wealthy, 2005), LifeShirt (Vivometrics, 2007), MyHeart Intelligent

Biomedical Clothes (MyHeart, 2008) and HeartCycle (Phillips Research 2008) which are invented by the greater awareness on personal wellbeing of humans to keep them fit by continuous monitoring.

2.4.3 Fashion and entertainment

A fascination with technology means that the incorporation of cutting edge technology is common in the fashion industry. Designers such as Alexander McQueen, Erina Kasihara, Diana Drew and Hussein Chalayan have all produced ranges that explore the integration of technology into clothing. Suzanne Lee's book Fashioning the Future: Tomorrow's Wardrobe (Lee, 2005), takes an in-depth look at the relationship between fashion and techno-logy. The incorporation of electronic technologies into everyday clothing remains relatively uncommon. Entertainment in the form of music and communications is currently leading the way, with the integration of iPod and mobile phone control systems being examples of the few attempts at promoting smart clothes and wearable technology for everyday use. This is likely to expand in the future to include more sophisticated devices such as portable media and games players.

2.4.4 Military, public sector and safety

The military has been one of the largest offerers of wearable computing and wearable technologies. Communication and battle-field command systems use a combination of personal, vehicle- (ground, air and water), static and satellite technologies that all work together. For example in the US military, they are very active in the development of smart clothing and wearable technology solutions (Ajey Lele, 2015). US military aims to introduce the Naval Air Technical Training Center's (NATICK) Future Force Warrior programme by 2020 which is a fully developed bionic warrior suits. This suit would include intelligent armor, bio monitoring, weaponry, communications and exoskeleton (NATICK, 2006).

In UK police forces, suits with head mounted cameras and Personal Data Assistants (PDA) are used for storage and transmission systems to record information as they patrol and interview suspects and witnesses. This will act like the in-car video recording systems. Safety products for monitoring personnel in hazardous or remote environments are also highly desirable, such as monitors of chemical exposure levels and bio-physical status. The military wearable technology could be classified on the basis of sensor application as follows:

2.4.4.1 Improving Aiming Capabilities

Present generation rifles with sensors can track targets, detect wind and weather, and calculate the optimal flight path for the bullet so that soldiers could aim the targets without actually looking at them, shooting around corners or over hills and barricades.

2.4.4.2 Monitoring the physical state of soldiers while on the move

The physical condition of a soldier like vitals such as heart rate, breathing, and hydration could be monitored by putting tiny biosensors on their body. Also the sensors devised to detect commanders in critical situation like injuries and help them to resolve their condition.

2.4.4.3 Better communication between troops and military animals

The field of military wearable technology was expanded to monitor health condition of animals like horse, mules and dogs which are participating in military campaigns by using sensor technologies. For example, a bomb-sniffing dog can be trained to activate a specific kind of sensor for a specific kind of bomb, instantly alerting its trainer and also remotely relaying the information to the commander.

2.4.4.4 Providing 360-degree battlefield awareness

Soldier suits designed with sensors to inform the situation in the surrounding environment include location, weather condition, topographic details, satellite/radar image and enemy troop concentrations could be helpful for the fighters (OleSkaar, 2015).

2.5. Wearable electronics

Electronic textile is distinct from wearable computing technology, because emphasis is given on the integration of textiles with electronic components like microcontrollers, sensors and actuators. The basic materials essential for constructing electronic textiles are conductive threads integrated fabrics and digital and communication systems for integration into every day health care monitoring garments, the electronic components should be designed in a functional, robust, unobtrusive, small and inexpensive way (Ashokkumar and Venkatachalam, 2007). Wearable electronics also called as smart clothing, intelligent clothing and wearables is defined as the clothing that functions with electronics on the moving body. Begun in the last 1960s with embedding computing devices in everyday objects, the field achieved interest with the miniaturization of components in the 1980s and 1990s (Lee, 2005).

A new industrial revolution is happened as the technical textile driven apparel industry and the electronic industry joins together with their different cultures in design development and production processes. In bringing wearable electronic technology to market a joint project plan and timely cooperation between 'wearables' and textiles helps to fashion the design successfully and to optimize costs says Roepert (2006). Electronic equipments occupies an important place in our society and becomes indispensible when used as exchange medium of information, sound, light and method. If electronics is cloaked by wearing a textiles wrapping it comes closer to our life than ever before (Longereis et.al,2009).

Protection and esthetics are the two major characteristics associated with textiles as clothing. But with the demand for advancement and quickly altering needs of today's consumers, a third characteristic called 'intelligence' is raised that is being integrated into fabrics to produce intelligent or interactive textiles. The term wearable electronics denotes the class of fabric structures that integrate electronic elements with textiles and can since changes home environment and act according to it.

The wearable electronics system is being designed to meet the recent and innovative applications in the fields of military, public safety, health care, space exploration, sports and consumer fitness (Honarvar and latifi, 2017). During the last year, the design and development of wearable electronic systems for health care monitoring has garnered huge attention in the scientific community and the industry due to the increasing health care costs and recent technological advances in miniature bio-sensing devices, smart textiles, microcontroller and wireless communication (IEEE, 2010).

In today's fast world, an individual is most likely to forget or leave his/her personal device behind (for eg: smart phone, smart watch, etc), but never walk out of the home without clothes therefore, this is another reason for compelling textiles or clothing with electronics to form wearable electronics concept. The wearable motherboard or smart shirt is the first such innovation of compelling textiles and electronics, thus paving the way for today's wearable revolution (Rajamanickam, et.al, 2002).

2.6. Production of smart clothes by wearable technology

The process of creating smart clothing by wearable technology has to consider so many factors that it has to be collaborative between end-users, textile specialists, electronics, fashion and clothing designers and manufacturers. The collaboration between these sectors is sometimes difficult, with differences in language, working practices, development timeframes and marketing strategies. The complexity and broadness of knowledge required makes smart textile research interesting but also challenging. From a slow start, this new industry sector now seems to be growing at a good pace, with many new products being released and new companies getting involved in the development of smart clothes and wearable technology (Botticini, 2014).

In the first generation of these systems (1980s), electronic devices were simply attached to garments or included in pockets. In the second generation (2000s), electrical connectivity and function were introduced by the inclusion of conducting yarns within the fabric structure. Conductive fabrics have been widely used for nearly two decades to dissipate static energy and protect from electromagnetic fields alongside other attributes such as thermal regulation, anti-allergic and anti-bacterial properties. However, it was soon realized that fabrics constructed with conductive fibres such as carbon, gold, stainless steel, silver, or copper could offer great potential by facilitating the integration of 'soft' networks into fabrics, thus making them 'smart'. Unlike most technical textiles, smart textiles are not passive in their function, they can sense and respond to stimuli such as touch, temperature or heartbeat (Rossi and Veltink, 2010).

Intelligent textiles can incorporate antennas, global positioning systems (GPS), mobile phones and flexible display panels, without compromising the inherent characteristics of the fabric. The conductive yarns can look, feel and behave like a traditional fabric. The fabric itself is often used as a ‘switch’ in an electronic circuit to perform a function for another external electronic device. In electronic textiles, the conductive elements can provide power, deliver input and output signals or act as a transducer. They sense and react to mechanical, thermal, chemical, magnetic or other kinds of environmental stimuli.

Depending on the application, electronic functionality can be fully integrated or a modular approach can be chosen, where clothing provides a kind of ‘platform’ for several possible modules. Wearable computing has developed in parallel, being more focused on the development of advanced highly portable computing technology, but it has had an important influence on smart clothes and wearable technology. In the past (before 2000s), large-scale uptake of smart clothes have been inhibited by the lack of sufficiently advanced technologies. This would often lead to products not meeting the required needs and expectations of potential users. The technology is now starting to mature and the products that are being introduced are beginning to live up to consumer expectations. The industry is still in its infancy and has a long way to go, but the journey is going to be very exciting (McCann, 2009).

Due to the variety of electro-conductive materials, including monofilament metal wires and conductive yarns, conductive circuits can be implemented directly into the textile structure by technologies such as weaving and knitting to produce electrically conductive fabrics. However, the integration of conductive yarns in a structure is a complex and seldom a uniform process as it needs to be ensured that the electrically conductive fabric is comfortable to wear or soft in touch rather than hard and rigid. Woven fabric structures can provide a complex network that can be used as elaborated electrical circuits with numerous electrically conducting and non-conducting constituents, and be structured to have multiple layers and spaces to accommodate electronic devices (Vervust, 2012).

A typical system architecture design of a wearable electronic/ photonic product is shown in Figure.3. It comprises at least several basic functions like interface, communication, data management, energy management and integrated circuits.

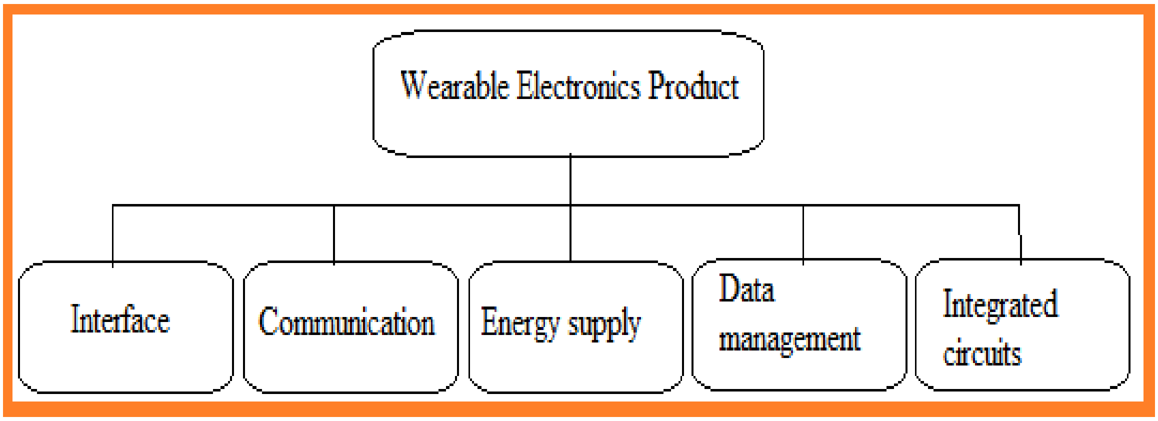

Figure .3 System Architecture Design

The main components of a wearable system that provide the showed functions are:

- sensor unit: registration of biometric and environmental data and of user commands;
- network unit: transmission of data within the wearable computer and to external networks;
- processing unit: calculating, analyzing and storing data;
- power unit: supplying energy;
- Actuator unit**:** adapting to situations, creating an effect like displaying data (Gandhi et al, 2014).

2.6.1 Sensors - an input device in Smart textiles (Wearable electronics)

Sensor is a device that coverts information from a domain of interest into a useful electronic signal and in simple terms, it is a sensing chip (device) used to sense the physical, mental chemical and biological data from the human body. (Abidoye et.al, 2011). Sensors are defined by advancement in micro-electro-mechanical systems(MEMS) and nanotechnologies helping to create miniature and inexpensive sensing solutions for various electrical, mechanical, chemical, optical and other variables of interest that can be obtained from or around the human body (Sazonov and Neuman 2010).

Sensor is defined as an electronic component, sub system, or module whose purpose is to detect changes in its environment and send that information to other electronics, frequently a mobile/laptop/computer processor. A sensor is always associated with other electronics components, whether as simple as a light or as complex as a computer. Sensors are used even in everyday objects like lamps which dim or brighten by touching the base and, touch-sensitive elevator buttons (tactile sensor) besides innumerable applications. With advancement in micro machinery technology and easy use of microcontroller platforms, the usage of sensors has expanded beyond the traditional fields (Bennett, 2003).

Sensors are considered as eyes, ears and sense of touch within an electronic circuit that converts some form of physical property such as a chemical process, light intensity and mechanical change into a form which can be interpreted by an electrical circuit. The process of converting one form of energy into other energy is also called transduction (Martin, 2009). Researchers like Coyle et al(2009) explain sensors as part of a garment need to be innocuous, so as to not distract the wearable from their normal activities and daily routine. A sensor is a device which measures a physical quantity from surrounding and converts them into a single that can be read by observer or by an instrument.

Types of Sensors

A sensor system usually consists of sensors, measuring and processing circuits, and an output system. Sensors can be used to measure quantities of interest in three ways:

(i) Contact: This approach requires physical contact with the quantity of interest. There are many classes to sense in this way—liquids, gases, object such as the human body, and more. Deployment of such sensors obviously perturbs the state of the sample or subject to some degree. The type and the extent of this impact is application-specific. Comfort and biocompatibility are important considerations for on-body contact sensing. For example, sensors can cause issues such as skin irritation and fouling of the sensor when left in contact for extended periods of time (Wang, et al., 2011). Contact sensors may have restrictions on size and enclosure design. Contact sensing is commonly used in healthcare and wellness oriented applications, particularly where physiological measurements are required, such as in electrocardiography (ECG), electromyography (EMG), and electroencephalography (EEG). The response time of contact sensors is determined by the speed at which the quantity of interest is transported to the measurement site. For example, sensors such as ECGs that measure an electrical signal have a very fast response time. In comparison, the response time of galvanic skin response (GSR) is lower as it requires the transport of sweat to an electrode, a slower process (Fraden, 2010).

On-body contact sensing can be further categorized in terms of the degree of "invasion" or impact. For example, sensors introduced into human organs through small incisions or into blood vessels for in vivo glucose sensing or blood pressure monitoring. Non-invasive sensors simply have contact with the body without effect, as with pulse oximetery (Chen, et al., 2012).

(ii) Noncontact: This form of sensing does not require direct contact with the quantity of interest. It is commonly used in ambient sensing applications like applications based on sensors that are ideally hidden from view and, for example, track daily activities and behaviors of individuals in their own homes. Sensors that are used in non-contact modes, passive infrared (PIR), for example, generally have fast response times (Sharief et al, 2010).

2.6.2. Joining the Electronic Component

Electrical circuits can be developed by weaving or knitting of conductive threads into a fabric structure in order to interconnect electronic devices placed at different points on the fabric. In order to route the signals in these circuits, interconnections need to be developed between orthogonal conductive threads and these interconnections can be termed as crossover point interconnections. Regardless of the conductive materials used to develop the electronic textile, the electronic components and power supply must be either attached or embedded into the textile to create a truly interactive electronic textile. Soldering, bonding, stapling, and joining are some of the methods being used to accomplish electronic component and power supply integration (Dhawan et .al., 2004).

(i) Soldering

Soldering involves mounting or placing the components directly onto the textiles surface using solders like soft alloys of lead (Pb), tin (Sn), or sometimes silver (Ag). In order to enable proper circuit wiring and contact between the textile and electronic units' agent locking as a method of bonding in smart textiles can be implemented more traditionally by soldering. Soldering achieves good electrical contact within the textile. However, soldered components are not suitable for applications where they could potentially come in contact with a user's body, due to their toxicity. Furthermore, fabric flexibility is often compromised, making soldering unfavorable for many apparel applications (Nakad, 2003).

(ii) Bonding:

Bonding involves using conductive adhesives to embed components into textile substrates. Conductive adhesives can be developed according to the end use application. Therefore, this method is more favorable over soldering for apparel applications. Non-toxic, highly conductive, highly durable, and moderately flexible conductive adhesives can potentially be used to bond rigid components with flexible textile substrates. Conductive adhesives present a viable fabrication process for embedding components into textile substrates (Marculescu, et.al, 2003).

(iii) Stapling

Components can also be stapled into conductive stitched circuits to create electronic textile circuitry. In this, pressure forming a component to grip a sewn conductive trace within the textile substrate. When the substrate flexes or bends the conductive trace is free to move within the pressure-formed component, forming a self-wiping conductivity between the fabric and the components. In addition, normal flexing of the textile stretches the pins that attach the component to the substrate, accelerating wear and tear on the textile (Martin, 2007).

(iv) Joining

Joining involves attaching an electronic component's thread frame directly to a stitched fabric circuit. Threads leading out of the electronic component can be stitched, punched, or woven through the substrate and can also be connected to other components. Joining components to textile substrates constrains the components to specific locations allowing the conductive threads to be evenly balanced (Buechley, 2008).

2.6.3. Communication technology

Communication technologies and communication applications have been rapidly changing and developing, especially in recent years. The medium of communication by which the information is transmitted through the air without cables and by using electromagnetic waves like infrared, radio frequencies and satellite is called wireless communication technology. In the area of wireless technologies and applications, these have found their way into many areas that previously have been considered as science fiction. The use of communications in textile and fashion is a relatively new discipline and is an existing development in its rapid evolution and the pervasive nature of its incorporation into everyday life. A development of technologies in communications is to combine textile technologies and fashion with wireless communication, to provide piconets-micro communicationsnetworks around the human body (Lam, 2008). There are three areas to analysis in deciding the communication technology for health care monitoring:

- Personal Communications Network (PCN) - to receive the information provided by the various sensors in the smart clothing, and to store and prepare this to be transferred for analysis.

- Wide Area Network (WAN) - how to take the information stored by the PCN and transfer it to another physical location; this could be in another part of the country or anywhere in the world.

- Information Systems (IS) - how to analyze the data received, to monitor the subjects under observation and provide reporting information to end users (Stalling and William, 2005).

The most commonly used communication technologies in Wearable electronics are Bluetooth Low Energy (BLE), Wireless LAN (WiFi) and Zigbee.

2.6.3.1. Bluetooth

Bluetooth wireless technology is a short range communication medium to connect fixed devices portably and maintains high levels of security. The key features of Bluetooth technology are robusts, low power consumption, and low cost and most commonly in wireless communications market. During pairing with devices, it identifies and connects to any two devices easily. It also prevents interference from other non-paired external devices in the area. It preserves battery life by using only required power supply.

Bluetooth technology has achieved global acceptance because Bluetooth enabled devices in proximity uses radio waves to communicate between devices that have a range of 15-50 feet. Bluetooth enabled electronic devices can communicate wirelessly by connecting through short-range, micro networks known as piconets. Each device can simultaneously communicate with up to maximum of seven other devices within a single piconet. Bluetooth enabled devices can enter and leave radio proximity by dynamically and automatically established piconets. This enables users to enjoy a variety of solutions such as a hands-free headset for voice calls and synchronization with Personal Digital Assistant (PDA), Apple iPhone, laptop, and mobile phone applications.

2.6.3.2. Wi-Fi

Wi-Fi is a form of low-power wireless communication used by many electronic devices such as laptops, systems, smart phones. A wireless router serves as the communication hub in its setup and these networks are extremely limited in range due to low power of transmissions. Wi-Fi is a common home networking applications that provides portability without need of any cables. Wi-Fi networks need to be secured with passwords for security purposes in order not to be accessed by others.

Advantages

- Ease of integration and convenience is achieved by allowing users to access network resources from nearly any convenient location.
- Can access internet even outside of their normal working environment in case of emergence of public wireless networks is needed.
- Expandability of network is possible with the existing equipment when there is sudden increase in number of clients.

Disadvantages

- Radio Frequency transmission and wireless networking signals are affected by a wide variety of interference that are beyond the control of the network administrator.
- Wireless networks may be utilized by some of the various other encryption technologies leads to security problems.
- When need of increase in range for a larger structure, additional access points need to be purchased.
- It is a complex process to set up during installation of an infrastructure-based wireless network.

2.6.3.3. ZigBee

ZigBee is a wireless communication designed to satisfy the unique needs of low cost wireless sensor, low power consumption, and control networks. It can be used almost anywhere, as it is easy to implement and requires little power to operate. ZigBee has been developed for receiving data from simple structure like the data from the sensors. For example in previous inventions, a wearable e-nose prototype which looks like compact armband was developed for monitoring the auxiliary odor released from the human body with the use of ZigBee wireless technology. ZigBee is used in commercial applications like sensing and monitoring applications. ZigBee gives flexibility to do more with the reliable wireless performance and extremely long device battery life.

2.6.4. Portable power sources

Electronic devices have become a necessary part of everybody in their modern life to carry something like watches, mobile phones, music players, cameras and laptop computers. Special electronic devices essential and important for health care applications such as cardiac pacemakers, hearing-aids, and temperature or pulse rate monitors are in trend. All of these devices require a power supply to function its performance effectively and for that batteries have been employed in almost all of them. The battery was invented by Alessandra Volta in 1800, is a well-established electrical power source (Buchanan, 2001).

Power consumption required by wearable electronics covers a wide range of power levels, from a few micro-watts to tens of Watts. Currently, conventional batteries cannot be fully integrated into textile structures because of their rigidity. However, they may be embedded into clothing without causing significant inconvenience to the wearers if the power level required is low. For example, button batteries have been considered, apart from providing power, as buttons or decorations for smart jackets. The most commonlyused batteries on today's markets are lead acid, alkaline, nickel-cadmium(NiCd), nickel-metal-hydride(NiMH), lithium ion (Li-ion) and lithium polymer (Li-polymer).

Fuel cells have a substantially large theoretical energy density and are seen as a possible technology to meet the power requirement of wearable computing at the high performance end. A fuel cell is an electrochemical device that converts hydrogen and oxygen into water and, in the process, produces electricity and heat. However, in terms of high energy density, small dimension and flexibility, significant effort toward research is still needed to realize its full potential as a solution to the power problems of wearable computing. High performance computing requires a relatively large power supply, usually in the range of 50 W (Vielstich et al., 2003).

To develop a sustained power supply which covers the lifetime of smart textiles is an extremely difficult challenge. A medium-term solution is to combine power harvesting with energy storage. Power harvesting devices continuously convert various forms of ambient energy into electricity, while the storage devices accumulate (Konarka, 2010). The challenge is to efficiently convert the limited energy available around the human body into electrical power. The development of miniature thermoelectric devices in recent years opens up a possibility for wearable applications. A more adventurous attempt is to develop flexible thermoelectric thin films or polymers that can be woven into fabrics (Beeby,2010).

The Lithium Ion battery provides the highest energy density with a large charge cycle, making it the fastest growing and most promising battery for numerous portable applications. Lithium Ion Polymer is a potentially lower cost version of the Li-ion and it can be potentially flexible (Solicore, 2010).

2.6.5. Formation of electronic module

Miniaturization of electronic components has made it possible to build small portable and handheld computer devices that can be carried almost anywhere and at any time. The smart textile requires a central processing unit that will carry out data from the different sensors and decide action on the basis of the results. The processing unit consists of hardware and software where the software causes unique dynamic behavior in real time. The traditional package of computing material is a computer that allows data processing as well as communication. The processing unit is a complex structure of electronic circuitry that executes stored program instructions and the structure include integrated circuits, power supply, secondary storages and communications technologies (Worden, 2008).

Microcontroller contains all essential elements of a microcomputer on a single chip for building simple products of wearable electronics with any design. It is applied in the fields of real time applications, industrial control and instrumentation and intelligent computer peripherals like smart textiles. The advantages of microcontroller are

- It has many bit handling instruction hence controlling is more effective.
- Time taken to complete a control function using microcontroller is less.
- Microcontroller IC chip itself contains Memory (RAM, ROM, as EPROM) Parallel and duplex serial ports to interrupt controller and D/A converters.
- It can function as a computer with the addition of no external digital parts.
- The pins of microcontroller are programmable that is capable of having several different functions depends on the wishes of the programmer high speed of operation and even it can handle boolean functions.
- Process control equipment using microcontroller are cheaper, occupies less space and contain more number of internal registers.
- It can be used in motor, robotics, in missile guidance and control, in medical instrumentation, oscilloscopes, telecommunications, smart textiles, wearable electronics, automobiles, driving an LCD(liquid crystal display), frequency and temperature measurement, period measurement and pulse width measurement.

Over recent years, the development of mobile and wearable technologies to collect data from human vital signs and activities has grown to a great extend. At present, there exist a variety of operating systems in wearable market. Developers are difficult to choose which operating system for the device. The application for one operating system is not suitable for another. Since operating system is essential for wearable devices, we should select wearable operating systems based on the following objectives.

- The design of the operating system should be more convenient for users to use wearable devices.

- The operating system should be managed more effectively and take advantage of resources like hardware, software and data of wearable devices.
- The operating system should permit new system functions to be developed, tested and included scalability
- The operating system should support integrated and collaborative network work of different manufacturers and devices so that it can achieve the portability and interoperability of applications.
- The operating system should be able to run multiple applications concurrently.

Android is expected to build a uniform and standard operating system platform, accelerating to the development of wearable devices.