CHAPTER 1

INTRODUCTION

1.1 GENERAL

In recent years, interdisciplinary studies have been the mainstream in research discourses and practices. Traditionally, many fields of science and engineering have been separate and distinct. Recently there has been a considerable movement and convergence between these fields of endeavour and their results have been astonishing. Smart technology for materials and structures is one of these results. Smart materials and structures can be defined as the materials and structures that sense and react to environmental conditions such as those from mechanical, thermal, chemical, electrical, magnetic or other sources. According to the manner of reaction, they can be divided into passive smart, active smart and very smart materials. Passive smart materials can only sense the environmental condition or stimuli; active smart materials will sense and react to the conditions or stimuli; very smart materials can sense react and adapt themselves accordingly. An even higher level of intelligence can be achieved from those intelligent materials and structures capable of responding or activated to perform an action in a manual or pre-programmed manner. Such textile materials and structures are becoming possible as the result of a successful marriage of traditional textiles with material science, sensor and actuator technology, advanced processing technology, communication, artificial intelligence, biology, etc.
Electronics is often viewed as a hard subject. Silicon chips and their packaging have a physical form that is solid and rigid, in a word hard. However, this notion will begin to change as electronics starts to become soft. That is, electronics and textiles starting to merge, and what will come out of this are a plethora of soft electronic components, such as: fabric antenna’s, switch, sensors, displays, solar cells and eventually, though in the distance future, computing cloth. Depending on the degree of integration, the combination of electronics and textiles can be divided into three categories: wearable electronics, textronics and fibertronics. The classical definitions of wearable electronics are the science and technology related to generation, transmission, modulation and detection of electrons. The wearable electronics are device that has the above functions, always attached to a person and is comfortable and easy to keep and use. In other words, it is apparel with unobtrusively built-in electronics functions. A typical system architecture design of a wearable electronics product comprises of at least several basic functions such as interface, communication, data management, energy management and integrated circuits.

1.2 WEARABLE ELECTRONICS

An emerging new field of research that combines the strengths and capabilities of electronics and textiles into one: wearable electronics are opening new opportunities, it is also called smart fabrics, have not only wearable capabilities like any other garment, but also have local monitoring and computation, as well as wireless communication capabilities. Technology is indeed the catalyst that can rapidly transform health care and the practice of medicine. So, any technology to minimize the loss of human life and/or enhance the quality of life has a value that is priceless. The Wearable Electronics fulfills the twin roles of being a flexible information infrastructure that will facilitate the paradigm of ubiquitous computing; and a system for
monitoring the vital signs of individuals in an efficient and cost-effective manner with a "universal" interface of clothing.

In this research work an attempt has been made on technology development consisting of textile fabrication, incorporating the optical Fibre in the warp and weft direction for detecting bullet penetration; process development (design rule generation) for establishing inter-Fibre electrical connects; sensor mounting technology; distributed chip mounting technology; processor attachment and interconnect technology; and inter garment electrical and optical interconnect technology. Also this research work focuses on integrating electronics and conventional garment to produce wearable electronic products.

Man-made fibres are robust and versatile, and cheap to produce in large quantities. Numerous electrically conductive fabrics already exist in the market. The main factor in the selection of conductive fabrics is the application. In this research work extensive experimental studies have been made in the selection of suitable fibre for wearable textile systems and different fabric production technologies were tried with variety of fibres. Polymeric Optical Fibres of different diameters, core conductive Fibres, Nichrome wires and core optical fibres were selected, tested for its functionality and the feasibility of textile integration was studied. A materials and manufacturing survey was conducted to determine the best performing and most durable materials to withstand the rigors of textile manufacturing and potential military use.

These fibres were made into several assimilation techniques in textile production to produce the textile fabrics. Based on the fabrics produced garments were produced, which can be utilised for defence as well as commercial applications. Wearable Electronics are manufactured using commercially available materials using traditional textile manufacturing
methods. The electrical performance of the conductive fibres and fabrics are investigated by adapting established measurement methods and the materials are selected based on the size and feasibility of fabrication through weaving, knitting, and nonwoven and embroidery methods. An attempt has been taken for development of special fabrics using polymeric optical fibres and copper filament and their light signal transferring efficiency in terms of light intensity and electrical properties were reported. The physical characteristics of these conductive fabrics are studied. A sensorised and signal transferring fabric has been designed and developed using the optical core conductive fabrics for data transferring.

Among these, care was taken to integrate dissimilar processes to be integrated into the simple processors. Special sensors like, biological sensor selected from pulse rate, respiratory rate and physical sensors including barrier penetration (optical sensor for projectile penetration sensing) was put in place to measure the vital parameters and for the biometric measurements. The signal conditioning units and the processing units of these conventional sensors are being replaced by the miniaturized circuits.

In the case of wearable electronics, the complexity of the system is higher because the electronic components will need to convert electrical signals into output and/or input into electrical signals. Processors such as transistors, diodes and other non-linear devices are needed to amplify signals, process simple arithmetic operations and store data gathered. Central processing units for smart clothing systems often include small 8–16-bit microcontrollers. Microprocessors and controllers of different technologies were used in this research work to accomplish the task of integrating textile and electronics. These garments are developed with integrated circuits and operating at very low voltages. The fabrics and the garments produced were tested using a dedicated test rig developed for this research work and the test
results were compared with that of the conventional method of measuring the biological and vital parameters.

The monitoring system can consist of a combination of several such units, positioned at different locations to perform specific functions, and communicate with each other. One of the challenges of interactive wearable electronic textile systems is the effective transfer of data or power between different modules of the system. For practicality, weight and design purposes, it is often convenient to spread out the sensors, actuators and microcontrollers over different strategic locations on the body. This distribution of information micro-hubs requires an effective and comfortable network of communication. The transmission of signal from the garment to the remote end is tested with the help of RF and GSM communication technique. A dedicated communication protocol has been developed for the communication between the made garment and the remote unit. Apart from this the garment has inbuilt standard communication methodologies for location monitoring purposes. All these communication and the protocols have been made as per the Indian and the International standards. In the remote end, a Graphical User Interface was developed to identify the location of the wearer and this software can be integrated to the garment by standard protocols and communication technologies. The wearable electronics garment circuit development goals are to produce flexible, cost effective with globally distributed sensors and randomly positioned sensors with low power consumption. Although initial application is for combat casualty care, the information processing capability of the garment renders it equally useful for other applications too.

To power up the circuits used in the wearable electronics garment, technique has been tried to integrate the flexible solar cells and conventional PV panel with the appropriate clothing. Integration of flexible solar cells into clothing can provide power for portable electronic devices. The clothing-
integrated photovoltaics, their scope and limitations, the status of flexible solar cells, and its design, as well as prototype solutions for wearable electronics applications were tested. The methodology of combining solar cells in the clothing and the integration drawbacks and the solutions were discussed.

1.3 OBJECTIVES

Based on the above discussions, the following are the objectives of the thesis:

- To develop suitable conductive yarn for wearable electronics.
- To build up a suitable methodology by modifying the conventional textile manufacturing methods to produce specialty fabrics.
- To design and develop low power miniaturized electronics circuits with sensors and actuators for vital parameters, biometric measurements and physical status monitoring applications.
- To integrate the speciality fabrics and the miniaturized electronic circuits to produce wearable electronic garments.
- To formulate a dedicated communication protocol and user friendly Graphical User Interface at the remote for monitoring purposes.
- To design, develop and fabricate a methodology to integrate the conventional panels and the flexible solar cells in the clothing to power up the wearable electronic garments.
- To devise a test rig to assess the wearable electronic yarns and fabrics.
To fulfill the above objectives the following methodology has been adopted. The selection of conductive fibres was based on different samples obtained from various companies and it was tested as per the electrical and textile standards. The conventional fibres were also combined with specialty fibres for these applications. Textile fabrics were produced using standard methodology with major modifications in the actual processes. The usual method of measuring the vital parameters of the human beings and the physical status monitoring was devised using miniaturized and flexible circuits which can consume low power. Special care was taken to integrate the circuits and the garment to produce wearable electronic products, so that the circuits in the garments would not provide discomfort to the wearer. Different communication media were used for the communication purposes and tested for its validity apart from the dedicated communication protocol for the wearable electronic garments. Dedicated software using Visual Basic and LabVIEW was developed to monitor the physical status and the vital parameters measurements. Flexible solar cells and the conventional photovoltaic panels were tested for its integrity with the wearable electronics to give power supply to the electronic circuits used in the garments.

Research on the construction of wearable electronics is also buoyant for applications such as clinical and general health monitoring, performance during sports and military uses, including life sign and injury monitoring, position and location tracking and communication systems. This research work will help in mass commercialization of wearable textile systems. Smart clothing is perceived as the next generation of both fashion and electronic products. Its influence rises dramatically, as indicated by the rapid increase in research and development projects in the last five years. It offers a large number of possibilities and opportunities for new business and new product lines. As a result, the research and product developments have been carried out by multi-national companies and leading academic institutes.
Many researchers describe smart clothing as a marriage of textiles and electronics. Based on this description, it can be assumed that it requires collaborative work from the fashion and electronic industries. The trends in smart clothing development suggest that technology gradually becomes an integral part of fashion. Also this research work is helpful to resolve all the technicalities in developing the wearable electronic products.

1.4 DISSERTATION OUTLINE

**Chapter 1** presents an outline to the basic concept of wearable electronics, related issues and the objectives of the thesis with justification.

**Chapter 2** deals with the detailed wearable electronics survey carried out regarding the selection of materials, sensors, controllers, signal conditioning devices, the method of integrating textile and electronics and textile machineries used for developing the wearable electronic products.

**Chapter 3** provides the materials used in the development of wearable electronics and methodology for manufacturing the fabrics, the procedure for performance analysis and testing methods carried out.

**Chapter 4** describes the detailed investigations carried out on modifications methods in the textile machineries, problems faced in the different fabric production technologies for wearable electronics.

**Chapter 5** presents the design and implementation of circuits for wearable electronics and integration of the circuits in the developed fabrics.

**Chapter 6** discusses the different products developed using wearable electronic integrated fabrics.
Chapter 7 deals with development of software using Visual Basic and LabVIEW to integrate the wearable electronic products and the communication methods used to connect it to the remote station.

Chapter 8 enumerates the design and development of flexible solar tent for powering the wearable electronic products.

Chapter 9 explains the design and development of garment integrated wearable electronic products and its applications.

Chapter 10 concludes the investigations carried out by bringing together the important results of this research work.

Pages to follow elucidate the investigations carried out on the developed wearable electronic product methodologies and conclude with important results of this Thesis.