MANTECH Publications

Journal of Electronics and Electromagnetic Technology
Volume 1 Issue 2

Applications of Electronic Textiles in Medical Fields

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Abstract

Electronic textile fabrics that can function electrically as electronics and behave physically as textiles which enable computing, digital components and electronics embedded in them. Recent advances in technologies bringing clothing, technology and textiles together to create fabrics with capabilities for users as varied as athletes, patients, soldiers and ordinary consumers. After the invention of metallic yarns, it is found easy to use electronic chips in textile materials. Manufacturing of smart products demands a complex and innovative technological approach by combining conventional textile manufacturing technologies as weaving, knitting and embroidery with technologies originating from the electronic sphere, such as coating, lithography and ink-jet printing. The implement of truly wearable instrumented garments which are capable of recording biomechanical variables are crucial in several fields of applications.

Keywords: *Electro active fabrics, Smart textiles, Textile sensors, Metallic yarns, Fibre optic sensors.*

INTRODUCTION

E-textiles are the emerging field of textiles in which many of the sensors are being developed for several applications, including bio-monitoring, motion sensing and wearable computing. The field of smart textiles not only covers the textile discipline alone but also covers some **other disciplines like electronics, polymers, and material science,** etc and some researches also try to incorporate the whole electronic assembly into the fibre/polymer level [01]. Smart textiles **can perform the functions of sensors,**

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data processing, actuator and communication.

Benefits of e-textiles are a new emerging interdisciplinary field of research, bringing together specialists **in information technology, Microsystems, materials and textiles. E-textiles** offers advantages like no wires to snag environment, large surface area for sensing, invisible others, cheap manufacturing, etc [02]. The focus of this new area is on developing the enabling technologies and fabrication techniques for the economical manufacture of large area, flexible and comfortable information systems that are expected to have unique application for both the consumer electronics and aerospace/military industries.

E-textiles or smart textiles, smart garments, smart clothing, electronic textiles or smart fabrics, whatever the definition they all have a digital component or electronic embedded within them. Recent advances, such as embroidery circuits into fabrics or transparent sensor material that can be printed on to textiles are helping to create a range of technologies that bring together the clothing, technology and textile industries to create **fabrics with capabilities for users as varied as patients, soldiers, athletes and ordinary consumers** [03]. Research has seen significant developments in electrically conductive yarns and threads, conductive polymers, shape memory materials, phase changing materials, self-cleaning and anti-microbial materials, as well as **NANOMATERIALS.** As a result, more applications are moving beyond the laboratory, with **end-user applications for the medical, health and fitness, military and security**, fashion and non-clothing applications beginning to appear.

Functioning of e-textiles is dependent on five **main components**, such as **interconnected, hardware, software, platforms and performance metrics** [04]. Platform is the main fabric which involves various structures and manufacturing +processes. The interconnected architecture concerns with the designing, fusing of data paths and intermingled electronic circuits. The hardware constitutes the microchips, sensors and other such mechanisms and is a vital element for e-textiles. All kinds of information processing and communication are taken care by the software in e-textiles. The performance metrics plays a pivotal role in evaluating all the **remaining four parameters, such as costs, manufacturing aspects,**

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physical dimensions and data flows. E-textiles can be used in the areas of **healthcare to study and scrutinise cardio vascular, respiratory and neurological disorders**.

The applications of wearable electronics and the textiles fibres used for wearable electronics have been described in the book referred as "**Electronics in Textile and Clothing: Design, products and Applications"** [05]. It includes coverage of the different yarn types and fabric production techniques and modifications needed on conventional machines for developing fabrics using the speciality yarns. The coverage includes problems faced during the production processes and their solutions. Novel sensors, speciality yarns, body sensor **networks (BSN)** and the development of flexible solar tents used for power generation round the coverage. The development of fabric integrated **wearable electronics products for use in mobilhealth care system, smart cloth for ambulance remote monitoring electronic jerkin, heating gloves and pneumatic gloves are also discussed.**

Smart textiles find applications and have outstanding outlooks almost in every sphere of human activities. Many research projects are dedicated to exploring and developing smart textiles for medicine and health care. Use of such smart textile materials vary from **in-vitro-applications to in-vireo** use as asset in everyday activities and accomplishing such functions as philological monitoring and communication with environment [06]. Another field of smart textiles applications is technical textiles for monitoring of **structural health, automotive, civil geo-technical and other engineering industries**. Besides high functionality, some smart and intelligent textiles have outstanding aesthetic values and find applications in fashion and design. Despite a variety of smart textile applications, a significant role has the research that focuses on intelligent systems for health care and medicine. The main drivers encouraging development of this segment are socially demographical situation in **Europe and other developed countries**, high composition on the textile market and new scopes of available technologies, information and communication engineering.

Promising recent developments in material processing, device design and system configuration have enabled the scientific and industrial community to focus their efforts on the realization of smart textiles.

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Multi-functional electro active fibres and fabrics will give the traditional textile industry a new additional value, the possibility of making daily life healthier, safer and more comfortable, bringing technological advances closer to the public through the use of easy-to-u interfaces between humans measuring devices and actuators [07]. In fact, all components of **interactive electromechanical systems can be made from polymeric** materials to be woven directly into textiles structures or printed or applied onto fabrics.

The fabrication of electronic systems onto substrate which are not only flexible but also conformable to the **human body represents a break-through in many areas of applications such as virtual reality**, teleoperation, telepresence, ergonomics and rehabilitation engineering. The possibility to realize sensing textiles by coating traditional fabrics with smart materials has opened the way to implement a new type man-machine interface technology [08]. These **fabrics enable the realization of wearable sensing garments** capable of recording proprioceptive maps with no discomfort for the subject and negligible motion artifacts' caused by sensor-body mechanical mismatch.

During the last decades the use of **fibre-optic-based sensors (FOS)** has been gaining acceptance in a number of applications in the fields of civil engineering, the automotive industry and medicine [09]. **These sensors allow the measurement of physical and chemical parameters employing a large number of working principles and configurations.** Fibre optic technology is particularly attractive for application in smart clothing because it allows both sensing and signal transmission. Moreover, **polymer optical fibres (POFs)** are cheap, light weight, flexible, and robust and they are able to measure high strain values without damage. The **use of FOSs of textiles is particularly attractive in some medical fields** because of the possibility to use this technology during MR procedures, the cost reduction of key optical components and the improvement of component quality as well as good metrological properties of the sensors.

Sensorial materials are the basis for intelligent products and systems, autonomously interacting with each other and real human users in the environment. Such products and systems will increasingly govern our lives and contribute to our efforts toward energy

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savings, safety and security, mobility and health [10]. Hybrid integration into material allows the use of standardized sensor manufacturing processes and constitutes a first step toward sensorial materials. In **glass fibre reinforcement plastic (GFRP) and carbon fibre reinforcement plastic (CFRP),** particular the interconnection with optical fibres can be a part of the base material itself, reducing the amount of foreign material.

During the **20th century** tremendous progress has been achieved in the field of biomedical engineering. This achievement can be attributed to the development of novel electronics and fibre optics, optical devices and systems. In the **21st century the development of smart structures and intelligent systems** will form the basis for more **innovations in bio-medical engineering applications.** Ranging from health monitoring and diagnostic systems to intelligent artificial body parts, such as the smart Artificial Heart, will be able to accommodate any physical changes in the body and modify the blood circulation to optimise the health conditions [11]. Successful developments of the proper smart fabrics with embedded sensors and net works is mainly dependent on the development of the **proper miniature sensors technology and on the integration of these sensors** into textile structure [12]. The methodology of integration into textile structures has to be developed. The development of smart fabrics with embedded fibre optical systems is applied in **health monitoring and diagnostics.**

Smart fabric technology has a great deal to offer patient monitoring. Sensors integrated right into the textiles provide the least annoying way to monitor vitals, because one cannot notice it as would notice any other type of clothing. **Hex Skin** has **developed a biometric** "**Smart Shirt"** that allows the users lab quality analysis just by getting dressed. What's more is that the sensors are actually made of textiles, with next to no hardware in the shirt **[13]. Top 5 medical applications for smart fabric technology** have been discussed by the author in the above article.

Smart fabrics and interactive textile wearable systems regroup activities along two different and complementary approaches i. e, '**application pull' and 'technology push'**. This includes personal health management through integration, validation and use of smart clothing and other networked mobile devices as well as projects targeting the full **integration of**

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sensors/actuators, energy sources, processing and communication with the clothes to enable personal applications such as protection/safety, emergency and healthcare [14]. This article includes the origin and introduction of smart textile and integrated wearable electronics for sportswear, industrial purpose, automotive and entertainment applications, healthcare and safety, military, public sectors and new developments in smart textiles.

E-textiles such as a bed sheet or mattress that are integrated with pressure sensors to manage and prevent bed sores by making sure the patient around on the surface enough is something that is garmenting a lot of interest from companies. If e-textiles continue to prove to be successful, may start off as a high end luxury feature before it gets adopted on mass. One interesting project is being **developed in VTT Technical Research Centre of Finland** where researchers have created smart fabric that can be clothing or blankets that calculate whether a **patient needs to be cooled or warmed** based on the initial data measured from the person**.** These garments could also be used by surgeons that get too hot during an operation with the clothing adjusting to the temperatures of the body during surgery [15].

ELECTRONICS IN TEXTILES

Electronic textiles are fabrics that can function electrically as electronics and behave physically as textiles which enable computing digital components and electronics to be embedded in them. Part of the developments of wearable technology, they are referred to as intelligent clothing or smart clothing that allow for the incorporation of built-in technological elements in everyday textiles and clothes. **Early 1990's MIT students** started research on **smart clothing for military** use and beginning of the **integration between fashion and technology was observed in 1998**, most notably by Levi and Phillips Electronics. **In 2001** integrated medical uses in clothing started by **Zoll Life Vests and Life Shirt by Vivo Metrics [02].**

According to the development related to current technology, **Zoll Life Vest**, **wearable defibrillator is used for heart palpitations or an alarming rhythm of heart detection,** the vest gives a signal to the patient. If the signal is not stopped by the patient, then the defibrillator gives off the conducting gel, then sending a shock to the patient. Vivo Metrics Life Shirt, places ECG sensors on the body which then the data is transmitted to the data recorder,

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which is then transmitted to the doctor. Intelligent Garment for **21st Century Georgia Tech Wearable Mother Board (Smart Shirt) for Combat Casualty Care** has led the World's FIRST Wearable Mother Board or an intelligent garment for **21st century**. **Georgia Tech Wearable Board** (Smart Shirt) provides an extremely good sensing, monitoring and information processing devices.

To use this new technology, **a combat soldier attaches sensors to the body**, pulled the smart shirt on and **attaches the sensors to the smart shirt.** The smart shirt functions like a mother board and with plastic optical fibres and other speciality fibres woven throughout the actual fabric of the shirt. To pin point the penetration of bullet, a signal is sent from one end of the plastic optical fibre to a receiver at the other end. The emitter and receiver are connected to a **Personal Status Monitor (PSM)** worn at the hip level by the soldier. If the light from the emitter does not reach the doctor, inside the **PSM**, it signifies that the smart shirt has been penetrated. The soldier's vital signs heart rate, temperature, respiration rate, etc, are monitored into two ways, through the sensors integrated in the shirt and through the sensors on the soldier's body, both of which are detected by the PSM. Information on the wound and **the soldier's condition is transmitted electronically from PSM to a medical triage unit and the physician determines the injuries of the soldier.**

THE SMART AND INTERACTIVE TEXTILES

Smart material is a generic term for a material that in some way reacts to its environment. **Smart materials** can be classified in many different ways, for example depending on their transforming function: property change capability, energy change capability, discrete size/location or reversibility. Smart materials can also be classified depending on their **behaviour and function as passive smart,** active smart and very smart. Another way of classifying them is to look at the role they could have in a smart structure **[14].** The materials of our surroundings are being intellectualized. Whereas, in the past, we needed several components to satisfy a certain function but technology today has allowed us to satisfy the same function with fewer components. Examples of the reduction of components and matter are; **a complex sensor system** replaced by a **piezoelectric film and the mechanical key board replaced by the membrane**. Conductive yarns and fibres are made of composite

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stainless or fine continuous conductive metal-alloy combination of fibres with conductive materials can be completed by the methods like, (**i) fibres filled with conductive material (carbon or metallic particle), (ii) fibres coated with conductive polymers or metal and (iii) fibres** spun with thin plastic conductive threads. Concepts of FIVE interactive textile samples have been developed by the authors **[14].** The concepts are based on the following sensors; pressure sensors, sound sensors, light sensors, strain sensors and actuator along with shape memory alloys, light emitting diodes, electroluminescent materials, photovoltaic cells, optical fibres, thermo chromatic and photo chromatic inks. It can be mentioned that some materials are both photo chromatic and actuators, such as thermo and photo chromatic inks. More concepts including other sensors and actuators could be developed to be included in the future.

The possibility to realize **sensing textiles by coating traditional fabrics with smart materials (piezoresistive, piezoelectric and piezocapacitive polymer)** has opened the way to implement a new type of man-machine interface technology. These fabrics enable the realization of wearable sensing garments capable of recording **proprioceptive** maps with no discomfort for the subject and negligible motion artefacts caused by sensor-body mechanical mismatch **[08].** In the study, **the sensors were characterized in terms of quasi-static and dynamic electro-mechanical transduction properties and thermal and aging properties of the sensing fabrics have also been assessed.** A simple thermal characterization procedure was performed to determine how temperature influenced the **piezoresistive** of the sensors. Resistance verses time for unstrained sample was measured to evaluate their aging behaviour.

Recent advances such as embroidering circuits into fabrics or transparent sensor material that can be printed on to textiles are helping to create a range of technologies that bring together the clothing, technology and textile industry to create fabrics with capabilities for users as varied as athletes, patients, soldiers and ordinary consumers. Using smart fabric technology company like **Glove in the USA** has developed **Wearable Advanced sensor Platform (WASP)**, which is being developed to track a fire fighter's heart rate, body temperature, respiration rate, activity levels, posture and other factors as well as provide tracking and improve

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overall situational awareness **[03].** Research has seen significant developments in electrically conductive yarns and threads, conductive polymers, shape-changing materials, phase-changing materials and **self-cleaning and anti-microbial materials**. As a result, more applications are moving beyond the laboratory, with end-users applications for the medical, healthcare and fitness, military and security, fashion and non-clothing applications beginning to appear. **Medical is expected to be the largest market** for smart textiles and could be using for **patients with chronic diseases, such as diabetes,** where problems could be monitored continuously with updates regularly sent to their physicians.

FIBRE OPTIC TECHNOLOGY IN MEDICAL TEXTILES:

The growing interest in smart textiles for medical applications is driven by the aim to increase the mobility of the patients who need a continuous monitoring of physiological parameters. **Fibre Optic technology based on FOS** is particularly attractive for application in smart textiles because it allows both sensing and signal transmission. Moreover, polymer optical fibres (POFs) are cheaper, light weight, flexible and robust and they are able to measure high strain values without damage. Smart technical textiles are the definition of textiles that can interact with environment. Their ability to sense physical and chemical parameters can be assessed by embedding several kinds of sensors. Recently a smart textile based on the use of a periodic fibre optic microbe and sensor has been proposed for heart beat and respiratory monitoring [09]. Regarding the application of smart textiles in medicine and health care, they allow the continuous monitoring of physiological parameters of great importance, like respiratory activity, and heart beat. The monitoring of these parameters can be performed by **several approaches, and different devices are commercially available. The main advantage to integrate FOSs into smart textiles is the possibility to develop MR compatible systems.**

Today, sensorial materials mainly consist of embedded sensors produced separately and integrated into the material afterward. This hybrid integration allows the use of standardized sensor manufacturing processes and constitutes a first step toward sensorial materials. But local of the sensor signals and facilities to derive meaning from them is necessary to base decision on it. **As the optical fibre can be made of the same material or a material**

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similar to it, this can offer a solution for the problem of non-homogeneity that otherwise threatens to weaken the material [10]. The majority of common sensor network concepts can be divided into the following groups:- wired electronic sensor nodes, wireless electronic nodes, optical sensor networks and electronic sensor nodes with optical interconnections.

Within the field of optical sensor network, **fibre optical methods** are most frequently **used in various scientific and industrial applications.** In these optical fibres are used as the sensing and interconnecting component at the same time. **Fibre Bragg Grating (FBG)** consists of a segment of optical fibre reflecting a particular wave length of light **(Bragg Wave Length)** and transmitting all other wave lengths. This is realized by a periodic variation of the refractive index within the fibre core. Straining of fibre is caused either by mechanical or thermal load or by combination of both alters the characteristic length of the grating, which corresponds to the Bragg Wave Length. **Using different Bragg Wave Lengths, even optical sensor networks can be realized,** which consist of several distributed sensing elements in a single optical fibre.

A second approach to temperature measurement with glass fibres is the so-called **distributed temperature sensing (DTS).** The minimum attenuation of glass fibres is limited by Rayleigh scattering. This scattering originates from particles in the fibre much smaller than the wave length of the **transmitted light. Induced thermal influences another scattering, the so-called Ramen scattering**, exists within glass fibres. This scattering causes interactions between transmitted light and thermally enhanced molecular oscillations. As the temperature-dependent Ramen Scattering is spectrally shifted relative to the incident light, amplitude and frequency differences of the scattered photons can be used to measure the location of heating within the fibre and the temperature itself. As the energy supply is realized via the optical fibre, the available energy at each single sensor node is limited by the size of the active photodiode area, its efficiency, the optical power inserted into the optical fibre and the number of branches within the network. **System designers have to find a trade-off between an acceptable size of the sensor, the system's cost and the necessary power for the microcontroller and the attached sensors**.

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ELECTRONICS IN MEDICAL TEXTILES:

E-textiles are the emerging field of textiles in which many of the **sensors are being developed for the several applications including bio-monitoring, motion sensing and wearable computing.** The field of smart textiles not only covers the textile discipline alone but also covers some other disciplines like electronics, polymer, material science, etc [01].

There are some researches which try to incorporate the whole electronic assembly into the fibre/polymer level. **Smart textiles** can perform the **functions of sensors, data processing, actuator and communication.**

Smart textile sensors can be produced in **two different techniques**, the one based on the **existing sensor technology** and the other one by which the **textile itself converted into a conductive material and used as a sensor.** The sensors will help to measure some of the **body parameters like, angle measurement, breathe measurement, ultrasound blood flow, electrical properties of skin, mechanical properties of skin, blood pressure, etc**. Textile sensors can provide a huge number of data, but there are some problems. Actuators are the system which measures the environmental influence on the applied sensors and it optimise the influence of the environment on the sensor which helps to get the accurate results. In textile materials, the communication can be done through optical fibres or by conductive yarns. The **main problem in incorporating the conductive wire or optical wire in the textile structures is the degree of bending**.

The basic principles to produce the textile based strain sensors are namely; (**i) using optical fibre assembly (ii) inter leaving the conductive yarns into the knitted structures (iii) conductive yarn braided structure (iv) coating with highly conductive polymer and (v)inter leaving the conductive yarns into the woven structures**. The development of smart textiles will lead to enter into the new era. **The electronics are having the wide range of applications in garments**. The conductive textiles will help in designing the sensors for various applications.

Smart textiles **find applications** and have outstanding out looks **in every sphere of human activities.** Many research projects are dedicated to exploring and developing smart textiles for medicine and health care. Use of such smart textile material vary

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from **in vitro applications to in vivo** use as an asset in everyday activities and accomplishing such **functions as philological monitoring and communication with environment**. Despite a variety of smart textile applications, a significant role has the research that focuses on intelligent systems for health care and medicine. **The first attempt to manufacture bio-monitoring clothing has already started over a decade as reported [06].**

Smart textiles for healthcare include textile sensors, actuators, and wearable electronics systems embedded into textiles that enable registration and transmission of physiological data and wireless communication between the wearer and the operator, for example patient and medical personnel. **Such systems ensure patients' mobility, thereby providing a higher level of psycho-physiological comfort, especially when a long term bio-monitoring is required.** Generally, applications of smart textiles for medicine and healthcare vary from the surgical applications of single yarns to complex wearable and military and auxiliary systems for personalized healthcare. Due to new functions, several new categories must be highlighted, which are **textile drug-release systems, textiles for therapy and wellness.**

Temperature sensors based on smart textiles technology can provide evaluation of temperature changes on skin surfaces and in the near-body environment. Textile sensors for **respiratory rate (RR)** estimation also find a number of applications in protective and combat clothing, smart textiles for prevention of sudden infant death syndrome and monitoring of vital sign for geriatric or disabled patients. **Humidity sensors developed via smart textiles for healthcare are related to ulcer prevention, monitoring of sweat rate and moisture in wound**. A pH sensitive coating immobilized on fabric performed as pH environment indicator and a biased **LED** performed a quantitative sweat analysis. Since e-textiles act as a second skin, they are being used for unique purposes especially in the healthcare industries. These fabrics are designed to provide comfort and functionality at the same time. **The amalgamation of operative clothes and integrated electronics has given rise to usage of e-textiles in the healthcare sector.** Smart sensor system helps in monitoring and communicating a patient's condition since

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they detect, acquire and transmit physiological signals [04].

ELECTRONICS IN TEXTILES AND CLOTHING FOR DESIGN AND PRODUCCTS:

Electronics in textiles and clothing: design, products and applications covers the fundamentals of electronics and their applications in textiles and clothing product development. The book emphasises the interface between electronics and textiles materials, dealing **diverse methods and techniques used in the industrial practices [03].** It explores ways to integrate textile materials with electronics for communication/signal transferring applications. It also discusses wearable electronic products for **industrial applications based on functional properties and end users in sectors such as defence, medicine, health monitoring and security.** It includes coverage of different yarn types and fabric production techniques and modifications needed on conventional machines for developing fabrics using speciality yarns. **Novel sensors, speciality yarns, body sensor networks**, **and the development of flexible solar tents** used for power generation round out the coverage. It also covers the development of fabric-integrated wearable electronic products for use in **mobile healthcare systems, smart cloth for ambulatory remote monitoring electronic jerkin, heating gloves and pneumatic gloves.**

Three kinds of electro active materials, namely **conducting polymers, dielectric elastomers and carbon nanotubes** were investigated by the scientists in the laboratory as stated [07]. An emerging concept of healthcare, aimed at a continuous monitoring of vital signs to provide assistance to patients, is gaining wider consensus. Advance in both sensor technology and communication technology and data treatment from the fundamental basis for a new generation of healthcare assistance systems, **the use of intelligent materials enables the design and production of new generation of garments with distributed sensors and electrodes.** Wearable non-obtrusive systems will permit the user to perform everyday activities with minimal training and discomfort.

The authors **[11]** have done **two successful works in bio-medical application,** which has been presented and discussed in their article. The first one is based on the development of a **smart bone fixation device for rehabilitation and treatment**. The second is on the development of smart

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fabrics for many applications including health monitoring and diagnostics. The smart bone fixation device presented in the article is an example of how smart structures can be integrated into various rehabilitation devices and artificial body parts for continuous health monitoring and improvement. Also, the developed remote sensory systems embedded into woven fabrics, has been proven **to operate successfully in monitoring any perturbation induced in the textile fabrics** as well as monitoring environmental conditions.

According to the author [13], conventional wearable vitals monitoring devices already offer sleep monitoring devices like smart mattress, smart sheets and smart pillow cases. Using smart fabric in the hospital gowns that patients are already wearing to wirelessly transmit their vitals is a useful application in medical field. Advances in the sensors themselves may eventually be able to track brain damage by identifying bruising or anomalies in blood flow. **A wearable recorder for babies can be used,** which tracks vital as well as changes in body temperature **sensors integrated into the hiker's clothing** could perform a variety of **life-saving actions** once it senses declining vitals.

FUTURE OF MEDICAL SMART CLOTHING

One of the **emerging markets is smart clothing for healthcare,** the idea of **weaving electronics into a shirt, a blanket, a bandage, a knitted cap or to perform specific patient care functions.** Smart clothing or e-textiles as a whole are still in its infancy and practical applications that are being used in hospitals and other care facilities. Many of the academic endeavours are moving forward and working toward commercialization, innovations in high-tech fabrics and the microelectronics are opening even further possibilities for healthcare related e-textiles. Some of the ideas and early pilot projects involve t-shirts that relieve chronic back pains, shirts with stretch sensors for monitoring respiratory rate patients with chronic lung disease, soft all-day belly bands that monitor uterine contractions and fatal heart rate in pregnant women, pressure monitor stocking for use by diabetic patients or even a shirt that delivers shocks to patients experiencing serious heart problems. Some experts see smart clothing replacing **besides monitoring in hospitals with shirts that track heart rate, blood pressure, oxygen intake and more. Hepatic feed or the use of touch in a user interface design holds much**

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promise in e-textiles because it can be easily miniature and does in moving mechanical parts.

CONCLUSIONS

Electronic textiles or e-textiles are newly emerging interdisciplinary field of research which brings together specialists in information technology, Microsystems, materials and textiles. Smart textiles can sense and react to environmental conditions or stimuli from mechanical, thermal, chemical, magnetic or other sources. These fabrics are easily integrated into truly wearable, instrumented garments, capable of recording kinaesthetic maps of human motor functions with no discomfort for the subject. The adoption of smart fabrics will be determined by attitudes, applications, and product appearance, as well as by focusing on genuine needs and the technology will need to become commercialized and easily consumed so it is seamless and invisible from sight to succeed. The use of smart textiles based on FOS in respiratory and heart beat monitoring is just in its beginning stages, but their good metrological performances and the possibility to monitor patients in real time during MRI procedures motivates to continue research effort devoted to this topic. In composite materials, FBG sensors are a good solution due to their simple integration. The development of smart textiles will lead the textile to enter into the new era. Technology and material solutions incorporate fibre, textile and electronics manufacturing technology with application of materials with electrical, chemical, mechanical and optical reaction. The idea of using smart structures in bio-medical applications will have a strong impact on the advancement of health monitoring and diagnostics systems.

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