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SMART TEXTILE: APPLICATION, DESIGN AND MARKETING (REVIEW)

Barakat.G.

Apparel Dept. - Faculty of Applied Art- Cairo

ABSTRACT

During the last years, the traditional textile industry strategy has changed to support the innovation and the creation of new products and functionalities. This has allowed the consolidation of the emergence of "Smart Textiles". Advances in material science have added intelligence to textiles and created "smart" clothes, which can sense and react to environmental conditions or stimuli. Such textiles find uses in many applications: military, security, personalized, healthcare, hygiene and entertainment.

Intelligent garment design is a multidisciplinary subject. In order to successfully introduce smart textiles in fashion, there is a need for a multitude of methodologies. Areas like art, technologies, social science for examples, need to be combined in order to transform technology into a meaningful form of use. A snapshot has been given the current state of the market and how it will grow in the next years, with market forecasts through 2020.

Keywords: Smart Textiles, innovation, functionalities, intelligent textiles, design, Marketing

I. INTRODUCTION

Smart textiles represent the next generation of fibers, fabrics, and articles produced from them. Many intelligent textiles have the protection and safety features. **[1, 2]** These developments are the result of active collaboration between people from a whole variety of backgrounds and disciplines: engineering, science, design, process development, and business and marketing. **[3]** Such evolution could only be conceived through a combination of recent advances in fields as diverse as fiber and polymer research, advanced material processing, microelectronics, sensors, nanotechnologies, telecommunication, informatics, and biochemistry,….etc. **[4]**

"Smart textiles" is one of the new fields of textile, which is finding its unique applications in various fields such as civilian, medical, military, and various other sectors. They are used now in many industries and applications that are greatly beneficial to the mankind. **[5]**

II. DEFINITION OF SMART TEXTILES

Smart textiles are defined as textiles that can sense and react to environmental conditions or stimuli from mechanical, thermal, chemical, electrical or magnetic sources. **[1, 6, 7]**

Smart textiles are defined also as "the combination of electronic and conventionally textile materials, and which able to sense for the physical stimuli from the external environment and then perform some reactions against them. Smart textiles not only protect the human body from extreme environments, but can also monitor signals, and communicate wirelessly. **[8, 9]**

IJARSE
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III. CLASSIFICATION OF SMART TEXTILES.

According to functional activity smart textiles can be classified into four categories:

3.1 Passive Smart Textiles*:* The first generations of smart textiles, which can only sense the environmental conditions or stimulus. **[10, 11]**

3.2 Active Smart Textiles*:* The second generation has both actuators and sensors, which sense and react to the condition or stimuli. **[4, 6, 12]**

3.3 Ultra Smart Textiles*:* Very smart textiles are the third generation of smart textiles, which can sense, react and adapt themselves to environmental conditions or stimuli. **[1, 3, 13]**

3.4 Materials with a higher level of intelligence: can be achieved from those intelligent materials and structures capable of responding or activated to perform a preprogrammed function manner. **[10, 12, 14]**

IV. SMART CLOTHES COMPONENTS

The smart textiles consist of two types of materials, the textile and the electronics. **[15]** These components must all be integrated into textiles while still retaining the usual tactile, flexible and comfortable properties that we expect from a textile, with adding new functionalities to textiles. **[16, 17]**

The textile fibers used must be at least semiconductors of electricity so that the electronics in the garment can be easily integrated. They can be used collectively with Textile fibers to form fibers that can be woven/ sewn together and that conduct electricity. However, these fibers are still quite stiff due to their metallic nature. **[1, 18].**

4.1 Sensor materials and structures

There are many kinds of sensor, thermal, Pressure, Chemical, and Biosensor (sensing of blood glucose levels). **[3, 4, 5]**

4.2 Actuator materials and structures

Actuators respond to a signal and cause things to change color, release substances, change shape and others. Chromic materials are widely used in smart textile applications. **[8]**

4.3 Conductive materials

Conductors are a group of materials that conducts electricity, due to their conductive properties; the most conductive materials are silver and copper. **[8]**

4.4 Electronics

The smart system will require a central processing unit that will carry out data to the different sensors and decide action on the basis of the results. The processing unit is a complex structure of electronic circuitry that executes stored program instructions. **[5, 7, 15]**

V. APPLICATION OF SMART TEXTILES

5.1 Military Field

One of the main reasons for the rapid development of smart textiles is the military industry. This is because they are used in different projects such as uniforms that change color to improve camouflage effects, **[13, 17, 19]**

IJARSE
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ISSN (P) 2319 - 8346

beside of monitor vital signs, monitoring environment hazards such as toxic gasses, and wireless communication to a central unit which allows medics to contact with the infected. **[15]**

5.2 Medical Field

There is growing interest of smart textiles which use in medical applications because of increasing the mobility of patients, who need a continuous monitoring of physiological parameters. **[20]**

Intelligent medical textiles have the potential to substantially change the provision of health care services for large population groups, like those suffering from chronic diseases (such as cardiovascular, diabetes, respiratory and neurological disorders) and the elderly with specific needs**. [21, 22]** where they can quietly monitor the wearer's heart rate, respiration, temperature, blood pressure and a host of other vital functions, alerting the wearer or physician if there is a problem. **[23, 24, 25]** Although they still in the first stage, the medical electronic textile technology has a great prospectus in the future. **[5, 26]**

5.3 Sports Field

The sports segment is the leading application area for both smart clothing and body sensor devices. There are A variety of products available in the market today such, shirts, sports bras, shorts, and smart socks, all targeting different areas of the body and gathering different biometric data. Body sensors mostly include monitor heart rate, **[24]** sensing capabilities to provide instantaneous awareness of the physiological condition of the athlete, thus providing valuable information about the athlete's physical abilities, training status, and responses to various training regimens. **[17]**

5.4 Safety Protection and Positioning

It is necessary to make protection measures for safety and positioning. Since 1988, Finland began the research on intelligent rescue clothing, and then gradually developed the smart clothing which can measure human physiological data and save a life. Then MOTOROLA has launched safety protection, entertainment, and leisure in the integration of electronic ski jacket**. [13]**

5.5 Beauty of Decoration

Using the unique optical fiber materials and paint to design different patterns and achieving the changes in clothing style and color through the shape memory materials and photochromic materials**. [13]**

5.6 Fashion/Lifestyle

Scientists consider Smart textiles and clothing as a means for "achieving closer interaction with technology". **[23]** When it comes to the implementation in terms of marketable products the focus is still mainly on technical aspects, rarely on appealing or emotive garment results. **[7, 3]** The integration of the technical components into the garment is deficient, partly because of components – particularly the batteries – are bulky and heavy, and partly because on the engineers' side, a lack of understanding of the role of fashion in society is prevalent. **[27]**

During the last decade, smart and interactive textiles have been widely used in technical clothing, protective garments for electromagnetic shielding and static charge dissipation, flexible solar cell panels, heating elements, pressure sensors, and chemical sensors, fabrics for dust and germ-free clothes power sources, and wireless devices**.[28]**

IJARSE
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VI. SMART TEXTILES AND DESIGN

The relationship between technology and design is crucial and the disciplines are strictly linked to each other. The role of design is to make the technology easy to use. **[29]**Smart garments are clothes which provide some additional functionality to the classical physical and socio-cultural functions of clothing. **[16]** The clothing must balance functional elements with both structural design and aesthetic considerations, including the important subjective element of comfort. **[29]**

Although there are many literatures related to the "design", they focus more on the development and evaluation of the function of smart clothing, while they ignore the aesthetic design for the garment. **[13]**

In order to introduce smart textiles in fashion, there is a need for collaboration between many fields like art, technologies and social science to transform technology into a meaningful form of use. **[15]**

Divisions between art and science Pursuing aesthetics and developing technology are perceived as two separate activities. For instance, an artistic designer may have no skill or knowledge of how to use technology; the scientist, on the other hand, does not understand why and how people judge beauty. The basis of the division between aesthetics and technology is because art designers are driven by aesthetics, senses, and trends, whereas scientists are driven by functionality, efficiency, and invention. **[30, 31]** The use of high-tech has also opened up new territory for fashion design. [5, 32]

The process of designing the clothes starts from problem exploration and analysis to determine the characteristics required of the new product and defined by the potential users. In this initial step must determine the type of user; the gender, age, shape, lifestyle and socio-economic group of the proposed user, besides an analysis of users clothing preferences. This data may be gathered through interviews, direct and indirect observation and questionnaires. **[29]**

In the research which designer performs, also reviewing, analyzing and comparing between earlier and existing products, It is essential to gather initial information about product price, size and color ranges; new and existing materials, thread and fastening components; manufacturing processes; garment labeling regarding aftercare; fashion and design content. Based on research and sampling, a comprehensive study of contemporary fashion, color, texture, line, and relevant cultural contexts informs the final selection of product characteristics, both functional and aesthetic. **[32]**

After a preliminary research, innovations, evaluation, and selection can be introduced of proposed designs, and also the manufacturing of prototype follows afterward. After the evaluation and testing of the prototype, which includes a testing against the set of criteria identified in the design brief, preferably by trials with the user group. If prototype shows satisfactory performances for the specific group of users and their specific hazards, the actual production process will start. **[29]**

A major challenge in wearable computing at present is how to interconnect components and to find alternatives to conventional silicon and metal components which are difficult to integrate with soft textile substrates. Smart textiles must be flexible enough to be worn for long periods of time, without causing any discomfort to the wearer. **[33, 17, 34]**

The results reveal that the current strategy of embedding a wide range of electronic functions in a garment is not suitable. This is primarily because it does not match the users' requirements, purchasing criteria and lifestyle. **[7, 34]**

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

6.1 Design Elements

6.1.1 Technology

Technology is a key element of design of smart clothing. It directly affects function, and comfort intelligent clothing, also it will indirectly affect the appearance of clothing. Therefore, the promotion of technology is a double-edged sword, it should not only ensure the intelligent clothing wearable but also electronic devices must be hidden in it. This makes that the development of smart clothing will great opportunities and challenges to the technical design. **[13, 35, 36]**

6.1.2 Materials

Materials undergo the transition from structural materials to functional materials to intelligent materials. The raw material structure of smart clothing materials has become more upscale and diversified. Because of the particularity of smart clothing, the requirements for materials differ from ordinary clothing. In addition to the basic functions like covering the body, protection against the cold and many other things, it has functions of automatic temperature control, automatic color changing and transmission of information….etc. **[13, 17]**

6.1.3 Structure Model

Smart clothing is the embodiment of beauty of technology, the beauty of function and beauty of aesthetic in the structure design. The study of the structure model is to explore the aesthetic expression of art and science and technology in the design of clothing. **[13]**

6.1.4 Color

The color is an important factor in intelligent garment design. It not only embodies the matching relationship between clothing and human plays a specific role in the technical function but also plays a role in visual perception in the aesthetic creation design. The smart clothing which is able to perceive the external environment change, and change color because of the change of temperature, pressure, light, humidity and structure, So color can be used as interactive identification to express and transfer information. **[13, 37]**

6.2 Design Evaluation [8]

Whether smart garment meets the design requirements or not, sum up the following aspects need to be considered.

6.2.1 Wearability: Evaluate of clothing comfort on the basis of physics analysis. It contains the fabric properties, such as permeability, weight, easy to wear, etc.

6.2.2 Availability: The main task is enforceability, including electronic equipment, the operation of the system, the transfer, reaction, storage and processing speed of data, data connection and power supply capacity, etc.

6.2.3 Reliability: Special performance with different environment required, including the wrinkle resistant, waterproof, shearing resistance, strong tensile, warm, moisture absorption and so on.

6.2.4 Washability. Whether can be washed or not, whether can be normally used after washing or not, service life of the electronic products, the dimensional stability of fabric etc.

6.2.5 Maintainability: It mainly includes the service life and replacement of the built-in electronic devices, battery charging, the system software update, etc.

6.2.6 Observability: The clothing design modeling, color collocation, concealment of the distribution of electronic components, etc.

IJARSE
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6.2.7 Manufacturability: The estimate of cost price, the rationality of the design, whether to be applicable or not.

VII .SMART GARMENTS –USABILITY AND AESTHETIC

Usability can be defined according to the International Standards Organization (ISO) **[15]** as the "extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use".

There are three main principles of design: a) early focus on users and tasks, b) empirical measurement, and c) iterative design. **[26]**

This implies that designers should bear the end user in mind throughout the whole design process. **[38, 39]** An important and widely applied method to integrate the end user into the development process is to conduct usability tests, in which test users interact with prototypes of the product in a typical usage scenario to carry out real tasks while their performance and reactions to the product is observed, recorded, and empirically analyzed. **[26, 12, 3]**

7.1 Influencing factors in usability tests [8]

There are four factors influencing in usability tests:

- **System prototype**: Prototypes are often used in usability tests in place of an operational product because usability tests are for the most part conducted early in the development process when a fully operational product is not yet available. Prototypes, however, might differ considerably from the final product. This can have an influence on the results of usability tests.
- **Testing environment:** the usability test scenario can differ from the real usage scenario, for reasons of measurability and controllability of influencing factors, usability tests are often conducted in laboratories. **[27]** The lab environment is an environment that differs considerably compared to the real usage scenario, which can have an influence on the results of usability tests.
- **User characteristics:** Characteristics of test participants (such as i.e. competence, attitude or state) may differ from the future user, which might influence the results of usability tests.
- **Task scenarios**: The task scenarios given in usability tests may not be representative enough compared to the real usage situation. As a consequence of a restricted budget in usability tests, often only a selection of possible tasks is selected. (figure1)

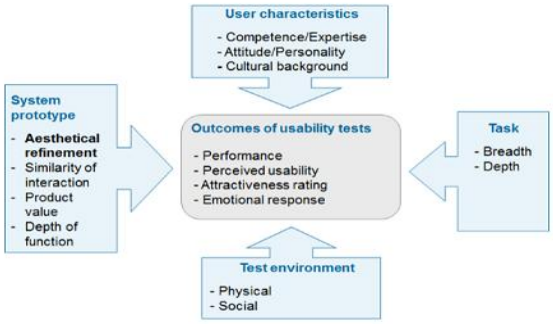

Figure (1) four factors influencing in usability tests [16]

IJARSE
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Some studies indicated that design aesthetics influence other outcome measures of usability tests, such as user behavior, and user emotions. [40, 18] Where is highly probable that the different outcome measures are severely biased by the aesthetical refinement of the product prototype. **[41, 42]**

Although design aesthetics seems to play a very important role in usability tests, a recent study has indicated that the positive influence of design aesthetics on subjective usability measures vanes with an increased duration of the user-product interaction. **[18, 40, 43]**

VIII - MARKETING OF SMART CLOTHES

The global smart textile market has experienced tremendous growth over the past few years owing to the rapid rise in the number of end-user sectors. Currently, industries such as the automotive, healthcare, and sports are showing an increased uptake of smart textiles. These textiles offer significant potential for medical and healthcare applications as they make diagnosis and risk assessment far more accurate and quick. The growth of the telemedicine market is also expected to have a positive impact the growth of the global market as smart textiles are equipped with sensors that record parameters and transmit them to a central unit.

On the other side, the high price of smart textiles as compared to conventional textiles is limiting the widespread adoption of smart textile. The market was valued at US$1.97 bn in 2015 and is estimated to reach US$3.81 bn by 2020, rising at 14.0% from 2014 to 2020. **[44, 45]**

The majority of this market will be driven by sports applications, but it will still represent less than 1% of the global sports apparel market, which is worth more than $140 billion today. **[24]**

The global wearable technology market is expected to grow from $750 million in 2012 to $5.8 billion in 2018, while the number of wearable devices shipped is expected to rise from about 13 million in 2013 to 130 million in 2018. In this context, it is estimated that the size of the wearable technologies market will increase from $1.4 billion in 2013 to $19 billion in 2018. **[34]**

Despite the rapid growth of wearable technology in fitness tracker and smartwatch categories, other categories are lacking dramatic growth, In particular, smart clothing which represents less than 1% of the global wearable's market.(figure 2,3) The lack of expansion in this category is due to many factors:

- Technical challenges with sensor size, sensor accuracy, and device power
- Cultural challenges in data privacy, device cost, and style. **[47]**

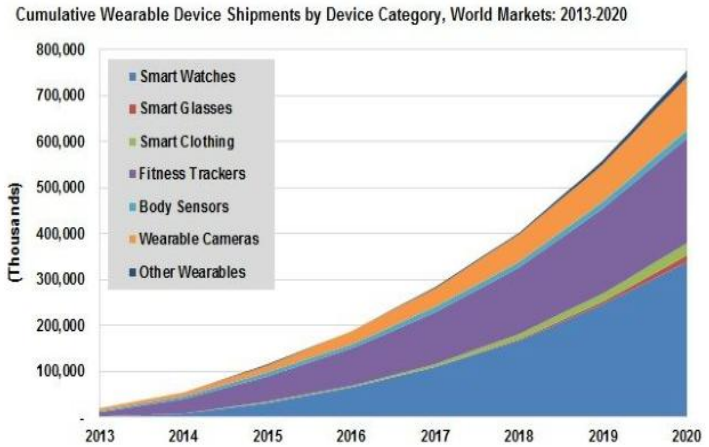

Figure (2) Cumulative wearable device shipments by device category, world markets: 2013-2020

IJARSE
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One of the largest challenges to smart clothing adoption is the lack of compelling use cases for personal electronic consumers and the market value of developing and selling devices to end users. To realize the potential of smart clothing, companies must develop products and services that provide both personal data insights to end users as well as providing big data analytics that provides and delivers commercial value to companies building it. Professional athletics, military industry, and healthcare have the significant market potential **[47]**

The slow adoption might be due to a lack of obvious use cases for consumers starting with a basic lack of public awareness. Although recent Google searches show "Smart Clothing" still is not largely aware of the increasing in popularity, user's market offerings. According to a recent survey of 2,407 consumers in developed and emerging markets, of wearable technologies, people are least of smart clothing and textile products. **[48]**

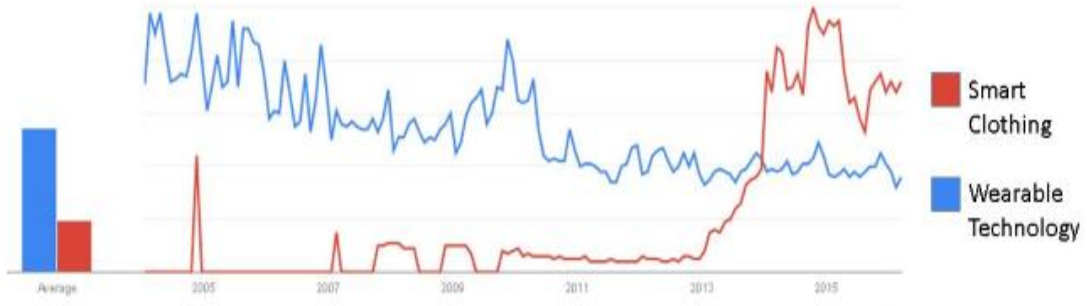

Figure (3) world markets of smart clothing and wearable technology: 2005-2015

A new marketplace for smart textiles is available. In which they provide new functions and features that can enhance performance and comfort. The Integration of; textiles, electronics, and advanced smart materials, is a result of diminishing size, and low price of components such as transistors, and resistors. **[48]**

IX. THE FUTURE OF SMART CLOTHES

An undergarment that needs no washing, An outer garment which can be worn, both in summer and winter, a garment which lights up in the night, this is where the future textiles are marching towards. **[30]**

It is expected that these technologies will be rapidly and easily adopted by individuals, and they will find extensive use in both social life and work activities. **[46]**

Market growth is likely to be slow due to high prices of finished products of smart textiles as compared to conventional textiles. Rising number of research and development for product and technological innovation is expected to provide new opportunities for market growth. The Transportation segment accounted for the largest demand for smart textiles about 38% in 2013. New applications such as measuring heart rate, smart seat belts and functioning of steering wheels hold immense potential in the automotive industry. **[23]**

X. CONCLUSION

Smart Textile represents the next generation of textiles anticipated for use in fashion, furnishing and technical textile applications. The vision of Smart Textile is to create textile products that interact by combining smart

IJARSE
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materials and integrated computing power into textile applications, which offers an opportunity to develop textiles with a new type of behavior and functionality.

Smart textiles also have the potential to make people's daily life more comfortable and safe. There is an effort to make electronic devices a genuine part of our daily lives by embedding entire systems into clothing. Such textiles find uses in many applications ranging from military and security to personalized healthcare, hygiene, and entertainment. Smart clothing needs to satisfy users with regard to usability and functionality. To do justice to all those requirements, it is crucial to consider the user with his or her needs and limitations throughout the whole development process.

Markets for Smart clothing has given a snapshot of the current state of the market and how it will grow in the next years, with market forecasts from 2013 through 2020.

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