Advance Research in Textile Engineering

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Austin Publishing Group

Review Article

Applications of Nanotechnology in Textiles: A Review

Hassan BS[1], Islam GMN[1]* and Haque ANMA[2]
[1]School of Textile Science & Engineering, Wuhan Textile University, PR China
[2]Department of Textile Engineering, Daffodil International University, Bangladesh

***Corresponding author:** Islam GMN, School of Textile Science & Engineering, Wuhan Textile University, Wuhan 430073, PR China

Received: April 29, 2019; **Accepted:** August 05, 2019; **Published:** August 12, 2019

Abstract

Nanotechnology applied in smart textiles has modernized the textile world. Fabric touch pads, bullet free jumpsuits, invisible coatings and advance fibers turned the basic textiles into smart textiles. ICPs (inherently conductive polymers) known as artificial muscles are developed from nanomaterials which are used to match biological muscles. AgNPs (silver nanoparticles) treated fabrics are the most effective antiseptic bandages or dressings. Conductive inks impregnated with gold, nickel and copper nanoparticles are used as encapsulation like pressure pads. Carbon doped polymers built with iPod controls and fabric switches retain the piezoelectric properties. Woven optical fibers perform multi-functions in textiles i.e. deformation detection, light transmission, sensing and data transmission device. Light emitting textiles is another concept for the transfer of graphic and multi colored surfaces. Phase change materials fabrics work as thermostat i.e. maintains the optimum temperature. Smart textiles based on nanotechnology are specially designed for military purposes to monitor the stress and failure in human body during combat conditions. Moreover, Nylon nanofibers are utilized as protective clothing for the filtration applications, whereas Fiberglass and Carbon nanotubes are widely used in air filtration industry. However, the engineered nanomaterials cannot be ignored from human health and environmental perspective which suggest proper consideration while getting benefit from this technology.

Keywords: Nanotechnology; Smart textiles; Sportswear; Nanoparticles; Phase Change Materials.

Introduction

Technology and advancement reformed the whole world. Mesoscopic physics came into front line with the emergence of nanotechnology. It comprises of Nano engineering and nanotechnology [1]. Nano science, nano engineering and nanotechnology are very promising scientific areas that alter the potential applications upto an incredible extent.

Nanomaterials are basically smaller units of scientific knowledge constituting molecular and atomic structures. Nanoparticles, nanofluids, nanowires and nanofilms all give rise to implausible applications in the field of science and technology i.e. microbiology, optics, electronics, textiles, biomedical, coatings, aerospace, materials science, energy, plastics and mechanics etc. Conventional materials impregnated with nanoparticles possessing enhanced properties owing to large surface area of nanoparticles. A visible shift of change in properties has been seen while moving from microscopic to nanoscopic level. For example ceramics are very useful materials but brittleness of ceramics lemmatizes its applications owing to reduction of the grain size upto nanoscale and renders ceramics into deformable material [2]. Nanoparticles retain unique properties by precise and controlled arrangements of molecules and atoms. The materials made from the nanotechnology owning high quality and fewer shortcomings because of bottom-up technology. According to bottom-up technology macroscopic structure can be made into tiny structures utilizing fewer materials and less cost [2].

For understanding and better utilization of nanotechnology, biologists, material specialists, physicists and engineers should worked together. Nano systems (nanometer-scale systems) also need the modernized and advanced equipment, so engineering and applied sciences should share their capabilities. Nanotechnology needs the strong interaction between science and technology. This interaction is possible when all the fields of science share their capabilities but keep their inherent identities [3-4]. To wear the cloth is a characteristic of a human. Human skin needs protection from surroundings and climates i.e. rain, cold and heat etc. Socially humans use clothing to reveal their culture. After fulfillment of basic needs of clothing, there was a shift in human thought to utilize textiles instead of only clothing. After home looms there raised the concept of textile industries. Besides turning towards clothing needs, textile industries started focus on non-clothing areas of textiles i.e. technical textile. The primary role of technical textile is to provide technical function and performance features rather than aesthetics and decoration characteristics. Technical textiles played its role in many areas including environment, transport, multidimensional (1D, 2D, 3D) materials, health, construction, furniture and hygiene etc. With the advancement in the scientific knowledge and practices, new doors are opened in the field of technical textiles [5, 6]. Instead of the basic purpose of covering the body, fabric now can be developed with some specific properties for special uses in our daily life, such as static protection, self-cleaning, shrink resistance, stain resistance, fire resistance, electrical conductive, fragrance release, UV protection, water repellent (hydrophobic), moisture management, high strength, antimicrobial and wrinkle resistance by incorporation of nanotechnology [7]. Besides advancement in all the fields of science, textile is also impacted by nanometer-scale systems. The first research on nanotechnology in textiles was taken on by a supplementary of

Citation: Hassan BS, Islam GMN and Haque ANMA. Applications of Nanotechnology in Textiles: A Review. Adv Res Text Eng. 2019; 4(2): 1038.

the US-based Burlington Industries, US Nano-Tex [8]. Now textile industries have already been prospered as a result of advancement in nanotechnology. Improvement in the performance of textiles and accomplishment of extraordinary functions of textiles are the outcomes of nanotechnology. The key benefit of nanotechnology is based on the nanostructure, nanoscale additives, nanoscale thin membranes, engineered nanomaterials and nanoscale transistors etc. Materials that can efficiently be produced by nanotechnology is more durable, sieve like, lighter in weight , conductive, stronger and may possess many other individualities [7].

Accomplishing a scientific research is not enough for the commercialization of any product, it takes time to discover the right purpose and technology e.g. electrospinning, thin films and conductive polymers were introduced a long time ago and now they include into the research game. So it will take some time to commercialize the application of nanotechnology in textiles. How much time it will take is an intellectual question. Smart textiles are a kind of sensitive materials that can sense the stimuli i.e. they can respond to magnetic, mechanical, electrical, thermal or chemical. Smart textiles have many uses in every field i.e. health care, environment, military and hygiene etc [9]. Such kind of textiles may be called as passive or active depends upon how they are performing functions. Smart textiles go through various treatments and used as composites and coatings that result in sensor materials or wireless data transmission. Recently, world of textiles combined with different fields to achieve increased performance and extra- ordinary properties. For example synchronization of textiles and electronics yield extra-ordinary properties. Flexibility, high surface to volume ratio and roll to roll handling are possible in electronics after combination with textiles [10-11]. Different non-textile materials are now incorporated in textiles like coatings and conductive materials in fibers [12]. Now it is possible to attain smartness in textile by manipulation of nanoparticles, nanofilms and nanocoatings. Moreover, enhanced electrical conductivity, high mechanical strength and thermo stability are not difficult to achieve.

Smart textiles are also taking the game in the field of interior designs [13]. They provide exclusive properties i.e. haptic, optical and acoustic properties to the interior products. These features make the interior products extra-ordinary and expensive from selling point of view. Smart furniture is introduced in interior designs by the combination of electronics and textiles. Electronic systems like power switches and user interface are now utilizing for the interactive surfaces, power cable and car interiors by the producers, architectures, inventors and engineers [14-16]. Nanotechnology used in different segments of textiles is shown in Figure 1.

Figure 1: Nanotechnology used in different segments of textiles.

Developments in nanotechnology Applied in Textiles

Nanotechnology in textile finishing

Coated Nanoparticles: Nanotechnology also has a great influence in textile finishing. It not only introduced the new finishes but also developed new application methods in textiles. Smooth, controllable and highly functional chemical finishes have been made [17]. Nanoparticles finishes can pass through the localized sites on textiles through technical and electrostatic approach [18]. Nano-coating is applied usually on the smooth and the planer substance. Nano-coating is done by various techniques i.e. sol gel coating, electro deposition, microwave heating method, dip coating, electrochemical deposition, spin coating and vacuum evaporation. Each method has some limitations and its application depends upon the end use. The adhesive forces between the material being used for coating and coating are electrostatic, covalent bonding and hydrogen bonding [19].

Semi-conductor ceramics and metallic oxides nano-finishes can be applied on textiles to get specific properties i.e. flame retardency, water repellency, oil repellency, thermal resistivity and antimicrobial properties etc. Nanoparticles of Fe, pd/pt and Ag are manipulated into textile products to achieve conductive heating, conductive and magnetic properties. Nano-finishes are also used for medical purposes. Ag is very important with biological point of view. It has been used in bio-treatment for more than hundred years ago. Silver has natural anti-fungal and anti-bacterial features. Polyester non-woven and colloids treated with nano-silver particles are highly bacteriostatic. Prohibition of bacterial growth in nano-silver particles makes it useful to use in socks. These nanoparticles are widely used in wound, scald and burn dressings. Electrostatic, thermal and padding methods are utilized to apply nano-finishes on textiles. Ag nanoparticles applied on textiles through padding technique possessing excellent laundering ability. Antimicrobial filters are made by manipulation of antimicrobial agents (Ag with nanofibers). Many nanofiber membranes like cellulose, PAN, (polyacrylonitrile) and PVC (polyvinyl chloride) containing Ag nanoparticles possessing antimicrobial properties. Engineered nanomaterials containing Ag and $Ag+$ nanoparticles are utilized as antimicrobial filters with sufficient transport properties [20].

Besides Ag nanoparticles, titanium oxide and magnesium oxide nanoparticles are also used as biological protective agents. They can be manipulated by electrostatic methods and spray coatings. Nanoparticles finishes can convert a material into sensor based material. For instance, piezoceramic particles that are operated into the textiles can detect the pulse and heart beat by conversion of mechanical force into electrical signals. Zinc oxide and titanium oxide nanoparticles are used for oxidative catalysis, UV protection and fiber protection. Silicon dioxide and aluminum oxide nanoparticles with polypropylene or polyethylene coatings are used as super water repellent purposes. Ceramic nanoparticles are also developing for

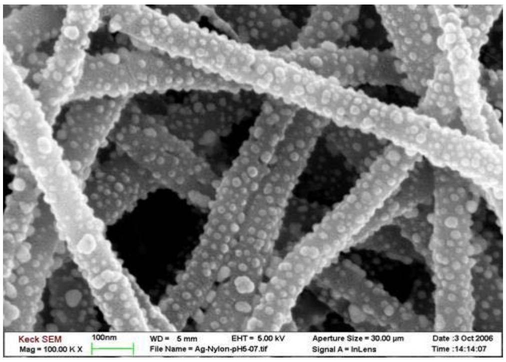

Figure 2: Nylon nanofiber coated with Ag [41].

enhanced abrasion resistance. Nanoparticles of indium tin oxide are used as infra-red protective clothing. Nylon fiber containing zinc oxide particles enhanced the antistatic and shielding effect.

Nanofibers can be made by different techniques. Electrospinning is an uprising technique for the production of nanofibers. Electrospun nanofibers have applications in many fields. These fibers have capability to absorb (VOC) volatile organic compound. Activated carbon is used for many years to the remove the toxic chemicals by absorption. Electrospun nanofibers replaced conventional activated carbons for desorption and absorption of toxic chemical and VOC [21]. Nanofiber coated on the conventional filters makes the slip flow phenomena more prominent. Owing to large surface to volume ratio and smaller size, nanofibers distribute airflow from the surface which makes the slip flow process significant. The fact that reduction in diameter ultimately enhanced the filtration capability makes the nanofibers highly efficient [22-23]. Nanotechnology applied in textiles also placed the positive influence in medical field. For example, ultraviolet rays have very adverse effect on human beings and environment. Due to ozone layer depletion many harmful rays reached to the earth surface. They can cause serious health problems like skin cancer, blisters, bumps, red blotchy, eye damage, sunburn and premature wrinkling etc.

To minimize interaction of UV rays to skin metal oxide nanoparticles are made. Titanium oxide, magnesium oxide, zinc oxide and aluminum oxide are the metal oxides that inhabit the UV absorption, photocatalytic, electrical conductivity and photo-oxidizing capability [24-25]. Nanoparticles of these metal oxides work against the biological and chemical toxic agents. Mostly zinc oxide and titanium oxide nanoparticles are used as UV blockers [26-29]. Coating into the textiles always has the risk of durability. Silver nanoparticles coated on cotton fibers through pad dry cure method showed high laundering durability, preserving the antibacterial properties and anti-fungal properties against many pathogens even after many washes. These properties of silver nanoparticles make the usage of nanoparticles on textiles worthwhile [30]. Organic or inorganic titanium oxide and titanium dioxide affect the properties of textiles i.e. photo stabilizing wool, super-hydrophobic, photo-catalyst, co-catalyst for cotton crosslinking, antibacterial, gas sensor, self-cleaning, hydrophilic, dye degradation and solar cell. Carbon nanotubes utilized as chemical absorbers, electrically conductive device, antistatic, antimicrobial, and fire retardant. Clay nanoparticles used as UV absorber, antibacterial and flame retardant. Gold nanoparticles are electrically conductive and antibacterial agents [31-33]. Table 1 shows different nano materials used for various kinds of finishing on textiles.

Nylon Nanofiber: Nylon nanofibers coated with silver has antibacterial properties against gram negative E.coli and staphylococcus aureus bacteria. Electrospun nylon 6 nanofibers coated on cotton/nylon woven fabrics are used for filtration purpose. 99.5% efficiency is achieved without any surrendering in pressure drop and loss in air permeability by using nylon 6 nanofibers [17,40]. Nylon fabric coated with electrospun nanofibers incorporating the nanoparticles of ZnO, SrTiO3 and TiO2 possessing self-cleaning features. It has been proved by characterization techniques that fabrics treated with such nylon (polyamide66) nanofibers retaining high photo activity after repeated wash and dye degradation [20-22]. Figure 2 shows a SEM image of nylon nano fiber coated with Ag.

Conductive textiles

Conductive Polymers: ICPs (inherently conductive polymers) have exclusive properties of actuation and sensing. The unique chain structure comprised by the conjugated double bonds is responsible for the electrical conductance of these polymers. Conductive polymers like polyaniline, polyacetylene, polythiophene and polypyrrol (PPy) are incorporated into the textile materials and work as sensing and actuating materials [42]. PPy-based fabricated supercapacitors were reported with cycling stability in recent past [43]. Electrical conductivity changes in polymers like polypyrrol, polyacetylene and poly 3, 4-ethylenedioxythiophene (PEDOT) etc as a result of

Table 1: Nanomaterials practiced in textile finishing.

Finishing	Nano materials used	References
Protection from UV	ZnO, TiO_2	26-29
Improved staining and fade reduction	Nanoporous hydrocarbon, Carbon black, SiO2 matrix	27, 34
Moisture absorbency	TiO_2	26
Self-cleaning properties and water repellency	TiO_2, Fluoroacrylate, CNT, SiO_2 matrix	35-36
medicinal products or fragrances	Montmorillonite (nano clay), SiO_2 (as matrix)	37
Antistatic and conductive	Carbon nanotubes (CNT), Carbon black, Copper, Polypyrrole, Polyaniline	38-39
Durability	Metal oxides like Al_2O_3, SiO_2, ,ZnO, CNT, Polybutylacrylate	26
Antibacterial	Chitosan, Ag, SiO_2 matrix, ZnO and TiO_2	26-27
Fire proofing	Boroxosiloxane, CNT, Montmorillonite (nano clay), Sb_3O_2	36

Figure 3: Use of conductive polymers. [47].

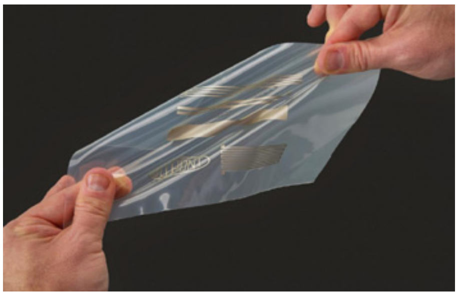

Figure 4: Conductive ink introduced by DuPont [50].

external deformation. Electrical behavior is governed by the two reasons, osmotic removal or transfer of solvent in/out and change in polymer structure backbone. Mostly polypyrrol is used as conductive polymers due to its high elasticity and high mechanical strength. It never destroys the texture and shape of the textile materials. So organic piezo-resistive sensors developed by using the conductive polymers [44]. They can be used as artificial muscles due to their ability to work on physiological fluids by exerting the mechanical force as a result of electrochemical reactions. This mechanical sensing ability is of extreme importance with respect to tissue engineering owing to its influence on the behavior of cells. A polypyrrol based actuator system can be incorporated on a chip based on mechanical stimulation. This actuator system is responsible for transformation of mechanical signals to epithelial cells. They are also used as micro-grippers and blood vessel sealers. Inherently conductive polymers are light weight and actuators can produce the mechanical response of 1 mega Pascal as a result of electrical force of 1 volt. Their capability to work at surprisingly low voltage (1 volt) makes them an ideal material to use for tissue scaffolds [45-46]. Figure 3 depicts an example of conductive polymer which is also called smart second skin.

Stretchable Circuits as Conductive Inks: Now-a-days it is possible to construct electronic connections in textiles that are harmless and portable. Garment can be made conductive at any site. Conductive ink applied by screen and ink jet printing creates conductive areas on textiles. Inks can be made conductive by adding metals as nickel, carbon, gold, silver and copper to conventional printing inks to make them conductive. The printed areas on textiles

Figure 5: Optical fibers in home decorations [53].

Figure 6: Embrace baby blanket [54].

can be utilized as pressure pads or electronic switches. Conductive ink can be used in medical field as monitoring device and as excellent active wear. These inks are quite cheaper, flexible and comfortable with respect to other conductive materials i.e. conductive yarn and polymers [48]. Now focus is shifted towards dielectric encapsulated and Ag based conductive inks. Ag based conductive inks are made up of polyurethane film that manipulated silver flakes are treated at 120°C. There electrical resistivity is very low. To cover or wrap wires (containing conductive inks) insulated inks are also used. Stretchable circuits are formed by the combination of insulated and conductive inks. To monitor the human body bio signals are used that are easily detected by conductive inks. Electronic inks have been developed on textiles by some companies. Such kind of inks printed on textiles is connected to some sensory elements that monitor the stress level, breathing rate and heartbeat. Battery module which is in wireless connection with some smart device using the sensory elements embedded on the shirts can detect the signals coming from the body [49]. Figure 4 shows conductive ink which was introduced by DuPont.

Optical Fibers: Optical fibers are produced by the combination of liquefied glass and sand particles. In this combination particular diameter/thickness is achieved and liquefied glass is taken out from the tiny openings (bushings) as filaments by cooling with cold air/water [16]. These filaments are sized with particular chemical (in liquid form) to protect the filaments. Finally optical fibers are winded and packaged. Optical fibers are incorporated into the textile materials for many purposes. Plastic optical fibers are quite famous for incorporation into textiles. Plastic optical wires are used widely owing to its resistance against electromagnetic radiations and heat. These optical fibers perform multi-functions in textiles i.e. deformation detection due to strain and stress, light transmission, chemical sensing and data transmission. Plastic optical fibers are

Figure 7: Boomer Jumpsuits [60].

weaved into the textiles and are responsible for transmission of the light. This kind of optical fibers are used in fashion industry and data transmission applications [46]. For aesthetic appeal and as a therapy, flexible assortments of LEDs are incorporated in the fabric. This type fabric falls into the category of light emitting textiles that can transfer images, messages, information and graphics. These textiles are used as a therapy to affect the mood of individual and to optimize the positive behavior [51-52]. Figure 5 shows an example of optical fiber use in home decorations.

Medical Use

Phase change materials can store, release and absorb heat as the material melts or freezes. Thermoregulation of human body is maintained by the phase change materials. Phase change materials are protected in the polymer shells by microencapsulation. These polymers are then applied as coatings or finishes on the textiles during production. Such materials made the cloths adoptive to human body temperature. These cloths maintain human body temperature i.e. when it is cold it retains the body heat (such as embrace baby blanket in Figure 6) and keeps body cool when outside is hot vice versa. They can replace the incubators owing to their ability to maintain the human body temperature [45].

Military/Security

There is a real need of protection and comfort in risky and life threatening environment. Enhanced performance and unique functionality are the key objectives to tackle the emergency and hazardous situation specifically for military and security purposes. Much advancement has been made in the field of defense e.g. a T- shirt is designed on which optical fibers are integrated which works like a computer on conductive fabric. Affected locations and wounds are precisely detected with the help of optical fibers (that are integrated into the garment of armor) [31]. Wireless communication utilizing conductive wires makes it possible to detect the variations in human body during combat situations [55]. Now focus is shifted to design special jumpsuits that can be used as light weight bullet proof textiles. These jumpsuits will be used in battlefields to detect injuries, health issues and pulse rate. Conductive polymers that are incorporated onto woven textile material worked as chemical sensors. These are formed to monitor hazards that may affect the health of an individual. For toxic gases i.e. nitrogen dioxide and ammonia less detection of ppm are devised [56-59]. Figure 7 shows an example of nanotechnology application in jumpsuits.

Figure 8: Carbon nanotube applications in body armor [65].

Textile based sensors

Carbon Nanotubes (CNTs): Carbon nanotubes are used as fillers in different polymers that enhanced the mechanical, heating and chemical properties of polymers. Carbon nanotubes based polymers composites are used as sensing materials against stimulus comprising of pH, gasses, temperature, pressure, chemical vapors, light, strain and liquid. Carbon doped polymers have are used as piezoelectric materials that works as stretch actuators [61]. For high performance textiles, sensing garments are made by the combination of carbon black powder and silicone. In electric blankets previously heating coils are used, now it can be modified by using carbon doped polymers. Now it is possible to make the whole surface of the fabric conductive by making the carbon based fabrics. In this way heating elements are created in the garments [61].

Coatings on the textiles are used to achieve high performance and enhanced functionality. CNTs coatings are used now on textiles for sensing applications for example general cotton yarns are converted into e textiles by coating of carbon nanotubes. Basically polyelectrolyte based coating of carbon nanotubes is done on the cotton yarns. Now it is possible to detect the blood protein (albumin) with the help of CNTs coated cotton yarns. Not only on the threads/ yarns can carbon nanotubes be coated on the fabrics and polymers. They may be utilized as lithium ion battery [62]. Development of self powering energy textile was also reported that transform solar energy into electrical energy from CNTs [63]. Another report was found which studied carbon-activated cotton threads on textile also for energy generation [64]. Figure 8 shows lighter body armor which is made for soldiers from CNTs.

Sports Wear

Sports industry is researching to achieve individual comfort and performance. Many products are designed to achieve the desired comfort level i.e. moisture management fabrics and waterproof breathable fabrics. For moisture management a membrane of PTFE polytetrafluoroethylene is used [46]. To achieve the desire comfort level a fabric with proper evaporation, wicking properties and breathable properties is required. Natural fibers absorb the moisture; hence they have poor moisture management properties. To achieve proper moisture management synthetic micro fibrils are used. These

Figure 9: Microcontroller driven alarm tone in intelligent knee sleeve [70].

Figure 10: Fabric keyboard [72].

synthetic fibers have good wicking properties. Now-a-days textiles are designed to adopt the human body changes, hence fulfilling needs of the users and the essential comfort properties. Special kinds of shoes are deigned with motor and a microprocessor that can sense the user's running style and adjust its shock absorbing features. Likewise some textiles are also designed that have wireless connections with the smart devices to trace the pace, distance, time and calories burned [55, 66-69]. Figure 9 shows an intelligent knee sleeve with microcontroller driven alarm tone.

Fashion/Lifestyle

Expansion and uprising of advanced textiles to achieve improved performance and enhanced functionality lead the textiles into the world of fashion and esthetics. Designers always find a way to create inspiration and art into textile. Optical fibers are utilized for data and light transmission. At the same time they are used in fashion industry to produce esthetic and decorative textiles. It is the part of the lifestyle to have a digital camera, advanced featured wrist watch, MP3 player and mini-laptop. Nanotechnology made it possible by converting the macrostructures into the nanostructures [3, 6]. Thin film technology makes the electronics into very thin and flexible films that can be integrated into the textiles. Touch pads, fabric, snowboarding jackets, electronic switches and pressure pads can be integrated into textiles [52]. Musical jeans developed in 1997. Now it has new features with advanced textiles incorporation. It has a fabric keyboard made up of polyester composite yarns and conductive fibers of stainless steel. The polyester yarns and stainless steels are joined by embroidery. Fabric keyboard is manipulated in jeans. This keyboard is highly responsive and sensitive to touch [56, 69]. On mechanical impact it produces music, rhythms and may connect with internet MP3 file. It has a control unit which takes energy from wind, solar and mechanical impact [71]. Figure 10 shows an example of electro conductive touch pad fabric keyboard from Eleksen.

Discussions

Technology and scientific research in the field of nanotechnology give world-shattering results. It modernized the life style by synchronization of many fields of science. Textile engineers have made incredible research in the zone of materials that altered the conventional textile technology. Electrospinning, microencapsulation and nanoscale structure formation laid the foundation of smart textiles. Usage of non-textile material into the textile material drastically improved and devised the new applications. Non-textile materials that also include electronics made the textile materials more capable to utilize. Smart textiles are light weight, organic, low power, flexible and low cost [11].

Technological advancement doesn't mean that commercial success is achieved. To understand it, history gives us proof that to discover something doesn't mean that commercial success is achieved. It takes time to wait for the right use to arise and commercialized the technology. Many technologies i.e. thin film electronics and electrospinning are introduced but it took time to them to get revolutionized. The followings points are of great importance with respect to commercializing of a technology. For example smart textiles have following features to commercialize:

- Are Smart textiles appointed for particular application field?
- Are smart textiles are meant to be replace the previous technologies or to meet the present needs?
- What are the positive aspects of smart textiles?
- What are the limitations of smart textiles?
- What makes smart textile unique in comparison with existing textile?

To judge any material, testing and characterization techniques are devised. Characterization technique measures the ability or quality of a material to retain its final geometry and properties on application of external stimulus. Testing of nanotechnology applied in textiles is rather a kind of tough job than testing regular textiles. In the case of regular textile, it is not difficult to measure tensile or wear resistance. For characterization spectroscopy techniques, advanced microscopy and calorimetry are required. Material parameters are critical in engineering. Nanomaterials possessing exclusive features that need intense monitoring and regulation of parameters to retain the original performance. If the materials requirements are not fulfilled, then it will alter the basic properties or features of the product. Nanotechnology is predominant in research and testing for proceeding to production controlled specifications of materials are very important. Besides revolutionizing many grounds, nanotechnology is also incorporated into the healthcare. Nanotechnology failed after the first trial for health care application owing to unachieved medical consistency at reasonable price. So, main commercial emphasis is now on life style regulation. Major drift is towards the sports applications. Textile apparel companies and research companies are now working in co-operation to plan the unique ways of sharing athletic performance and tracking. In fashion industry esthetics is the main concern rather than functionality, so smart textiles are quite difficult to utilize in fashion industry. Besides the positive sides of everything, there are always some shortcomings. Application of nanotechnology has modernized the textile industries; on the other hand it has some drawbacks. Textile firms are quite aware with the dark side of nanomaterials [42].

To evaluate the toxicity of engineered nanomaterials different methods are formulated. Standards have been made to measure the toxicity of nanomaterials i.e. IEC/TC113 and ISO/TC229. Environmental, health and safety regulations will be improved by standards. ISO standards for nanotechnologies are accessible for hazards moderation and workplace safety. But we can't say anything what are the present adverse effects of nanotechnology in textiles, how they will be utilized and applied. There is reported some risk approaches related to engineered nanomaterials in the literature. Engineered nanomaterials are used for many purposes i.e. façade coatings, finishing and in various textile products. Engineered nanomaterials are made to get high mechanical, chemical and physical properties that lie in the nanostructure of materials. These properties are utilizing in different fields like medical, transport and construction etc.

Scientists working on nanoscience introducing the risks associated with the engineered nanomaterials that are used for facade coatings and textiles. New model is developed that describes the toxicity and mathematical modeling for engineered nanomaterials' behavior. In literature, it is mentioned that by wastewater treatment almost 90 % of nanoparticles of silver and other engineered nanomaterials can be eliminated. But the behavior of Ag nanooxides has not yet completely discovered. So zinc nanoparticles and zinc nanooxides could be risky for the surroundings. There is always a risk while using engineered nanomaterials. It is possible that engineered nanomaterials may be incorporated to the large sized particles and then released into the atmosphere. Nano Titanium dioxide is the part of engineered magnetic materials that may cause disturbance to cellular characters i.e. lungs and brains etc. Engineering nanomaterials may also carry toxic substance with it. Nanoparticles can enter more easily into the lungs and may cause tissue damages. But precisely nothing can be said on the engineered nanomaterials' dark side. Though, it is noteworthy that few researchers have examined the prolonged toxicity of engineered nanomaterials [73]. There are a lot of uncertainties to measure the adverse effect of engineered nanomaterials on human health. According to recent tests it is concluded that different types of engineered nanomaterials have not stirred any serious effects after exposure with skin. All the world community of researchers recommends the investigations of engineered nanomaterials for risk calculation. This is important in construction sector as fifteen to thirty % faced coatings are built from nanomaterials [74-76].

Conclusions

Nanotechnology applied in textiles modernized many aspects of routine life and all the scientific disciplines. The major task in this field is to find replacements to metal components and conventional silicones which are not integrated into smart textiles yet. Smart textiles should have high flexibility to be used for long span of time and to maintain the comfort level of user. Tactical features and flexibility are the key characteristics of smart textiles. Smart textiles are comprised from different components which should be detachable and recyclable. Such kind of textile materials should be designed according to comfort of the end user, so it should be made by the co-ordination of designers, researchers and sports experts. DIY (do it yourself) approach should be started for the commercialization of textiles. But before doing any practice, probable outcomes should be kept under well consideration as the engineered nanomaterials may have adverse effect on human health as well as environment.

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Adv Res Text Eng - Volume 4 Issue 2 - 2019
ISSN: 2572-9373 | www.austinpublishinggroup.com

Citation: Hassan BS, Islam GMN and Haque ANMA. Applications of Nanotechnology in Textiles: A Review. Adv Res Text Eng. 2019; 4(2): 1038.