academicJournals

Vol. 5(4), pp. XX-XX, XX 2013
10.5897/ JETR-09-040
ISSN 2006-9790 © 2013 Academic Journals
http://www.academicjournals.org/JETR

Journal of Engineering and Technology Research

Full Length Research Paper

Application of nanotechnology in textile engineering: An overview

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Accepted 20 May, 2013

The use of nanotechnology in the textile industry has increased rapidly due to its unique and valuable properties. There is a considerable potential for profitable applications of nanotechnology in cotton and other textile industries. Its application can economically extend the properties and values of textile processing and products. The use of nanotechnology allows textiles to become multifunctional and produce fabrics with special functions, including antibacterial, UV protection, easy-clean, water- and stain repellent and anti-odour. The future success of nanotechnology in textile applications lies in areas where new principles will be combined into durable, multifunctional textile systems without compromising the inherent textile properties, including processability, flexibility etc. The present study highlights the applications of nanotechnology in textile industries, with an emphasis on improving various properties of textiles.

Key words: Antibacterial, antistatic, nanotechnology, wrinkle resistance, water repellence.

INTRODUCTION

The fast development and changes in life style has attracted peoples towards a more comfort and luxurious life. People are moving towards small, safer, cheaper and fast working products which not only reduces the work load but also help them to carry out their works at a much greater pace with minimum efforts. There have been development of gadgets that are much smaller in size like micro-chip, nano capsules, carbon tubes, memory cards, pen drives etc which reduces the problems of transport, and storage and are also much faster and reliable by which we can carry out more of our work in less time. In the formation and development of such products nanotechnology plays a very important and vital role.

The term nanotechnology (sometimes shortened to "nanotech") comes from nanometer – a unit of measure of one billionth of a meter of length. The concept of Nanotechnology was given by Nobel Laureate Physicist Richard Feynman, in 1959. Nanotechnology is defined as the understanding, manipulation, and control of matter at the length scale on nanometer, such that the physical, chemical, and biological properties of materials (individual atoms, molecules and bulk matter) can be engineered, synthesized or altered to develop the next generations of improved materials, devices, structures, and systems (Feynman, 1959; Taniguchi, 1974). Generally, nanotechnology deals with structures that are sized between 1 to 100 nm in at least one dimension and involves developing materials or devices possessing dimension within that size. Nanotechnology creates structure that have excellent properties by controlling atoms and molecules, functional materials, devices and systems on the nanometer scale by involving precise placement of individual atoms (Kathiervelu, 2003). Although nanotechnology is a relatively recent

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development in scientific research,the development of its central concepts happened over a longer period of time. The emergence of nanotechnology in the 1980s was caused by the convergence of experimental advances. The early 2000s also saw the beginnings of commercial applications of nanotechnology, although these were limited to bulk applications of nanomaterials, such as the silver nano platform for using silver nanoparticles as an antibacterial agent, nanoparticles-based transparent sunscreens, and carbon nanotubes for stain-resistant textiles (Wang et al., 2004; Wang and Chen, 2005).

Throughout history, the textiles sectors have been used worldwide in a wide range of consumer applications. Natural fibers, such as cotton, silk, and wool, along with synthetic fibers, such as polyester and nylon, continue to be the most widely used fibers for apparel manufacturing. Synthetic fibers are mostly suitable for domestic and industrial applications, such as carpets, tents, tires, ropes, belts, cleaning cloths, and medical products. Natural and synthetic fibers generally have different characteristics, which make them ideally suitable mainly for apparel. Depending on the end-use application, some of those characteristics may be good, while the others may not be as good to contribute to the desired performance of the end product. As stated previously, nanotechnology brings the possibility of combining the merits of natural and synthetic fibers, such that advanced fabrics that complement the desirable attributes of each constituent fibre can be produced (Qian and Hinestroza, 2004; Wang and Chen, 2005; Wong et al., 2006).

In the last decade, the advent of nanotechnology has spurred significant developments and innovations in this field of textile technology. By using nanotechnology, there have been developments of several fabric treatments to achieve certain enhanced fabric attributes, such as superior durability, softness, tear strength, abrasion resistance, durable-press and wrinkle-resistance. The (nano)-treated core component of a core-wrap bi-component fabric provides high strength, permanent anti-static behavior, and durability, while the traditionally-treated wrap component of the fabric provides desirable softness, comfort, and aesthetic characteristics.

The use of nanotechnology in the textile industry made it multifunctional which can produce fibres with variable functions and applications such as UV protection, antiodour, antimicrobial etc. In many cases smaller amounts of the additive are required, for the saving on resources. The success of Nanotechnology and its potential applications in textiles lies in various fields where new methods are combined with multifunctional textile systems, durable etc. without affecting the inherent properties of the textiles including softness, flexibility, washbility etc. Keeping the above factors in consideration, the present review highlighted the use of nanotechnology in textile industry and textile engineering, the types and methods of preparation of different nano composites used in textiles.

BASIC NANOTECHNOLOGY

Two main approaches are used in nanotechnology that is, the bottom up approach and the top-down approach. In case of the “bottom-up” approach, the different type of materials and the instruments are made up from different types of molecular components which combine themselves by chemical ways basing on the mechanism of molecular recognition. In case of the “top-down” approaches, various nano-objects are made from various types of components without atomic-level control. Materials reduced to the nanoscale can show different properties compared to what they exhibit on a macro scale, enabling unique applications. The basic premise is that properties can dramatically change when a substance’s size is reduced to the nanometer range. For instance, ceramics which are normally brittle can be deformable when their size is reduced, opaque substances become transparent (copper); stable materials turn combustible (aluminum); insoluble materials become soluble (gold) (Sherman and Jonathan, 2003; Burniston et al., 2004).

Nanoparticles can be prepared from a variety of materials such as proteins, polysaccharides and synthetic polymers. The selection of materials in mainly depended on factors like size of the nanoparticles required, inherent properties such as aqueous, solubility and stability, surface characteristics i.e. charge and permeability, degree of biodegradability, biocompatibility and toxicity, release of the desired product, antigenicity of the final product etc. Polymeric nanoparticles have been prepared most frequently be three methods (1) Dispersion of the performed polymers; (2) Polymerization of the monomers and (3) Ionic gelation of the hydrophobic or hydrophilic polymers. However, techniques like supercritical fluid technology and particle repulsion in non- wetting templets (PRINT) have been also used in modern days (Chen, 2002; Kathiervelu, 2003; Anonymous, 2003b).

NANOTECHNOLOGY IN TEXTILE INDUSTRY AND TEXTILE ENGINEERING

Of the many applications of nanotechnology, textile industry has been currently added as one of the most benefited sector. Application of nanotechnology in textile industry has tremendously increased the durability of fabrics, increase its comfortness, hygienic properties and have also reduces its production cost. Nanotechnology also offers many advantages as compare to the conventional process in term of economy, energy saving, eco-friendliness, control release of substances, packaging, separating and storing materials on a microscopic scale for later use and release under control condition (David, 2002). The unique and new properties of nanotechnology have attracted scientists and researchers to the textile industry and hence the use of nanotechnology in the textile industry has increased rapidly. This may be due to the reason that textile technology is one of the best areas for development of nanotechnology. The textile fabrics provide best suitable substrates where a large surface area is present for a given weight or a given volume of fabric. The synergy between nanotechnology and textile industry uses this property of large interfacial area and a drastic change in energetic is experienced by various macromolecules or super molecules in the vicinity of a fibre when changing from wet state to a dry state.

The application of nanoparticles to textile materials have been the objective of several studies aimed at producing finished fabrics with different functional performances. Nanoparticles can provide high durability for treated fabrics as they posses large surface area and high surface energy that ensure better affinity for fabrics and led to an increase in durability of the desired textile function. The particle size also plays a primary role in determining their adhesion to the fibers. It is reasonable to except that the largest particle agglomerates will be easily removed from the fibre surface, while the smallest particle will penetrate deeper and adhere strongly into the fabric matrix (Kathiervelu, 2003; Wang and Chen, 2005).Thus, decreasing the size of particles to nano-scale dimensional, fundamentally changes the properties of the material and indeed the entire substance.

A whole variety of novel nanotech textiles are already on the market at this moment. Areas where nanotech enhanced textiles are already seeing some applications include sporting industry, skincare, space technology and clothing as well as materials technology for better protection in extreme environments. The use of nanotechnology allows textiles to become multifunctional and produce fabrics with special functions, including antibacterial, UV-protection, easy-clean, water- and stain repellent and anti-odour (Kathiervelu, 2003).

Types of nanomaterials

Nanocomposite fibers

A composite is a material that combines one or more separate components. Composites are designed to exhibit the best properties of each component. A large variety of systems combining one, two and three dimensional materials with amorphous materials mixed at the nanometer scale (Lee et al., 2003). Nanostructure composite fibers are intensively used in automotive, aerospace and military applications. Nanocomposite fibers are produced by dispersing nanosize fillers into a fibre matrix. Due to their large surface area and high aspect ratio, nanofillers interact with polymer chain movement and thus reduce the chain mobility of the system. Being evenly distributed in polymer matrices, nanoparticles can carry load and increase the toughness and abrasion resistance. Most of the nanocomposite fibers use fillers such as nanosilicates, metal oxide nanoparticles, graphite nanofibers (GNF) as well as single-wall and multi-wall carbon nanotubes (CNT) (Sennett and Welsh, 2003; Dongand Huang, 2002). Some novel CNT reinforced polymer composite materials have been developed, which can be used for developing multifunctional textiles having superior strength, toughness, lightweight, and high electrical conductivity (Lei and Juan, 2003).

Carbon nanofibers and carbon nanoparticles

Carbon nanofibers and carbon black nanoparticles are among the most commonly used nanosize filling materials. Nanofibers can be defined as fibers with a diameter of less than 1 mm or 1000 nm and are characterized as having a high surface area to volume ratio and a small pore size in fabric form (Joshi and Bhattacharyya, 2011; Qian and Hinestroza, 2004). Carbon nanofibers can effectively increase the tensile strength of composite fibers due to its high aspect ratio, while carbon black nanoparticles can improve their abrasion resistance and toughness. Several fibre-forming polymers used as matrices have been investigated including polyester, nylon and polyethylene with the weight of the filler from 5 to 20% (Harholdt, 2003).

There are numerous applications in which nanofibers could be suited (Huang et al., 2003). The high surface area to volume ratio and small pore size allows viruses and spore-forming bacterium such as *anthrax* to be trapped. Filtration devices and wound dressings are just some of the applications in which nanofibers could be utilized. Researchers are investigating textile materials made from nanofibers which can act as a filter for pathogens (bacteria, viruses), toxic gasses, or poisonous or harmful substances in the air. Medical staff, fire fighters, the emergency services or military personnel could all benefit from protective garments made fromnanofibers materials.

Clay nanoparticles

Clay nanoparticles are resistant to heat, chemicals and electricity, and have the ability to block UV light. Incorporating clay nanoparticles into a textile can result in a fabric with improved tensile strength, tensile modulus, flexural strength and flexural modulus. Nanocomposite fibers which utilize clay nanoparticles can be engineered to be flame, UV light resistant and anti-corrosive. Although there have been a number of flame retardant finishes available since the 1970's, the emission of toxic gasses when set ablaze make them somewhat hazardous. Clay nanoparticles have been incorporated into nylon to impart flame retardant characteristics to the textile without the emission of toxic gas. The addition of clay nanoparticles has made polypropylene dyeable. Metal oxide nanoparticles of TiO_2, Al_2O_3, ZnO and MgO exhibit photocatalytic ability, electrical conductivity, UV absorption and photo-oxidizing capacity against chemical and biological species. The main research efforts involving the use of nanoparticles of metal oxides have been focused on antimicrobial, self-decontaminating and UV blocking applications for both military protection gears and civilian health products (Joshi and Bhattacharyya, 2011; Qian and Hinestroza, 2004; Coyle et al., 2007). Nylon fibers filled with ZnO nanoparticles can provide UV shielding function and reduce static electricity on nylon fibers. A composite fibre with nanoparticle of TiO_2 or MgO can provide self-sterilizing function (Harholdt, 2003).

Carbon nanotubes

Carbon Nanotube is a tubular form of carbon with diameter as small as nanometer (nm). A carbon nanotube (CNT) is configurationally equivalent to a two dimensional graphene sheet rolled into a tube. They can be metallic or semiconducting, depending on chirality.CNT are one of the most promising materials due to their high strength and high electrical conductivity. CNT consists of tiny shell(s) of graphite rolled up into a cylinder(s) (Wang et al., 2004; Daoud and Xin, 2004). CNT exhibit 100 times the tensile strength of steel at one-sixth weight, thermal conductivity better than all but the purest diamond, and an electrical conductivity similar to copper, but with the ability to carry much higher currents. The potential applications of CNTs include conductive and high-strength composite fibers, energy storage and energy conversion devices, sensors, and field emission displays. Possible applications include screen displays, sensors, aircraft structures, explosion-proof blankets and electromagnetic shielding. The composite fibers have potential applications in safety harnesses, explosion-proof blankets, and electromagnetic shielding applications. Continuing research activities on CNT fibers involve study of different fibre polymer matrices such as polymethylmethacrylate (PMMA) and polyacrylonitrile (PNA) as well as CNT dispersion and orientation in polymers (Scott and Holly, 2007; Wang et al., 2004).

Nanocellular foam structure

Polymeric materials with nanosize porosity exhibit lightweight, good thermal insulation, as well as high cracking resistance at high temperature without sacrifices in mechanical strength (Daoud and Xin, 2004). By choosing the pretreatment condition to the fibre, the transverse mechanical properties of the composite can be also enhanced through the molecular diffusion across the interface between the fibre and the matrix. The nanocomposites clearly surpass the mechanical properties of most comparable cellulosic materials, their greatest advantage being the fact that they are fully bio-based and biodegradable, but also of relatively high strength. A potential application of cellular structure is to encapsulate functional compounds such as pesticides and drugs inside of the nanosizecells. One of the approaches to fabricate nanocellular fibers is to make use of a thermodynamic instability during supercritical carbon dioxide extrusion and reduce the size of the cellular fibers that can be used as high-performance composite fibers as well as for sporting and aerospace materials (Lei and Juan, 2003).

Properties of nano textile fibres

Water repellence

The water-repellent property of fabric created by nano-whiskers, which are hydrocarbons and 1/1000 of the size of a typical cotton fibre, when added to the fabric create a peach fuzz effect without lowering the strength of cotton. The spaces between the whiskers on the fabric are smaller than the typical drop of water, but still larger than water molecules; water thus, remains on the top of the whiskers and above the surface of the fabric. However, liquid can still pass through the fabric, if pressure is applied to it (Wong et al., 2006; Russell, 2002).

Nanosphere impregnation involving a three-dimensional surface structure with gel forming additives which repel water and prevent dirt particles from attaching themselves are also used. Once water droplets fall onto them, water droplets bead up and, if the surface slopes slightly, will roll off. As a result, the surfaces stay dry even during a heavy shower. Furthermore, the droplets pick up small particles of dirt as they roll, and so the leaves of the lotus plant keep clean even during light rain. By altering the micro and nano-scale surface features on a fabric surface, a more robust control of wetting behavior can be attained. It has been demonstrated that by combining the nanoparticles of hydroxylapatite, TiO_2, ZnO and Fe_7O_3 with other organic and inorganic substances, the audio frequency plasma of fluorocarbon chemical was applied to deposit a nanoparticulate hydrophobic film onto a cotton fabric surface to improve its water repellent property (Wang et al., 2004; Zhang, 2004).This sort of surface engineering, which is capable of replicating hydrophobic behavior, can be utilized in developing special chemical finishes for producing water-and/or stain- resistant fabrics while complementing the other desirable fabric attributes, such as breathability, softness and comfort.The surfaces of the textile fabrics can be appreciably modified to achieve considerably greater abrasion resistance, ultraviolet (UV) resistance, electromagnetic and infrared protection properties.

UV-protection

Inorganic UV blockers are more preferable to organic UV blockers as they are non-toxic and chemically stable under exposure to both high temperatures and UV (Yang et al., 2004; El-Molla et al., 2011). Inorganic UV blockers are usually certain semiconductor oxides such as TiO_2, ZnO, SiO_2 and Al_2O_3. Among these semiconductor oxides, titanium dioxide (TiO_2) and zinc oxide (ZnO) are commonly used. It was determined that nano-sized titanium dioxide and zinc oxide are more efficient at absorbing and scattering UV radiation than the conventional size, and are thus better to provide protection against UV rays . This is due to the fact that nano-particles have a larger surface area per unit mass and volume than the conventional materials, leading to the increase of the effectiveness of blocking UV radiation (Kathiervelu, 2003; Yang et al., 2003).

Various researchers have worked on the application of UV blocking treatment to fabric using nanotechnology. UV blocking treatment for cotton fabrics are developed using the sol-gel method. A thin layer of titanium dioxide is formed on the surface of the treated cotton fabric which provides excellent UV protection; the effect can be maintained after 50 home launderings (El-Molla et al., 2011). Apart from titanium dioxide, zinc oxide nano rods of 10 to 50 nm in length are also applied to cotton fabric to provide UV protection. According to the studies on the UV blocking effect, the fabric treated with zinc oxide nanorods were found to have demonstrated an excellent UV protective factor (UPF) rating (Wong et al., 2006). This effect can be further enhanced by using a different procedure for the application of nanoparticles on the fabric surface. When the process of padding is used for applying the nanoparticles on to the fabric, the nanoparticles get applied not only on the surface alone but also penetrates into the interstices of the yarns and the fabric, i.e. some portion of the nanoparticles get penetrate into the fabric structure. Such Nanoparticles which do not stay on the surface may not be very effective in shielding the UV rays. It is worthwhile that only the right (face) side of the fabric gets exposed to the rays and therefore, this surface alone needs to be covered with the nanoparticles for better UV protection. Spraying (using compressed air and spray gun) the fabric surface with the nanoparticles can be an alternate method of applying the nanoparticles.

Antimicrobial

Although many antimicrobial agents are already in used for textile, the major classes of antimicrobial for textile include organo-silicones, organo-metallics, phenols and quaternary ammonium salts. The bis- phenolic compounds exhibits a broad spectrum of antimicrobial activity. For imparting antibacterial properties, nano-sized silver, titanium dioxide,zinc oxide, triclosan and chitosan are used (Burniston et al., 2004). Nano-silver particles have an extremely large relative surface area, thus increasing their contact with bacteria or fungi and vastly improving their bactericidal and fungicidal effectiveness. Nano-silver is very reactive with protein and shows antimicrobial properties at a concentrations as low as 0.0003 to 0.0005%. When contacting bacteria and fungi, it will adversely affect cellular metabolism and inhibits cell growth. It also suppresses respiration, the basal metabolism of the electron transfer system, and the transport of the substrate into the microbial cell membrane (Wong et al., 2006). Furthermore, it inhibits the multiplication and growth of those bacteria and fungi which cause infection, odour, itchiness and sores (Yang et al., 2003). Some synthetic antimicrobial nano particles which are used in textiles are as follows. Triclosan, a chlorinated bis- phenol, is a synthetic, non-ionic and broad spectrum antimicrobial agent possessing mostly antibacterial alone with some antifungal and antiviral properties. Chitosan, a natural biopolymer, is effectively used as antibacterial, antifungal, antiviral, non-allergic and biocompatible. ZnO nanoparticles have been widely used for their antibacterial and UV-blocking properties.

Antistatic

An antistatic agent is a compound used for treatment of materials or their surfaces in order to reduce or eliminate buildup of static electricity generally caused by the triboelectric effect. The molecules of an antistatic agent often have both hydrophilic and hydrophobic areas, similar to those of a surfactant; the hydrophobic side interacts with the surface of the material, while the hydrophilic side interacts with the air moisture and binds the water molecules (Dong and Huang, 2002). As synthetic fibers provide poor anti-static properties, research work concerning the improvement of the anti-static properties of textiles by using nanotechnology has been at large. It was determined that nano-sized particles like titanium dioxide, zinc oxide whiskers, nanoantimony-doped tin oxide (ATO) and silanenanosol could impart anti-static properties to synthetic fibers. Such material helps to effectively dissipate the static charge which is accumulated on the fabric (Wong et al., 2006). On the other hand, silanenanosol improves anti-static properties, as the silica gel particles on fibre absorb water and moisture in the air by amino and hydroxyl groups and bound water.Electrically conductive nano-particles are durably anchored in the fibrils of the membrane of teflon, creating an electrically conductive network that prevents the formation of isolated chargeable areas and voltage peaks commonly found in conventional anti-static materials. This method can overcome the limitation of

Table 1. Some finishing based developments through nanotechnology in textile industries.

S. No	Application in textile	Nanomaterial used	References
1.	Electro conductive and antistatic	Carbon black, Carbon nanotubes (CNT), Cu, Polypyrrole, Polyaniline	Sennette and Welsh (2003), Dong and Huang (2002), Anonymous (2003)
2.	Increase durability	Al_2O_3, SiO_2, CNT, ZnO, Polybutylacrylate	Burnistan et al. (2004)
3.	Antibacterial	Ag, Chitosan, SiO_2 (as matrix), TiO_2, ZnO	Burnistan et al. (2004) Wong et al. (2006)
4.	Self-cleaning/ dirt and water repellent	CNT, Fluoroacrylate, SiO_2 (as matrix), TiO_2	Lei and Juan (2003), Zhang (2004)
5.	Moisture absorbing	TiO_2	Burnistan et al. (2004)
6.	Improved staining / reduce fade	Carbon black, Nanoporous hydrocarbon on Nitrogen coating, SiO_2 (as matrix)	Wong et al. (2006) Song et al. (2001)
7.	UV protection	TiO_2, ZnO	Burnistan et al. (2004) Wong et al. (2006) Kathiervelu (2003), Yang et al. (2003)
8.	Fire proof	CNT, Boroxosiloxane, Montmorillonite (nano clay), Sb_3O_2	Zhang (2004)
9.	Controlled release of active agents, medicinal products or fragrances	Montmorillonite (nano clay), SiO_2 (as matrix)	Harholdt (2003)

conventional methods, which is that the anti-static agent is easily washed off after a few laundry cycles (Anonymous, 2003).

Wrinkle resistance

To impart wrinkle resistance to fabric, resin is commonly used in conventional methods. However, there are limitations to applying resin, including a decrease in the tensile strength of fibre, abrasion resistance, water absorbency and dye-ability, as well as breathability. To overcome the limitations of using resin, some researchers employed nano-titanium dioxide and nano-silica to improve the wrinkle resistance of cotton and silk respectively (Wong et al., 2006). Nano-titanium dioxide employed with carboxylic acid as a catalyst under UV irradiation to catalyses the cross-linking reaction between the cellulose molecule and the acid. On the other hand, nano-silica when applied with maleic anhydride as a catalyst could successfully improve the wrinkle resistance of silk (Song et al., 2001; Zhou et al., 2003). More over the wrinkle recovery of the fabrics can also be improved to a great extent by imparting techniques like padding and exhaustion beside the use of nano-materials to the fabrics. Studies also have suggest that treatment of fabrics with microwaves are more wrinkle resistant as comparable to oven curing, because it generates higher frequency and volumetric heating which minimizes the damage from over drying.

Nanoparticles in textiles finishing

Fabric treated with nanoparticles of TiO_2 and MgO replaces fabrics with active carbon, previously used as chemical and biological protective materials. The photocatalytic activity of TiO_2 and MgO nanoparticles can break harmful and toxic chemicals and biological agents. These nanoparticles can be pre-engineered to adhere to textile substrates via spray coating or electrostatic methods. Textiles with nanoparticles finishing are used to convert fabrics into sensor-based materials which has numerous applications. If nanocrystalline epiezoceramic particles are incorporated intofabrics, the finished fabric can convert exerted mechanical forces into electrical signals enabling the monitoring of bodily functions such as heart rhythm and pulse if they are worn next to skin.

Fabric finishing by using nanotechnology

Finishing of textile fabrics made of natural and synthetic fibers to achieve desirable surface texture, color and other special aesthetic and functional properties, has been a primary focus in textile manufacturing industries. In the last decade, the advent of nanotechnology has spurred significant developments and innovations in this field of textile technology (David, 2002). Fabric finishing has taken new routes and demonstrated a great potential for significant improvements by applications of nanotechnology (Table 1). The developments in the areas of surface engineering and fabric finishing have been highlighted in several researches. There are many ways in which the surface properties of a fabric can be manipulated and enhanced, by implementing appropriate surface finishing, coating, and/or altering techniques, using nanotechnology. A few representative applications of fabric finishing using nanotechnology are schematically displayed in the Figure 1.

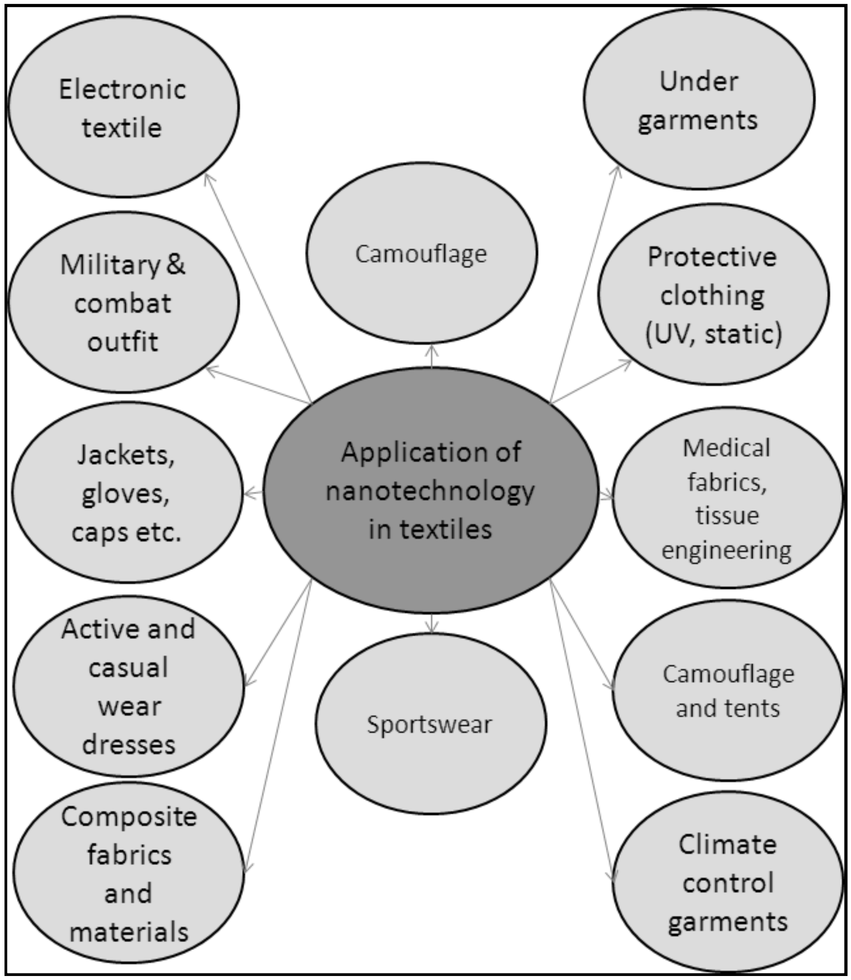

Figure 1. Some representative applications of nanotechnology in textiles.

Nanotechnology provides plenty of efficient tools and techniques to produce desirable fabric attributes, mainly by engineering modifications of the fabric surface. For example, the prevention of fluid wetting towards the development of water or stain-resistant fabrics has always been of great concerning textile manufacturing. The basic principles and theoretical background of "fluid-fabric" surface interaction are well described in recent manuscript. It has been demonstrated that by altering the micro and nano-scale surface features on a fabric surface, a more robust control of wetting behavior can be attained. The alteration in the fabric's surface properties enables to exhibit the "Lotus-Effect," which demonstrates the natural hydrophobic behavior of a leaf surface. This sort of surface engineering, which is capable of replicating hydrophobic behaviour, can be utilized in developing special chemical finishes for producing water and/or stain- resistant fabrics (Song et al., 2001; Russell, 2002). In recent years, several attempts have been made by researchers and industries to utilize similar concepts of surface-engineered modifications through nanotechnology to develop high performance textile and smart textile. The concept of surface engineering and nanotextile develops hydrophobic fabric surfaces that are capable of repelling liquids and resisting stains, while complementing the other desirable fabric attributes, such as breathability, softness, and comfort (Anonymous, 2003b; Chen, 2002;Song et al., 2001;Russell, 2002). The Table 2 describes about the nano-materials used in textile application and their possible function functions.

CONCLUSION

Nanotechnology is growing by leaps and bounds and it has been introduced in many fields including the textile industries. There is a considerable potential for profitable applications of nanotechnology in cotton and other textile industries. Its application can economically extend the properties and values of textile processing and products. By deploying nanotechnology, ultra strong, durable and specific function oriented fabrics can be efficiently

Table 2. Overview of the nanomaterials used in textile application and their functions.

S.No	Nano products	Application and properties
1.	Nano-Tex	The fabric shows very good wrinkle-resistance and changes to the fibre do not affect the natural hand feel and breathability of the fabric
2.	Nanosphere	Schoeller developed an Impregnating treatment; Nanosphere that makes fabrics water and soil resistant.
3.	Nano-Pel	Water-and-oil repellent finishing is effective for cotton, linen, wool and silk, polyester, nylon and acrylic
4.	Smart clothes or textile with nano finishing	Silver is used due to its natural anti-bacterial and anti-fungal properties. It inhibits the multiplication and growth of those bacteria and fungi which cause infection, odour, itchiness and sores. Nano silver particles are widely applied in socks to prohibit the growth of bacteria. It is also applied to a range of other healthcare products such as dressings, for burns, scald, skin donor and recipient site.
5.	Magnetic Nanoparticles (mNPs)	Composed of magnetic elements (iron, nickel and cobalt) which are coated with a layer of fatty acids and are used as new means of confirming specific ailments or releasing drugs at exact points within a living system.

produced for a number of applications including medical, military and industrial apparels etc. As mentioned, nanotechnology overcomes the limitations of applying conventional methods to impart certain properties to textile materials. There is no doubt that in the next few years, nanotechnology will penetrate into every area of textile industry.

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