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Review Article

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Novel Applications of Nanotechnology in Modification of Textile Fabrics Properties And Apparel (Review)

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Abstract

Nanotechnology (NT) deals with materials 1 to 100 nm in length. The fundamentals of nanotechnology lie in the fact that the properties of materials drastically change when their dimensions are reduced to nanometer scale. Nanotechnology is increasingly attracting worldwide attention because it is widely perceived as offering huge potential in a wide range of end uses. The unique and new properties of nanotextiles have attracted not only scientists and researchers but also businesses, due to their huge economical potential. The use of nanotechnology in the textile industry has increased rapidly due to its unique and valuable change in fabric properties. Nanotechnology also has real commercial potential for the textile industry. This is mainly due to the fact that conventional methods used to impart different properties to fabrics often do not lead to permanent effects, and will lose their functions after laundering or wearing. Nanotechnology can provide high durability for fabrics, because nano-particles have a large surface area-to-volume ratio and high surface energy, thus presenting better affinity for fabrics and leading to an increase in durability of the function. In addition, a coating of nano-particles on fabrics will not affect their breath ability or hand feel. This review paper will be introduced by first discussing nanotechnology as a whole. Next, the paper will continue on to discuss nanotextile, its fabrication process. Finally, nanoparticles and some novel application of it in fabric properties have been presented. Risk factors including nanotoxicity, nanomaterial release during washing, and environmental impact of nanotextiles based on life cycle assessments have been evaluated.

1. Introduction

The concept of nanotechnology is not new; it was started over forty years ago. According to the National Nanotechnology Initiative (NNI), nanotechnology is defined as the utilization of structures with at least one dimension of nanometer size for the construction of materials, devices or systems with novel or significantly improved properties due to their nano-size. Nanotechnology not only produces small structures, but also an anticipated manufacturing technology which can give thorough, inexpensive control of the structure of textile fabrics. Nanotechnology can best be described as activities at the level of atoms and molecules that have applications in the real world. Nano-particles commonly used in commercial products are in the range of 1 to 100 nm. Nanotechnology is increasingly attracting worldwide attention because it is widely perceived as offering huge potential in a wide range of end uses. The unique and new properties of nanotextiles have attracted not only scientists and researchers but also businesses, due to their huge economical potential. Nanotechnology also has real commercial potential for the textile industry. This is mainly due to the fact that conventional methods used to impart different properties to fabrics often do not lead to permanent effects, and will lose their functions after laundering or wearing. Nanotechnology can provide high durability for fabrics, because nano-particles have a large surface area-to-volume ratio and high surface energy, thus presenting better affinity for fabrics and leading to an increase in durability of the function. In addition, a coating of nano-particles on fabrics will not affect their breathability or hand feel[1,7].

Nanotechnology brings an enormously promising and bright future for textile fabrics finishing. Trends in global textile industry reveals that the survival of the conventional textile business is very difficult in current scenario even after an enormous capital investment because the numbers of competitors are increasing at high speed, consequently, conventional textile products are available in the market at large with very competitive prices, and hence the profit percentage is reduced to the minimum level [2].To survive with this situation of world textile market the development of new product or material is demanded by customer. The potential of nanotechnology in the development of new materials in the textile industry is considerable [3]. Although Nanotechnology is still in its infancy, it is already proving to be a useful tool in improving the performance and properties of textiles fabrics and generating worldwide interest [4]. The application of nanostructures results in increasing the efficiency of the textile fabrics and it creates unique properties. Increasing customer demand for durable and functional apparel manufactured in a sustainable manner has created an opportunity for nanomaterials to be integrated into textile substrates. Nanomoieties can induce stain repellence, wrinkle-freeness, static elimination, and electrical conductivity to fibers without compromising their comfort and flexibility. Nanotextiles also offer a wider application potential to create connected fabrics and garments that can sense and respond to external stimuli via electrical, color, or physiological signals. These multi-use benefits may include one or more of the following: tissue engineering scaffolds, improved surface cleaning, wettability, strike-through, comfort, stain resistance, soil removal, malodor control, modification of surface friction, reduced damage to abrasion, , anti-abrasion, antibacterial, fireproof, UV resistant, anti-stain and anti-shrinkage in the fabrics; therefore, sport and domestic clothes with anti-odor, antibacterial, waterproof, anti-stain, and fireproof and color enhancement properties relative to surfaces unmodified with such nanoparticle systems [5,14].

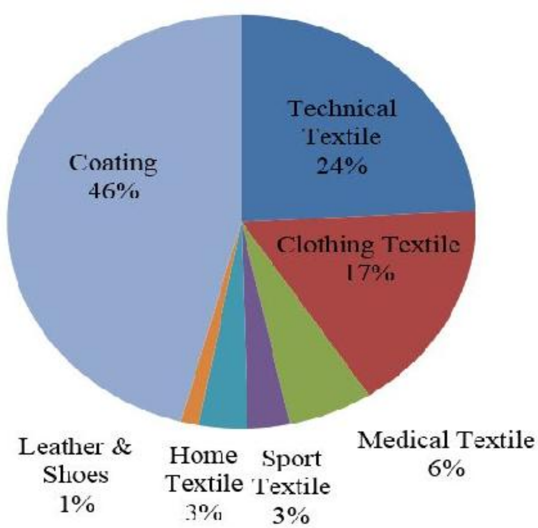


Fig.1.Demonstrates the classification of nanoproducts in textile industry[8].

As is seen in Figure 1, nanocoatings have a share of 46% of nanoproducts in textile industry. The share of various enterprises in nanotechnology applications are 24% in technical fabrics, 17% in clothes, 6% in medical fabrics, 3% in sport and domestic fabrics, and 1% in leather and shoes[8].

Figure 2 demonstrates the share and number of products made by various countries. As is observed, the United States possesses the highest number of nanoproducts in textile industry by having 49 individual products[8].

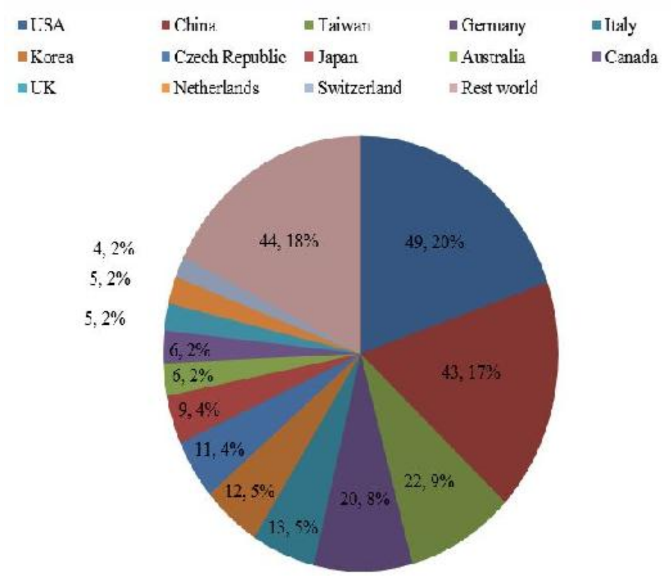


Fig.2.Number and Share of Countries in Nanoproducts in Textile Industry[8]

2. Production Methods of Nanotextile

The production processes of nanoengineered textiles are different. The key difference among them is whether synthetic nanoparticles are integrated into the fibres or the textile, or are applied as a coating on the surface, and/or whether nanoparticles are added to the nanoscale fibres or coating elaborated in figure 3 [6,9]. Nano finishing comprises of different fabric coating technique used by applying nano particles onto textile fabrics and apparels [6,10]. Coating is a common technique used to apply nano-particles onto textiles fabrics. The coating compositions that can modify the surface of textiles fabrics are usually composed of nano-particles, a surfactant, ingredients and a carrier medium (Cramer, 2003) [6,11]. New coating techniques like sol-gel, layer-by-layer, plasma polymerization, etc. can develop multi-functionality, intelligence, excellent durability and weather resistance to fabrics [6,10]. One of the applications of nanotechnology in textile industry is in polymeric materials for producing conventional fibres such as PES (Polyester), PA (Polyamide) and PP (Polypropylene) in nano scale [6,11]. A way of producing nanotextile products are nanofibres which is produced by electro spinning process. In this spinning process fibres are produced with dimensions of nanoscaling. Another way of nano fiber production is split spinning which involves splitting a filament into multiple smaller filaments form but this process is under development till. Nano structured composite fabrics have led to the exploration of high strength and superior performance fabrics, while many other applications in nanofibre,yarn or fabric are still way off future [6,12]. Nano-textiles have multifunctional properties like high surface area, a small fibre diameter, good filtration properties, thin layers and high permeability [6]. By producing nano composite fibres is another way of nanotextile production. A nanocomposite is comprised of a combination of two or more different substances of nanometer size, thereby producing a material that generally has enhanced specific properties due to the combined properties and/or structuring effects of the components [6,15]. These products include warming and cooling textiles, conductive textiles, communicating textiles, textile sensors and actuators, digital fashion, chromatic textiles, etc. with applications in the medical field, sport and leisure, the military and first-responders market, and intelligent applications in buildings [6, 14,16]. In this case nantextile fabrics are incorporate into fibers, yarns or fabrics to improves its mechanical, electrical, optical or biological properties. However, a wide variety of nanofillers, whiskers and nanofibers with structural modification can be used in nanocomposite coatings [6,13, 15].

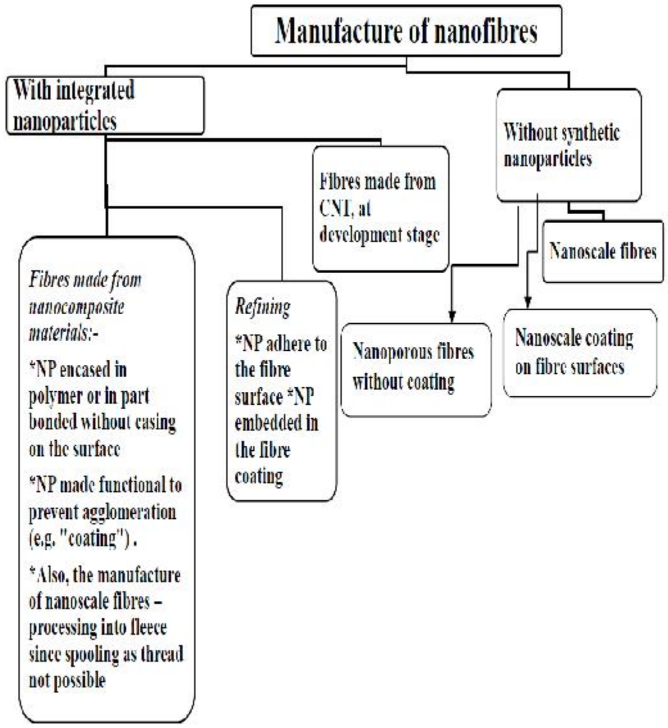


Fig.3.Manufacture of nanofibres (NP: nanoparticles, CNT: carbon nanotubes); [6,17]

Two basic strategies are used to produce nanoparticles: 'top-down' and 'bottom-up'. The term 'top-down' refers here to the mechanical crushing of source material using a milling process. In the 'bottom-up' strategy, structures are built up by chemical processes (Figure 4). The selection of the respective process depends on the chemical composition and the desired features specified for the nanoparticles[18].

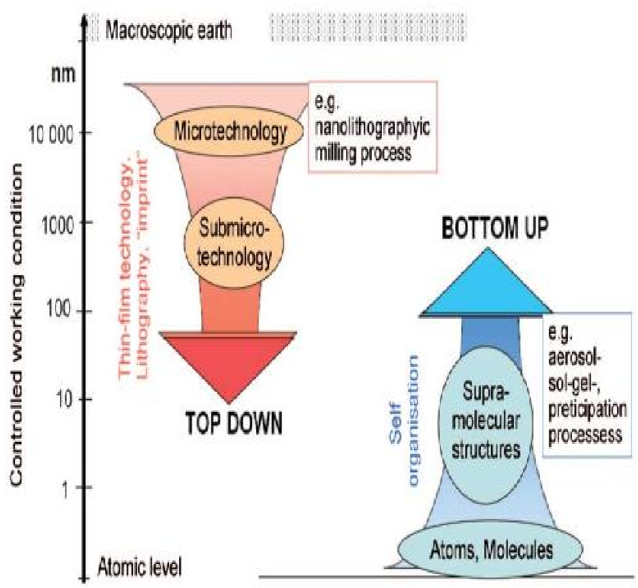


Fig.4. Methods of nanoparticle production: top-down and bottom-up. (Image: Laboratory for Micro and Nanotechnology, Paul ScherrerInstitut)[18]

3. Novel Application of Nanotechnology in Modification of Textile fabrics and Apparel properties.

Due to the advancement of nanotechnology in the manufacturing of fibers/yarns including the development of fabric finishes, the applications and scopes are widespread in the area of textiles for the last few decades. The recent advancement of fabric finishes is greatly contributed to the advancement in the area of nanotechnology. By combining the nanoparticles with the organic and inorganic compounds, the surfaces of the fabrics treated with abrasion resistant, water repellent, ultraviolet (UV), electromagnetic and infrared protection finishes can be appreciably modified. In the most recent age, Titanium-dioxide (TiO2) nanoparticles have been utilized for the UV protection. The usage of nanoengineered cross-link agents during finishing process enhances the wrinkle resistance of cotton fabrics. The newly developed micro encapsulation technique is being used in textile industry for flame or fire retardant agents. Microcapsules using siIver nanoparticles (Silver Cap) have been developed for providing anti-microbial effects and for odor control[19].

*Fig.**5.**Applications of nanotechnology in textiles[19]*

3.1. Water Repellence

Nano-Tex improves the water-repellent property of fabric by creating nano-whiskers, which are hydrocarbons and 1/1000 of the size of a typical cotton fiber, that are added to the fabric to 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. The performance is permanent while maintaining breath ability[7,20,21].

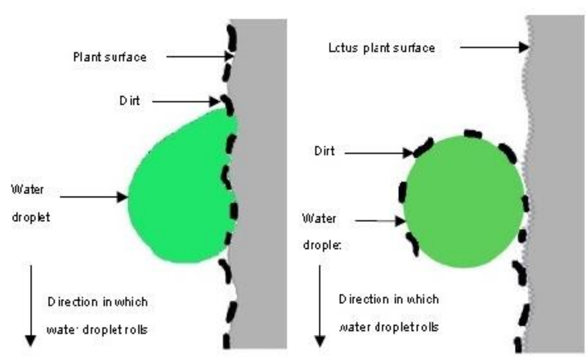


Fig.6. Mechanism of water repellence on textiles fabrics applied by NanoSphere technology; (a) water droplet rolls down on the fabrics, (b) water droplet rolls down a lotus fabrics[7,20,21]

3.2. Self-Cleaning Textiles

The realization of self-cleaning properties on textile surfaces by using the nanotechnology includes a vast potential for the development of new materials or new products and applications for known materials. Self-cleaning garments have been developed, keeping nature as a role model considering self-cleaning property of plant leaves and insects. They also showed that such an alteration in the fabric‘s surface properties is capable of exhibiting the —Lotus-Effect, we which demonstrates the natural hydrophobic behavior of a leaf surface [6]. A surface with a water contact angle larger than 150° and a low sliding angle (the critical angle where a water droplet with a certain weight begins to slide down the inclined plate) is usually called a superhydrophobic surface. Superhydrophobic surfaces have attracted much interest because of their potential practical applications such as anti-sticking, anti contamination, and self-cleaning coating figure 7.

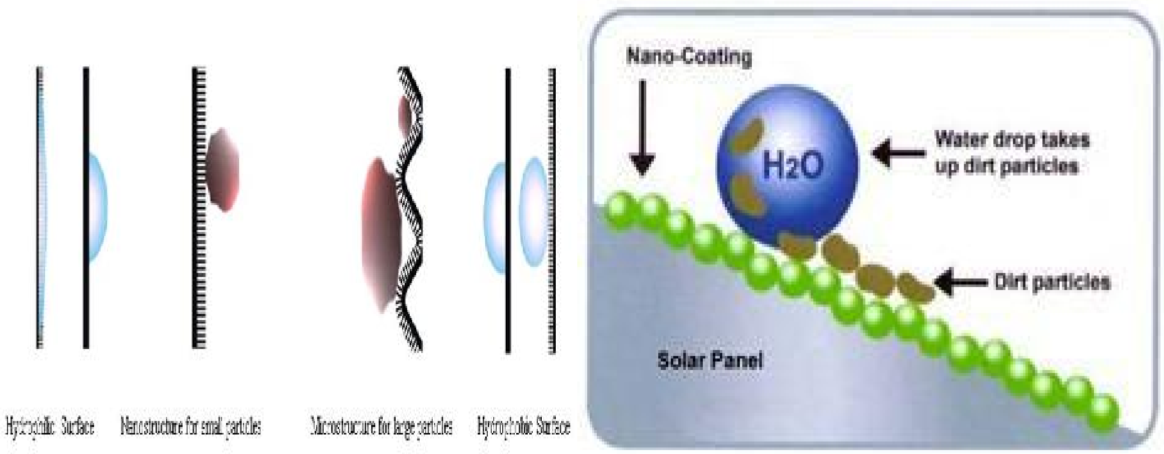


Fig.7.Self-cleaning mechanism using nanoparticles in fabric finishing[7,20].

3.3. Wrinkle Resistance Finish

Nano-Tex has launched a new nanotechnology-based wrinkle-free treatment that is said to offer an improved performance while preserving fabric strength and integrity – providing an alternative to harsh traditional processes. Chemicals and processing methods reduce a fabric's tear and tensile strength. This means there are certain fabrics and garments that are Wrinkle-free textiles are popular and convenient for time-pressed consumers, but traditional not candidates for wrinkle-free technology, such as lightweight fabrics or slim fitting garments. Sometimes fabrics also need to be over-engineered or "beefed up" in order to withstand the fiber degradation caused by traditional wrinkle-free solutions. Either way, current technologies either do not work on all fabrics – or the brand/retailer has to incur additional expense just to accommodate the destructive properties of wrinkle-free chemistry. The nano-scale molecular structure in Nano-Tex's new Fortify DP technology penetrates more deeply in the fiber to improve wrinkle-free performance. Additionally, it uses a longer and more flexible cross-linking chain which reduces fiber stress under tension, thus reducing the significant strength loss associated with traditional wrinkle-free chemistry.

3.4.Textiles as Sensors/Wearable Technology

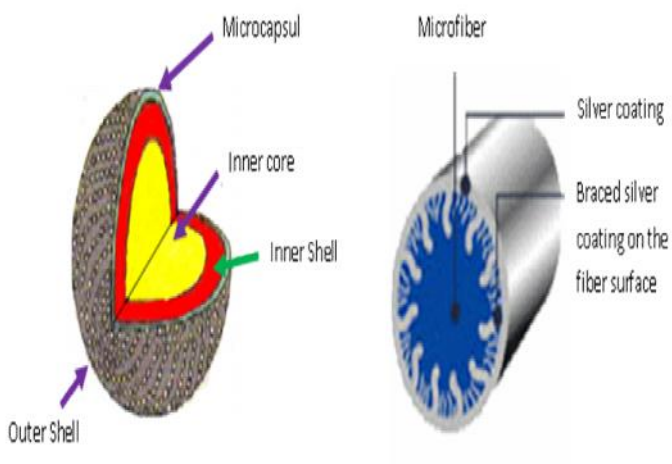
The unique characteristics of nanofibers, such as greater surface area and porosity -got Margaret Frey thinking about fabricating a textile that could act as a sensor. She envisions a material, perhaps something that looks like a sponge, that anyone could easily use to swab a piece of fruit or meat, or wipe a food or surgical preparation surface, to detect the presence of hazardous bacteria such as E. coli or anthrax. If the contaminant is detected, the fibers would capture it and alert the user by changing color or becoming fluorescent [22].

Smart or Functional materials usually form part of a 'Smart System‘ that has the capability to sense its environment and the effects thereof and, if truly smart, to respond to that external stimulus via an active control mechanism. Smart materials and systems occupy a 'Technology space‘, which also includes the areas of sensors and actuators [6,19,20,21]. You could have a shirt in which the electrically-conducting fibres allow cell phone functionality to be built in without using metallic wires or optical fibres [6,19,20,21]. As fashion and technology converge, SOFT switch is providing the enabling fabric interfaces to allow electronics to function within clothing figure 8 [6,19,20,21].

Fig.8.Wearable Technology (SOFTswitch)[6]

3.5. Anti-Bacterial Finish

For imparting anti-bacterial properties, nano-sized silver, titanium dioxide and zinc oxide have been used so far. Metallic ions and metallic compounds display a certain degree of sterilizing effect. It is considered that part of the oxygen in the air or water is turned into active oxygen by means of catalysis with the metallic ion, thereby dissolving the organic substance to create a sterilizing effect6. With the use of nano-sized particles, the number of particles per unit area is increased, and thus anti-bacterial effects can be maximized (Figure 8). Nanosilver 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 proteins. When contacting bacteria and fungus, it will adversely affect cellular metabolism and inhibit 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. Furthermore, it inhibits the multiplication and growth of those bacteria and fungi which cause infection, odour, itchiness and sores. Hence, nanosilver particles are widely applied to socks in order to prohibit the growth of bacteria.[1,14]



(a) **(b)**

Fig.9.Silver based nanoparticles representing a) structural view of a silver nanoparticle containing functional microcapsule; b) cross-section of fiber coated with silver nanoparticle.

3.6. UV Protective Finish

The most important functions performed by the garment are to protect the wearer from the weather. However it is also to protect the wearer from harmful rays of the sun. The rays in the wavelength region of 150 to 400 nm are known as ultraviolet radiations. The UV-blocking property of a fabric is enhanced when a dye, pigment, delustrant, or ultraviolet absorber finish is present that absorbs ultraviolet radiation and blocks its transmission through a fabric to the skin .Metal oxides like ZnO as UV-blocker are more stable when compared to organic UV-blocking agents. Hence, nanoZnO will really enhance the UV-blocking property due to their increase surface area and intense absorption in the UV region. For antibacterial finishing, ZnO nanoparticles scores over nano-silver in cost-effectiveness, whiteness, and UV-blocking property.

Fabric treated with UV absorbers ensures that the clothes deflect the Harmful ultraviolet rays of the sun, reducing a persons UVR exposure and protecting the skin from potential damage. The extent of skin protection required by different types of human skin depends on UV radiation intensity & distribution in reference to geographical location, time of day, and season. This protection is expressed as SPF (Sun Protection Factor), higher the SPF Value better is the protection against UV radiation[19,20,21]

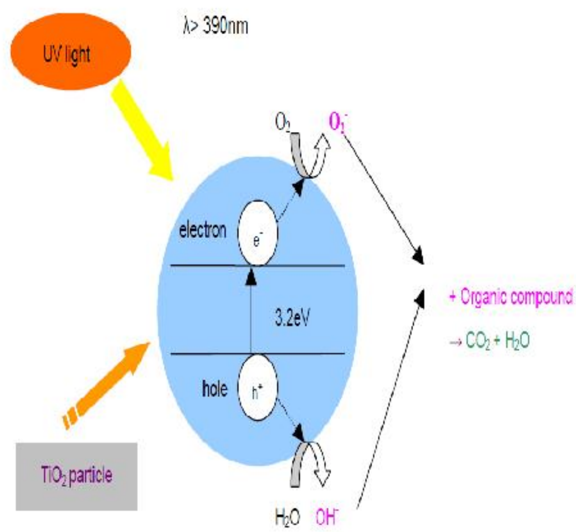


Fig.10. Photocatalysis mechanism of titanium dioxide

3.7. Anti-Static Finishes

Static charge usually builds up in synthetic fibers such as nylon and polyester because they absorb little water. Cellulosic fibers have higher moisture content to carry away static charges, so that no static charge will accumulate. As synthetic fibers provide poor anti-static properties, research work concerning the improvement of the anti-static properties of textiles by using nanotechnology were conducted. It was determined that nano-sized titanium dioxide, zinc oxide whiskers, nano antimony-doped tin oxide (ATO) and silanenanosol could impart anti-static properties to synthetic fibers. TiO2, ZnO and ATO provide anti-static effects because they are electrically conductive materials. Such material helps to effectively dissipate the static charge which is accumulated on the fabric. On the other hand, silanenanosol improves anti-static properties, as the silane gel particles on fiber absorb water and moisture in the air by amino and hydroxyl groups and bound water[19,20].

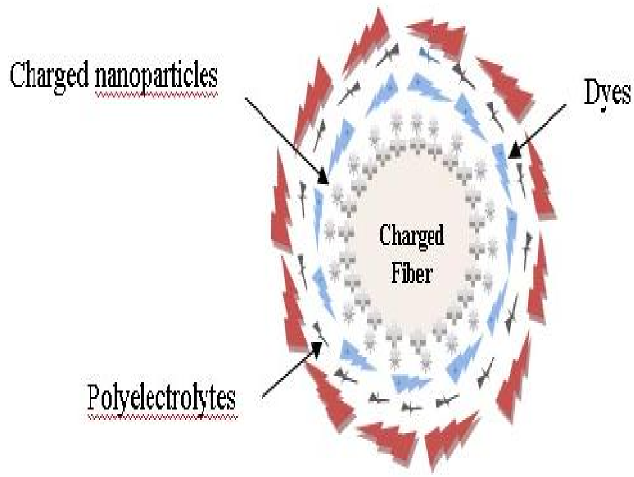


Fig.11. Electrostatic self-assembly of nanolayers on charged textile fibers.[19,20]

4. Economical and Environmental Aspects

The unique properties of nanomaterials have attracted not only scientists and research workers but also businesses, because of their huge economic potential. The national science foundation reports that nano-related goods and services will increase to a US$ 1 trillion market by 2015. This amount is larger than the combined businesses of the telecommunications and information technology industries. Several hundred billion Euros are forecast to be created by nanotechnology in the next decade (19). The nano materials markets could expand to US$ 4 billion by 2007. It was believed that 2 million new employment opportunities would be created in order to meet the worldwide annual production demand of US$ 1 trillion in 10-15 years. Nanotechnology may impart favorably on the environment as well. By using less resource without sacrificing performance, nanotechnology may save raw materials and also upgrade quality of life.[17,19]

Conclusion

There is a considerable potential for profitable applications of nanotechnology in the textile industries. Its application can economically extend the properties and values of textile processing and products. Nanotechnology is opening up a demand for higher precision, greater density and lightning speed combined with the intellectualization and miniaturization to progress into the next generation of apparels. The commercial application of nanotechnology has already been introduced in many prospect of textile arena. To create, alter and improve textiles at the molecular level and increase durability and performance beyond that of normal textiles are possible now. To continue this favorable trend, the textile industry should contribute more to research in nanotechnology and intensify its collaboration with other disciplines. As maximum smart clothing may contain electronic device which must causes adverse effect on environment. If pure nanomaterials are manufactured or there is the mass use of materials finished with nano particles, then the recycling systems may be upgraded to keep pace with these technological developments. Nano technology brings opportunities and challenges for textile industries which can make this huge market more profitable and expanded.

Seven properties imparted to textile fabrics/ materials using nanotechnology have been highlighted in this paper review. As mentioned above, nanotechnology overcomes the limitations of applying conventional methods to impart certain properties to textile fabrics/materials. There is no doubt that in the next few years, nanotechnology will penetrate into every area of textile industry.

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