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Nano technology: A boon for textile finishing

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Abstract
Nano technology is gaining popularity in various areas of application, out of which textile is one such. It has real commercial potential for the textile industry due to its unique and valuable properties. It is an approach that combines chemistry and physics to impart extra-ordinary properties to any material due to large surface area-to-volume ratio of the Nano materials. Nanoparticles may consist of various elements and compounds having the dimension between 1 to 100 nm having 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 of finishes. The present status of nanotechnology used in textiles was reviewed, with an emphasis on improving various properties of textiles. Research involving nanotechnology to improve performances or to add extraordinary functions to textile materials is flourishing. In the next few years, there is no doubt that nanotechnology will cover every field of textile industry.

Keywords: nano technology, boon, textile finishing

Introduction

The concept of nanotechnology is not new; it was given by Nobel laureate Physicist Richard Feynman, in 1959. The term nanotechnology comes from nano meter - a unit to measure of one billionth of a meter of length. According to the National Nanotechnology Initiative (NNI), nanotechnology is defined as the utilisation of structures with at least one dimension of nanometre size for the construction of materials, devices or systems with novel or significantly improved properties due to their nano size (Yadav, 2006; Patra and Gouda, 2013) [24, 17]. It is an emerging interdisciplinary technology that has been blooming in many areas during the recent decade, including materials science, mechanics, electronics, optics, medicine, plastics, energy, electronics, and aerospace (Das *et al.*, 2013) [5].

The application of nanotechnology has grown in textiles industry rapidly due to its unique and valuable properties. Nano *tex* - a US based company was the first to initiate the work of nanotechnology in textiles. By using nanotechnology this industry developed several textiles finishes; Nano *Pel* (technology for stain resistance), Nano *Touch* (core wrap fabric), Nano *Care* (wrinkle free fabric) and Nano *Dry* (hydrophilic finishes for synthetic) and later many companies studied the uses of nanotechnology in textiles (Gopalakrishnan, 2013) [6].

Nanoparticles can provide high durability for treated fabrics as they own 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 sizes play a primary role in determining their adhesion to the fibers because largest particle agglomerates can be easily removed from the fibre surface, while the smallest particle penetrates deeper and adhere strongly into the fabric matrix (Kathiervelu, 2003; Wang and Chen, 2005) [11, 21]. Thus, decreasing the size of particles to nano scale dimensional, fundamentally changes the properties of the material and certainly the entire substance. Various nanoparticles used for imparting these textile finishes are:

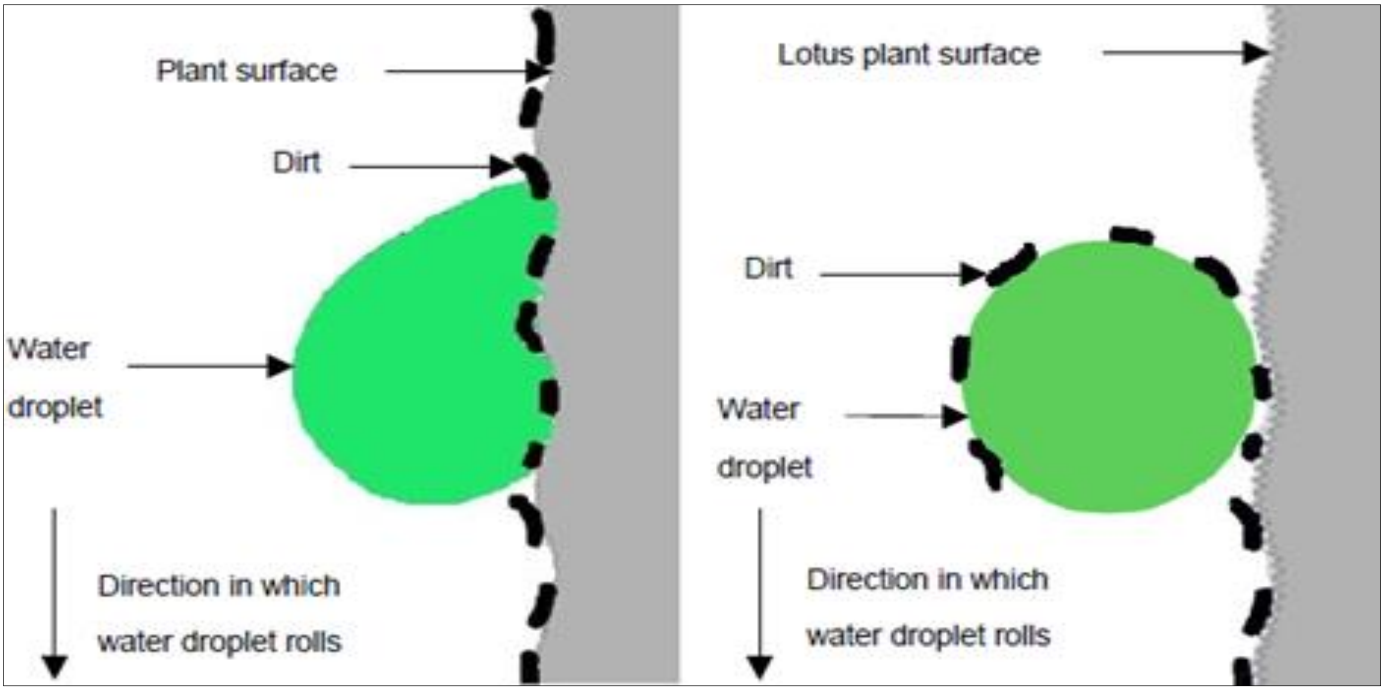
Nano Particles Used in Textile Finishing

Sl. No.	Nanoparticles	Properties
1	Silver Nanoparticles	Anti-bacterial
2	Fe Nanoparticles	Conductive magnetic properties
3	ZnO and TiO_2 Nanoparticles	UV protection, fiber protection, oxidative catalysis
4	TiO_2 and MgO Nanoparticles	Chemical and biological protective performance, self-sterilizing function.
5	SiO_2 or Al_2O_3 Nanoparticles with PP or PE coating	Super water repellent finishing, moth proofing
6	Indium-tin oxide Nanoparticles	IR protective clothing
7	Ceramic Nanoparticles	Resistance to abrasion
8	Carbon black Nanoparticles	Resistance to abrasion, chemical and impart electrical conductivity
9	Clay Nanoparticles	High electrical, heat and chemical resistance, anti- moth
10	Cellulose Nano-whiskers	Wrinkle resistance, stain resistance

The primary functions of finishing of the fabric are to achieve desirable hand, surface texture, colour and other special aesthetic and functional properties. Conventional methods of finishing of textiles often do not lead to permanent effects and loose their functions after laundering and wearing. Due to the large surface area to volume ratio and surface energy, nanotechnology provides better affinity for the fabrics and increases the durability of the finishes (Wong *et al.* 2006) [23]. There are various potential applications of nanotechnology in the textile industry; some of the well-known properties imparted by nano treatment are UV-protection, water repellence, anti-bacterial, anti-static, wrinkle resistance, anti-moth and flame retardation.

i. UV Protection: Ultraviolet radiation is the energetically high, short wave length light between 290-400 nm. The ultraviolet radiation (UVR) band consists of three regions: UV-A (320 to 400 nm), UV-B (290 to 320 nm) and UV-C (100 to 290 nm). UV-C is totally absorbed by the atmosphere and does not reach the earth. UV-A causes little visible reaction on the skin but decrease the immunological response of skin cells. UV-B is most responsible for the development of skin cancers. The awareness of UV radiation of health and hygiene has increased the demand for functional or protective textiles (Kullavanijaya and Lim, 2005) [12].
One of the approaches to improve the UV blocking property of fabrics is to coat the surface with nanoparticles inorganic oxides such as TiO_2, ZnO, SiO_2 and Al_2O_3. Among these TiO_2 and ZnO are commonly used as they absorb and scatter UV radiation than the conventional size and thus better able to block UV. Nanoparticles 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. Rayleigh's scattering theory predicts that in order to scatter UV radiation between 200-400 nm, the optimum particle size will be between 20-40 nm (Wong *et al.*, 2006) [23].
Prasad (2006) [24] coated cotton fabric with nano ZnO. This nano ZnO coating on cotton fabrics resulted in uniform and very thin coating due to nano size hence, the breathability of coated sample was significantly higher than the control. Also the nano ZnO coated cotton fabric was proved to have better UV-absorption property as it was able to scatter UV radiation on the fabrics surface.
Becheri *et al.* (2008) [2] reported that the application of nano sized ZnO on wool and cotton fabric increased UV light blocking properties in the region between 300-400 nm. This effective shielding of UV radiation was due to the UV scattering capacity of ZnO nanoparticles on the fabrics surface.
Sundaresan *et al.* (2011) [20] used nano TiO_2 with acrylic binder on the cotton fabric using pad dry method and found that the UPF values of the treated fabric was increased and had better UV protection than the untreated fabrics

ii. Water Repellence: Water repellent finish is used to protect textile fabrics from wetting, without adversely affecting the other properties such as air permeability of the finished fabrics by reducing the free energy at the textile surface. The degree to which the amount of water can be attached to a surface is determined by the surface free energy with lower surface energy could not be wetted with water (Wang *et al.*, 2014) [22]. Potential applications of highly water repellent textile materials include rainwear, upholstery, protective clothing, sportswear, and automobile interior fabrics, etc.
Super hydrophobic surfaces such as leaves of the lotus plant are extremely difficult to wet. The contact angles of a water droplet when exceed 150° and the roll-off angle is lesser than 10° is referred to as the Lotus effect (Latthe *et al.*, 2014) [14]. Once water droplets fall onto leaf of lotus plant, 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 (Wong *et al.*, 2006) [23].



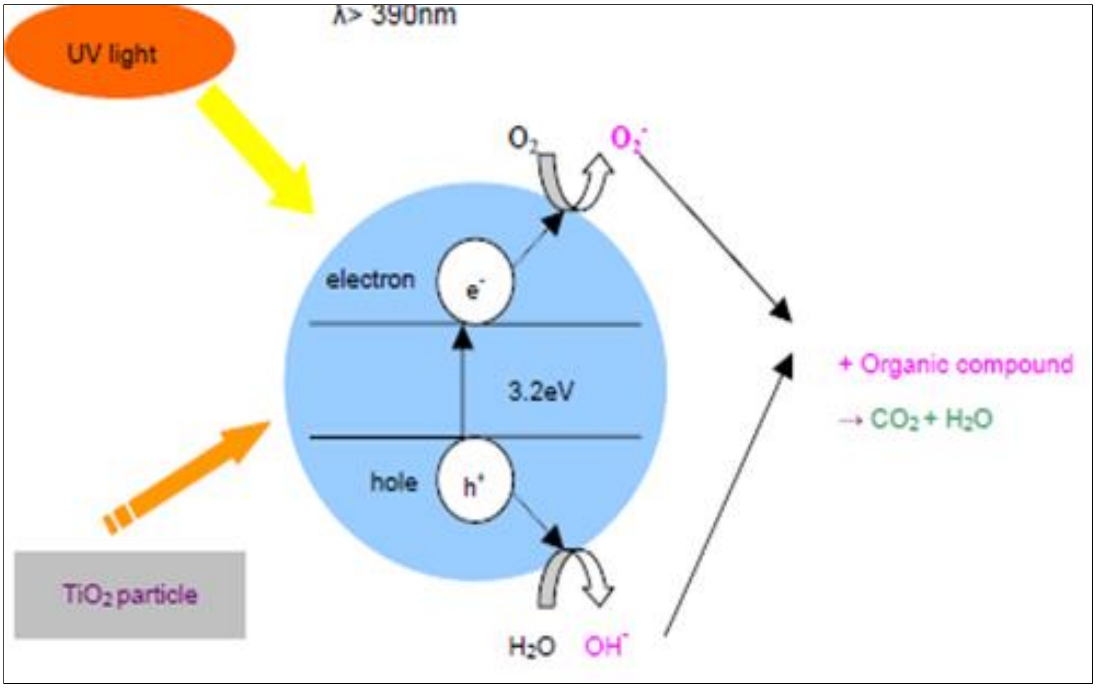
Source: Wong *et al.*, 2006 [23]

Fig 1: Comparison between a plant leaf and lotus leaf when a water drop falls onto it

Hydrophobic property can be imparted to a cotton fabric by coating it with a thin nano particulate plasma film. The audio frequency plasma of some kinds of fluorocarbon chemical was applied to deposit a nano particulate hydrophobic film onto a cotton fabric surface to improve its water repellent property (Zhang *et al.*, 2003) [27]. Super hydrophobic surfaces are focused on the surface functionalization of silica nanoparticles with non-fluorinated alkylsilanes or fluorosilanes. Cotton fabrics treated with silica nanoparticles (synthesized via sol-gel process) in combination with very low amount of water-repellent agent exhibits super-hydrophobicity with a contact angle above 130 ° (Bae, *et al.*, 2009; Przybylak, *et al.*, 2016) [1, 18].

III. Anti-bacterial: The growth of micro-organisms has negative effects not only on textiles but also on the wearer, since it results in biodegradation of textile materials along with their dissemination as a health risk. An effective antimicrobial finish should be quick acting, able to kill or stop the growth of microorganisms (Lee *et al.*, 2003) [15].

For imparting anti-bacterial properties, nano sized silver; titanium dioxide and zinc oxide are used as metallic ions and metallic compounds display a certain degree of sterilising 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 sterilising effect (Figure-3).



Source: Wong *et al.*, 2006 [23]

Fig 2: Photocatalyst action of TiO2

Titanium dioxide (TiO_2) is a photocatalyst; once it is illuminated by light with energy higher than its band gaps, the electrons in TiO_2 will jump from the valence band to the conduction band, and the electron (e^-) and electric whole (h^+) pairs will form on the surface of the photocatalyst. The negative electrons and oxygen will combine into O_2, the positive electric holes and water will generate hydroxyl radicals. Since both are unstable chemical substances, when the organic compound falls on the surface of the photocatalyst it will combine with O_2^- and OH^- respectively and turn into carbon dioxide (CO_2) and water (H_2O). This cascade reaction is called oxidation-reduction. Through the reaction, the photocatalyst is able to decompose common organic matters in the air such as odour molecules, bacteria and viruses (Yang *et al.*, 2013) [25].

Lee *et al.*, (2003) [15] achieved antibacterial efficacy of Nano sized silver colloidal solution on the cotton, polyester, cotton polyester blend and polyester spandex blend fabrics. The antibacterial efficacy of the fabrics was maintained after many times laundering.

Gupta *et al.* (2008) [8] concluded that the in situ formation of Ag nanoparticles in a grafted polymer network of cotton fabric was an effective method for the preparation of antibacterial fabrics. These fabrics exhibited biocidal action against the bacteria *E. coli*, thus showing great potential to be used as an antiseptic dressing or bandage, which are in high demand for biomedical applications.

Gouda (2012) [7] synthesized nano zirconium-oxide and nano silver-oxide for cotton gauze fabrics. The reduction rate of colony count of treated fabric with nano silver oxide against gram positive and gram negative bacteria were 99.9% and 97% respectively. Treatments given to fabrics were durable to wash and killed the bacteria even after 30 laundering wash cycles.

iv. Anti-Static: Static charge usually builds up in synthetic fibres such as nylon and polyester because they are hydrophobic in nature. Cellulosic fibres have higher moisture content to carry away static charges.

Nano particles have the properties to impart anti-static properties to textiles. These are the electrically conductive materials and dissipate the static charge which accumulates on the fabric. Nano sized titanium dioxide, zinc, nano antimony-doped tin oxide (ATO) and silanenanosol can impart anti-static properties to the textile materials. 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 (Wong *et al.* 2006) [23].

Das *et al.* (2014) [5] indicated that nanotechnology has been applied in manufacturing anti-static garment. W.L. Gore and Associates GmbH used nanotechnology and polytetrafluroethylene (PTEE-Dupont's Teflon®) to develop anti-static membrane for protective clothing. Gore-Tex® I Work wear protected the wearer from electrostatic discharges. Electrically conductive nanoparticles durably anchored in the fibrils of the Gore-Tex® I membrane of Teflon, creating an electrically conductive network that prevented the formation of isolated chargeable areas and voltage peaks commonly found in conventional anti-static materials. This method overcomes the limitation of conventional methods, i.e. the anti-static agent is easily washed off after a few laundry cycles.

Yeon *et al.* (2007) treated wool fabric with a sulphur nano silver colloidal solution (SNSE) having Ag/S complex in ethanol base. For anti-static property of wool fabric having nano silver particles, frictional electrostatic voltages of samples were measured. The satisfied anti-static effect was displayed by treatment with SNSE in high concentration of silver on the wool fabric surfaces.

v. Anti-Moth: Moth attacks animal origin materials like woollens, mohair, bristles and fur. One of the major threats to wool fabric is moth attack as the larvae of *Tineola bisselliella* and *Anthrenus verbasci* are causing severe attack to woollens. Wool goods stored in badly ventilated, dark and humid atmosphere with a temperature range of 30-35°C provide favourable conditions for moth attack. The basic building block of wool is proteins, with major constituents of keratin and cross linked by disulphide bridges. The wool degrading larvae are able to break disulphide bonds in wool during digestion by the action of a reducing agent present in their intestinal tracts, causing damage to woollens (Cox and Pinniger, 2007) [4]. Nano clay particles have unique chemical properties which make them suitable for the application on textiles.

Jose *et al.* (2017) [19] investigated the moth proofing performance of nano kaolinite-coated wool fabric against *Anthrenus verbasci.* It was found that 1.0% nano kaolinite treatment at room temperature treatment was found to be more effective than high-temperature treatment in terms of weight loss and mortality rate of wool moth.

vi. Wrinkle Resistance: One of the most important factors that influence the quality of fabric is the ability of fabrics to recover from induced wrinkles. Fibre, yarn, fabric characteristics and finishing processes contribute to the development of wrinkles. To overcome this phenomenon wrinkle resistant finish is applied to the textile substrate (Can *et al.*, 2009) [3].

Das *et al.*, 2014 [5] highlighted that 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, nanoparticles were being employed to achieve wrinkle free fabrics.

Wong *et al.* (2006) [23] used nano titanium dioxide with carboxylic acid as a catalyst under UV irradiation to catalyse the cross-linking reaction between the cellulose molecule and the acid. The results showed that the application of nano silica with maleic anhydride successfully improved the wrinkle resistance property of silk.

Lam *et al.* (2012) [13] investigated the wrinkle-resistant property of cotton treated with 1, 2, 3, 4-butanetetracarboxylic acid (BTCA) and catalysed by sodium hypophosphite (SHP) in the presence of nano-TiO_2. 0.1-0.2% TiO_2 was the optimum concentration to enhance the wrinkle-resistance of BTCA-SHP-treated cotton fabrics.

vii. Flame Retardant Finish: A fire retardant material is a substance which reduces the spreading of flame when exposed to fire, while fire resistant substances which do not catch fire when exposed. Flame-retardant finishes provide important performance characteristics to textiles such as protection of wearer from unsafe apparel**,** fire fighters and emergency personnel, protection, floor coverings, upholstery and drapery (Norouzi, 2015) [16].

Nano particles coated textile material show the good flame retardant property. Nano particles such as nano clays, ZnO, TiO_2, etc. can be used to impart these finishes to the textile materials. Hashemikia and Montazer (2012) [9] coated TiO_2 nanoparticles on the surface of cotton/ polyester knitted fabrics using citric acid as a cross-linking agent and sodium hypophosphite (SHP) as a catalyst. The presence of SHP as a phosphor source and TiO_2 increased the char residue of the fabrics by 21%. TiO_2 accelerated dehydration of cellulose in high temperature which leads to char barrier formation and an increment in the efficiency of crosslinking between the phosphorus compound and cotton. Additionally, it was suggested that TiO_2 can act as dust or wall on cotton that absorbs heat and dissipates in the combustion zone.

Samntha *et al.* (2017) **[19]** used nano ZnO and applied on bleached jute fabric using. 0.01% nano ZnO particles in a dispersion on of 10% Potassium Methyl Siliconate (PMS), which showed a good level of fire retardancy comparable with a commercial flame retardant formulation SARA Flame CFW applied on the same jute fabric to achieve the same level of LOI (limiting oxygen index) value.

Conclusion

Textile industry has already impacted by nanotechnology. The development in the applications of nanoparticles has been very rapid in past years, particularly in the field of textile finishing. These nano size materials are able to enhance the properties of conventional textiles in areas such as water repellence, UV-protection, anti-bacterial, anti-static, wrinkle resistance, flame retardant and anti-moth properties of textile materials. Research involving nanotechnology to improve performances or to create unprecedented functions of textile materials is flourishing. There is no doubt that in the next few years, nanotechnology will penetrate in every area of textile industry.

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