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Advanced Functionalization of Textiles by Nanofinishing: A Review

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Abstract

This paper reviews the applications of nanotechnology in terms of nanofinishing in textile products. Textiles appearance, handle, performance and texture can be modified by finishing process to be suitable for the end uses. Functional finishing process involves surface modification by both mechanical and chemical techniques, which can be applied on traditional textile materials to incorporate new functionalities and value addition. Nanofinishing is concerned with control and processing technologies in the sub nanometer range and so must play a vital role in the fabrication of extremely precise and fine parts. Finishes can be emulsified into nano-micelles, made into nano-sols or wrapped in nanocapsules that can adhere to textile substrates more evenly. The possibility of applications of nanoparticles in different forms and applying methods are discussed in this paper in order to implement advanced functionalization. Developments of anti-static textiles, ultraviolet (UV) resistant textiles, self cleaning textiles, antibacterial textiles by nanofinishing process are also discussed.

***Keywords:** Nanofinishing, Nano-particles, Nanotechnology, Textiles, Surface.*

1. Introduction

Influenced by constantly evolving consumer lifestyles within the last two decades, textile industry globally adopted a forward-looking approach to create new conceptual textile systems for the 21st century, based on so called knowledge-based textile materials. This strategy aims the development of futuristic human-friendly textile products which would redefine the role of textiles and expand the capabilities to affect human life by efficiently fulfilling advanced expectations of modern lifestyle. Nevertheless, in addition to conventional technologies, novel specific technologies are needed to create knowledge-based textile materials with new advanced functionalities and environmental responsiveness [1]. Nanotechnology is the engineering of functional systems at the molecular scale. With the advent of this technology, today nanofibers, nanocomposite, nano-particles and intelligent garments are developing in the market.

Especially a new area has developed in the area of textile finishing called "Nanofinishing". Nanofinishing is a finishing process with nanotechnology to functionally or protectively build more unique or better qualities to textiles as a result of their novel and fascinating properties, and applications of nanomaterials superior to their conventional counterparts [2]. The first commercial application of nanotechnology became available in terms of nanofinishing. Nanofinishing is introduced on the textile materials in a controlled and ordered way while chemical finishing is done randomly. Demands for functionality and intelligence of wearable textiles increasing and pose lot of challenges in product development [3, 4, 5, and 6]. The technology can be used for desired textile attributes, such as fabric softness, durability, breath ability and in developing advanced performance characteristics in fibers, yarns and fabrics. Growing awareness of health and hygiene has increased the demand for bioactive or antimicrobial and UV-protecting textiles.

Nanotechnology has real commercial potential for the textile industry, because conventional methods have no permanent effects and lose their functions after laundering or wearing. In addition, normal finishing can affect air and moisture transfer of the fabric. On the other hand, treating textiles with nanomaterials is a method to improve its properties, which making them longer durable, nicer colours etc. Fiber provides large surface area for a given weight or 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 macromolecules or super molecular clusters in the vicinity of a fiber when changing from a wet state to a dry state [7]. Nanotechnology can also be used in the opposite manner to increase the ability of textiles, particularly synthetics, to absorb dyes. Until now most polypropylenes have resisted dyeing, so they were deemed unsuitable for consumer goods like clothing, table cloths, or floor and window coverings. A new technique being developed is to add nanosized particles of dye friendly clay to raw polypropylene stock before it is extruded into fibers. The resultant composite material can absorb dyes without weakening the fabric.

2. Different structures of nano-particles

Structures with three dimensions in the nano-scale are known as nano-partilces. Since atoms and molecules belongs different behavior than those of bulk materials, so nanofinishing by nano-particles develop innovative and advanced functional properties in the treated textile materials. The whiskers get hooked on the fibers to alter the fabric property. It makes the fabric stain, water and wrinkle resistant, but keeps the fabric breathable and soft. The three dimensional molecular nano-net covers the core fiber completely. It can inject linen property into a synthetic fiber, as a result wicks body moisture fast, dries quickly and gives the cooling effect. Nano sheet wraps the fiber completely to cover it and alter its property, which enhance the fabric robustness and color fastness.

3. Nano-particle Application Methods

There are various application methods for textile nano particle, such as sol-gel techniques, plasma polymerisation, pad-dry-cure method, dip coating, foulard process, chemical vapor deposition (CVD), electro spraying process, layer-by-layer deposition method etc. First of all nano-particle is synthesized and then applied on of these methods. Some of them are described below.

3.1 Electrospraying process:

The nano-particles such as metal oxides or fluorocarbon can be deposited onto the textile surface by using an electro spraying process. The electro spraying process has a conventional configuration consisting of a charged syringe fed with polymer solution and a grounded collector plate. When a liquid or emulsion is subjected to an electric field of several kilovolts produced by a high-voltage power supply, the droplet at the capillary tip of the syringe, which is kept in place by the surface tension of the liquid, is also charged and overcomes the forces of surface tension resulting in elongation of the droplet into a conical shape. Further increase in the attractive force of the electric field by means of increased voltage produces a charged jet of liquid that is channeled to the ground [8].

3.2 Layer-by-layer deposition method

Layer-by-Layer deposition is a thin film fabrication technique. The films are formed by depositing alternating layers of oppositely charged materials. The dissociation of certain materials in solution form into their nano-size cationic and anionic groups of molecules which is utilized to alternatively and repeatedly deposit nano-scale layers of the nano ionic components of the materials. This repeated cationic anionic assembly deposition of nano particles of certain polymeric components on a substrate can exhibit significantly improved functionalities of the end-product. For example, deposition of silver in nano format on a cotton fabric provides satisfactory antimicrobial and wound-healing features [9].

3.3 Sol-gel process

It is a process for making very small particle 20 to 40 nm. A liquid precursor of the particle is dissolved in a solvent, usually alcohol, water is added and then acid or base. The mixture is coated or cast. The precursor then decomposes to form the fine ceramic particles. If the particle concentration is high enough, the mixture gels. The gel is dried, and then heated at high temperature to sinter the ceramic, giving the desired ceramic film or fiber. During this drying and sintering process, shrinkage occurs through loss of solvent and air, and this shrinkage must be carefully controlled to avoid cracking.

3.4 Wet chemical/Dip coating

Continuous dip coating is an easy and popular way of creating very thin films onto textile substrates. It is also known as impregnation or saturation method. In this method, the substrate is immersed for a certain time (known as dwell time) in a tank which contains coating polymer and then material is squeezed out by passing though nip rollers or a set of doctor blades to give a fixed net pick up of the resin [10].

4. Antistatic Textiles

Static electricity can cause many processing problems for textile materials, especially those made from hydrophobic synthetic fibers. In most dry textile processes, fibers and fabrics move at high speeds over various surfaces which can generate electrostatic charging from frictional forces. This electrical charge can cause fibers and yarns to repel each other, leading to ballooning. Fabrics and nonwovens are also affected by static charges, causing materials handling problems. 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 nanosized titanium dioxide [11], zinc oxide whiskers [12], nano antimony-doped tin oxide (ATO) [13] and silane nanosol [14] 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, silane nanosol 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 [15].

5. UV-protective Finish

An overexposure to UV radiation can cause sunburn and some forms of skin cancer. In humans, prolonged exposure to solar UV radiation may result in acute and chronic health effects on the skin, eye, and immune system. However the most deadly form - malignant melanoma - is mostly caused by the indirect DNA damage (free radicals and oxidative stress). This can be seen from the absence of a UV-signature mutation in 92% of all melanoma (10). Previously organic and in organic UV absorbers were coated on the textile material they prevent UV radiation effectively but they are less durable. As UV blockers usually certain semiconductor oxides such as TiO2, ZnO, SiO2, and Al2O3 can be used. Among these semiconductor oxides, TiO2 and ZnO are commonly used. Through study showed that nanosized titanium dioxide and zinc oxide are more efficient at absorbing and scattering UV radiation [6, 16].

6. Self Cleaning Effects for Textiles

One of the most common ways to use nanotechnology in the textile industry is to create stain and water resistance. To do this, the fabrics are embedded with billions of tiny fibers, called “nanowhiskers”, which are waterproof and increase the density of the fabric. The nanowhiskers can repel stains because they form a cushion of air around each cotton fiber. When something is spilled on the surface of the fabric, the miniature whiskers actually cohesively prop up the liquid drops, allowing the liquid drops to roll off. This treatment lasts, for about 50 home wash cycles before its effectiveness is lost [17]. The best known example with regard to a water and soil-repellent finish is the lotus-effect. On the basis of lotus leaf concept scientist developed a new concept “Self cleaning textile” the textile surface which can be cleaned by itself without using any laundering action. Self cleaning surface possess a water contact angle greater than 150° and a very low roll off angle. Water through these surfaces easily rolls off and completely cleans the surface in the process. Self cleaning fabrics not only repellant to water but are also resist stains, dirt, and odor and are antimicrobial as well. Self cleaning textiles can be developed by using photo catalysts, using microwaves, using carbon nano tubes, and using silver nano-particles [18]. We know that wet ability strongly depends on two properties the surface free energy and the surface roughness. Surface free energy is an intrinsic property of the material that can be controlled by chemical modification, such as fluorination and other hydrophobic coatings.

7. Antimicrobial Effects for Textiles

Neither natural nor synthetic textile fibers are resistant to bacterial or pathogenic fungi. The nano-particles of silver (Ag), TiO2 and zinc oxide (ZnO) exhibit high antibacterial activity [19, 20, 21, and 22]. Nano-silver particles are widely applied to socks in order to prohibit the growth of bacteria. In addition, nano-silver can be applied to a range of other healthcare products such as dressings for burns, scald, skin donor and recipient sites. Because of photo catalytic feature, nano TiO2 are proved to show antibacterial property. Several papers have reported the use of the photo catalytic property of TiO2 for developing antibacterial textiles [23]. On the other hand, zinc oxide is also a photo catalyst, and the photo catalysis mechanism is similar to that of titanium dioxide; only the band gap is different from nano TiO2. Nano ZnO provides effective photo catalytic properties once it is illuminated by light, and so it was employed to impart antibacterial properties to textiles [24].

8. Commercially Available Products

Nano-Tex™ has developed wrinkle resistant fabric, stain resistant, anti-static and UV protection fabrics [25-27]. Scholler® company's products include soft shells technology for functional stretch multi-layer fabrics: dynamic climate controlled extremely air-permeable, light and water and wind resistant clothing and gloves [28-30]. On the other hand Bugatti has developed jacket with a nanosphere finish, which has the moisture management features [31]. Ski jacketes for developing grime-resistant, windproof, waterproof, and breathable fabrics have been developed by another company named Franz-Ziener [32]. Institute for soldier nanotechnologies (ISN) develop textile materials for soldiers: light weight, strong, abrasion/wear resistant, durable, impact energy absorbent, temperature controlled water proof, improved camouflage, and embedded with multipurpose micro/nano sensors [33-34]. Nano- Plem' technology is claimed by Toray, Japan. This imparts water- repellant characteristics and color resilience to nylon and polyester fabrics, and Terylene/ wool blends. Mincor TX TT, a nanofinish from BASF, is a composite material consisting of nanoparticles embedded in a carrier matrix. This finish may provide solution for the fabrics like polyester awning, sunshades, flags and sails that are generally required to remain continuously in outdoor environment; therefore these cannot be cleaned in washing machine. Synthetic fibers can be made soft and comfortable like cotton. Nano- TouchTM fabric technology is known to permanently graft an outer layer of cotton- like properties around a synthetic fiber core.

8. Conclusion

The impact of nanotechnology in the textile finishing area has brought up innovative finishes as well as new application techniques. Particular attention has been paid in making chemical finishing more controllable and more thorough. Nanofinishes being developed for textile substrates are at their infantile stage. Nano finishing can replace traditional finishing technique of textile products and readymade clothing with products of superior quality and lower production costs. A wide variety of clothing and apparel from Levi, Adidas, Nike and home furnishings are commercially available that now comprise some form of nanotechnology, especially antimicrobial and stain- and wrinkle-resistant clothing. Bangladeshi textile industry yet not taken any initiative to established nanofinished based industry due to lack of resource person. Furthermore, this technology is not so cost effective but has many other advantages like low weight, longevity, durability etc. In future, one can expect to see many more developments in textiles based on nanotechnology.

9. References

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