IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE)
e-ISSN: 2348-019X, p-ISSN: 2348-0181, Volume 4, Issue 1 (Jan. - Feb. 2017), PP 01-06
www.iosrjournals.org

Application of Nanotechnology in the field of Textile

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Abstract: *The choice of aesthetic properties as well as the functional properties of textile products is increased extensively day by day to the customers. That's why, new technology is developed in different areas of technical textiles to fulfill the satisfaction of customers. Nanotechnology is one of the most important areas, which is increasing significantly at the present time. Various types of high performance textiles are produced now a days by different finishing, coating or manufacturing technique of producing fibres or fabrics as well as nano sized (10^{-9}m) particles are imposed on finished clothing. This nanoengineered textiles cover from the protective clothing, smart textiles , hygiene textiles, antiballistic or bullet proof vest or functionally finished clothing like water repellent or wrinkle resistance clothing. Nanotechnology offers the developments of fibre for human which have both conventional property like comfort (cotton) and modern property like water repellent property (GORE TEX). 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 field with an emphasis on improving various properties of textiles.*
Keywords: *Nanotechnology, nanofinish, functional textile, high performance clothing, smart textiles.*

I. Introduction

Nanotechnology brings an enormously promising and bright future for textile industries. The unique and new properties of nanomaterials have attracted not only scientists and researchers but also businesses, due to their huge economical potential [1]. 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 of textiles and generating worldwide interest [4]. 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, and color enhancement properties relative to surfaces unmodified with such nanoparticle systems [5]. Application of scientific knowledge to manipulate and control matter in the nanoscale in order to make use of size and structure dependent properties and phenomena, as distinct from those associated with individual atoms or molecules or with bulk materials [6,23]. Nanotechnology overcomes the limitation of traditional processes or technology by improving certain properties. Nanotechnology deals with the effect that properties of materials can change drastically when the particle size falls below approximately 100nm [8]. The basic premise is that properties can dramatically change when a substance's size is reduced to the nanometer range [20]. One of the hottest trends in the fashion industry today is 'nanotechnology,' which is invisible to the naked eye but is utilized to increase the performance and the functionality of textiles [13]. Textile technology can improve such a level by using nanotechnology so that the application of this specialized textile products can be used for diversified fields like medical textile, geo textile, textiles for protection from severe environmental or washing condition, dyeing process and finishing processes. Different nano treatments or finishes can impart the textiles with significant and special properties like breathability, water repellence, soil resistance, wrinkle free property, flame retardancy, anti static property, UV protection, wicking property etc. Recent technologies have allowed the traditional functionality of textiles to be extended. Advances in material science have added intelligence to textiles and created "smart" clothes.

II. Production of Nanotextiles

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 figure1[3]. Nano finishing comprises of different coating technique used by applying nano particles onto textile fibres [8]. Coating is a common technique used to apply nano-particles onto textiles. The coating compositions that can modify the surface of textiles are usually composed of nano-particles, a surfactant, ingredients and a carrier medium (Cramer, 2003) [8]. New coating techniques like sol-gel, layer-by-layer, plasma polymerization, etc. can develop multi-functionality, intelligence, excellent durability and weather resistance to fabrics [4]. 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 [8]. 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 fibres have led to the exploration of high strength and superior performance fibres, while many other applications in nano fibre or yarn are still way off future [12].

Nano-fibres have multifunctional properties like high surface area, a small fibre diameter, good filtration properties, thin layers and high permeability [8, 14]. 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 [18].

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 [7, 23]. In this case nanomaterials are incorporate into fibres, 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 [15, 18].

A. With integrated nanoparticles:

- Fibres made from nanocomposite materials
  ∗NP encased in polymer or in part bonded without casing on the surface
  ∗NP made functional to prevent agglomeration (e.g. "coating")
  ∗Also, the manufacture of nanoscale fibres – processing into fleece since spooling as thread not possible
- Fibres made from CNT, at development stage
- “Refining”
  ∗NP adhere to the fibre surface
  ∗NP embedded in the fibre coating

B. Without synthetic nanoparticles:

- Nanoscale fibres
- Nanoscale coating on fibre surfaces
- Nanoporous fibres without coating

Fig.1: Manufacture of nanofibres (NP: nanoparticles, CNT: carbon nanotubes); [39]

III. Application of Nano textiles

Nano textiles are used now a days numerously, it ranges from fashioned technological clothing to protective occupational dresses, environmental waste savings to functional finished clothing. The application of nanotechnologies to textiles affords an expanded array of properties with potential for improved and novel use in materials and products [23].

Nanotechnology can reduce the use of water as the nanostructure and surface functionality can be imparted using dry techniques on fabric [18].

It has a great effect on environment and the process is also eco friendly. Conductive yarns and fibers are made by mixing pure metallic or natural fibers with conductive materials [26]. On the other hand, It's proven that the addition of carbon nano-tubes to a common commercial polymer, polypropylene, leads to eliminate “die swell” effect, causes in swelling of polymers when passing through the capillary tube in electro-spinning process. This improvement enhances the strength of the fibres against the high voltage between capillary tube and the collector [8].

Static electricity and metallic ions play a vital role also in case of finished textiles. Potential uses for electro-spun fibres are in filtration, wound dressings, tissue engineering, nanocomposites, drug delivery devices and sensors [9,10,20]. Metallic ions and metallic compounds display a certain degree of sterilizing effect [1].

Resists Static is the first permanent anti-static treatment for synthetic fibers. Not only does it repel static, but the treatment also repels statically attractive substances such as dog hair, lint and dust [21]. TiO_2, ZnO and TiO_2 nanoparticles are electrically conductive materials and help dissipate the static charge in these fibers

[4]. There are many ways in which the surface properties of a fabric can be manipulated and enhanced by implementing appropriate surface finishing, coating or altering techniques, using nanotechnology [25]. Electro conductive fibers to be used for the protection from radiation emitted by electronics [10, 22].

Nanotechnology has the potential to being revolution in the field of technical textiles for the benefit of humanity [11, 14]. In today's performance market, microencapsulation in textiles includes the application of fragrances, skin softeners, insect repellent, and antimicrobial agents [13].

Fabrics can be functionalised at the surface for tissue engineering, drug delivery or topic treatments, such as the use of chitin for wound healing [24]. With the use of nano-sized particles, the number of particles per unit area is increased, and thus anti-bacterial effects can be maximized [1].

Todays medical science depends extensively on nanotechnology. Recent developments of nanotechnology use to save human life and keep them in suited state. These include: monitoring heart rate, breathing, body temperature and other physiological parameters; Measuring activity, for example determining the number of steps taken, the total distance travelled, Acting to actively stimulate muscles e.g. using electrical muscle stimulation; Work against activity to provide 'smart' resistance training; Record aspects of performance, such a foot pressure or specific joint movements; Protect against injury [26].

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 [1, 16, 19, 27]. Development of nano-functional fibers has been directed to the manufacturing of hygienic fabrics for undergarments. Several companies are using these new fibers to develop odor-free clothing, such as socks, stockings, and undergarments, etc. For example, socks containing nano-particles of silver minimize foot odor [25, 28]. The Korean company, Hyosung, is one of the world's major nylon manufacturers [23]. Within its suite of 'Mipan'functional fibres, the company has developed 'Nano Magic Silver' nylon fibres containing silver nanoparticles to eliminate up to 99.9% of various harmful bacteria [29]. The developed 'Mipan Nano-Magic Silver' is a material proven to function far better in its antibiotic function than any other material used currently as antibiotic fibres [20].

Carbon nano fibres and carbon black nano particles are effective reinforcing materials for composite fibres [30]. Both nano materials also lead to high chemical resistance and electrical conductivity when used in composite fibres. Composite fibres with nano-sized clay particles or flakes (hydrated alumino silicate) exhibit excellent flame retardance, UV blocking power and inertness to corrosive chemicals [20, 30]. A UV-protective textile is a textile that provides protection from UV light in addition to reducing the risk of skin injury related to exposure [13]. A thin layer of TiO_2 nanoparticle is formed, on the surface of treated cotton fabric, which provides excellent UV protection, the finish is durable up to 50 home launderings [24].

Textile based nanoproducts starting from nanocomposite fibers, nanofibers to intelligent high performance polymeric nanocoatings are getting their way not only in high performance advanced applications, but nanoparticles are also successfully being used in conventional textiles to impart new functionality and improved performance[4]. Improvements in performance and added functional characteristics of different working clothing would be of immense assistance within professions such as the defense forces and emergency response services like fire fighter suit. Researchers are also investigating textile materials made from nanofibres 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 from materials such as these [3]. Being evenly distributed in polymer matrices, nanoparticles can carry load and increase the toughness and abrasion resistance; nanofibers can transfer stress away from polymer matrices and enhance tensile strength of composite fibers. Additional physical and chemical performances imparted to composite fibers vary with specific properties of the nanofillers used [12].

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 [22, 31, 32]. The need for textiles with, for example, very high anti-ballistic properties, antibacterial activity, flame retardant, colour modification for camouflage, RF shielding, protecting in biological warfare, to name some, is very high in this sector and nanotechnology can offer a vast array of solutions giving leading hedge products [24].

While technology may be hidden through invisible coatings and advanced fibers, it can also be used to dramatically change the appearance of the textile, giving new and dazzling effects. Light emitting clothing's are finding their way onto the elegant couture catwalks, suggesting a future trend in fashionable technical garments. For example, consider the T-shirt. Research is being done that will use nano technology enhanced fabric so the T-shirt can monitor your heart rate and breathing, analyze your sweat and even cool you off on a hot summer's day. What about a pillow that monitors your brain waves, or a solar powered dress that can charge your iPod or MP4 player? [11].

'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 [26, 33]. 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 [20,34]. As fashion and technology converge, SOFTswitch is providing the enabling fabric interfaces to allow electronics to function within clothing figure 2 [40].

Fig.2 Wearable Technology (SOFTswitch)

The introduction of moisture management technology goes beyond these sportswear examples to casual clothing, such as Coolmax® and Coolplus® found in socks, underwear and outerwear or Dri-Power® fleece with fibers that wick away moisture to keep one cool in summer and warm in winter[13].

In the more distant future, "smart textiles" that can monitor variables such as the driver's condition; however, privacy issues may arise. The increased use of textiles in the car contributes to the reduction of the car weight and hence fuel consumption and CO_2 emissions [2, 35].

The inferior properties of cotton fibers and yarns can be enhanced or complemented by engineering the physical, chemical, and surface characteristics of cotton fibers/yarns, in order to develop the desired textile attributes, such as fabric softness, durability, and breathability and the advanced performance characteristics, viz., water repellency, fire retardancy, antimicrobial resistance, etc. [22].

For cotton fabrics, wrinkle resistance can be developed by using the nano-engineered cross-linking agents during the fabric finishing process. Besides the wrinkle resistance, such finishing is also capable of eliminating toxic agents, while maintaining the desired comfort properties of cotton [25, 36]. On the other hand, nano-silica was applied with maleic anhydride as a catalyst; the results showed that the application of nano-silica with maleic anhydride could successfully improve the wrinkle resistance of silk [1]. The basic principles and theoretical background of "fluid-fabric" surface interaction are well described in a recent manuscript by Schrauth et al. [37]. They have 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.

They also showed that such an alteration in the fabric's surface properties is capable of exhibiting the "Lotus-Effect," which demonstrates the natural hydrophobic behavior of a leaf surface [25]. 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 3 [24].

A super hydrophobic surface is the one that can bead off water droplets completely; such surfaces exhibit water droplet advancing angles of 150^o degree or higher [4]. NanoSphere® provides optimum impregnation of textiles. The waterproofing is excellent and the oil and grease repelling properties at a level never achieved before. Ketchup, honey, coffee, red wine and many other substances simply run off the nano-structured surface. And even if they fail to run off of their own accord, the stain can easily be rinsed off under running water [20].

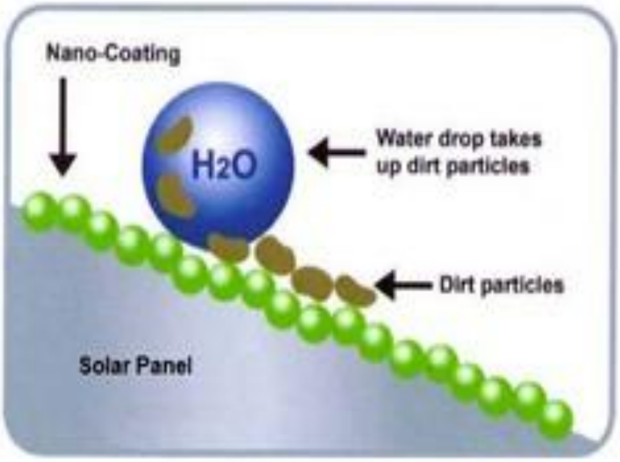

Fig.3 Nano coating self cleaning textile

IV. Conclusion

The application of nanotechnology is growing day by day in different fields including the textile industries. 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. Jennifer Sass, senior scientist at the US Natural Resources Defense Council (NRDC), warns that the very qualities that make a product more useful at the nanoscale could also make it more toxic, or more bioavailable. Nano waste may come as biggest environmental issue in this time of global warming. 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. There is no doubt that in the next few years, nanotechnology will penetrate into every area of textile industry.

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