

Recent Advances in Nanotechnology for Functional and Smart Textiles: Materials, Surface Engineering, Applications and Future Perspectives

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ABSTRACT

The use of nanotechnology in textile industry increased rapidly in last few years and this is mainly due to deploying nanotechnology. The textiles treated with nano material are aimed at producing finished fabric with different functional performance. Therefore, nano finishing of textiles has become an important surface modification in textile industry. Nanotechnology involves engineering on a small scale to create smaller, cheaper, lighter, and faster process that can do more things with less raw materials. Various types of high performance textiles are produced nowadays by different functional finishing, coating or manufacturing techniques of producing fibres to fabrics as well as nano sized particles are imposed on finished clothing. These nano engineered textiles cover from the protective clothing, smart textiles, hygiene textiles, antiballistic or bullet proof vest or functionally finished clothing like water repellent, fire retardant, UV protection, antimicrobial, self-cleaning and wrinkle resistance clothing without affecting the bulk properties of fibers and fabrics. This review highlights the applications of nanotechnology in textile field with an emphasis on improving various properties of textiles.

Keywords : Nanotechnology, functional textiles, nanomaterials, textile surface modification, smart textiles.

INTRODUCTION

Nanotechnology is the study of extremely small structures having size of 0.1 to 100 nm. The prefix “nano” is a Greek word which means “dwarf”. The word “nano” means very small or miniature size. However it is also inherent that these materials should display different properties such as electrical conductance chemical reactivity, magnetism, optical effects and physical strength, from bulk materials as a result of their small size. It involves engineering on a small scale to create smaller, cheaper, lighter, and faster devices that can do more things with less raw materials.

Nanotechnology is the treatment of individual atoms, molecules, or compounds into structures to produce materials and devices with special properties. The development in the field of nanotechnology started in 1958. It has already revolutionized in the field of medicine, electronics and composites and it is in the process of booming energy, environment, cosmetics, textiles, food and agriculture. Magnetic nanoparticles

embedded in polymer matrices are good example of functional nanostructures having potential application in electromagnetic interference shielding, magneto-optical storage, biomedical sensing and flexible electronics.

Nanotechnology in textiles

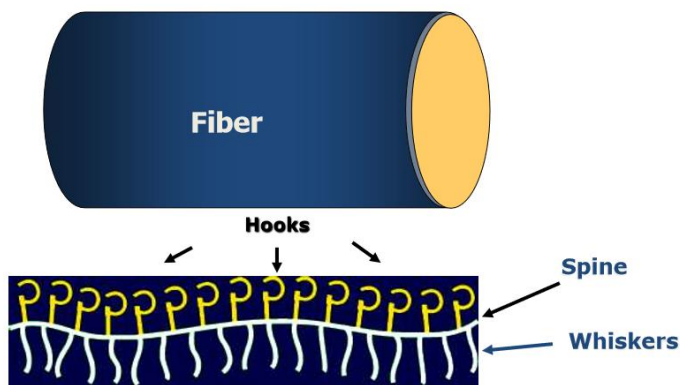
Textile industry is also experiencing the benefits of nanotechnology in its diverse field of applications. The evolution of unique and new properties of nano materials have attracted not only scientists and researchers but also businesses, due to their huge economical potential [1]. Nanotechnology overcomes 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 [2]. Imparting of conventional methods to fabric for different properties will lose their functions after several laundering or wearing and also it will reduce breathability and Comfort. But nanotechnology can provide high durability for fabrics because, nano-particles have a large surface area-to-volume ratio and high surface energy. Coating of nano-particles on fabrics will not affect their breathability as well as hand feel. Nanotechnology has the potential to being revolution in the field of technical textiles for the benefit of humanity [3,4].

There is no doubt that in the next few years nanotechnology will penetrate into every area of the textile industry. Some current research in nanotechnology incorporate certain properties to textiles like:

- Antimicrobial
- Electrical conductivity
- Fire resistance
- Fragrance release
- High strength
- Moisture management
- Shrink resistance
- Stain resistance
- Static protection
- UV protection
- Water repellent (hydrophobic)
- Wrinkle resistance
- Self-cleaning

Different structures of Nano Particles:

1. WHISKERS

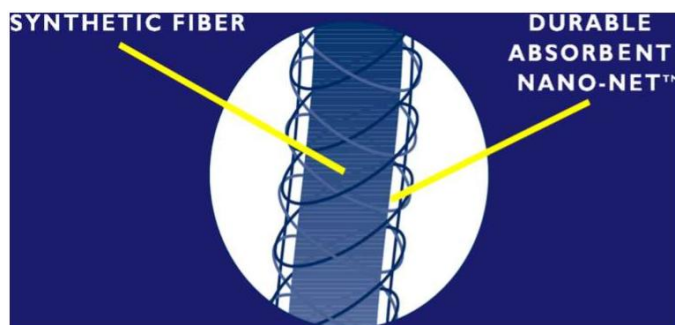


The whiskers get hooked on the fibers to alter the fabric property

Value addition due to Nano Whiskers:

- Water and oil repellency
- Superior durability
- Breathable
- Fabric remains soft, natural
- Wrinkle resistance

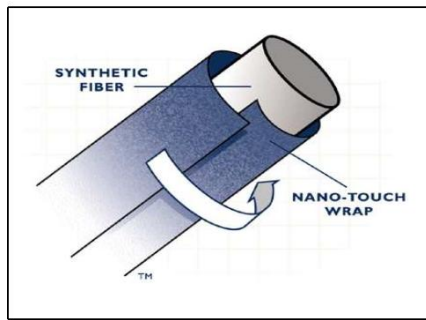
2. NET



Value addition due to Nano Net:

- Alters the property of synthetic fibers like Polyester to give a feel of cotton & linen.
- Wicks body moisture fast.
- Dries quickly & gives the cooling effect.

3. WRAP



Nano sheet wraps the fiber completely to cover it & alter its property. Three-Dimensional Molecular Nano Net covers the core fiber Completely

Value addition due to Nano Wrap:

- Strength and
- Durability
- Improvement in colourfastness
- Crease Retention
- Static Resistance [5]

Nanotextiles are subdivided into four major types: -

- Nanofinished textiles
- Nanocomposite textiles
- Nanofibrous textiles
- Nano-enabled nonwovens

Nanofinished textiles: Nanofinished textiles are those textiles in which nanoscale property are applied after the base textile has been fabricated. This includes post-manufacture treatments and coatings to apply nanomaterials or create nanostructured surfaces on fabric or fibre media. Additive nanomaterials include metal nano-objects (such as silver for antimicrobial functionality) or clay nano-objects (for fire resistance). Nanostructured surfaces may also include those roughened by treatments (hydrophobicity for self-cleaning). Nanofinished textiles may require the addition of intermediate steps for coating or treatment. The majority of nanotextiles are already on the consumer market fall within this category. Nanofinishing can provide accessible means for established textile manufacturers to engage with nanotextiles.

Nanocomposite textiles: Nanocomposite textiles are textiles which have composite fibre materials containing one or more nanostructured or nanoscale components. This type of nanotextile centres upon pre-manufacture integration of nanoscale properties into fibrous components. The materials like carbon nanotubes (for enhanced fibre strength) and rare earth metal doped nanoparticles (for luminescence) are added to produce the nanocomposite textile. Polymer matrices are the most prevalent in nanocomposite fibres. However, other matrices may also be useful. Similar to nanofinished textiles, nanocomposite fibres may not require significant changes to the manufacturing process. If the matrix material is the same shape and size as the process has been designed for, only small alterations may be necessary to integrate the composite component. If the fibre material is entirely changed by choosing a different matrix material or

significantly altered by the composite properties, significant reconfiguration may be needed. Alterations to the base material achieved at the research level may face challenges in scaling up to production to realize a stable composite material. These nanotextiles have promise, but currently represent a relative minority in commercialized form.

Nanofibrous textiles: Nanofibrous textiles have fibres with nanoscale dimensions. Nanofibres have a nanoscale cross-sectional area but they may or may not have a nanoscale length. Fibre material may be either a single material or a composite (which, based on the fibre dimensions, may also be a nanocomposite). Nanofibres can also be nanofinished. These nanotextiles focus on fabricating fibres to exploit nanoscale properties. These properties may emerge either from the nanomaterial composition such as fibres made of carbon nanotubes, giving them very high strength or from the scale of the individual fibres such as filter media, giving them increased fibre surface area and nanoscale porosity). Fibre fabrication for nanofibrous textiles typically would be new. Not only does initial fabrication of the fibre require a process that can create nanofibres (such as electrospinning or forcespinning, which are not conventional drawing methods), but all of the subsequent steps in the manufacturing process must accommodate these smaller fibres. For woven textiles, the technology does not exist on an industrial scale to weave fibres of this size. Beyond that, dyestuffs and laminations may have to be reformulated for nanofibres. Incorporating nanofibres into textiles may be accomplished through entangling or encapsulating the fibres in a larger fibre. While research into nanofibrous textiles is widespread, little has reached significant commercialization. Its development, however, may afford exciting applications and opportunities.

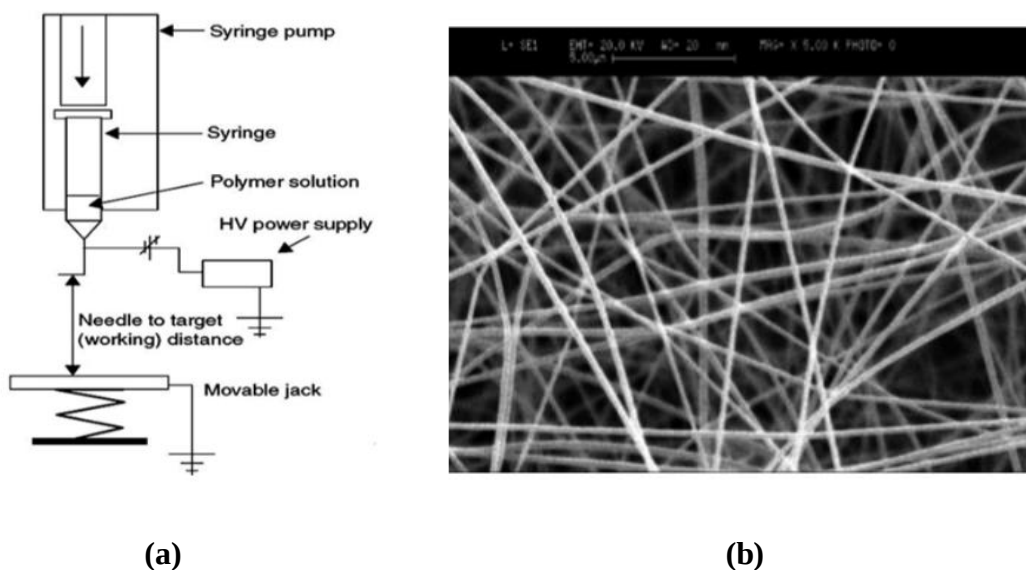


Figure: (a) Schematic diagram of electrospinning set up (b) Electrospun nanofibrous web under SEM

Nano-enabled nonwovens: In nonwovens Nanotechnology can be used in improvement of properties to benefit textile processing such as adhesive properties may be enhanced or conventional methods of securing layers may be replaced with adhering nanostructured surfaces. Other nanoscale functionalities

may utilize nanofilms or coatings in layers or barriers, such as for antibacterial properties, energy production (for solar power) and luminescence (for colour control).

ULTRA VIOLET PROTECTIVE FINISH

In recent days consumers have become increasingly aware of the need for sun protection, which is related to the incidence of sun-induced skin damage and its relationship with an increased exposure to UV light. Although avoiding the sun can help to stay away from UV rays, but the most frequently recommended form of UV protection is the use of suitable clothes, hats and sunscreens. [6] In today's world advanced material technology makes it possible to turn clothing into a guard against skin cancer, particular melanoma caused by excessive exposure to ultraviolet radiation (UVR) from the sun. UV resistant property can be given to the fabric by changing the structure of the constituent fabrics, varying the weave, changing the shades in dyeing or applying a suitable finishing agent on the fabric.[7,8]

UV blocking treatments for cotton fabric has been developed using ZnO and TiO₂ nanoparticles. Knitted fabrics containing ZnO nanoparticles showed moderate to high ultraviolet protection factor (UPF) values, whereas 50+ UPF values were measured for the TiO₂ coated samples. The performance of titanium dioxide as a UV finish can be effectively imparted to the surface of silk and lyocell union fabrics by the application of TiO₂. The UPF test shows improvement in the UV absorbency activity of the TiO₂ treated fabrics. Similar results indicate the use of UV resistant fabric for protecting the body against solar radiation. These treatments were durable up to 25 washes. The developed processes can be easily adapted to the existing textile machinery, making it industry viable.[9,10]

HYDROPHOBIC FINISH

A super hydrophobic surface is that surface that can bead off water droplets completely. A self-cleaning surface thus results, which help in rolling water droplets across the surface and can easily pick up the dirt particles to leave behind a clean surface. Taking the inspiration from the nature there have been several approaches researched to create super hydrophobic surfaces on textiles, which mimic the nano structured Lotus leaf. Hydrophobic surface can be produced in two ways:

1. By creating rough structure on a hydrophobic surface.
2. By modifying a rough surface using materials with low surface free energy.

Super-hydrophobic cotton surfaces can be prepared by sol-gel method based on silica nanoparticles and perfluorooctylated quaternary ammonium silane (PFSC) coupling agent. In this combined technique, nano-roughening and surface energy lowering are introduced with the help of two components which mimic the lotus leaf [11]. Besides amino functionalized silica nanoparticles can also be applied on epoxy functionalized cotton fabric which can result in excellent super-hydrophobicity ($\sim 170^\circ$).

The functionalization of silica and cotton surface helps to create strong bond between the fibre and particles producing nano roughening on fibre surface, which is very robust and durable [12].

The lotus leaf effect can be mimicked on cotton surface by using nanosilica or nanoclay (kaolinite) particles. The nanoparticle deposited under same condition on cotton fabric surface. The performance of nanosilica is best due to its smaller dimension and uniformity in creating the roughened surface. This is due to the plate-like structure of nanoclay, which somewhat hinders the rolling of water from fabric surface. Nanosilica and nanoclay based nanoparticles can be successfully used to create super-hydrophobic cotton fabric having contact angle of $>150^\circ$, where the water droplets just roll on the surface of the fabric, taking away the dust.

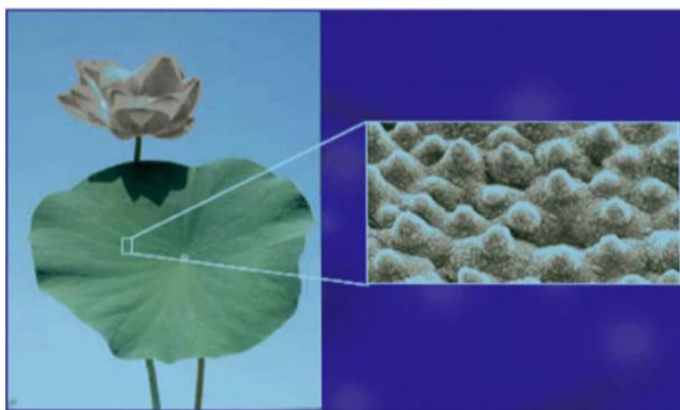


Figure: Lotus leaf effect and a SEM image of its surface

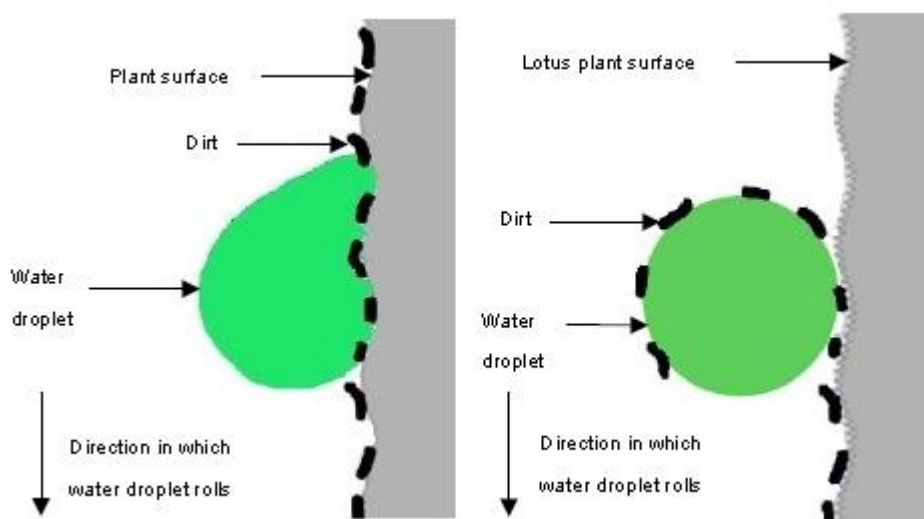


Figure: Mechanism of water repellence

FIRE RETARDENT FINISH

Faming combustion is a gas-phase oxidative process, which requires oxygen (or air) from the atmosphere. Depending on the chemical composition and on their thermal and fire properties, textile fibers and fabrics need substances such as halogen, sulphur, phosphorus, nitrogen, boron, metals etc to attain flame retardency [13,14] These additives can be directly introduced into synthetic fibers during the

spinning process such as grafting to the polymer backbone or copolymerization reactions or can be deposited on the synthetic or natural fiber/fabric surface [15,16]

Sol-gel derived silica coatings (thickness about 360nm) were exploited in order to decrease the flammability of regenerated cellulose fibers (namely, viscose) [17]. Different methods can be successfully exploited for obtaining fire-retardant textiles, sol-gel and layer-by-layer represent an easy and affordable way to design well-controlled (nano)architectures on the fabric surface, i.e., the most critical region exposed to a flame or to a heat source.

Use of nano ZnO for fire retardant finish of textiles is rather a new conception. Fire retardant finishing of jute using different organophosphates and other chemicals are available from earlier reports [18,19,20]. ZnO was generated by coprecipitation method followed by its application on bleached jute fabric using 0.01% nano ZnO particles in a dispersion of 10% Potassium Methyl Siliconate (PMS), which shows a good level of fire retardancy. The nano ZnO treated fabric shows LOI value 35 and minimum char length of 1 cm with satisfied level of washing fastness for five cycles of wash.

ANTIBACTERIAL FINISHES

The growth of microorganisms on textiles, especially natural fibres-based textiles, could be due to large surface area along with availability of proper conditions for growing, i.e. temperature, oxygen, moisture and nutrients. The growth of microorganism has negative effects not only on textiles but also to the wearer, since it results in biodegradation of textile materials along with their dissemination as a health risk. Therefore a need of antimicrobial finish on textile is required which should be, quick acting to be effective, able to kill or stop the growth of microorganisms, it has to be durable to wash or dry cleaning, compatible with other ingredients in the finishing formulation, has minimal impacts on both the environment and the product quality, easy to apply for low cost and low toxicity criteria.

A range of antimicrobial textile finishes and products have been reported and quite a few have been commercialized, which are based on much superior antimicrobial properties of silver in nanoform. Silver" has been used in jewellery and for food utensils. It is a well-known fact that the growth of bacteria and microorganisms in food or water is prevented when stored in silver vessels due to its antibacterial properties. Nano silver particles containing antimicrobial dressings have been incorporated in wound care and have gained wide acceptance in medical industry, as a safe and effective means of controlling microbial growth in the wound, resulting in improved healing. A range of nano silver based medical textiles for health and hygiene has been developed and commercialized.

The method of producing durable silver containing antimicrobial finish is to encapsulate a silver compound or nano particle with a fibre reactive polymer like poly (styrene co-maleic anhydride). **Prof. Yang** has patented a process for preparing a silver nano particle containing functional microcapsule having the intrinsic anti-microbial and therapeutic functions of silver as well as additional functions of the products contained in the inner core of the capsule.

In these microcapsules, the silver nanoparticles are on the surface of the capsule. Yarns treated with microcapsules showed effective anti-microbial activity against various bacteria, fungi and chlamydia that included *Escherichia coli*, *Citrobacter*, *Bacillus subtilis* etc., which can be used in medical industry as a safe & effective means of controlling microbial growth in the wound bed.

Antimicrobial Action of Silver:

Attachment to the bacterial cell membrane;

Absorption/diffusion into the cell;

Coagulation with bacterial proteins/enzymes.

Iodoforms, phenols and thiophenols, heterocyclics, inorganic salts, nitro compound, urea, amines and formaldehyde derivatives, have been applied for anti microbial treatment of textiles, ZnO nanoparticles shows strong antibacterial activities on a broad spectrum of bacteria on cotton [21-26], polyamide [27] and bamboo fabric [28]. Besides, excellent multifunctional textiles with a good UV protection in addition to a very good antibacterial properties against Gram positive and Gram negative bacteria can be obtained using ZnO in combination with synthetic [29] as well as natural organic polymers such as chitosan [30].

Moreover, some part of plants also have antibacterial properties such as each part of the neem presented active antimicrobial effectiveness to block the proliferation of the bacteria. Recently, a small number of studies has demonstrated neem' used in textiles to evaluate its antimicrobial activity. However, cotton and cotton/polyester blended fabric treatment with seed and bark extracts were reported [31-33]. Moreover, synthesis of silver nano-particles using extract of neem leaf for cotton treatment was also used [34]. Another plant-based source belongs to the Liliaceae family Aloe vera (*Aloe barbadensis*), its leaf extract has antibacterial and antifungal potential and have been used for dressing gauzes, sutures and other medical textile applications [35,36].

Antimicrobial products can be classified into:

- i) bacteriostasis i.e. that stops the growth and spread of microbes,
- ii) bactericides, i.e. that actually kill microbes.

An effective biocide must reach and interact with its microbial target sites. The Bacteriostatic mechanisms of action of antimicrobial finishes are including preventing cell production, blocking of enzymes, damaging cell membrane, and/or destruction of the cell wall and poisoning of the cell from within. The antimicrobial efficiency of biocide formulations varies greatly between different types of microorganisms. Resistance to disinfection follows the decreasing order: *Mycobacterium* > Gram -ve bacteria > Gram +ve bacteria.

ANTISTATIC FINISH

In the world of polymers static electricity is a common problem, because of the polymers act as electrical insulators. So there is a need of antistatic finish. Antistatic finishes are generally applied when the antistatic nature of a substrate is to be maintained. The role of an antistatic agent is to prevent generation of electricity within different textile materials. It can be applied to textile material either by coating, finishing or addition in the polymer dope. Antistatic agents are added to the bulk of the polymer forming a pathway for the charges to flow from the polymer surface to ground. External antistatic agents are applied externally from solutions to the textile surface through a variety of methods including padding baths, spraying, plasma grafting, vapour deposition, coating finishing, etc. external antistatic agent have hydrophobic and hydrophilic functions in their molecular structure. The hydrophilic part orients itself towards the air and promotes the moisture absorption, resulting in better ion mobility and dissipation. [37]

Synthetic fibers such as nylon and polyester absorb less water because of which these are prone to electric charge accumulation. It has been reported that nano sized TiO₂, ZnO whiskers, nano antimony-doped tin oxide and silane nanosol can also be used to impart antistatic properties to synthetic fibers. TiO₂ and ZnO nanoparticles are electrically conductive in nature and can be used to dissipate the static charge in these fibers.[38]

NANO TECHNOLOGY FOR WRINKLE FREE TREATMENT

Nano textile 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 textiles 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. [39]

MILITARY TEXTILES

In recent days nanotechnology have covered a vast area at military clothing. The protective clothing in military is mostly expected to help maximize the survivability, sustainability, and combat

effectiveness of the individual soldier system against extreme weather conditions, ballistics, and NBC (nuclear, biological, and chemical) warfare [40].

Cellulose fibre filled with TiO₂ nano-particles, from in situ synthesis can be used as a catalyst in fuel cells[41]. Literature reveals about the application of Nanocomposites in body armor [42-44]. Electrospun fibers (nano fibers) are applied to wound dressing because porous mats made of fibrous structures can protect wound from bacterial penetration by the aerosol particle capturing mechanism, providing a good path for the transport of vapor [45,46]. Electrospun nonwoven mats are also potentially useful as the supports or carriers for drug delivery because of their high specific surface area [47,48].

Scientists have demonstrated that carbon nanotube fibres can be easily woven into textiles. Carbon nanotube yarns of various diameters (3.2–100 µm) have been made by spinning. Carbon nanotubes in a yarn will have much better mechanical strength than loose individuals [49-54]. They are being considered to make useful articles such as artificial muscles [55] reinforced materials, bulletproof vests, explosion-proof blankets, etc.

METHODS FOR GENERATION OF NANOCOATINGS ON TEXTILE

Sol gels technique

The sol-gel process is one of the most widely used methods in material science. It is a wet process that is broadly employed in the textile field using a simple pad or dip coating [56, 57]. Nano Sol-gel method has been applied for preparing self cleaning, antibacterial, and water repellent finishes on fabrics.

Anatase titanium dioxide nano crystals were prepared by sol-gel method. In this procedure, tetraisopropoxide was added to deionized water containing acetic acid at the room temperature and the aged sample was used for coating the cotton fabric by a dip-pad-dry-cure process. It was shown that the treated fabric had a remarkable photo catalytic self cleaning performance and it had ability to decompose a colorant and degrade red wine and coffee stains as well as proper protection against UV radiation. [58] another study shows superhydrophobic fabric with silica nanoparticles was achieved by sol-gel process. To prepare a spherical silica nanoparticle, Tetraethoxysilane (TEOS) was added to the mixture of distilled water, ethanol and ammonium hydroxide. Ammonium hydroxide acts as a catalyst. The textile fabric were treated in the sol of silica nanoparticles and cured. The fabric treated shown the water repellent property and the contact angle of 130° was achieved [59]

Exhaust (High temperature) method:

In exhaust method the weighed fabric samples were placed in a steel beaker and required concentration of nano particles in dispersed solution form was added, keeping the fabric to dispersion ratio 1:20. The beakers were closed and heated in infrared heating chamber (Texcare make, India) up to 80°C

for 30 min. After that; the beakers were cooled and the fabric samples were dried at ambient temperature.[60]

Pad batch (room temperature) method:

Required concentration of nano particle dispersion was prepared and poured into a tray and then the fabric was immersed in it for 30 min. This chemically soaked fabric was then padded through the padding mangle maintaining 100% expression. The fabric was then rolled and kept for 24 h in the wet condition by wrapping with an aluminum foil to avoid air contact as well as loss of evaporation. After 24 h, the fabric was unwrapped and dried at ambient temperature.[60]

Magnetron Sputter Coating:

Sputter coating is one of the physical vapor deposition (PVD) methods. Nanocoatings by physical treatments methods have attracted a great deal of attention because of the environmentally friendly technology. Thin film sputtering fabrication has become a common manufacturing process for a variety of industries and sputter coating has been used to deposit various materials on the textile fabrics. It has been found that a quadruple magnetic field increases the deposition rate, so magnetron sputter systems are widely used for thin film deposition. Magnetron sputter coating is a vacuum process that applies a high voltage across a low-pressure gas to create reactive gas molecules. During sputter coating, reactive gas molecules strike a target and cause atoms from the target to travel to the substrate [61-63]. Metals and metal oxides can be deposited on the textile fabrics using magnetron sputter coating. For example, zinc oxide (ZnO) and copper (Cu) [64,65] nanostructure were deposited on the nonwoven fabrics by sputter coating. Magnetron sputter coating has also been used for depositing nano structure thin film on the surface of nonwovens. In the sputter coating process, time has important impact on the grain sizes of the particles and the surface smoothness.

Plasma technique:

Plasma is a dynamic mix of ions, electrons, neutrons, photons, free radicals, Meta stable excited species and molecular and polymer fragments. Plasma can be achieved in different atmospheric conditions, either low pressure or atmospheric pressure and also can be achieved in different types of power including low-frequency, radio-frequency, or Microwave [66]. The plasma technology is widely applied in textile and polymer industries for a wide range of application such as shrink-resistance, anti-scratch, superhydrophobic, superhydrophilic, and flash-fire resistance. It is a suitable technique for modifying the structure and topography of the surface as well as depositing of nanocomposites into the surfaces [67-69]. Furthermore plasma methods including radio frequency plasma (RF-plasma) and microwave plasma (MW-plasma) have been applied as a pre-treatment to improve deposition process, and then the loading of TiO₂ on the textile surface is done by wet chemical technique that leads to form a controllable and uniform modification of the textile surfaces with increasing the polarity and hydrophilicity of the textile surface. These modified coated textiles show a remarkable photo-oxidative activity under the

visible light [70]. Nanocoatings with water repellency property were fabricated using plasma. Hydrophobic textile is achieved by atmospheric air plasma containing aerosol and injecting fluorocarbon directly into the plasma dielectric barrier discharge. In this process, the aerosol atomization of fluorocarbon dispersion is used to promote the chemical grafting. This is a useful chemical grafting method. It was shown that an atmospheric plasma treatment is not adequate to crosslink the nano fluorocarbon coating so to increase the degree of cross-linking the treated fabric must undergo a thermal curing at 180 °C [71,72].

Layer-by-layer (LBL) technique:

Layer-by-layer (LBL) technique is another method for fabricating a thin layer film and is based on the concept of self assembled nano layers. LBL process causes to enable modifying multicomposite molecular assemblies with a control on the molecular structure and a high degree of control over the thickness. There is more attraction using electrostatic selfassembly (ESA) because of the simplicity and efficiency. In LBL method, polyelectrolytes with opposite charge were alternately deposited on the fabric surface with wash steps in between. For increasing the thickness, cycles of adsorption can be repeated [73, 74]. LBL technique incorporated to nanomaterials was used for applying a thin nanocomposite on the fabric surface and wide range of functionalities have been imparted to fabric with LBL method [75-77]. In LBL depositions, cationic sites are usually generated on the surface. ZnO nanoparticles were applied on cationized cotton via LBL method. 2,3-epoxy propyl trimethylammonium chloride (EP3MAC) was used and reacted with the hydroxyl groups of cellulose to create cationic charges on the surface of the fabric. In the deposition process, the cationized cotton was dipped into sequential solutions alternately as anionic ZnO solution, deionized water, cationic ZnO solution and deionized water. The cotton fabric treated with bilayers films showed excellent antibacterial activity and UV protection [78].

Nanomaterial embedded textile:

Finishing fabric with nanomaterial is not permanent especially against washing, therefore the nanomaterial has to be fixed into the textile fabric. Three different methods have been suggested to embed nanoparticles on the polymeric matrix. In the first method a cross linking agent is used to entrap nanocomposites. Crosslinkable polymers such as binders have been suggested for this purpose [79,80]. Secondly, an in situ synthesis of nanoparticles on the fabric in order to increase the stability of nanoparticles has been employed as an alternative method of fixation [81]. The other method involves embedding nanoparticles on the fiber polymeric matrix using a carboxylic acid which is a new method with remarkable advantages [82-87]. Cross linkable polysiloxan has been used for stabilizing silver nanoparticles on the textile surface which also has many unique properties such as softness and flexibility [88]. Moreover, using binders to improve the stability of silver nanoparticles and ZnO was elucidated [79,80].

On the other hand, carboxylic acids have been used for embedding various nanomaterials such as CNTs, fumed silica, and silver nanoparticles. To prepare CNT embedded textile, CNTs have been absorbed to the surface using by exhaustion method followed by aftertreatment with BTCA [82,83]. In another method nano silver and nano fumed silica by BTCA have been applied synchronous on the fabric surface [84-87]. Ultimately, In situ synthesis of silver nanoparticles in boiling point led to stabilized nanoparticles. The synthesis process in the boiling temperature led to the swelling of the fibers and molecular chain and thence it is assumed nanoparticles to form and penetrate into the fabric structure and after the treatment they remained there [81].

CONCLUSION

The survival of textile industry depends primarily on the diversification of end products to meet the national as well as international demands. Nanotechnology is a new evolution which can bring opportunities and challenges for textile industries which can make this huge market more profitable and expanded. Modifying textiles by numerous nano-sized particles from TiO₂, silica, iron oxide, zinc oxide etc. is one approach for enhancing and imparting new functionalities to various types of fibers and forms of textile materials. Nano materials have increased surface area and nano scale effects, they are able to enhance the physical properties of textiles in areas such as anti-microbial properties, ultra violet protection, water-repellency, soil-resistance, anti-static, flame retardant properties, anti ballistic, dyeability, and strength of textile materials. Nano finishing can replace traditional finishing technique of textile products and readymade clothing with products of superior quality and lower production costs. Nanotechnology has emerged as the 'key' technology, There is no doubt that in the next few years, nanotechnology will penetrate into every area of textile industry.

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