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A Review

Application of nanotechnology in textile

■ SHIPRA KAUSHIK

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Author for correspondence:
SHIPRA KAUSHIK
Department of Home Science, Teerthanker Mahaveer University, MORADABAD (U.P.) INDIA
Email: shiprakaushik14@gmail.com

■ **ABSTRACT :** Use of nanotechnology in the textile industry has increased rapidly due to its unique and valuable properties. If the criterion is to produce very minute particle size fibres and materials, the nano technology is the only way to achieve the same. The present paper highlights the applications of nanotechnology in textile industries, with an emphasis on improving various properties of textiles.

■ **KEY WORDS:** Nanotechnology, Fibres, Yarns, Textiles, Technical fabrics, Nano finishes

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Nanotechnology is an emerging interdisciplinary technology that has been booming in many areas during the recent decade. Its profound societal impact has been considered as the huge momentum to user in a second industrial revolution. The concept of nanotechnology has been started about for the last half century ago and it has already been established it's potentiality in the textile applications. The use of nanotechnology in textile industry has increased rapidly due to its unique properties of applications. The present status of nanotechnology which is using in textile industry is reviewed, with an emphasis on improving the properties of textile materials. Due to immense economical potentiality and unique properties of nanomaterials, nanotechnology has attracted both the economical and scientists concern. It is used to develop desired textile characteristics, such as high tensile strength, unique surface structure, soft hand, durability, water repellency, fire retardancy, antimicrobial properties, and the like.

Application area of nanotechnology in textile finishing :

The application of nanotechnologies to textiles affords an expanded array of properties with potential for improved and novel use in materials and products. Changed or improved properties with nanotechnologies can provide new or enhanced functionalities. How are these realized in materials and processes? How do they appear in end products? The information presented in this section is not exhaustive, but does reflect current national and international research, and commercial activities in nanotextiles.

Nano-enabled properties :

Properties associated with current nanotechnology research for use in textiles include:

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

As examples, antimicrobial textiles include anti-odour, antifungal and antibacterial textiles. This applies to products whose fibres possess intrinsic bactericidal properties or will acquire them through subsequent treatments (chemical finishing, nanotechnologies, addition of bactericidal metals, etc.). Products have potential applications in apparel and intimate apparel, but also in a number of non-apparel applications (furniture, carpets, etc.). These textiles significantly reduce or even eliminate traditional textile-care operations (washing, spin drying, drying, ironing). Properties include spill, wrinkle, oil and stain resistance.

Many products use, or with commercialization will use, chemical, physical or electronic technologies to respond passively or actively to thermal, chemical, biological, electromagnetic and mechanical stress. 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.

These are properties and applications with potential to provide value in products. Some can be achieved by conventional means, e.g., wrinkle resistance, but with research, alternatives or improved means via nanotechnologies may be found. Lower processing costs, less energy usage or reduced chemical processing may be other value-added factors resulting from the use of nanotechnologies. Much of this is at a research/ concept stage, with some application in products now.

How is this being achieved in textiles? Integration of nanotechnologies into textile products is being realized in coatings, treatments, fibre material composites and nanoscale fibres. Nanotextiles have been subdivided into four major types:

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

Types of nano textiles :

Nanofinished textiles :

Nanofinished textiles are those that apply a nanoscale property added after the base textile has been fabricated. This includes post-manufacture treatments and coatings to apply nanomaterials or create nanostructured surfaces on fibre media. Additive nanomaterials to date include metal nano-objects (such as silver for antimicrobial functionality) or clay nano-objects (for fire resistance). Nanostructured surfaces may include those roughened by treatments (hydrophobicity for self-cleaning).

For existing process lines, nanofinished textiles may only require the addition of intermediate steps for coating or treatment. The majority of nanotextiles 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 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 source materials added to produce the nanocomposite textile include, for example, carbon nanotubes (for enhanced fibre strength) and rare earth metal doped nanoparticles (for luminescence). 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. These true nanofibres have a nanoscale cross-sectional area and 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 may 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. Some means of 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.

Nano-enabled nonwovens :

Nanotechnologies in nonwovens may make use of improvements in properties to benefit textile processing; for example, adhesive properties may be enhanced or conventional methods of securing layers replaced with adhering nanostructured surfaces. Other nanoscale functionalities may utilize nanofilms or coatings in layers or barriers; for example, for antibacterial properties, energy production (for solar power) and luminescence (for colour control).

Nanotextile properties :

Table 1 provides a list of nanotechnology properties undergoing research or being applied in nanotextiles.

Standards along the supply chain :

Depending upon the type of nanomaterial, manufacturing for textiles may or may not be a simple derivative of current macroscale processes. A nano-object raw material may be purchased as an incoming component for integration into a process line. The material sourcing stage of the supply chain will be affected by standards, with a need for compliance to ensure consistent raw materials. Standards on grading or specifying materials (such as silver nanoparticles, nanofibrous media, etc.) may be useful. Safe handling of materials; means for process control, paying attention to key control characteristics; and quality inspection of output may be supported by standards.

Production of nanomaterials may require advanced equipment not typical within the textile industry; for example, treatment chemicals, polymer composites and thin film coatings. Nano-object generation may use advanced machines (such as ball mills, solgel apparatus and plasma torches). Consideration of workplace safety when using these processes and waste management review may apply. Operations with established quality assurance and health and safety systems, in accordance with management system standards, will find new or modified nano-enabled processes easier to implement.

For nanofinished textiles, one must consider the nano-object being applied. Spraying techniques, chemical baths and electrostatic adhesion are a few general categories. Some of these techniques are similar to current post-processing methods, such as dyeing; however, new considerations tailored to nanomaterials may be required.

For nanocomposites, the matrix must be produced first and then fibres fabricated. Techniques may be adaptable from conventional fibre fabrication. While the process may be compatible with the composite material, changes in properties, such as strength, may confound the process.

Nanofibrous textiles will be more complex, requiring new processes from basic fibre fabrication to the finished textile. To achieve nanoscale fibre dimensions, new manufacturing techniques must be used ranging from electrostatic to mechanical spinning. Post-drafting both woven and nonwoven products would require modified techniques to assemble the fibre media. At a high level, the processes used may not be that distant from those used for macroscale fibres; however, current infrastructure may not be compatible for nanofibrous textile manufacture.

Test methods and characterization :

Testing and characterizing nanotextiles may pose challenges not found in regular textiles. On the macroscale, such as wear or tensile tests, the means are not very different if using nano-enabled materials or components. The integrity of a nanomaterial may be certified by the supplier, but if verified in-house, for a nanomaterial or nanostructured surface, advanced microscopy, calorimetry and spectroscopy techniques may be required. Standards may be a resource for testing requirements and best practices for such measurements.

Material specifications are critical in manufacturing. Nanomaterials have unique properties requiring close control of parameters so as not to alter performance. If a batch of nanoparticles used for a nanofinishing process is not within specifications, it may not perform according to the properties it is designed for. Parameters in addition to size may require precise control. Material specification standards are still at the early stages of development. Research is currently

Table 1 : Nano-particles and potential textile applications

Sr. No.	Nano-particles	Properties
1.	Silver Nano-particles	Anti-bacterial finishing
2.	Fe Nano-particles	Conductive magnetic properties, remote heating.
3.	ZnO and TiO_2	UV protection, fibre protection, oxidative catalysis
4.	TiO_2 and MgO	Chemical and biological protective performance, provide self-sterilizing function.
5.	SiO_2 or Al_2O_3 Nano-particles with PP or PE coating	Super water repellent finishing.
6.	Indium-tin oxide Nano-particles	EM / IR protective clothing.
7.	Ceramic Nano-particles	Increasing resistance to abrasion.
8.	Carbon black Nano-particles	Increasing resistance to abrasion, chemical resistance and impart electrical conductivity, colouration of some textiles.
9.	Clay nano-particles	High electrical, heat and chemical resistance.
10.	Cellulose Nano-whiskers	Wrinkle resistance, stain resistance, and water repellency.

predominant for nanotechnologies, preceding scaling up to production, at which time production standards, such as material specifications, will become prevalent. Product sector-specific standards (e.g., coatings for nanotextiles) will need industry involvement to be developed; for example, to provide technical content.

Product quality assessment and certification are other considerations. At the end-product level, performance-based standards for final products may not likely need revision. The bar may be raised as a result of improved function, but the testing method may remain as is. Often already in place, as deemed mandatory by regulation or purchasing specifications set by a customer, compliance with product standards requirements will, of course, continue. Products may be verified by "type tests" for conformity with requirements (on new product submissions) and then periodic reviews (follow-up visits) of whether the product still meets performance criteria in accordance with a certifying body's accredited requirements.

Standards are developed taking into consideration and based upon public, industry and regulatory interests. Standards may be relied upon by industry seeking objective guidance for the integration of nanotechnology into textiles.

Conclusion :

Nanotechnology is growing by leaps and bounds and it has been introduced in many fields including the textile industries. There is a considerable potential for profitable applications of nanotechnology in cotton and other textile industries. Its application can economically extend the properties and values of textile processing and products. By deploying nanotechnology, ultra strong, durable and specific function oriented fabrics can be efficiently produced for a number of applications including medical, military and industrial apparels etc. As mentioned, nanotechnology overcomes the limitations of applying conventional methods to impart certain properties to textile materials. There is no doubt that in the next few years, nanotechnology will penetrate into every area of textile industry.

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