NANOTECHNOLOGY AND ITS APPLICATIONS IN TEXTILES – A REVIEW

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ABSTRACT

The customer demand in improved appearance, functionality, and connectivity in fashion has motivated the development of nanotechnology-based textiles. Nanomoieties can induce stain repellence, wrinkle-freeness, static elimination, and electrical conductivity to fibers without compromising their comfort and flexibility. Nanomaterials also offer a wider application potential to create connected garments that can sense and respond to external stimuli via electrical, color, or physiological signals. This article gives an over view of nanoparticles in textile industry and their functions.

Key words : *Nanotechnology, Smart textiles, Intelligent textiles*

Abbreviations: Fe: Ferrum (Iron) **,** ZnO : zinc oxide**,**TiO_2: Titanium dioxide **,**SiO_2: Silicon dioxide **,**Al_2O_3: Aluminum oxide **,**PP: Polypropylene PE: Polyethylene

1. INTRODUCTION:

Modern Consumer got introduced to the technology and their demands for getting everything in one shot has become more priority, weather it is from simple mobile phone to smart phone or from personal computers to 2 two in one notebook tablets. Textile is not away from the new sophisticated demands from the consumer.

For example Cotton is one of the natural fibers used all over the world, it is known for its high absorbency, breathability and softness but on the down side cotton fibers have relatively low strength, low durability, easy soiling, and flammability. Whereas synthetic fibers have high strength and stain resistant but they lack in comfort. Nanotechnology (NT) is the answer to develop the desired qualities in single fiber at the molecular level. With the use of NT both the desired qualities of cotton and synthetic fibers can be achieved in one single fiber.

Nano-science and nanotechnology combined, have revitalized material science and led to the development and evolution of a new range of improved materials including polymers and textiles through nanostructuring and nanoengineering.

Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. Nanoscience and nanotechnology are the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering.The dimensions of roughly 1 to 100 nm (1 billion nm = 1m) in length is called NT. [1].

Organized nano structures as exhibited by either fibers, nanocoatings, nanofinishing, nanofibers and nanocomposites seem to have immense potential to revolutionize the textile industry with new functionality such as self-cleaning surfaces, conducting textiles, antimicrobial properties, controlled hydrophilicity or hydrophobicity, protection against fire, UV radiation etc. without affecting the bulk properties of fibers and fabrics.[2]

2. NANO FIBERS:

The Nanofibers are defined as fibers with diameters less than 100 nanometers [3]. In the textile industry, this definition is often extended to include fibers as large as 1000 nm diameter. These fibers have a large surface area per unit mass so that nonwoven fabrics of these nanofibers collected on a screen can be used for example, for filtration of submicron particles in separation industries and biomedical applications [4], such as wound dressing in medical industry, tissue engineering scaffolds and artificial blood vessels. The use of electrospun fibers at critical places in advanced composites to improve crack resistance is also promising.

3. NANO-PARTICLES

Nano particles are defined as a particle having one or more dimensions of the order of 100nm or less. These nano particles are used for fabric finishes to get desired property.

Table -1: Nano particles and their potential application in textiles: [5]

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

3.1 Nanotechnology in textiles:

Nanotechnology has opened immense possibilities in the textile finishing area resulting in innovative new finishes as well as new application techniques. Particular emphasis is on making chemical finishing more controllable and durable with significantly enhanced functionality by incorporating various nanoparticles or creating nanostructured surfaces, which led to an unprecedented level of textile performances such as

- Water repellence
- Anti-static property
- Wrinkle resistance
- Strength enhancement
- UV protection
- Computing
- Anti-bacterial / Odor control
- Sensors
- Optical displays

Nanofinishes are generally applied in nanoemulsion form, which enables a more thorough, even and precise application on textile surfaces. They are generally emulsified into either nanomicelles, made into nanosols or wrapped in nanocapsules that can adhere to textile substrates easily and more uniformly. Ideally nanoparticles or the molecules of these nano-finishes can be brought individually to designated sites on textile surfaces in a specific orientation and trajectory through thermodynamic, electro-static or other approaches. Since nanoparticles have a large surface area to volume ratio and high surface energy, they have better affinity for fabrics. Therefore these finishes are more durable, effective and do not adversely affect the original handle and breathability of the fabric.

3.2 Water and Oil Repellent:

Many water and oil repellent finishing chemicals are available which could be classified into wash resistant or not wash resistant on one hand and fluorocarbon containing or non-fluorocarbon based finishes on the other hand. Silicon based water proofing is also used either as such or in combination with fluorocarbon based agents. However the current market demands are for non-fluorocarbon based finishes because of growing environmental consciousness

Nano Care® and NanoPel® nanofinishes marketed by NanoTex Inc. USA, developed these finishes by using, tiny whiskers aligned by proprietary “spines” are designed to repel liquids and are attached to the fibers utilizing molecular "hooks”. These whiskers and hooks are very-very small in fact no more than 1/1000th the size of cotton fiber. These whiskers cause the liquids or semisolids to roll off the fabric thus cause minimal staining, which can be removed with simple washing. Since the attached whiskers are of nanoscale size, they do not affect the hand, breathability of fabric and can withstand 50 home launderings. Based on the new study conducted by Nadeeka D et.al using amphiphilic graphene oxide (GO) on cotton textiles also creates hydrophobic cotton textiles.[6]

3.3 Anti-static property:

Synthetic fibers such as Nylon and polyester are prone to static charge accumulation as they absorb less water. It has been reported that nanosized TiO_2, ZnO whiskers, nanoantimony-doped tin oxide (ATO) and silane nanosol could impart antistatic properties to synthetic fibers. TiO_2, ZnO and TiO_2 nanoparticles are electrically conductive materials and help dissipate the static charge in these fibers.

Nanotechnology has been applied in manufacturing an anti-static garment. W.L. Gore and Associates GmbH used nanotechnology and polytetrafluroethylene (PTEE-Dupont’s Teflon®) to develop an anti-static membrane for protective clothing. Gore-Tex® I Workwear protects the wearer from electrostatic discharges. Electrically conductive nano-particles are durably anchored in the fibrils of the Gore-Tex® I membrane of Teflon, creating an electrically conductive network that prevents the formation of isolated chargeable areas and voltage peaks commonly found in conventional anti-static materials. This method can overcome the limitation of conventional methods, which is that the anti-static agent is easily washed off after a few laundry cycles.[8]

The combination of Silver (Ag), gold (Au), and Zn oxide particles decreased the static voltage by 77.7%. In another study, Sb-NP-doped SnO_2 particles were utilized to impart antistatic properties to polyacrylonitrile fibers. [10]

3.4 Wrinkle resistance

Cellulose molecules in the cotton linearly organize themselves passing through the crystalline and amorphous sections of the fibers. Hydrogen bonds hold together cellulose molecules in their positions. Upon applying a force to the fibers, the cellulose chains displace from their original positions and hydrogen bonds re-form at new locations. Nanocoatings that prevent crease while maintaining comfort is desirable in textile products. Traditionally, fabrics are impregnated with resin to impart wrinkle resistance to textiles. However, this approach decreases tensile strength of the fiber, abrasion resistance, and dyeability while inducing hydrophobicity. To impart wrinkle resistance, nanoparticles have been applied to cotton and silk. TiO_2 nanoparticles with carboxylic acid as a catalyst were utilized to form cross-links between cellulose molecules and the acidic groups. [11][12]

3.5 Strength enhancement

Carbon nano tubes (CNT) reinforced polymer composite fibers have been developed to improve strength and toughness and to decrease weight. These composite fibers could be produced through melt-spinning of polypropylene and carbon particles.[13] Controlling the parameters in melt-spinning, the morphology, crystallinity, and mechanical properties of nanostructured polycaprolactone nonwoven mats were optimized. [14].

3.6 UV protection

Inorganic UV-blockers are more preferable to organic UV-blockers as they are non-toxic and chemically stable under exposure to both high temperatures and UV. Inorganic UV-blockers are usually certain semiconductor oxides such as TiO2, ZnO, SiO2 and Al_2O3. Among these semiconductor oxides, TiO2 [15] and ZnO [16] are commonly used. It was determined that nano-sized titanium dioxide and zinc oxide were more efficient at absorbing and scattering UV radiation than the conventional size, and were thus better able to block UV .This is due to the fact that 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.

3.7 Computing

Many innovations were made using nano technology to incorporate technology into garments . The integration of high-computing microprocessors and miniaturized computers can enable the capability to collect information throughout a garment. For example, the physiology of the body and posture data collection in garments could allow for correcting the unhealthy posture.

Kranthi Vistakula ,Dhama Apparel Innovations developed a nano tech clothing Clima wear, a line of jackets, shoes, helmets, and other gear that transforms on demand into personal heaters or A/Cs. At the press of a button, the apparel can get as cool as 64 degrees F and as hot as 104 degrees F for up to eight hours on a single set of batteries. And it’ll work in all kinds of ungodly weather, this extremely lightweight, which makes them ideal for athletes, soldiers, and pretty much anyone who doesn’t want to look like bulky in winter. The jacket weighs about as much as a pair of jeans [17]

AbsAthletic developed new performance apparel line, FIRE Wear,by using natural additive that is applied via nanotech engineering. The high-tech fabric also wicks moisture away from the body. This textile technology that incorporates a form of solar energy called far infrared energy (FIRE™). The fabric absorbs far infrared energy (whether outdoors or indoors) which increases metabolism and results in weight loss. The far infrared energy also helps dissolve unwanted cellulite. FIRE Wear is made of lightweight, polyester spandex constructed fabric that incorporates the company's Smart Fiber™ yarns. These yarns are impregnated with a special material before being knit into fabrics.[18]

Many more innovations like, smart textiles which can monitor, producing electricity using solar energy which can be used to charge mobile phone and tablets

3.8 Anti-bacterial / Odor control

Spread of infections in hospitals is the major concern, this can be controlled by using Ag, TiO2, and ZnO. These nanoparticles can be utilized to impart antibacterial and fungicidal properties to textiles Ag nanoparticles have large surface areas that increase their contact with bacteria and fungi. The antiseptic mechanism of Ag nanoparticles is based on reacting with proteins in these organisms and adversely affecting their cellular function and inhibiting cell growth.

Bacterial growth is the reason for the Odor, by using nanoparticles the bacterial growth is minimized and odor control is been obtained in fabric

3.9 Sensors:

Conducting polymers are attractive for creating textiles that enable the incorporation of sensors and actuators. Plasmonic optical fiber sensors can be fabricated via drawing techniques. Plasmonic sensors have been studied due to their high sensitivities for bio/chemical sensing. These sensors activate the drug release and helps in rehabilitations. Temperature, humidity, and pressure sensors have been incorporated in textiles. These studies have utilized photolithography and inkjet printing to create the sensors woven into textiles. Capacitive humidity and resistive temperature sensors were developed on flexible polymer foils and integrated into textiles. The development of electrical sensors in textiles that detect changes in resistance, capacitance, or inductance will require miniaturized chips incorporating multimeters, amplifiers, and analog-to-digital converters. Metal−organic frameworks built with rare earth elements and/or quantum nanorods have been immobilized on cotton fabrics at high concentrations. These materials have shown the potential to be used as colorimetric sensors to detect the presence of toxic gases via the luminescence of the Metal−organic frameworks or the electrical conductivity of the nanorods. These chemical sensors can be incorporated into uniforms, apparel, or any textile substrate. A dress designed by Matilda Ceesay used cotton mesh coated with a Cu benzene tricarboxylic acid Metal−organic framework customized for capturing and controlled release of permethrin (an insecticide) The designer aimed at functionalizing mosquito bed-nets commonly used as preventive measures in areas with a high prevalence of malaria.

3.10 Optical display:

Optical display on textiles is possible by using optical fiber (OF). The first mention of OF, included in textiles by weaving, appeared in the 70s-80s.[19] OF were developed primarily as a waveguide to transmit light between two ends of a fiber and typically consist of a transparent core covered by a cladding material that has a lower refractive index. Light is kept in the core by total internal reflection and can be transmitted over long distances without losses, hence their wide use in communication. They are also immune to electromagnetic fields. Due to their fine dimensions (0.125 - 2.0 mm) and their relatively good flexibility, OF can be easily shaped using textile processes (mainly by weaving). Therefore, the idea to create textile-based illuminated surfaces has naturally evolved.

Google ATAP's Project Jacquard. Along with conducted by Laura Devendorf and her 'collaborators' at California's UC Berkeley is the real game changer. Fabrics with smart threads can change the color of the fabric. They coated conductive threads with thermochromic pigments and explored how we could leverage the geometries of weaving and crochet to create unique aesthetic effects and power efficiencies. The thermochromic pigments change colours in slow, subtle, and even ghostly ways, and when we weave them into fabrics, they create calming "animations" that move across the threads.[20].

Table -2 Nano companies and their available products:

Company	Product	Advantage
Nano-tex	Fabric enhanced with nanowhiskers	Water and stain resistant
Aspen Aerogel	Fabric enhanced with nanopores	Insulates against heat or chill
BASF	Fabric enhanced with nanoparticles (Mincor® TX TT)	Dirt rinses off in rain, similar to property of the lotus plant
NanoHorizons	Fabric enhanced with silver nanoparticles	Reduces odors
Schoeller Technologies	Fabric enhanced with nanoparticles (NanoSphere®)	Water and stain resistant
Nanex	Water repellent coatings	
Nano Group	Fabric enhanced with various nano treatments	Liquid and stain resistant, UV protection, etc
Odegon Technologies	Fabric enhanced with nano-porous material that absorbs underarm odors	
Global Photonic	Fabric woven from thread that generates electricity from the sun (FlexPower™)	Flexible fabric that generates electricity
Konara	Fabric woven from thread that generates electricity from the sun (Power Fiber™)	Flexible fabric that generates electricity

4. FUTURE TRENDS

Nanotechnology has thus emerged as the 'key' technology, which has revitalized the material science and has the potential for development and evolution of a new range of improved materials including polymers and textiles. However there are many challenges in the development of these products, which need to be intensively researched so that the wide range of application envisaged can become a commercial reality. An excellent dispersion and stabilization of the nanoparticles in the polymer matrix is crucial to achieving the desired nano effects. The tendency to agglomerate due to extremely high surface area is the major problem facing the effective incorporation of nanoadditives in coatings/finishing as well as in nanocomposite preparation. Surface engineering of nanoparticles and combining them with functional surface-active polymers can bring the nanoparticles onto fibers/textiles without losing their superb, nanoscopic properties.

Many functional fabrics can be made by using the combination of nano particles in textiles , like self-cleaning textiles , these self-cleaning textiles are made by using combination of nano particles like water and oil repellent along with anti-bacterial property. Changing the display on the fabric and change of color of the fabric according to the wearer's interest or according to the external stimuli using the sensors. Nano technology made it possible to make these kind of intelligent and smart textiles.

Market for smart and intelligent textiles is growing fast, According to the market research, the global market for smart fabrics is forecast to grow to around two billion U.S. dollars by 2018.

5. CONCLUSION

Application and incorporation of nano particles and materials has been vary rapid in past years. Research involving nanotechnology to improve performances or to create unprecedented functions of textile materials is flourishing. next few years, nanotechnology will penetrate into every area of textile industry.

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