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APPLICATIONS OF NANO-TECHNOLOGY IN TEXTILES

Dr. Ranvir Kaur

Assistant Professor, Fashion Designing

Mata Ganga Khalsa College for Girls Manji Sahib, Kottan, Ludhiana

ABSTRACT

It is well known that cotton fabrics provide desirable properties such as absorbency, breathability and softness. But, their applications often are limited due to their inferior strength, durability, crease resistance, dirt resistance, and flame resistance. On the other hand, fabrics made with synthetic fibers generally are very strong, crease resistant and dirt resistant, but they lack the comfort properties of cotton fabrics. With recent advances in nanotechnology, it is possible to develop next-generation cotton-based fabrics that can complement the advantages of cotton and manmade fibers. Such advanced fabrics can be produced either by blending cotton with special man-made nano-fibers or by treating the yarns or fabrics with various design/material modifications at nano-scale. In this study, we have attempted to summarize the recent advances made in nano-technology and the latter's applications in cotton textiles, along with some ideas about the future research direction in this area. The use of nanotechnology in textiles can allow for the control of crystal structure, improved mechanical properties, improved resistance to chemicals, microbes, flame, and heat, improved electrical properties, improved coloration ability, and self-cleaning clothing.

I. INTRODUCTION

Nanotechnology is a growing interdisciplinary technology often seen as a new industrial revolution. Nanotechnology (NT) deals with materials 1 to 100 nm in length. The fundamentals of nanotechnology lie in the fact that the properties of materials drastically change when their dimensions are reduced to nanometer scale. Nowadays also the textile industry has discovered the possibilities of nanotechnology. So, we can define nanotechnology in textile as the understanding, manipulation, and control of matter at the above-stated length, such that the physical, chemical, and biological properties of the materials (individual atoms, molecules, and bulk matter) can be engineered, synthesized, and altered to develop the next generation of improved materials, devices, structures, and systems. 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.

Nanotechnology deals with the science and technology at dimensions of roughly 1 to 100 nanometers (1 Billion Nanometers = 1 Meter), although 100 nanometers presently is the practically attainable dimension for textile products and applications. The technology can be used in engineering desired textile attributes, such as fabric softness, durability, and breathability and in developing advanced performance characteristics, namely, water repellency, fire retardancy, antimicrobial resistance, etc., in fibers, yarns and fabrics. Enhancement of textile

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materials by nanotechnology is expected to become a trillion dollar industry in the next decade, with tremendous technological, economic and ecologic benefits. It was estimated that for the year 2003, the worldwide government funding for the research and development in the area of nanotechnology had increased to $3 billion annually [Paul et. al., 2003], in addition to the millions of dollars invested by private industries. Although, textile industry is a small part of the global research in the emerging areas of nano-technology, the fibers and textiles industries in fact were the first to have successfully implemented these advances and demonstrated the applications of nano technology for consumer usage.

II. ADVANCES IN NANO-FIBER/YARN DEVELOPMENTS

The discovery of Carbon Nano Tubes (CNT) by Iijima [1991], has led to the exploration of high strength and superior performance fibers. Recently, high-performance yarns were produced through super-aligned arrays of carbon nanotubes [Jiang et al., 2002]. Such yarns exhibit extraordinary mechanical properties, viz., the Young's modulus in the TPa range, tensile strength of about 200 GPa, elastic strain up to 5 %, and breaking strain about 20 %. Such synthetic nano fibers that are being produced by electrospinning process can significantly enhance the strength and conductivity of the fabric after suitable heat treatment. Hence, these nano fibers and yarns can also be efficiently used as super capacitors in electronic textile components [Dalton et al., 2002, Schreuder et al., 2002, Dersch, et. al. 2003, Zarkoob, et. al., 2004, and Subbiah, et. al., 2005]. It is also shown that by simultaneous reduction of fiber diameter and increase in twist (1000 times), nano yarns can be spun comprising Multi-Walled Carbon Nano Tube (MWCNT) that consist several (7 to 20 usually) concentric cylinders of Single Walled CNT. Such yarns provide specific mechanical properties (such as strength, toughness, energy damping capability, etc.), which then can be deployed to produce electronic textiles for supporting multi-functionalities, such as capability for actuation, energy storage capacity, radio or microwave absorption, electrostatic discharge protection, textile heating, or wiring for electronic devices [Zhang et. al., 2004]. In a recent patented technology, it is shown that the combination of "nano-fibrils" and strengthening fibers can be used for producing nonwoven fabrics for tissue engineering [Scardino and Balonis, 2001]. By enforcing small 2006 Beltwide Cotton Conferences, San Antonio, Texas - January 3 - 6, 2006 2498 amount of nano-fibers/particles in polymer matrix several nano-composites are being developed. By using melt spinning process polypropylene/nano-carbon fiber composites are spun that are capable of enhancing the modulus, compressive strength, and dispersion properties of the polymers significantly [Kumar et al., 2002]. Optimal crystallization and orientation of nanofibers yield excellent properties for micro-filtration applications in the medical field [Vijayaraaghavan and Karthik, 2004]. By suspending nano-antimony doped tin oxide particles during the fiber spinning process antistatic polyacrylonitrile fiber has been developed. [Wang et. al., 2004, Stegmaier et. al., 2004]. The desired functionality in the fibers can also be obtained by embossing the surface of synthetic fibers with nano structures [Halbeisen and Schift, 2004]. Moreover, integration of nano-sized antimicrobial particles into textile fibers can lead to the development of superior wound dressings.

III. MODERN APPLICATION OF NANOTECHNOLOGY IN TEXTILE INDUSTRY:

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Nanotechnology is increasingly attracting worldwide attention because it is widely perceived as offering huge potential in a wide range of end uses. The unique and new properties of nanomaterials have attracted not only scientists and researchers but also businesses, due to their huge economical potential.

Nanotechnology also has real commercial potential for the textile industry. This is mainly due to the fact that conventional methods used to impart different properties to fabrics often do not lead to permanent effects, and will lose their functions after laundering or wearing. Nanotechnology can provide high durability for fabrics, because nano-particles have a large surface area-to-volume ratio and high surface energy, thus presenting better affinity for fabrics and leading to an increase in durability of the function. In addition, a coating of nano-particles on fabrics will not affect their breath ability or hand feel.

IV. APPLICATION IN APPAREL INDUSTRY

Examples of industries where nanotech-enhanced textiles are already seeing some application include the sporting industry, skincare, space technology and clothing and material technologies for better protection in extreme environments. Treating textiles with nanotechnology materials is a method to improve the properties of the textile, making it longer durable, have nicer colours etc.

Swimming Suit:

The most widely recognized application t is in the shark-skin suit worn during world-record breaking Olympic swimming championship. The suit, which includes a plasma layer enhanced by nanotechnology to repel water molecules, is designed to help the swimmer glide through the water and has become a common feature of major swimming events as all competitors attempt to enhance their chances of winning.

Sporting Goods:

Running shoes, tennis racquets, golf balls, skin creams, and a range other sporting goods have also been enhanced by nanotechnology. As well as developing textiles to withstand extreme environments, scientists have looked to naturally existing viral nanoparticles that live in some of the harshest environments on earth, for new building blocks for nanotechnology. A garment that senses their surroundings and interacts with the wearer is an area of considerable interest. Such textile-based nanosensors could provide a personalized healthcare system, monitoring your vital signs as you run up a hill or responding to changes in the weather.

Flexible Electronic Circuits:

Nanoribbons form the basis for the chips which are so flexible they can wrap around the edge of a microscope cover slip and so stretchable they can be twisted into a corkscrew. The researchers are focusing applications development in the healthcare industry and believe these tiny, flexible electronic sheets could one day be used to line the brain to monitor activity in patients at risk of epilepsy or be integrated into surgical gloves to monitor a patient’s vital signs during surgery.

Lifestyle Applications:

Perhaps surprisingly the earliest commercialized applications of nanotechnology are seen in lifestyle applications. Textile and cosmetics are among the first products to use nanomaterials. The examples of nanotechnology materials and technologies in lifestyle application is bullet proof vests. Nanotube fibers are used to make a material seventeen times tougher than the Kevlar. Future developments are to use nanotechnology to create Smart and Interactive Textiles (SMIT) that can sense electrical, thermal, chemical, magnetic, or other stimuli.

V. APPLICATION IN PROPERTIES OF TEXTILE MATERIAL:

The properties imparted to textiles using nanotechnology include water repellence, soil resistance, wrinkle resistance, anti-bacteria, anti-static and UV-protection, flame retardation, improvement of dye ability, Self-cleaning fabrics and so on. Among them important applications are described shortly.

VI. WATER REPELLENCE:

Nano-Tex improves the water-repellent property of fabric by creating nano-whiskers, which are hydrocarbons and 1/1000 of the size of a typical cotton fiber, that are added to the fabric to create a peach fuzz effect without lowering the strength of cotton. The spaces between the whiskers on the fabric are smaller than the typical drop of water, but still larger than water molecules; water thus remains on the top of the whiskers and above the surface of the fabric. However, liquid can still pass through the fabric, if pressure is applied. The performance is permanent while maintaining breath ability.

VII. UV PROTECTIVE FINISH

The most important functions performed by the garment are to protect the wearer from the weather. However it is also to protect the wearer from harmful rays of the sun. The rays in the wavelength region of 150 to 400 nm are known as ultraviolet radiations. The UV-blocking property of a fabric is enhanced when a dye, pigment, delustrant, or ultraviolet absorber finish is present that absorbs ultraviolet radiation and blocks its transmission through a fabric to the skin.

Fabric treated with UV absorbers ensures that the clothes deflect the Harmful ultraviolet rays of the sun, reducing a persons UVR exposure and protecting the skin from potential damage. The extent of skin protection required by different types of human skin depends on UV radiation intensity & distribution in reference to geographical location, time of day, and season. This protection is expressed as SPF (Sun Protection Factor), higher the SPF Value better is the protection against UV radiation.

Self-cleaning Fabrics:

A self-cleaning cotton fabric known as nano-care was developed and is marketed by an American Company, Nanotex and stain-resistant jeans and khakis are available since 1990. Nanocare fabrics are created by modifying the cylindrical structure of the cotton fibres making up the fabric. At the nano scale, cotton fibres look like tree trunks. Using nano techniques, these tree trunks are covered in a fuzz of minute whiskers which creates a cushion of air around the fiber. When water hits the fabric, it beads on the points of the whiskers, the beads compress the air in the cavities between the whiskers creating extra buoyancy. In technical terms, the fabric has been rendered super-non wettable or super-hydrophobic. The whiskers also create fewer points of contact for dirt. When water is applied to soiled fabric, the dirt adheres to the water far better than it adheres to the textile surface and is carried off with the water as it beads up and rolls off the surface of the fabric. Thus the concept of “Soil-cleaning” is based on the leaves of the lotus plant.

Anti-static Finishes:

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Static charge usually builds up in synthetic fibers such as nylon and polyester because they absorb little water. **Cellulosic fibers** have higher moisture content to carry away static charges, so that no static charge will accumulate. 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 nano-sized titanium dioxide, zinc oxide whiskers, nano antimony-doped tin oxide (ATO) and silane nanosol could impart anti-static properties to synthetic fibers. TiO2, ZnO and ATO provide anti-static effects because they are electrically conductive materials.

Nano Technology for Wrinkle Free Treatment:

Nano-Tex 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.

Anti-bacterial Finishes:

For imparting anti-bacterial properties, nano-sized silver, titanium dioxide and zinc oxide are used. Metallic ions and metallic compounds display a certain degree of sterilising effect. It is considered that part of the oxygen in the air or water is turned into active oxygen by means of catalysis with the metallic ion, thereby dissolving the organic substance to create a sterilising effect. With the use of nano-sized particles, the number of particles per unit area is increased, and thus anti-bacterial effects can be maximised.

Economical and Environmental Aspects:

The unique properties of nanomaterials have attracted not only scientists and research workers but also businesses, because of their huge economic potential. The national science foundation reports that nano-related goods and services will increase to a US$ 1 trillion market by 2015. This amount is larger than the combined businesses of the telecommunications and information technology industries. Several hundred billion Euros are forecast to be created by nanotechnology in the next decade (24). The nano materials markets could expand to US$ 4 billion by 2007. It was believed that 2 million new employment opportunities would be created in order to meet the worldwide annual production demand of US$ 1 trillion in 10-15 years. Nanotechnology may impart favourably on the environment as well. By using less resource without sacrificing performance, nanotechnology may save raw materials and also upgrade quality of life.

VIII. CONCLUSIONS

There is a significant potential for profitable applications of Nano-technology in cotton and other textiles. Several applications of Nano-technology can be extended to attain the performance enhancement of textile manufacturing machines & processes. In future, interdisciplinary research collaborations will lead to significant advancements in the desirable attributes of cotton and cotton blend textile applications. The textile industry has

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the biggest customer base in the world. Therefore, advances in the customer-oriented products should be the focus for the future nanotechnology applications. The future research should be targeted on developing improved dirt, crease and shrink resistance properties in fabrics, temperature adaptable clothing and odor-less undergarments. We envision that by combining the optical fibers, micro mirrors, functional coatings and electronic textiles customized fabrics can be developed which can change its color as per the desire of consumer's taste. Several advances can also be made towards the development of strong fibers and fabrics for biomedical and military applications.

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