TEXTILES OF THE FUTURE? INCORPORATION OF NANOTECHNOLOGY IN TEXTILE APPLICATIONS

De Schrijver I., Eufinger K., Heyse P., Vanneste M., Ruys L.
Centexbel, Technologiepark 7, 9052 Zwijnaarde, Belgium

Nanotechnology is considered one of the most promising technologies for the 21st century. On the one hand there is the economical impact from new and optimised products. On the other hand one expects a strong contribution of nanotechnology in decreasing the ecological impact and consumption of natural resources. Nanotechnology has the potential to improve the effectiveness of a number of existing consumer and industrial products and is expected to have a substantial impact on the development of new applications.

What is nano?

The "nano" prefix denotes that at least one of the dimensions of these materials is in the order of 1-100 nanometre. A nanometre (nm) is a billionth of a metre, which is about 1/80000 of the diameter of a human hair, or 10 times the diameter of a hydrogen atom (Figure 1).

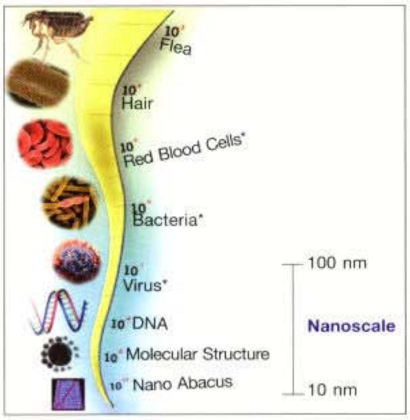

Figure 1: scaling of small objects in relation to the nanoscale

One refers to nanotechnology when either nanoscaled materials are produced (defined by e.g. their thickness, particle size or other structural features) or when the nature of a process involves the use of nanoscaled materials (e.g. sol-gel). Research and development in nanotechnology is directed toward understanding and creating improved materials, devices, and systems that exploit these new properties.

At nanoscale, the physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of individual atoms and molecules as well as bulk matter. For instance, ceramics, which normally are brittle, can be easily made deformable if the grain size is reduced to the nanometer range. Another example is the fact that a gold particle of 1 nm across shows a red colour. The ability to change physical properties of materials gives nanotechnology a potential impact across a wide variety of disciplines.

Nanotechnology in textiles

The wave of nanotechnology has shown a huge potential in the textile and clothing industry which is normally very traditional. The future success of nanotechnology in textile applications lies in areas where new functionalities are combined into durable, multifunctional textile systems without compromising the inherent favourable textile properties, including processability, flexibility, washability and softness.

A whole variety of novel nanotech textiles are already on the market at this moment. Examples of industries where nanotech enhanced textiles are already seeing some applications include sporting industry, skincare, space technology and clothing and material technology for better protection in extreme environments.

Perhaps one of the most widely recognized applications today is the shark-skin swimming suit in which the Olympic swimming champion Michael Phelps won several new world records. This suit contains a plasma layer to repel water molecules, designed to help the swimmer to glide through the water with minimum resistance. An example of the shark skin structure is given in Figure 2.

Figure 2: shark skin effect[1]

The textile market is changing thanks to nanotechnology. Better healthcare systems, protective clothing and integrated electronics are just some of the applications. The use of nanotechnology is allowing textiles to become multifunctional and produce fabrics with special functions: e.g. antibacterial, UV-protection, easy-clean, anti-odour,...

One of the applications of nanotechnology in textile industry is in polymeric materials for producing conventional fibres such as polyester, polyamide and polypropylene in nanoscale. Nanofibres have good properties such as high surface area, a small fibre diameter, good filtration properties and high permeability. Nanofibres can be obtained via electro-spinning application or bicomponent extrusion (islands in the sea technique).

Nanomaterials as additives in textile products

One of the most promising building blocks of nanotechnology are carbon nanotubes (CNTs). Next to natural carbon crystal structures, such as diamond and graphite, the fullerenes and CNTs have been developed during the past decennia (Figure 3).

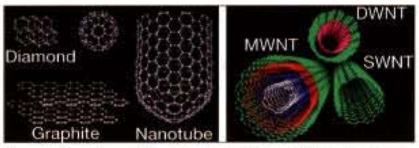

Figure 3: schematic representation of the structure of carbon crystal structures (left) and cross section of different carbon nanotube structures (right)

A CNT is a tube whose wall consists of C-atoms arranged in the same way as in a graphite layer. Several of these tubes can be stacked inside each other so that one speaks of single walled (SWCNT) or multi walled (MWCNT) carbon nanotubes, the diameters ranging from 0.4 to several nanometers. While SWCNTs can reach lengths of several mm, the MWCNTs are usually shorter. All CNTs show the tendency to aggregate, forming bundles that can reach a thickness of several hundreds of µm.

The properties of CNTs are quite exceptional. They are 100 times stronger than steel while having only 1/6th of its weight and their electric and thermal conductive properties are exceptionally good. Thanks to their high length to diameter ratio and their outstanding properties CNT/polymer composites are expected to create an important added value in diverse applications of textile products, even at low CNT concentrations. The percentage of CNTs needed to create a conductive composite material varies, depending on their dispersion, the intended level of conductivity and application. Centexbel assesses the use of carbon nanotubes as an additive in extrusion, coating and finishing applications[2, 3]. Also in private and European projects Centexbel is doing research on carbon nanotubes.

Also of interest are nanostructured metal oxides such as ZnO and TiO_2, which possess photo-catalytic abilities (photo-oxidizing capacities against chemical and biological species) and UV absorption properties, while MgO, Al_2O_3 and SiO_2 can increase the mechanical strength, abrasion resistance or the fire retardance of textile[4, 5].

Another important class of materials are clay nanoparticles or nanoflakes, which are composed of several types of hydrous aluminosilicates. Clay nanoparticles possess electrical, heat and chemical resistance and an ability of blocking UV light. For example, nanoparticles of montmorillonite are one of the most commonly used clays. Centexbel has performed research evaluating the added value of nanoclays in extrusion applications, like increasing strength and fire retardance[6].

Antimicrobial properties can be obtained by the addition of nanosilver. Silver nanoparticles are so small that they are virtually 100% surface area. Since the surface of silver is active against bacteria (via release of Ag^+ ions), the activity of a silver particle increases with its surface area. Nanosilver particles show antimicrobial properties in concentrations as low as 0.0003 - 0.0005%. For antimicrobial applications, these low concentrations compensate for the material cost of silver. Because of its effectiveness against a broad range of germs, even in small concentrations and over long periods of time, it is very interesting to incorporate nanosilver, which is non-toxic for higher life forms at these low concentrations, into textile materials (e.g. medical applications and packaging material). Centexbel is currently studying the incorporation of nanosilver into different textile materials for antibacterial applications[7].

Using nanosized fillers is one of the most common approaches to create nanostructured composite fibres. At Centexbel many of the nanomaterials listed in the previous section, including CNTs and nanoclays have been studied. One major challenge for the preparation of polymer compounds with nanofillers is the dispersion of the material. Due to the large surface area the nanoparticles tend to interact differently with the polymer matrix than the bulk materials. Other nanoparticles, for example CNTs, show a strong tendency to aggregate, and breaking up these aggregates is a major challenge, but important for fully utilizing the special properties of the nanomaterials. Formation of aggregates may also strongly interfere with the processing of compounds and yarns.

Nanotechnology for textile coating and finishing

One of the interesting areas for the application of nanotechnology in the textile industry are coating and finishing processes of textiles. Pioneering work in this area was performed by Nano-Tex. Subsequently an increasing number of textile companies has been and is investing in the development of processes involving nanotechnology. At Centexbel we are evaluating the addition of nanoparticles to coating and finishing products as well as the application of nanotechnology based coatings and finishing techniques, like sol-gel[8] and plasma[9, 10].

One example is the use of ZnO nanoparticle additives for UV-protection. As can be seen in Figure 4 below, the addition of 20% ZnO nanoparticles to the coating paste conserves the pull strength quite strongly after 200h of ageing in a QUV testing apparatus[4].

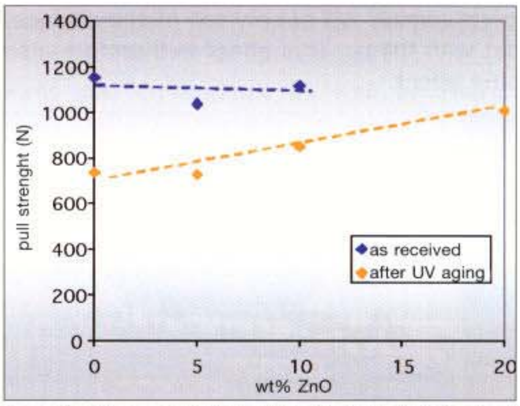

Figure 4: influence on the UV ageing of the pull strength of applying a polyurethane coating containing ZnO NP on a polyester fabric

Nanosized silver, titanium dioxide and zinc oxide are used for imparting self-cleaning and antibacterial properties. Metallic ions and metallic compounds display a certain degree of sterilizing effect. It is considered that part of the oxygen in the air or water is turned into active oxygen by a catalyst containing the metallic ion, thereby destroying the organic substance to create a sterilizing effect. Nanomaterials possess enhanced catalytic abilities due to their highly stressed surface atoms which are very reactive. With the use of nanosized particles, the number of particles per unit area is enormously increased.

For example under UV-illumination the surface of TiO_2 can be transformed creating a self-cleaning surface. The surface develops a strong affinity to water and oil, resulting in the formation of a sheet, which simply slides of the surface, taking any dirt with it. The surface also becomes catalytically active, breaking down any organic matter adhering to it. A nanostructured surface is desired to increase the active area to maximize the catalytic efficiency (Figure 5). TiO_2 is also active in removing organic substance from the air, and can therefore be used for air freshening and deodorizing[11].

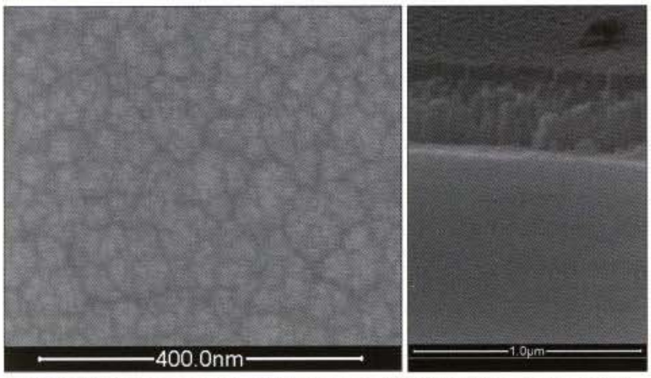

Figure 5: SEM image of a nanostructured TiO_2 thin film (400 nm) deposited by DC magnetron sputtering on glass: left top view, right cross section[12]

The major challenge for utilizing the photo-catalytic properties of these ceramics is to ensure that only the unwanted species are destroyed, not the organic material of the textile substrate and/or coating. The aim is to generate a specific coating structure which separates the catalytically active nanoparticles from the organic substrate by e.g. the use of a buffer layer[5].

Another example of self-cleaning surfaces is the creating of the lotus effect. Nanoscaled structures similar to those of a lotus leaf (Figure 6) create a surface that causes water and oil to be repelled, forming droplets, which will simply roll of the surface, taking any dirt with them. This effect is therefore also called the lotus effect.

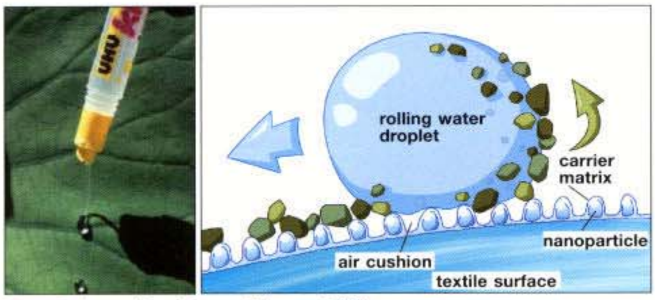

Figure 6: lotus-effect (Source: Mincor – BASF)

One of the major challenges when working with nano-additives in coating and finishing applications is to obtain a good pre-dispersion of the nanoparticles, which then can be added to the standard coating and finishing products. These nanoparticles dispersions are often not commercially available or not tailored to textile products. For this reason research into the preparation of coating and finishing formulations containing nanoparticles additives is a strong priority at Centexbel.

Conclusions

There is a significant potential for profitable applications of nanotechnology in textiles. Several applications of nanotechnology can be extended to attain the performance enhancement of textile manufacturing machines and processes. 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 the textile industry. However, there are still a lot of items to be taken in consideration before industrial commercialisation of the nanoproducts. First there is the issue of costs, which in some cases is hampering the development of nanoparticle coatings and makes mass production economically less viable. Besides cost, a key point is the question of the impacts of uncontrolled release of nanoparticles. Generally, the state of research into the health and environmental issues can be summed up as suggesting that the current results of studies on the impact are limited. In future, interdisciplinary research collaborations will lead to significant advancements in the desirable attributes of textile applications.

Acknowledgements

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Further references on the application of nanotechnology in textile applications

- S.C. Tjong, Materials Science and Engineering R53 (2006) 73-197.
- Mulcahy E,; Nano 9 (2008) 4-5.
- Sparkle Intertek Labtest, Nanotechnology in textile and clothing industry, Volume TX 001 (2006).
- Kathivelu S., D'Souza L., Dhurai B. Indian Journal of Science and Technology 1[5] (2008).
- Wong Y.W.H., Yuen C.W.M., Leung M.Y.S., Ku S.K.A., Lam H.L.I., Autex Research Journal 6 [1] (2006).
- Sawhney A.P.S., Cordon B., Singh K.V., Pang S.S., Li G., Hui D., Textile Research Journal 78 [8] (2008) 731-739.
- Qian L., Hinestroza J.P., Journal of Textile and Apparal. Technology and Managament 4 [1] (2004).

1 http://www.speedo80.com
2 IWT VIS-CO 60874, CNT
3 FP7 (NMP) Dephotex
4 4C (IWT 010518, Ceratex) and IWT VIS-CO 030917 Ceratex II
5 IWT VIS-CO 30916, Katalytische
6 IWT VIS-CO 20783 Nanoadditieven, VIS-CO 40754 Nanoadditieven II
7 IWT VIS-CO 070657 Nanozilver
8 IWT VIS-CO 40751 Sol-gel
9 IWT VIS-CO Plasma-Dadmac
10 FP6 (NMP) Acteco
11 I. De Witte, R. Van Olmen, L. Ruys, K. De Witte, P. Cool, Unitex nr 5 (2006) 10-14
12 K. Eufinger, D. Poelman, H. Poelman, R. De Gryse, G.B. Marin, Vacuum Technology and Coating 8 [1] (2007) 44-49