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NANOTECHNOLOGY IN TEXTILE INDUSTRY [REVIEW]

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Abstract: *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. Nanotechnology overcomes the limitation 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. Nanotextiles are nanoscale fibrous materials that can be functionalized with a vast array of novel properties, including antibiotic activity, self-cleaning and the ability to increase reaction rates by providing large surface areas to potential reactants. These materials are used not only as cloth fabric, but as filter materials, wound-healing gauzes and antibacterial food packaging agents in food industry. World demand for nanomaterials will rise more than two-and-a-half times to $5.5 billion in 2016 driven by a combination of increased market penetration of existing materials, and ongoing development of new materials and applications. In recent years was demonstrated that nanotechnology can be used to enhance textile attributes, such as fabric softness, durability and breathability, water repellency, fire retardancy, antimicrobial properties in fibers, yarns and fabrics. The development of smart nanotextiles has the potential to revolutionize the production of fibers, fabrics or nonwovens and functionality of our clothing and all types of textile products and applications. Nanotechnology is considered one of the most promising technologies for the 21st century. Today is said that if the IT is the wave of the present, the nanotechnology is the wave of the future.*

Key words*: nanotechnology, nanomaterials, nanotextiles, smart textiles*

1. INTODUCTION

The term “nano” comes from the Greek word “nanos” meaning “dwarf” and is used in the measuring system as a prefix to denote one billionth. A particle with a diameter of one nanometer is therefore 1 billionth of a meter in size (10^{-9} m = 10^{-6} mm).

The history of nanotechnology is generally understood to have begun in December 1959 when physicist Richard Feynman gave a speech, “There's Plenty of Room at the Bottom”, at an American Physical Society meeting at the California Institute of Technology in which he identified the potential of nanotechnology. Feynman aid it should be possible machines small enough to manufacture objects with atomic precision.

In 1974, Norio Taniguchi first used the word “nanotechnology, in regard to an ion sputter machine, to refer to “production technology to get the extra-high accuracy and ultra-fine dimensions, i.e. the preciseness and fineness on the order of one nanometer.”

In the 1980s, Eric Drexler authored the landmark book on nanotechnology, “Engines of Creation”, in which the concept of molecular manufacturing was introduced to the public at large. By the 1990s, nanotechnology was advancing rapidly. [1]

Today there are many who think that the next Industrial Revolution is right around the corner – because of nanotechnology. They think that nanotechnology will radically transform the world, and the people, of the early 21st century. It has the capacity to change the nature of almost every human-made object.

Nanotechnology has a huge influence on the chemical sciences, physical and medical sciences as well as on the world of informatics and materials.

Nanotechnology overcomes the limitation 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. [2]

2. DEFINITIONS

There are several definitions of nanotechnology and of the products of nanotechnology, often these been generated for specific purposes. Nanotechnology is the term given to those areas of science and engineering where phenomena that take place at dimensions in the nanometre scale are utilised in the design, characterisation, production and application of materials, structures, devices and systems.[3]

In the Vocabulary for Nanoparticles of the British Standards Institution (BSI 2005) the following definitions are proposed:

"Nanotechnology*:* the design, characterization, production and application of structures, devices and systems by controlling shape and size at the nanoscale."

"Nanomaterial*:* material with one or more external dimensions, or an internal structure, which could exhibit novel characteristics compared to the same material without nanoscale features.

The U.S. National Nanotechnology Initiatve (NNI) provides the following definition:

"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." [4]

Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale.

A nanometer is one-billionth of a meter. A sheet of paper is about 100,000 nanometers thick; a single gold atom is about a third of a nanometer in diameter. Dimensions between approximately 1 and 100 nanometers are known as the nanoscale.

Scientists have not unanimously settled on a precise definition of nanomaterials, but agree that they are partially characterized by their tiny size, measured in nanometers. A nanometer is one millionth of a millimeter - approximately 100,000 times smaller than the diameter of a human hair.

Materials engineered to such a small scale are often referred to as engineered nanomaterials, which can take on unique optical, magnetic, electrical, and other properties. These emergent properties have the potential for great impacts in electronics, medicine, and other fields. [5]

Nanotextiles are nanoscale fibrous materials that can be functionalized with a vast array of novel properties, including antibiotic activity, self-cleaning and the ability to increase reaction rates by providing large surface areas to potential reactants. These materials are used not only as cloth fabric, but as filter materials, wound-healing gauzes and antibacterial food packaging agents in food industry.[6]

3. NANOMATERIALS

Originally, nanomaterials filled requirements such as equipment used in the space program or in imaging devices. Now, they are prevalent as a necessity in many uses, such as in high-speed microprocessors. Silica, titanium dioxide, alumina, iron oxide, zinc oxide, clays and metals such as gold and silver and other nanoscale versions of conventional materials are now finding use in cosmetics, paint and coating products, construction materials, electronic equipment, motor vehicle components, pharmaceuticals and health care applications. Significant opportunities for market expansion will also exist in many smaller markets such as aerospace and defense, packaging, personal care products and sports equipment.

"World nanomaterials demand, $1 bilion, 2006."

"World demand for nanomaterials is expected to grow, from $3,7 bilion in 2008 to $90 billion in 2020." (**Fig. 1**)

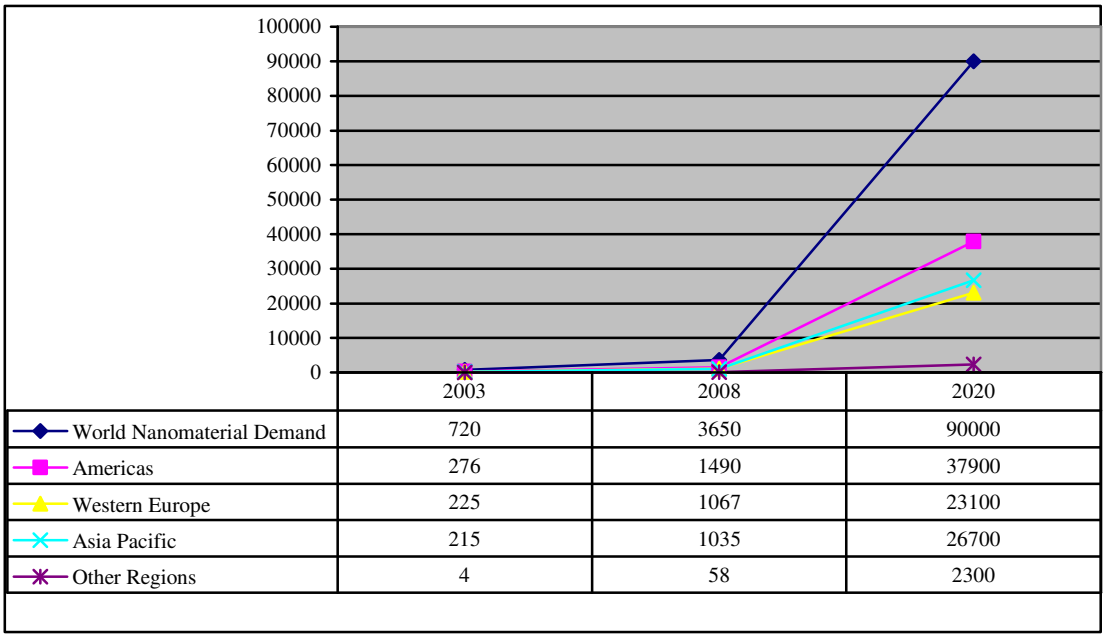
"By 2011, world demand for nanomaterials is forecast to reach $4.2 billion. In the longer term, the global market is projected to swell to $100 billion in 2025."

"Global nanomaterial demand will continue to rise, posting robust 21 percent annual gains to $3.6 billion in 2013. By 2025, nanomaterials are expected to reach over $34 billion in sales, having still only scratched the surface of their immense market potential."

"World demand for nanomaterials will rise more than two-and-a-half times to $5.5 billion in 2016 driven by a combination of increased market penetration of existing materials, and ongoing development of new materials and applications."

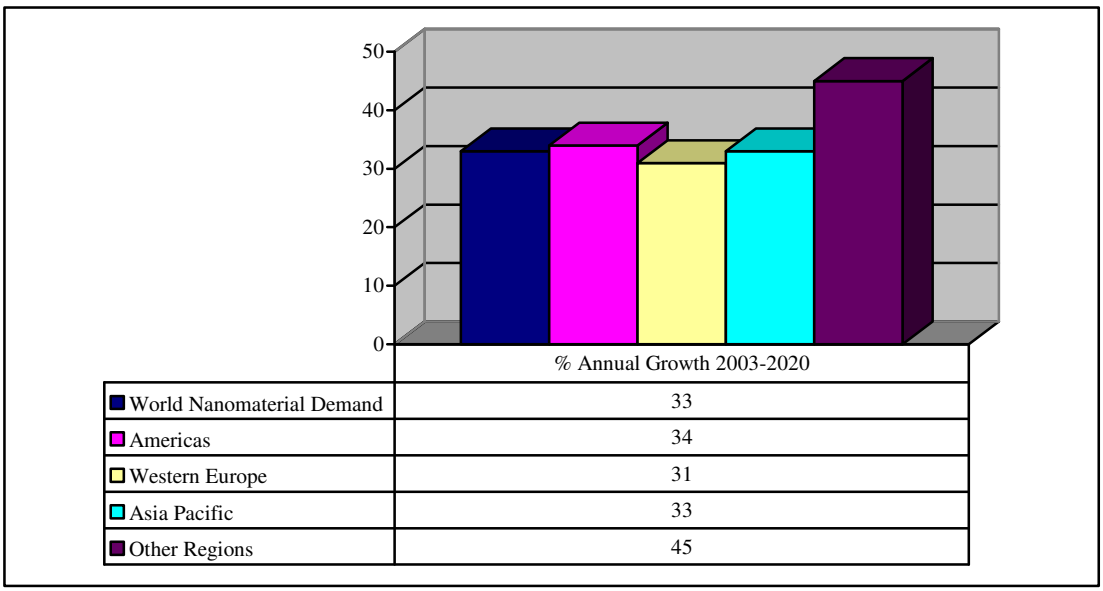
This afirmations are presented in the studies, "World Nanomaterials", editions 2007, 2010, 2012, from the industrial market research firm, The Freedonia Group, from Cleveland, Ohio, United States of America. [7]

In 2025 over $25 billion will be spent on formulations and intermediate materials for wearable technology, according to analyst Dr. Peter Harrop of IdTechEx. [8]



	2003	2008	2020
World Nanomaterial Demand	720	3650	90000
Americas	276	1490	37900
Western Europe	225	1067	23100
Asia Pacific	215	1035	26700
Other Regions	4	58	2300

Fig. 1: *World Nanomaterial Demand (million US dollars)*



	% Annual Growth 2003-2020
World Nanomaterial Demand	33
Americas	34
Western Europe	31
Asia Pacific	33
Other Regions	45

Fig. 2: *World Nanomaterial Annual Growth*

The US is and will remain the largest market for nanomaterials. Japan is a smaller nanomaterial market than the US, but is significantly larger than any other nation. From EU, Germany, France and the UK are the largest national markets in the region. The developing countries, in special China and India, will become increasingly important nanomaterial markets. (**Fig. 2**) By 2025, it is

expected that China will rise to overtake Japan as the second largest market for nanomaterials in the world behind the United States, accounting for twelve percent of global demand.

The Freedonia studies suggest that the cost will be a significant restraint on growth for nanomaterials, particularly in less developed regions.

A potential other restraining factor in many markets will be growing concern about the environmental impact and toxicity of nanomaterials.

4. NANOTECHNOLOGY IN THE TEXTILE-INDUSTRY

Nanotechnology has been discovered by the textile industry – in fact, a new area has developed in the area of textile finishing called "Nanofinishing". Making fabric with nano-sized particles creates many desirable properties in the fabrics without a significant increase in weight, thickness or stiffness, as was the case with previously used techniques. Nanofinishing techniques include: UV blocking, anti-microbial, bacterial and fungal, flame retardant, wrinkle resistant, anti-static, insect and/or water repellant and self-cleaning properties. [9]

Finishing of fabrics made of natural and synthetic fibers to achieve desirable hand, surface texture, color, and other special aesthetic and functional properties, has been a pri mary focus in textile manufacturing. In the last decade, the advent of nanotechnology has spurred significant developments and innovations in this field of textile technology. Fabric finishing has taken new routes and demonstrated a great potential for significant improvements by applications of nanotechnology. There are many ways in which the surface properties of a fabric can be manipulated and enhanced, by implementing appropriate surface finishing, coating, and/or altering techniques, using nanotechnology.[10]

Today, the main applications of nanotechnology in textiles (**Fig. 3**) refer to: nanofinishing in textiles, nano chemicals for textiles, nanocoating for textile materials, nano/smart silver for textile.

In recent years was demonstrated that nanotechnology can be used to enhance textile attributes, such as fabric softness, durability and breathability, water repellency, fire retardancy, antimicrobial properties in fibers, yarns and fabrics.

One of the most common ways to use nanotechnology in the textile industry is to create stain and water resistance. To do this, the fabrics are embedded with billions of tiny fibers, called "nanowhiskers" (think of the fuzz on a peach), which are waterproof and increase the density of the fabric. The Nanowhiskers can repel stains because they form a cushion of air around each fiber.

Nanotechnology can also be used in the opposite manner to increase the ability of textiles, particularly synthetics, to absorb dyes. Until now most polypropylenes have resisted dyeing, so they were deemed unsuitable for consumer goods like clothing, table cloths, or floor and window coverings. A new technique being developed is to add nanosized particles of dye friendly clay to raw polypropylene stock before it is extruded into fibres. The resultant composite material can absorb dyes without weakening the fabric. [9]

Nanotex is a leading fabric innovation company which provides nanotechnology-based textile enhancements to the apparel, home and commercial/residential interiors markets. For example, its product, Aquapel, is the next generation in water repellent, eco-friendly performance, providing advanced protection against rain, sleet, snow and spills. Using a proprietary hydrocarbon technology, Aquapel modifies fabric at the molecular level by permanently attaching hydrophobic 'whiskers' to individual fibers, without altering the fabric's natural breathability or feel. Plus, Aquapel is fluorocarbon free and PFOA free, making it the right choice for you and the earth. [11]

The other main use of nanoparticles in textiles is that of using silver nanoparticles for antimicrobial, antibacterial effects, thereby eliminating odors in fabrics. Nanoparticles of silver are the most widely used form of nanotechnology in use today, says Todd Kuiken, PhD, research associate at the Project on Emerging Nanotechnologies. [12]

The silver is made smarter through nanotechnology:

- lasts the expected life of the product
- uses the natural antimicrobial action of silver in controlling the growth of odor-causing bacteria, fungus, and mold
- is easily integrated into natural and synthetic fibers, foams, plastics, and coatings
- has been thoroughly tested and is eco-friendly
- meets regulatory requirements
- has a track record with products in the health care, textile, and industrial markets. [13]

Fig.3: *Some representative applications of nanotechnology in textiles []*

The future for textile applications using nanotechnology is exploding due to various end uses like protective textiles for soldiers, medical textiles and smart textiles.

For example, consider the T-shirt. Research is being done that will use nanotechnology-enhanced fabric so the T-shirt can monitor your heart rate and breathing, analyze your sweat and even cool you off on a hot summer's day. What about a pillow that monitors your brain waves, or a solar-powered dress that can charge your ipod or MP4 player? [9]

Nanotechnology has the potential to being revolution in the field of technical textiles for the benefit of humanity. [14]

5. QUALITY LABEL FOR NANOTECHNOLOGY

The Hohenstein Institutes, an accredited test laboratory and research institute, which was founded in Bönnigheim (Germany) in 1946, was launched in October 2005 its Quality Label for Nanotechnology, a litmus test as to whether is product is Nano or not. The certification of the textiles is based on their adherence to a strict definition of nanotechnology which can be applied to the textile sector, developed in conjunction with NanoMat [15], a Germany-based nanomaterials network: "Nanotechnology refers to the systematically arranged functional structures which consist of particles with size-dependent properties".

The program and quality label was instituted to help retailers and other textile and users determine if a textile product really incorporates nanotechnology or whether the name, as applied to a particular product, is merely an advertising message. The label offers retailers and consumers guidance in the maze of confusing advertising messages and forms the basis for reliable product comparison.

Testing of nanotechnology includes:

- determination of the type of nanotechnological finishing
- visual inspection of nanotechnological finishing using a scanning electron micro-scope
- quantification of the effect of the finishing (e.g. dirt repellence by measurements of contact angle on characteristic fluids, antimicrobial effects of Nano-Ag, UV protection of Nano-Ti/Nano-ZnO)
- determination of mechanical suitability for use
- laundering permanence
- determination of breathability and
- determination of biocompatibility. [16]

Fig. 4: *Hohenstein Quality Label "Nanotechnology"*

The testing program is tailored to the textile material and its areas of application. Testing is carried out on new textiles and after simulated conditions of use.

The requirements defined for the award of the label are product-specific. For example, for a pair of trousers with a soil-repellent finish, the breathability must not be significantly affected and the skin compatibility must be proven by tests for tissue compatibility. The resistance of the nano-finish to the effects of wear (abrasion resistance) and care are also tested. For care treatments, the stated function is guaranteed for a defined minimum number of washing and drying cycles. The additional parameters are also stated and explained on the Hohenstein Quality Label. [17]

6. CONCLUSIONS

Nanotechnology is considered one of the most promising technologies for the 21st century. Today is said that if the IT is the wave of the present, the nanotechnology is the wave of the future. After the quikly development from the last decade, in present nanotechnology has numerous applications in almost every industry, including textile industry. The development of smart nanotextiles has the potential to revolutionize the production of fibers, fabrics or nonwovens and functionality of our clothing and all types of textile products and applications.

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