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Nanotechnology in textile industry

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ABSTRACT

The article presents the application of nanotechnology in the textile sector. Textile engineering has been shown as an interdisciplinary field of science. Contemporary textile and clothing industry is based on the cooperation of different scientific fields including materials science, medicine, cosmonautics, nanotechnology and chemistry. At present, fast development is observed of innovative products in the clothing industry, and above all, of technical products.

Keywords**:** nanotechnology in textiles, nanofibers, innovations in textiles

1. INTRODUCTION

Innovation is nowadays an essential element of progress and economic development. Its most important goal is primarily to introduce qualitative change in the area of technology, marketing, work organization and management. Innovations can be a consequence of implementing new knowledge and modern technologies, but they can also result from combining already existing and well-established knowledge with technology. Textile industry, despite being perceived as not very innovative, belongs to the economic sectors where technological innovations are applied frequently and on an increasing scale. What should be mentioned here are, in particular, the latest solutions in the field of nanotechnology, textronics and biotechnology. Numerous scientific publications prove that modern technologies used in textile industry bring measurable effects in the form of manufacturing

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innovative products, characterized by unique properties, as well as products which deserve to be called "smart textiles" [1]. The aim of the article is to present the possibilities of implementing modern and innovative technologies into the textile sector, e.g. into nanotechnology, textronics or biotechnology and to discuss their numerous applications.

2. MATERIALS

Nanotechnology is a general name for the whole set of techniques and methods for creating various structures of nanometer sizes (0.1-100 nanometers), i.e. at the level of individual particles. Currently, nanotechnology is implemented in many fields, e.g. gene and tissue engineering, construction, architecture, machine, food and textile industry, composites, etc.

Nanofibers are fibers with a thickness smaller than 100 nm, i.e. 1 nm = 10^{-9} m (Fig. 1.) [2]. Such fibers can be produced by drawing, template synthesis and self-assembly, but the most common method is electrospinning [3].

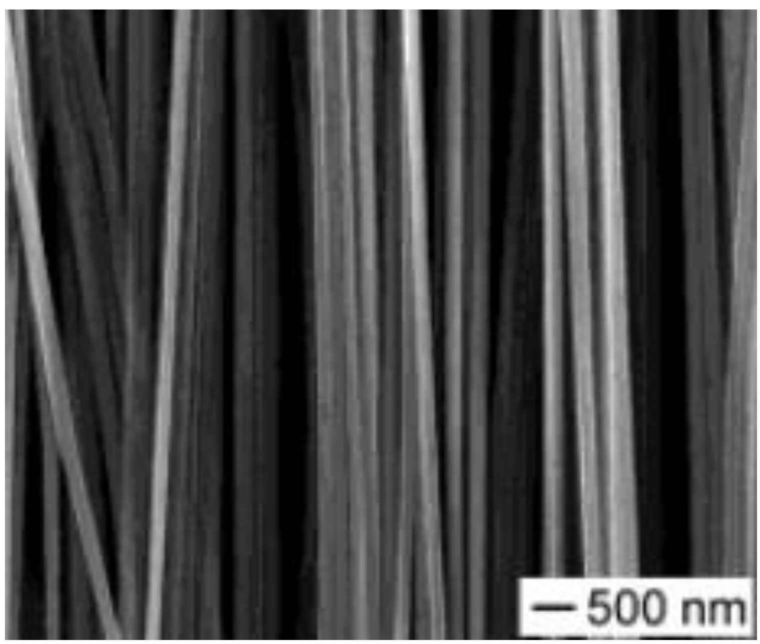


Figure 1. SEM image of carbon nanofibers [4]

Nanotechnology products are very popular in the textile sector, both in the field of fiber production and modification. Current technology makes it possible to produce ultra-thin fibers whose diameter can be smaller than or equal to 100 nm. They are produced from a variety of natural and synthetic polymers, however, the most well-known nanofibers are those made from protein, carbon, cellulose, acryl, ceramic polyamide and polyaniline. The characteristic feature of the obtained nanofibres is their extremely large specific surface area, which equals 0.1-1 g/m^2, which ensures excellent thermal, electrical, mechanical, chemical and biological properties.

The possibility of using different raw materials for the production of nanofibres allows them to be applied in specialized, sports, protective and everyday clothing, as well as in medicine, tissue engineering, cosmetics, space technology, molecular electronics, army, etc. [1, 2]. Applying nanofibers positively affects the functional properties of clothing [5]. Such clothing is characterized by great lightness, softness and delicacy. Products made of nanofibres are characterized by excellent biophysical properties, because such materials have very good cooling properties, they quickly absorb and release sweat and counteract the increase in body temperature. Another important property of nanofibres is their high resistance, which generates higher friction forces on the surface of the skin [6, 7]. This very important property has been used in the fat-burning underwear. The company Nanofront which introduced this underwear into the market declared that wearing the underwear for about 40 days would contribute to a reduction in body fat [1].

Due to their excellent liquid sorption capacities nanofibers can be also applied in medicine. It is possible to manufacture wound dressings in the form of self-supporting fibrous coatings, which accelerate wound healing. However, due to low porosity of the material the bacteria from the outside can penetrate into the wound. Nanofibers, especially carbon nanotubes, are also applied as drug carriers. Due to their nanometric dimensions, they allow the drug to enter the cells. Nanofibers in medicine are also used to manufacture vascular prostheses, surgical nets and scaffolds for the regeneration of bone, cartilage and nervous tissue (Fig. 2) [8].

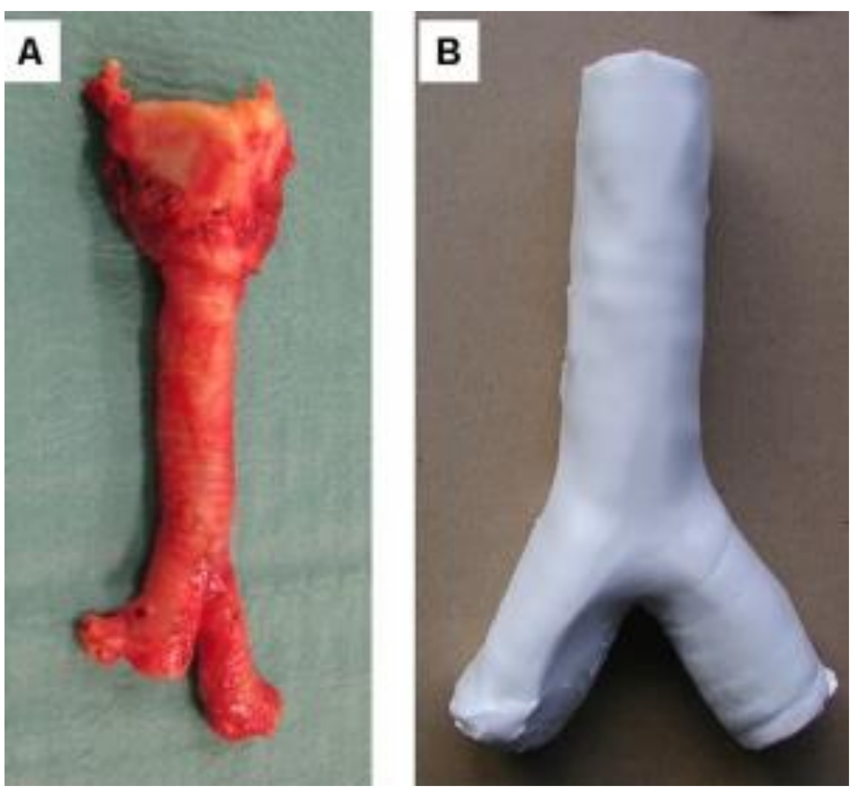


Figure 2. Native/natural trachea (**A**) and electrospun trachea **B** to be used in tissue engineering [9]

Filter materials are another example of nanofibers application. Manufactured in such a way, they are characterized by compact structure and can catch dirt particles which are up to several nanometers in size. In addition, they are characterized by good absorption properties- they can absorb up to 20 times more oil than they weigh, and then the oil can be recovered and the filters can be used again. Such filters are used in the automotive industry and in industrial filters [10].

Nanocomponent textiles, obtained by modifying the internal structure or surface of standard fibers are also increasingly popular. They are obtained by physical, chemical and physicochemical methods. The possibility of using even small amounts of nanoadditives enables to achieve various qualitative and quantitative effects. The most commonly used nanoadditives are layered silicates, graphite, silica, carbon nanotubes, metals and their compounds. However, silver ions are the most popular in textile industry, and are frequently applied in bedclothes, mattresses, towels, sports underwear and hosiery. Silver nanomolecules of 1-5 nm are usually added during the spinning process or applied in the form of coatings [5].

Silver or copper nanoparticles can be incorporated into all elements and materials for footwear production from the sole to the upper. Such a shoe obtains permanent antibacterial and antifungal protection. Additionally, clothing made of materials impregnated with nanosilver prevents sweat decomposition, thus eliminating the unpleasant odor. The mattresses and bedclothing impregnated with nano-copper and nanosilver are free from bacteria and fungi [10].

Elements of interior decoration and equipment, floor materials, upholstery, leathers and other materials modified with nanosilver create a completely new quality. Microbiological safety of furniture, interior decorations and equipment is certainly a desirable and advantageous effect for the target groups such as hotels, health services, gastronomy and education [11].

3. INNOVATIVE RESEARCH

Currently, at the Faculty of Materials Technology and Textile Design of the Lodz University of Technology, innovative research is carried out involving the modification of the surface of basalt fabric. The surface modification is carried out at the level of micrometers. For this purpose, the process of physical deposition (Physical Vapor Deposition) of chemical compounds from the gas phase was selected, consisting in the preparation of a coating on a specific substrate by applying physical application of ions, atoms and molecules. Coatings obtained as a result of the PVD process are used in many branches of industry, eg optics, electronics, for decorative purposes and are used for machine construction, because they protect them against wear and corrosion. The coatings obtained are above all very hard and resistant to wear. The use of the PVD process makes it possible to apply almost all materials. The PVD process methods give the possibility to obtain layers of different thicknesses and different physical and chemical properties [12,13].

A method of magnetron sputtering was chosen for depositing the coatings on the surface of the basalt fabric. The reactive magnetron sputtering method was initiated in 1936, when Penning, in order to increase plasma concentration, suggested using a transverse magnetic field to obtain a more suitable electrode sputtering. The method's efficiency is influenced by a magnetron, which is a device assembly that enables glow discharge occurring on crossed magnetic and electric fields. In 1959 Kisajewa and Paszkowa constructed an electrode mercury lamp constituting the first prototype of a magnetron, which was later transformed in 1974 by Chapin and as a result of the modification served as a flat magnetron for deposition of layers.

In various types of magnetron devices, the magnetic field created as a result of the use of magnets gathers a glow discharge focused on the surface of sprayed discs usually made of one or several materials. The electric discharge takes place in the mixture of inert gas and reactive gas, which is transmitted continuously to the working chamber of the device due to continuous wear. Argon, the most commonly used in the process, is the inert gas, which thins the reactive gas, allowing the stoichiometric composition of the produced coating to be controlled. The substrate is typically polarized by using a high 500 V negative potential, resulting in ion purification of the surface of the batch before the coating process takes place. The size and shape of the zones in which the deposition takes place, as well as the spatial shape of the plasma, depend primarily on the intensity of the magnetic field created, the gas pressure and the power that the magnetron is energized. Presented method of reactive magnetron sputtering (Fig. 3.) is currently the widest application due to very high spraying rate of the target material, as well as a reduced range of pressure values. working [14].

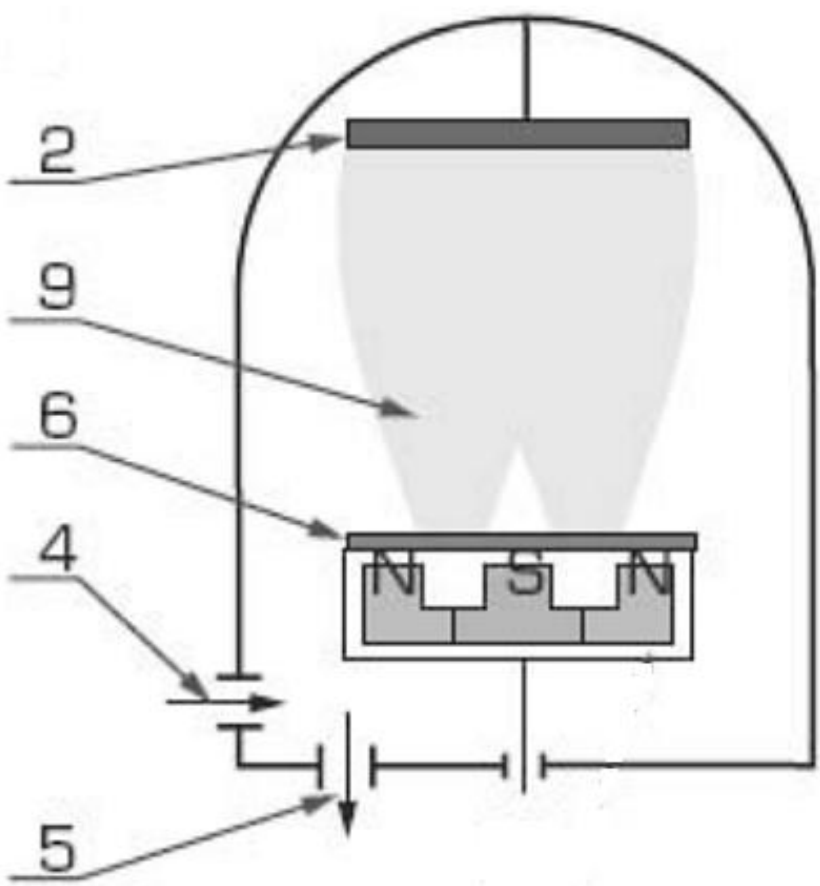


Figure 3. Scheme of magnetron sputtering [15]
2- covered item, 4- gas inlet, 5- entrance to the pump, 6- shield, 9- external electrode

With the selected method of the PVD process, thin layers of both single-component materials, as well as chemical compounds or alloys are obtained. On various substrates of completely different sizes and shapes, conductive, dielectric and semiconducting layers can be deposited. Nanowiar thin-film structures are mainly produced in the form of composites, mixtures and many layers.

An important advantage of using magnetron sputtering is the possibility of high-performance, yet even production of layers on surfaces of various sizes and shapes. The described advantage is very important due to industrial requirements [16].

The device for applying PVD coatings is presented below (Fig. 4.).

Figure 4. URM stand for coatings with PVD processes

3. 1. Research methodology

In order to determine the thickness of deposited coatings during magnetron sputtering on the surface of basalt fabric and to determine the content of individual elements, a scanning electron microscope produced by JOEL was used (Fig. 5.). The microscope is a JSM 6610 LV model.

Parameters of the scanning electron microscope:

- Magnification: × 5 to × 300,000,
- Automatic functions: Sharpness, brightness, contrast,
- Picture format: BMP, TIFF, JPEG

Figure 5. Scanning electron microscope

3. 2. Research object

The fabric was selected from basalt fiber yarn.

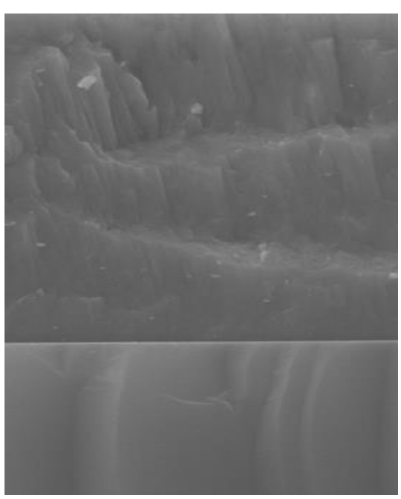
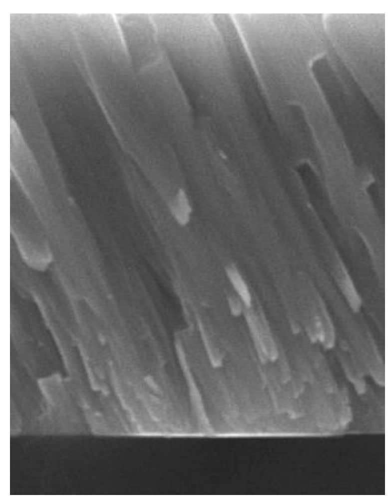
Table 1. Characteristics of the selected fabric

Fabric type	Fabric photo	Mass per unit area [g/m^2]	Weave	Thickness [mm]
Fabric made of basalt fibers		398	twill	0,55

3. 3. Test results

Table 2. Photographs of chromium and aluminum modified surface of basalt fabric along with photos for coating thickness assessment

Table 2. Actual view of the modification of the surface of the basalt fabric

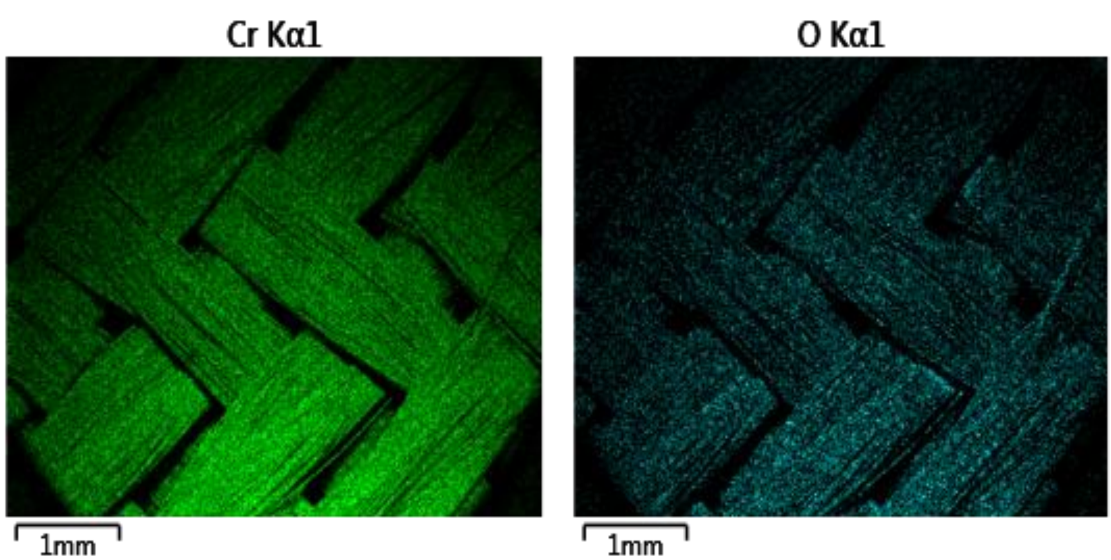
chrome	aluminum
	
Measurement of the thickness of the deposited chromium coating = 5 μm	The thickness measurement of the deposited aluminum coating = 5 μm
	

Below is an analysis of the content of individual elements on the example of a fabric made of chromium-modified basalt fiber yarn with a coating thickness of 5 μm (Fig. 6).

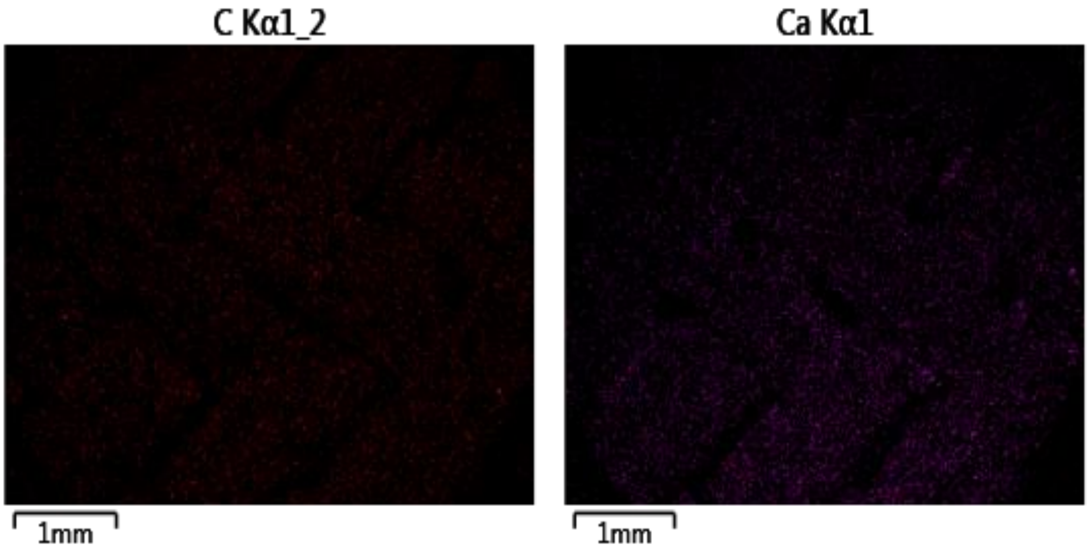
Figure 6. A chromium-plated coating with a thickness of 5 μm embedded on the surface of the basalt fabric -SEM

The content of particular elements in the coating:

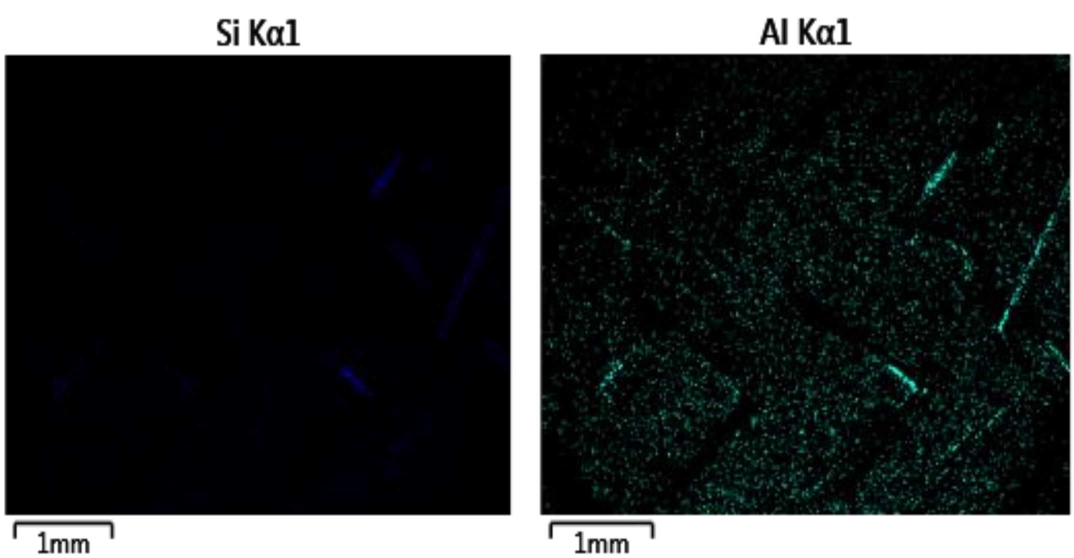
Chrome – green color,
Oxygen – blue color



Carbon – red color,
Calcium – purple color



Silicon - navy color,
Aluminum – blue color,



The table below (Table 3) contains numerical values of particular elements contained in the chromium deposit.

Embedded on fabric from basalt fiber yarn, 5 μm thick coatings exhibit adequate adhesion to the substrate and almost 100% cover the surface of the fabric. The presented tests are preliminary tests, checking the adhesion of the coating to the substrate.

Table 3. Percentage of individual elements in the 5 μm chromium coating:

Element	Percentage [%]
Cr	98,77
O	3,06
C	2,50
Ca	0,44
Si	0,33
Al	0,11

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4. CONCLUSIONS

Nanotechnology is an essential technology of the present times. It gives the opportunity to design lightweight, fast, and less or more efficient materials and systems [1]. Additionally, nanotechnology, thanks to applying novel solutions and modifications of well-known materials, offers new market opportunities in different fields, including medicine, specialized textiles, materials processing or agriculture. It should be mentioned that this technology is constantly evolving, and by combining various fields, new and innovative solutions appear in many scientific areas.

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