Techno Science
International Scientific
Journal of Technical
Sciences

Application of nanotechnology in improving the properties of textile fibres

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ABSTRACT

As an everyday need, textile requires the process of creation from raw materials to usable structures to be taken care of. As a foundation of textile, fibre, both natural and synthetic, is versatile and has to fulfil the physical, chemical, aesthetic, cultural and other FABRIC properties. Contemporary findings provide an opportunity to affect the properties during the fibre formation process, colouring and finally weaving and tailoring. The aim of this paper is to present one of the possibilities where fibre can be affected on a nanodimensional level. The process where electrified particles, electrons and ions, affect the fibre provides new dimensions to its surface. Therefore, our aim was to describe the process where ions affect the fibre quality.

Keywords: fiber, plasma, nanotechnology.

Introduction

As an everyday need, textile requires the process of creation from raw materials to usable structures to be taken care of. As a foundation of textile, fibre, both natural and synthetic, is versatile and has to fulfil the physical, chemical, aesthetic, cultural and other FABRIC properties. Contemporary findings provide an opportunity to affect the properties during the fibre formation process, colouring and finally weaving and tailoring. Here, the goal is to conduct processes reduced to nanodimensions, i.e. nanotechnology used to form the fibre surface. The inside of the fibre interacts with the environment using its surface. We will talk about the impact plasma has, as a phase of emerging substance in nature, on wool fibre. At a time where ecology has more stringent demands on textile industry, the importance of plasma and application of its technology gains greater importance. However, introducing plasma technology in the processes used in textile technology is still being researched and its implementation in the production process will require ecological awareness on the side of textile producers and end users. Reaching the desired effects and corresponding modifications in the properties of textile materials during plasma processing will require the knowledge of plasma processing parameters used in the process of producing materials. I shall either find a way (to success) or make one!

Plasma

Plasma (from Greek πλάσμα: moulding, forming) is a completely ionised matter - SUBSTANCE. Due to different properties in relation to the SOLID STATE OF MATTER, liquids and gases, it is common to consider it a special state of matter. Ionised gas has at least one electron separate from a part of its atoms or molecules.

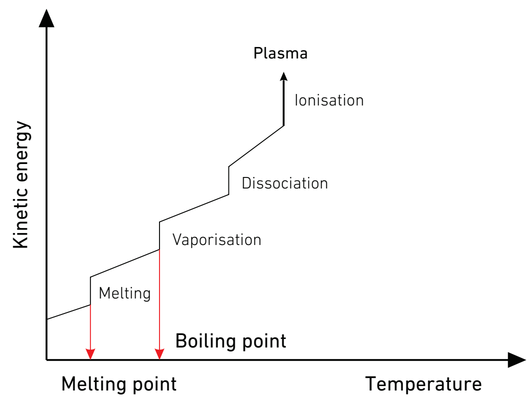

Figure 1. The concept of state of matter

In fact, by separating the negative electron from the atom or a group of atoms in a molecule one gains particles called ELECTRONS on the one and IONS on the other side. The process itself is called IONISATION which results from the energy used for the separation. Owing to the free charged particles (ions and electrons), plasma represents a good conductor for electric current and strongly responds to electric and magnetic fields.

With an increase in temperature to a several thousand degrees, the collision of atoms becomes stronger and intensifies, which in turn results in electron release from the atom structure and creates particles carrying charge; negatively charged electrons and positively charged ions. When they move, charged particles create electric and magnetic fields which results in energy necessary for further atom ionisation, i.e. a state of almost completely ionised matter - plasma. Gas is more or less ionised, at least to a small degree, but not all ionised gas is called plasma. Plasma is said to be a quasi-neutral gas composed of neutral and charged particles. From a macroscopic point of view, quasi-neutral gas is neutral, but its elements are electrically charged. Like gas, plasma does not have s specific form or volume, unless placed in a container, while under the influence of a magnetic field plasma can assume the desired form, for example a fibrous structure. Plasma exists, it can be found near conductors - wires tied to the pole of an electrode's electric source. Therefore, the ion concentration around this type of conductor is determined by the source's pole potential.

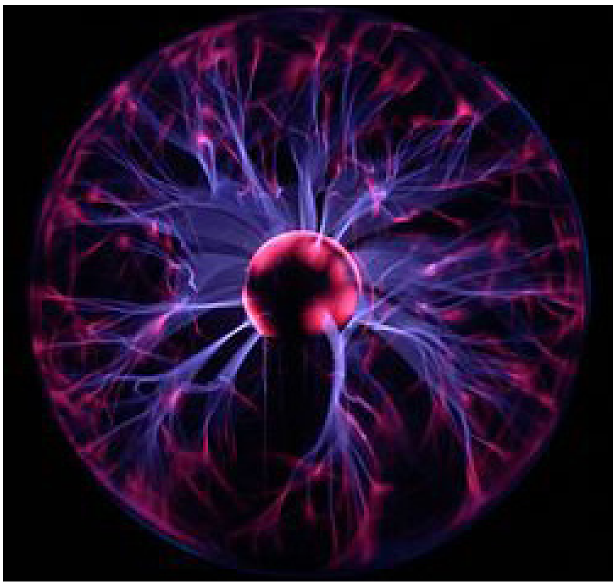

Figure 2. A plasma globe filled with a mixture of various gases with an electrode in the centre of the sphere

Plasma quality is determined using the electrode's potential (alternating-and its frequency), type of nearby gas and its pressure around the electrode. To reach the desired effects and corresponding modifications in the properties of textile materials during plasma processing, it is important to be familiar with the plasma processing parameters used in the process of producing materials. These parameters are: operating frequency, processing time, type of gas, gas flow, pressure (regulated with a vacuum pump in case of low-pressure plasma), the number of electrodes, as well as the distance between the electrode and surface of the substrate.

Textile-fibre and the metioned plasma parameters are interrelated

Research can be directed to a great number of materials-fibres and plasma parameters representing the subject of future research. In this paper, we will analyse the changes incurred in properties of wool fabrics after the preliminary treatment of samples using oxygen plasma, by applying standardised methods and procedures for evaluating the impact plasma has on modifications made in the properties of wool. Atoms and molecules are ionised, fragmented and stimulated, making a very reactive mixture of gasses that, in the production process, react with the sample both physically and chemically. Of course, the obtained effects, i.e. changes in the properties of the processed material's surface primarily depend upon the process gas and its physical and chemical properties and substrate characteristics, as well as upon the processing conditions. Cold plasma, both low and atmospheric-pressure plasma, can be used for textiles (the electron temperature is considerably higher than the ion temperature).

Low-pressure plasma system contains a vacuum chamber with an electrode, as well as carriers dependent upon the type of material and the sample which is being processed, because the way materials are processed is not continuous. The sample size is determined by the carrier size. To reach the low pressure, it is necessary to use a vacuum pump which, in a short period of time, has to ensure the pressure level ranging from 0.01 to 1 mbar.

The electromagnetic field in the system stimulates (at low pressure inside the vacuum chamber) the gas structure and causes acceleration of the free electrons resulting in the creation of plasma when their kinetic energy is high enough to make a plasma reaction (matter ionisation, fragmentation and stimulation). Creating plasma is visible because a light of different intensity appears (ranging from light blue to purple colour).

Figure 3. Creating plasma from light blue to purple colour

Modifying the surface of wool materials using plasma

Wool is a fibre consisting of the protein called keratin. Its molecular chain structure is highly complex and the morphological characteristics of the fibres are rather specific. The outer surface of fibres is covered in scales which is the main reason for wool being prone to felting. The shape of scales and the way they cover the fibre surface, as well as its tendency to felting can be considerably different due to the fibre fineness and the sheep's breed which results in a difference between fine and rough wool. The interior of the wool fibre consists of spindly cells creating the elementary wool substance cortex; rough fibres can have a hollow in the middle, the so called core or medulla.

Research conducted at the University of Zagreb, Faculty of Textile Technology have shown that oxygen plasma affects the quality of the wool substrate. That interaction in Plasma processing contributes to removing the hydrophobic layer from the surface of wool fibre, slight ablation of scales, and probably activates the surface chemically, which results in better molecular binding of colourants, significantly improves the depth to which the colour penetrates the wool sample and a better bath usage. Sorption properties have also been improved without any reduction of fracture force or fracture strain, but an increase, which probably manifests in the change of surface and better traction between the fibres, is recorded. Flexural rigidity as an indirect indicator of decline, tactile, aesthetic and utilisation characteristics is slightly increased which was expected after plasma processing in line with the results of research conducted by other authors.

It is known that plasma solely affects the surface layer on the nanoscale (until reaching the depth of around 100 nm in total), so the reaction between active chemical substances, plasma and substrates is expected to have such physical and chemical transformations, related to changes in the surface layer, affecting the changes of physical, chemical and mechanical substrate properties. Nanotechnology is present since the processes are conducted on a nanodimensional level.

Figure 4. Low-pressure plasma system apparatus

Plasma processing is primarily used for surface processing of materials because it only modifies the surface properties of textile materials while the elementary properties remain almost unchanged. Plasma functioning mechanism is monitored through several processes appearing when it interacts with the surface of materials, while distinguishing the following procedures:

- surface cleaning,
- surface etching,
- surface ablation,
- activation, plasma modification,
- deposition process,
- plasma polymerisation and the like...

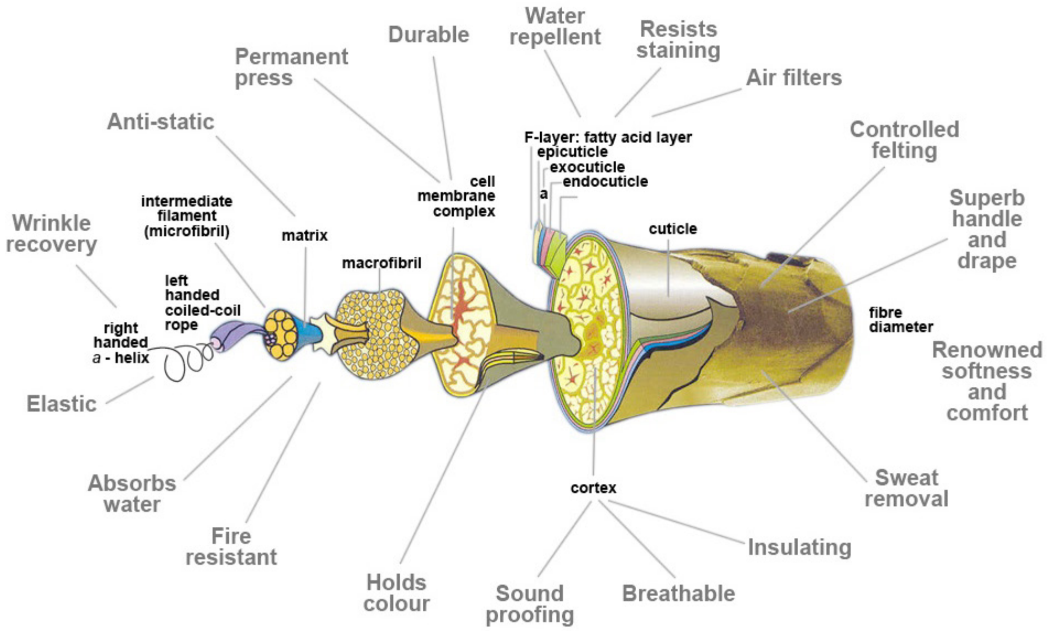

Figure 5: Wool fibre - morphological characteristics of fibre

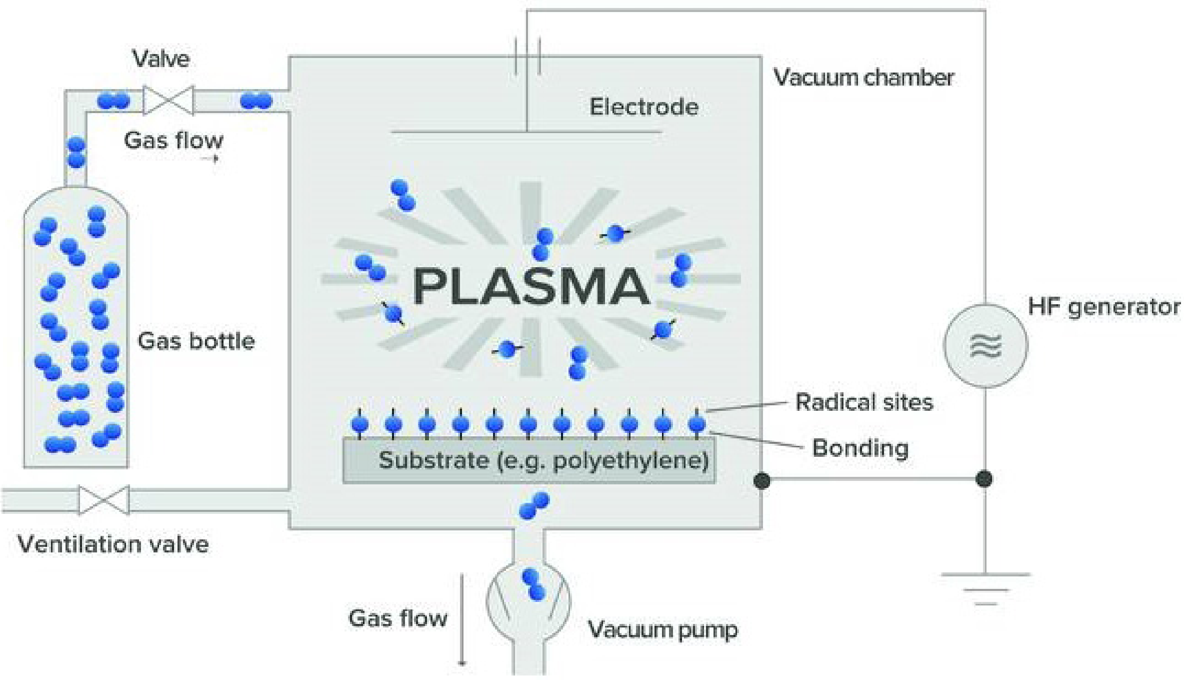

Figure 6: 40 kHz frequency low-pressure plasma system chart

Conclusion

Using plasma processing we make the desired changes, i.e. substrate surface modifications with the goal of obtaining a value-added product with the desired functional properties. During the process of production, plasma interacts with the substrate while physical and chemical changes occur in the processed material surface layer. At the same time, processing parameters have to be optimised: type of gas, force, gas flow, pressure, operating frequency, sample size and the number of electrodes. The aim of this paper is to explore the influence of low-pressure oxygen plasma on physical and chemical properties of the wool substrate. The samples were processed at a force of 300 and 500 W and during different time intervals without changing the values of gas flow, type of gas, operating frequency and sample size. The micromorphology analysis of the wool fibre structure has been conducted using a scanning electron microscope Tescan MIRA\\LMU to determine the changes at the surface of wool fibres by cleaning the fibre surface, changing the appearance and shape of scales, damaging the fibres by scoring, and the like. Unprocessed fibres have a proper scale surface. Upon plasma processing the cuticle has visible changes, especially when processed at 500 W, which can be seen in the damage incurred on the tips (after a minute of processing) and visible damage fully incurred on the scale after 5 minutes of processing. A greater amount of cuticle residue is visible at the fibre surface due to damaged scales. Hydrophilic properties of wool have been tested by using a vertical test according to the HRN EN ISO 9073-6:2003. standard and a qualitative and quantitative evaluation of wool hydrophilicity (wetting). At the same time, the height h [mm] of vertical water column front flowing through fabric was tested. The results show an increase in hydrophilicity after 30 seconds of plasma processing in relation to the unprocessed sample that is completely hydrophobic. In this way the fibre/textile material properties can be specifically modified. For example, reaching a better wetting ability which contributes to a better usage of colourants during the process of dyeing (printing). Besides that, plasma affects the adhesive properties and methods of cleaning materials without using harmful chemicals and without damage to the elementary properties (primarily non-mechanical) of materials processed in such a way.

Received: April 21, 2017
Accepted: May 25, 2016

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References

1. B. Vršnik: Temelji fizike plazme, Školska knjiga – Zagreb, Grafoplast d.d., 1996.
2. www://hr.wikipedia.org/wiki/Plazma_(fizika), web pregled 25. 4. 2016.
3. R. S.hishoo: Plasma technologies for textiles, Published by Woodhead Publising Limited in association with The Textile Institute, Abington Hall, Abington, Cambridge, England, (2007).
4. https://www.plasma.com/en/plasmatechnik/introduction-to-plasma, pregled 20. 10. 2016.
5. http://eskola.hfd.hr/proc_za_vas/proc-21/pus.htm, web pregled 25. 5. 2016.
6. http://3atoms.org/what-is-plasma-and-gans, web pregled 04. 6. 2016.
7. M. M. Radetić et al.: Modificiranje vune niskotemperaturnom plazmom, Tekstil 54, (6) 266-278, (2005)
8. S.Ercegović Ražić: Ciljana modifikacija svojstava tekstilnih materijala primjenom plazme i metalnih spojeva, doktorska disertacija, Sveučilište u Zagrebu, Tekstilno tehnološki fakultet, 2010 godina.
9. D. Hegemann: Plasma polymerization and its applications in textiles, Indian Journal of Fibre&Textile Resarch 31, 99-115, (2006).
10. C. W. Kan et al.: Low temperature Plasma on Wool Supstrates: The Effect of the Nature of the Gas, Textiles Research Journal 69 (6), 407-416 (1999).
11. R. Molina et al.: Low temperature plasma modified wool fabrics: surface study by SEM, Multidisciplinary Research and Education, FORMATEX 2004, 242-249, (2004).
12. S. Ercegović Ražić, R. Čunko: Modifikacija svojstava tekstilija primjenom plazme, Tekstil 58, 3, 55-74 (2009.).
13. H. U. Poll et al.: Penetration of Plasma effects into textile structure, Surface and Coatings Tecnology, 142-144, 489-493 (2001).
14. https://plasma.com/anwendungen/textilindustrie, web pregled 10. 6. 2016

15. R. Shishoo: Plasma Treatment – Industrial Applications and its Impact on the C&L Industry, Journal of Coated Fabrics 26, 26-35 (1996).
16. C. Wang and Y. Qiu: Influence Procesing Parameters on Penetration of Active Species in atmospheric Pressure Plasma Jet in Wool Fabrics, 3rd ITC&DC, Book of Proceedings, 366-371, October 08-11th 2006., Dubrovnik, Croatia.
17. I. M. Zuchairah et al.: Effect of Glow Discharged-Polymer Treatments on the Shrinkage Behaviour and Physical Properties of Wool Fibres, Textile Research Journal, 67 (1), 69-74 (1997).
18. D. Sun, G. K. Stylios: Investigating the Plasma Modification of Natural Fiber Fabrics - The Effect on Fabric Surface and Mechanical Properties, 639-640 (2005).

Nano tehnologija u poboljšanju svojstava tekstila

SAŽETAK
Tekstil kao potreba u svakodnevnici traži brigu o procesu nastanka od sirovine do upotrebljive strukture. Vlakno kao osnova za tekstil je raznoliko, kako prirodno tako i sintetičko i trebaju zadovoljiti fizikalna, hemijska, estetska, kulturološka i druga svojstva TKANINE. Savremena saznanja daju mogučnost utjecaja na svojstva kako u procesu formiranja vlakna, bojenja i najzad tkanja pa i krojenja. Cilj ovoga rada je da se iznese jedna od mogučnosti utjecaja na vlakno na nivou nanodimenzija. Proces djelovanja naelektrisanih čestica elektrona i jona na vlakno daje nove dimenzije površine vlakna. Dakle, cilj nam je bio da opišemo proces uticaja jona na kvalitet vlakna.

Ključne riječi: vlakna, plazma, nano tehnologija.