Nanofibres made from biocompatible and biodegradable polymers, with potential application as medical textiles

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REZUMAT – ABSTRACT

Nanofibre obținute din polimeri biocompatibili și biodegradabili, cu potențial de utilizare ca textile medicale

O parte importantă și în continuă dezvoltare a industriei textile este sectorul medical și cel conex, de igienă și îngrijire a sănătății. Recent, vălurile de fibre ultrafine obținute din polimeri biocompatibili și biodegradabili au fost obținute prin procesul de electrofilare. Proprietățile lor unice, cum ar fi raportul dintre suprafața mare și volum, dimensiunile mici ale porilor, porozitatea ridicată și posibilitatea introducerii compușilor terapeutici în nanofibrele electrofilate, au atras atenția cercetătorilor în ultima vreme. Această lucrare prezintă obținerea nanofibrelor PEO și PVA.

Cuvinte-cheie: electrofilare, nanofibră, văl de fibre, poli (alcool vinilic), poli (oxid de etilenă)

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An important and growing part of the textile industry is the medical and related healthcare and hygiene sector. Recently, ultrafine fiber webs made from biocompatible and biodegradable polymers have been obtained by the electrospinning process. Their unique properties such as high surface area-to-volume ratio, small pore sizes, high porosity, and the possibility of incorporation therapeutic compounds into the electrospun nanofibers has attracted the researcher's attention lately. This paper presents the obtaining of PEO and PVA nanofibers.

Keywords: electrospinning, nanofiber, web, poly (vinyl alcohol), poly (ethylene oxide)

INTRODUCTION

Electrospinning is one of the most widely used techniques in the 21st century, due to its adaptability and potential for applications in various domains, such as: wound healing, artificial skin, membranes for selective separation, target delivery system for active agents and molecules, scaffolds for tissue or bone engineering [1, 8]. Tissue engineering strategies are based on biological, medical and engineering disciplines, and aims to repair and regenerate damaged tissues or organs that no longer function properly. This is often achieved by development of a 3D porous matrix with similar biomechanical properties, enhanced with elements that sustain and promote tissue regeneration. Fibrous materials of submicron dimensions are potentially better candidates in skin wound treatment, when compared with normal dressing materials, such as cotton pads and bandages, due to a number of advantageous properties, including high porosity ratio, high permeability, biocompatibility and biodegradability [7].

Electrospinning represents one of most important process through which tailoring the material structure at nanometer scale becomes possible [2, 6]. Electrospinning uses an electrical field to create a charged jet of a polymer solution. At a critical voltage, the repulsive force overcomes the surface tension of the solution and a jet erupts from the tip of the capillary towards a grounded collector. The voltage applied is usually between 7 and 30 kV [3].

According to their purpose of usage, for which they have been selected, quick or slow degrading polymers can be used to generate nanofibres [9, 11, 13]. Polymers that have a longer degradation time offer better structural and mechanical support and can be effectively used for procedures like dialysis, tissue engineering and drug delivery systems. In contrast, polymers that are quickly degradable in vivo (due to enzymatic and hydrolytic activities) do not interfere with cellular activities and allow for the cell proliferation through the spaces created by the degraded fibers, that allow extracellular matrix to infiltrate and provide nutrition for the proliferating cells. The main characteristics of polymers, which compete in their selection, are: elasticity, resilience, presence of functional groups, etc. [4, 10, 14].

Many compounds for therapeutic purpose can be incorporated within nanofibers, by using two different methods. The simplest method is by blending, where the drug molecules and the polymer are miscible and electrospun together. The second possibility is to encapsulate the drug in micro-capsules or to conduct a core-shell electrospinning, to form drugs encapsulated in fibers. In order to generate a core shell structure a coaxial spinneret is needed [4, 5].

One of the main areas of research in biomedical application of electrospinning is drug delivery where the electrospun fiber releases the therapeutic agent

in the specific environment in which it is used. In addition, electrospun fibers maintain the integrity and bioactivity of the drug molecules due to the mild processing parameters [12]. Localized delivery of therapeutic compounds can significantly reduce the systemic absorption of the drug and reduce any side effects. In addition, the efficacy of the drug is also improved, due to localization of the treatment [4, 7].

EXPERIMENTAL WORK

Electrospun nanofiber web of poly (ethylene oxide) (PEO) and poly (vinyl alcohol) (PVA) were successfully prepared. The fibers, of 200–300 nm in diameter, were obtained by regulating the main parameters: solution concentration, the electric voltage, and the distance between the injection needle tip and the fiber collector. The fiber meshes were analyzed by scanning electron microscopy (SEM), which showed the properties of the fibers, such as: the diameter of the nanofibers, the regularity of the nanofiber shape, and the uniformity of the diameter.

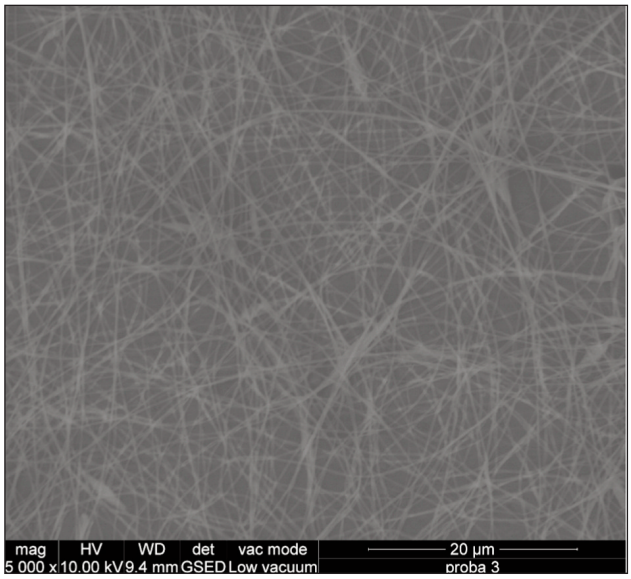
Materials

PEO with an average molecular weight and PVA with 80 % hydrolization degree was purchased from Sigma Aldrich and used as supplied. The concentration used for the electrospinning of the polymers was varied between 1,5 and 15 % (w/v) until electrospinning has occurred.

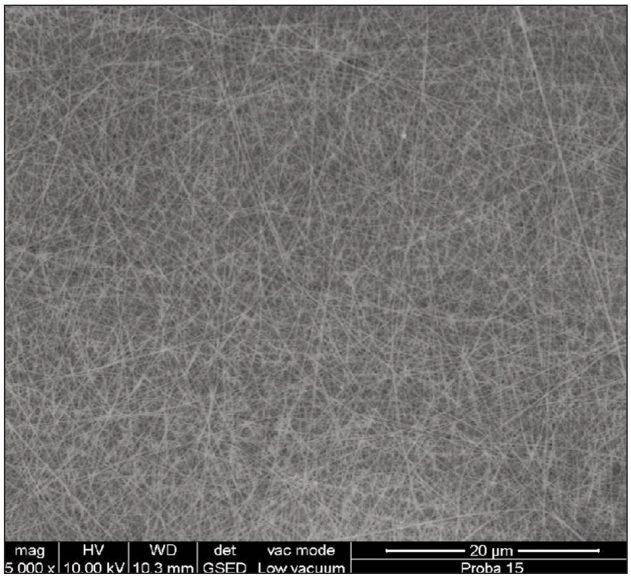
Method for electrospinning the prepared solution

The fibers were electrospun with a flow rate of 0.8–2 ml/h and a voltage of 10–18 kV and a distance of 15–20 cm between the needle and the grounded collector. Those conditions were experimentally optimized to obtain bead-free nanofibers and to have stable processing conditions.

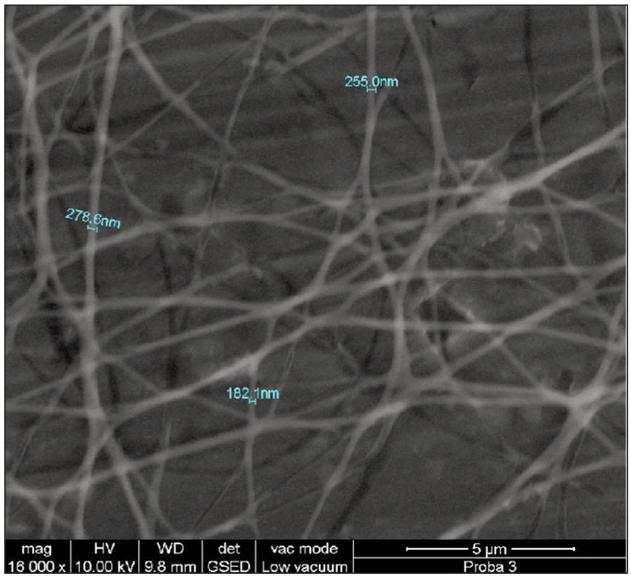
PVA fibers obtained in this study were smooth and randomly oriented, without beads, with diameter range



Microscopic SEM image of PEO nanofibers



Microscopic SEM image of PVA nanofibers



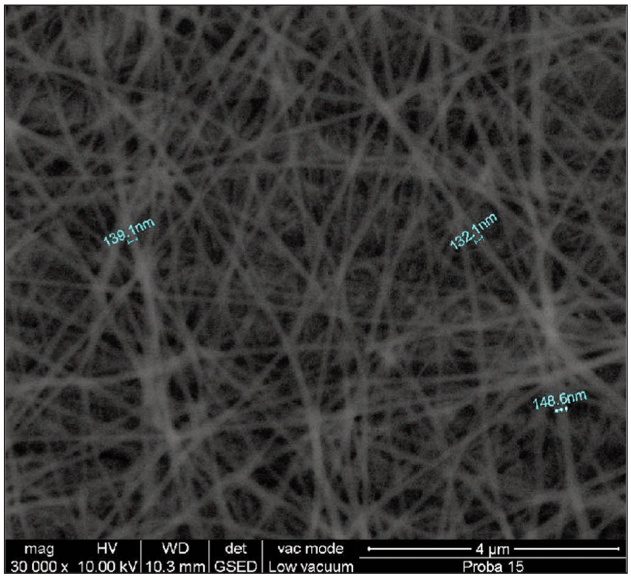


Fig. 1. SEM Images of PEO and PVA nanofibers

from 200 nanometers to 300 nm. For PEO fibers, beads have been noticed on the surface.
The experimental apparatus uses a high voltage power supply, a syringe pump and a collector system. The maximum allowed voltage was 30 kV. The flow rate was controlled by the syringe pump. The fibres were collected on a grounded metal collector plate of a rectangular base covered with cotton gauze. The electric field was applied between the syringe needle and the metal collector plate (grounded). The electric voltage was incremented until the fibre spinning was observed. The electric field can be changed by varying the distance between the syringe needle and the collector plate.

Methods for structural characterization

SEM Analysis – The surface aspect of the resulting porous webs were studied using a scanning electron microscope at an accelerating voltage of 10 kV. SEM photographs were taken at different magnification by using Quanta FEI SEM equipment.
The nanofibers *surface wettability* was assessed through the method of determining the contact angle of drops of distilled water that are placed on the surface of the web.

RESULTS AND DISCUTION

The nanofibres obtained using electrospinning processes are collected as a web by consecutive deposition of layers of randomly aligned nanofibers. Although the fibres cover primarily the metallic collector, a considerable quantity falls outside of the collector.

Nanofiber morphology

The characterization of PVA and PEO nanofibers was performed by using a FEI Scanning Electron Microscope at 10 kV voltages. The SEM images are given in figure 1.

The PEO solution has conducted to a random deposition of the nanofibres. Few beads are noticed to be present within the structure, produced at the beginning of the experiment, until a laminar flow of polymeric solution has been obtained. The fibre diameter varies between 182–280 nm.
In contrast, the PVA solution produced a structure of relatively more organized layers, without beads, with fiber diameters in rage of 132–149 nm.
Both structures can be present a dense network of pores of different sized, highly interconnected.

Surface wettability

The surface water absorption capacity was assessed through the method of contact angle, by placing drops of distilled water on the surface of the web. The equipment used was VCA Optima. No contact angle could be measured, as the water absorption was instantly.

CONCLUSIONS

Electrospinning was used to fabricate nanofibres of PVA and PEO. The effect of processing parameters such as voltage, tip-collector distance and flow rate on fiber diameter and its morphology has been evaluated. The morphology of fibers and their diameters were strongly influenced by the composition of the solution and the applied tension. The porous structure of the electrospun webs obtained, the biocompatibility and biodegradability of the polymers used make our electrospun scaffold an excellent candidate for biomedical applications. In vitro and in vivo experiments for evaluation of the biocompatibility of these PEO and PVA nanofibers is necessary.

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BIBLIOGRAPHY

[1] Nitilaksha Hiremath, and Gajanan Bhat, *Melt blown Polymeric Nanofibers for Medical Applications – An Overview, Nanoscience & Technology: Open Access,* available at: https://symbiosisonlinepublishing.com/nanoscience-technology/nanoscience-technology25.pdf.

[2] S. Liao, C. K. Chan, S. Ramakrishna, *Electrospun nanofibers: Work for medicine?* In: Front. Mater. Sci. China 2010, 4(1), pp. 29–33

[3] Miriam Haerst, Vera Seitz, Markus Ahrens, Cécile Boudot, and Erich Wintermante, *Silicone Fiber Electrospinning for Medical Applications,* In: 6th European Conference of the International Federation for Medical and Biological Engineering, IFMBE Proceedings, 2015, available online at: https://link.springer.com/chapter/10.1007/978-3-319-11128-5_134.

[4] Nishath Khan, *Applications of electrospun nanofibers in the biomedical field*, In: Studies by Undergraduate Researchers at Guelph, vol. 5, no. 2, 2012, pp. 63–73.

[5] A.C. Baptista, I. Ferreira and J.P. Borges, *Electrospun Fibers in Composite Materials for Medical Applications*, In: Journal of Composites and Biodegradable Polymers, 2013, 1, pp. 56–65.

[6] L.R. Manea et al, *Recent advances of basic materials to obtain electrospun polymeric nanofibers for medical applications*, In: IOP Conf. Series: Materials Science and Engineering 145 (2016) 032006.

[7] Anhui Wang, Chao Xu, Chuanwei Zhang, Yunna Gan, and Bin Wang, *Experimental investigation of the properties of electrospun nanofibers for potential medical application*, In: Journal of Nanomaterials, Volume 2015 (2015), Article ID 418932, available at: https://www.hindawi.com/journals/jnm/2015/418932/

[8] Haifeng Liu, Xili Ding, Gang Zhou, Ping Li, Xing Wei, and Yubo Fan, *Electrospinning of nanofibers for tissue engineering applications,* In: Journal of Nanomaterials, Volume 2013 (2013), Article ID 495708, available at: https://www.hindawi.com/journals/jnm/2013/495708/

[9] Nuno M Neves, Rui Campos, Adriano Pedro, José Cunha, Francisco Macedo, Rui L Reis, *Patterning of polymer nanofiber meshes by electrospinning for biomedical applications,* In: International Journal of Nanomedicine 2007:2(3), pp. 433–448.

[10] Moustafa M. Zagho and Ahmed Elzatahry, *Recent trends in electrospinning of polymer nanofibers and their applications as templates for metal oxide nanofibers preparation*, available at: https://cdn.intechopen.com/pdfs-wm/53008.pdf

[11] Bara, A., Marinescu, V., Chitanu, E., Banciu, C., Clicinschi, F., *Influence of process parameters on the morphology of polyacrylonitrile electrospun fibers*, In: Industria Textila, 2015, vol. 66, nr. 4, pp. 232–239.

[12] A. Shankar, A-F Seyam, S. Hudson, *Electrospinning of soy protein fibers and their compatibility with synthetic polymers,* In: Journal of Textile and apparel Technology and Management, vol. 8, Issue 1, 2013.

[13] R. Dersch, M. Steinhart, U. Boudriot, A. Greiner and J. H. Wendorff, *Nanoprocessing of polymers: applications in medicine, sensors, catalysis, photonics,* In: Polymers for Advanced Technologies, 2005; 16, pp.276–282

[14] Banciu, C., Bara, A., Chitanu, E., Lungulescu, M., Ion, I., Leonat, L., *Filtering membranes based on electrospun expanded polystyrene/β-cyclodextrin fibers,* In: 10th International Symposium on Advanced Topics in Electrical Engineering (ATEE), March 23–25, 2017, Bucharest, Romania, IEEE, pp. 223–226.

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