FORMATION OF NANOFIBRES WITH PVA/CS SOLUTIONS VIA ELECTROSPINNING TECHNIQUE

Šateikė J[1], **Milašius R**[2].
[1] *Kaunas University of Technology, Faculty of Mechanical Engineering and Design*
[2] *Kaunas University of Technology, Faculty of Mechanical Engineering and Design*

jurgita.sukyte@ktu.edu

EXTENDED ABSTRACT

Nanofibres were electrospun from bicomponent poly(vinyl alcohol) (PVA) and modified cationic starch (CS) mixed solutions PVA/CS with different mass ratio (75/25, 50/50, 35/65) at total concentration 12 wt% for all polymer compositions. Electrospinning technique using rotating electrode with tines was used in this paper due to obtain better results in previously described work[1]. In this work the effect of prepared polymer solution compositions on the structure and morphology of nanofibers was investigated. Moreover, pure PVA was used with the condition that the results can be compared with bicomponent PVA/CS solutions. Analyzing the structure and morphology of formed nanofibers webs it was noticed that lower diameter was formed from the PVA/CS with mass ratio 50/50 and 35/65. Also, it is possible to see that lower density of nanofibers web was formed compared with results of the pure PVA solution.

Key words: poly(vinyl alcohol), cationic starch, nanofibres.

1. INTRODUCTION

Electrospinning is a highly versatile technique that is applicable to a large variety of material, cost effective and capable of controlling fibre morphology. This technique is increasingly being used to produce nano-scale fibres from a wide range of biopolymer materials [2, 3].
Many natural polymers have excellent properties such as biocompatible, biodegradability and non-toxic. However, natural biopolymers are more difficult to fabricate than synthetic polymers due to its chemical structures, poor solubility and high surface tension. These limitations can be overcome by blending natural and synthetic polymers [4]. Starch is one of the most abundant polysaccharides and inexpensive biopolymer. Starch is becoming increasingly common for the fabrication of nanomaterials by electrospinning technique [5, 6, 7]. For this reason the main objective of this study was to analyze what content of cationic starch CS into electrospinning solution is more suitable for the formation of nanofibers and compare results with the same concentration of pure PVA polymer solution.

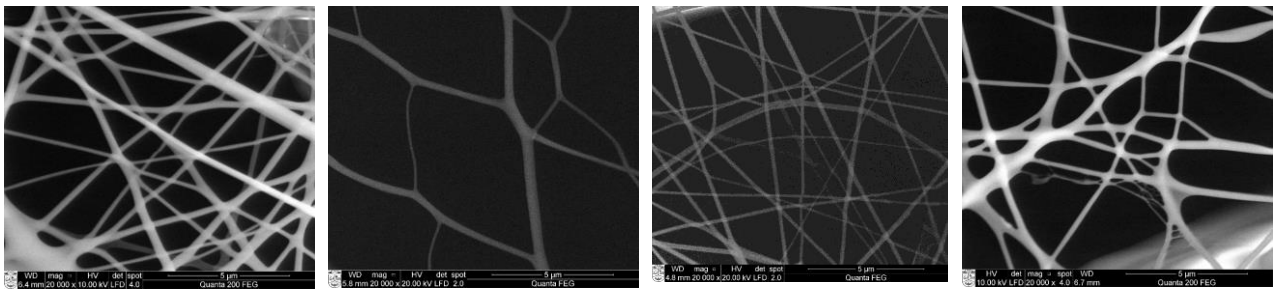
2. MATERIALS AND METHODS

Several types of polymer solution were prepared with a total concentration 12 wt% using electrode with tines for electropsinning process.
Electrospinning solutions of PVA/CS with different mass weight ratio 75/25, 50/50, 35/65 were prepared to find out which amount of CS is preferable for the electrospinng process. The pure PVA solution was prepared in order to compare the results of the electrospinning process with mixed PVA/CS solutions at different mass ratio.
Nonwoven material with nanofibres were formed by Nanospider (Elmarco, Czech Republic) electrospinning equipment. On this equiment's the rotating electrode with tines was covered by

a film of polymer solution. During all the experiments, the distance between the electrodes was 13 cm; the electrical potential applied varied between 35 and 70 kV; the temperature of the electrospinning environment was $t = 20 \pm 2$ °C, and the relative air humidity was $\varphi = 43 \pm 2\%$. The structure of non-woven material with nanofibres was determined using scanning electron microscope – (SEM) Quanta 200 FEG (FEI, Netherlands). The diameter of nanofibres was measured using image analysis system LUCIA 5.0 from every SEM image.

2. RESULTS AND DISCCUTION

Currently it is very complicated to form nanofibres using electrospinning technique from pure starch or starch derivatives. For this reason, in this work it was formed nanofibres from electrospinning solutions in which one of the components was modified cationic starch CS.
The previous work described the attempt to form nanofibres with a PVA/CS (mass ratio 75/25) solution at different concentrations (8, 10, 12 wt%) using two types of rotating electrodes: plain cylindrical and electrode with tines. The results showed that by using electrode with tines, the diameter of nanofibres was significantly decreased and nanofibres with higher density was formed. Furthermore, the concentration of the spinning solution using rotating electrode with tines had no effect on the diameter of the nanofibre. Meanwhile the concentration of the electrospinning solution had an effect on the diameter by using plain cylindrical electrode. For this reason, in this experiment part, nanofibres were electrospun from a solid concentration of 12 wt% PVA/CS polymer solution with the different mass ratio 75/25, 50/50, 35/65 using rotating drum electrode with tines.
The results showed, that it was possible to formed nanofibres of PVA/CS solution with mass ratio 50/50, 65/35 at the highest 65 kV and lowest 45 kV. Meanwhile electrospinning process with CS with mass ratio 75/25 into polymer solution and pure PVA allowed to form nanofibres at the highest 70 kV and the lowest voltage 35 kV. Hence, increasing CS content into the polymer solution had an infuence on electrospinning process. It was not possible to form nanofibres at lower (35 kV) applied voltage. All specimens in this work were electrospun at applied voltage 65 kV, as the process at high voltage is more intense than at the low voltage case.
The morphology of formed nanofibres was studied by SEM**.** SEM images of 12 wt% PVA and PVA/CS nanofibre webs with a different mass ratio (75/25, 50/50, 35/65) are presented in **Figure 1**. It was found out that electrospun nanofibres from pure PVA formed higher in density and diameter than PVA/CS with different amount of CS. This can be explained by the fact that blending PVA with other polymers, it does not allow nanofibres stick together.



a) b) c) d)

Figure 1. SEM images of nanofibrous webs: a) pure PVA; b) PVA/CS 75/25 mass ratio; c) PVA/CS 50/50 mass ratio; d) PVA/CS 35/65 mass ratio.

However, it is clearly observed that it was formed more stick nanofibres in the web from PVA/CS with mass ratio 35/65 solution. Therefore, it is possible to conclude that increasing the CS amount into the spinning solution was influenced for the morphology of nanofibre webs. The optimal amount of CS would be PVA/CS with mass ratio 50/50.

3. CONCLUSION

The quantity of starch in solution affects the electrospinning process – at a higher ratio of CS the higher applied voltage is needed for electrospinning process. While applying 70 V, which is acceptable for pure PVA and PVA/CS 75/25 ratio solutions, is too high for web formation using PVA/CS 50/50 and 35/65 ratio solutions – the discharges appear.
Analysing the morphology of nanofibre electropsun from 12 wt% PVA/CS solution with different mass ratio (75/25, 50/50, 35/65) it was noticed that increasing amount of CS into spinning solution the average diameter of nanofibres significantly decrease. The lowest average diameter of nanofibres formed from PVA/CS solution with mass ratio 50/50.

3. REFERENCES

1. Šukytė, J., Adomavičiūtė, E., Milašius, R., Bendoraitienė, J., Danilovas, P., Formation of Poly(Vinyl Alcohol)/Cationic Starch Blend Nanofibres via the Electrospining Technique: The Influence of Different Factors, Fibres & Textiles in Eastern Europe, 2012, 3 (92), 16-20.
2. Bhardwaj, N., Kundu, S.C., Electrospinning: A fascinating fiber fabrication technique, Biotechnology Advances, 2010, 28, 325-347.
3. Kleivaite, V., Milašius, R., Electrospinning - 100 Years of Investigations and Still Open Questions of Web Structure Estimation, AUTEX Research Journal, 2018, Vol.18, No.4, p. 398-404.
4. Talmoudi, H., Khenoussi, N., Adolphe, D., Said, A.H., Schacher, L., An in Situ Crystal Growth of Metal Organic Frameworks-5 on Electrospun PVA Nanofibers, Autex Research Journal, 2018, Vol 18, No.3, p. 308-313.
5. Adomavičiūtė, E., Milašius, R., Žemaitaitis, A., Bendoraitienė, J., Leskovšek, M., Demšar, A., Methods of Forming Nanofibres from Bicomponent PVA/Cationic Starch Solution, Fibres & Textiles in Eastern Europe, 2009, Vol. 17, No.3, p. 29-33.
6. Cardenas, W., Gomez-Pachon, E.Y.G., Munaz-Graziano, R., Preparation of potato starch microfibres obtained by electro wet spinning, Materials Science and Engineering, 2016, 138. 5.
7. Kong, L., Zeigler, G.R., Fabrication of pure starch fibers by electrospinning, Food Hydrocolloids, 2014, 36, 20-25.