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Formation of Chitosan Nanofibers by Electrospinning Method

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The paper presents the results of the preparation of the nanofiber coatings from chitosan biopolymer by electro-spinning. Structure and uniformity distribution of the fibers in the resulting coatings are investigated by a scanning electron microscope JEOL JSM-5610 LV. The optimum concentration of the chitosan solution in the mold, which provide forming nanofibers with fewer defects, was determined. The obtained data are used for the development of the technology for production of hemostatic and wound-healing dressings for medical purposes in order to organize their production at OJSC "Mineral Wax Plant".

Keywords: Chitosan nanofibers, Spinning solution, Electrospinning, Scanning electron microscopy, Nanofiber coating.

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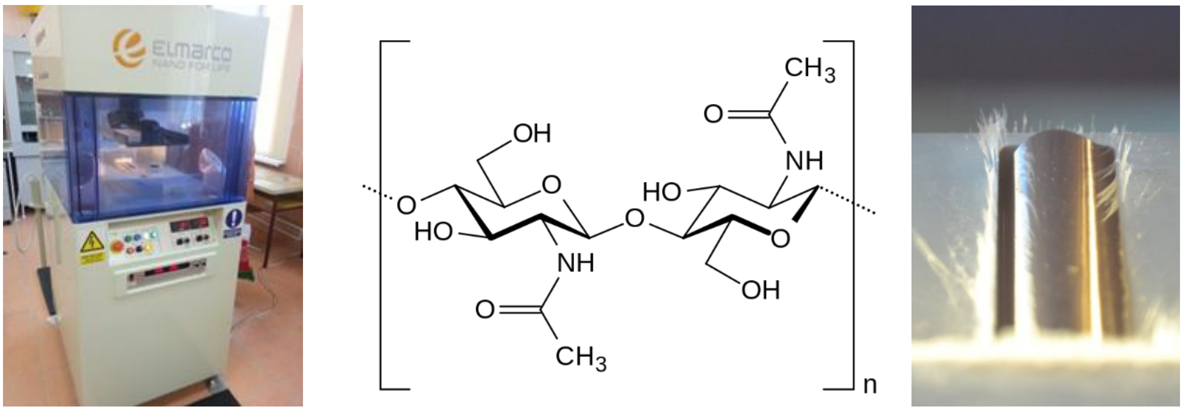
1. INTRODUCTION

In the field of nanotechnologies electrospinning from solutions of polymers of nanofibres by the Nanospider technology is the perspective way [1-2]. According to the equipment design and technology parameters fibers electro-spinning is referred to as a dry non-jetting method. In this method the initial deformation of the polymer solution, the subsequent transport of cured fibers at solvent evaporation and formation of the fibrous layer are carried out exclusively by electrical forces in a single workspace. One of the most promising technologies of nanofiber electroforming is Nanospider technology, which has several advantages to the traditional solution-capillary technology.

Nanofiber layers produced from biopolymers (chitosan, gelatine, collagen, polykaprolakton, etc., or combinations of these materials) can be used as a wound dressing for significant support of the wound healing process [3-4]. On the basis of results realized from in vitro and in vivo experiments, nanofiber materials have shown significant benefits. When using nanofiber material on contaminated wounds, it is possible to add antibacterial material and drugs to the nanofiber structure. Granulation and re-epithelialization of new dermal tissue can be enhanced by adding growth factor, and adding other materials which support proliferation of dermal tissue. The wound can be covered by a single nanofiber layer or it is possible to incorporate a nanofiber layer onto other carriers and cover the wound with this composite material [5].

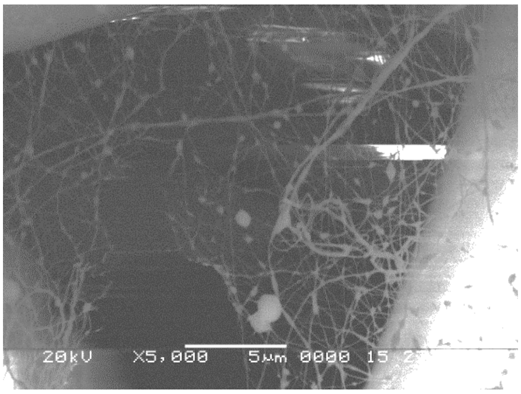
2. EXPERIMENTAL DETAILS

In this work Nanofibres from chitosan by the Nanospider technology on the NS WAB 500 S (“ELMARCO”, Czech Republic, Fig. 1a) are obtained. Chitosan produced from chitinte (Fig. 1b). The fiber formation occurs on the surface of the polymer solution wetting spinning electrode (Fig. 1c). High voltage in the polymer solution induces similar charges leading to elongation of the polymer solution in a thin stream. In the process of drawing the polymer electrostatic spray it may undergo a series of successive splitting into thinner jet at a certain ratio of the viscosity, surface tension and density of electric charges in the fiber. The obtained jets are turning into fiber, and under the action of electrostatic forces drift to the grounded substrate, which has opposite electric potential value. It should be noted that the polarity in the process of electrospinning can be reversed when the capillary is grounded, and the high voltage is applied to the substrate.



a b c

Fig. 1 – Laboratory tool NS WAB 500 “ELMARCO” (a), molecular structure of chitinte (b), process of electrospining (c)



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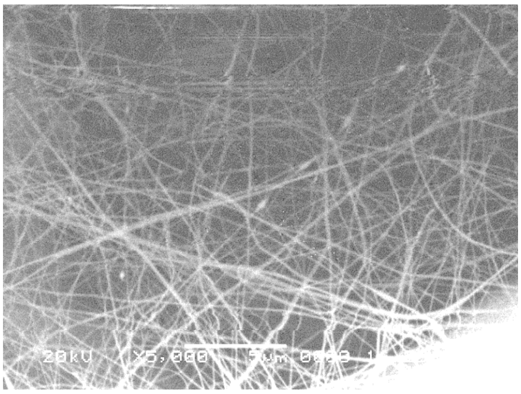

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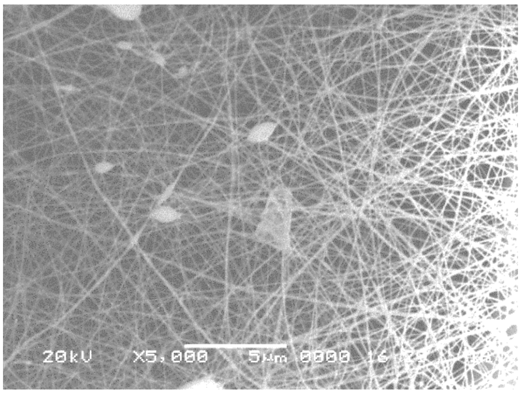

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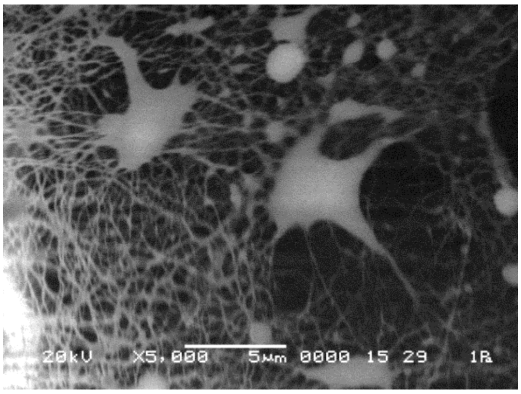

d

Fig. 3 – Material surface with nanofiber produced from a spinning solution with the concentration of chitosan: 1,0 wt. % (a); 2,0 wt. % (b); 3,0 wt. % (c); 4,0 wt. % (d)

3. RESULTS OF THE RESEARCH

The aim of the work was to investigate the structure and uniformity of nanofiber coating obtained at different concentrations of chitosan in the spinning solution and using substrates of different nature and density.

Fig. 2 shows photographs of the surface of the material with the nanofibers at different concentrations of spinning solution.

Regarding these data it is clear that increasing the concentration of chitosan from 1.0 wt.% to 4.0 wt.% in the spinning solution leads to defects in the coating of nanofiber in the form of droplets and spindle thickenings on fibers. The diameter of nanofibres ranges 20-250 nm. It is defined that the most reasonable concentration of chitosan (in the test interval) is 2.0 wt.%.

In next phase of the work electrode spacing was varied during the test, and it was as follows: 100, 133, 166, 200 mm. It helps to determine the optimum distance. The concentration of the chitosan solution was 2.0 wt.%.

In the case of interelectrode distance of 100 mm intensive formation of the Taylor cones was observed. The resulting coating was not uniform, with a large number of the defects (Fig. 4a). Acetic acid didn't have enough time to evaporate, so solvent odor kept for a long time.

Thus, increasing the electrode distance results in better drying of the fiber but decreases the Coulomb force. This adversely affects the formation of the Taylor cone. Findings of investigation have shown that the optimum distance is 166 mm. In this case a stable spinning of nanofiber coating occurs, which is characterized a small number of defects.

To determine the optimum voltage between the electrodes during the electrospinning of nanofibers tests were carried out at the following values: 60, 67, 73, 80 kW. The interelectrode distance was 166 mm, the rotational speed of the spinning electrode was 12 rpm.

At a voltage 60 kV between the electrodes intensive formation of the Taylor cone was observed, nanofibers coating was characterized by a small number of defects.

Increasing the voltage rises up the Coulomb force, which helps to reduce the spinning time, but in this case not all of the amount of solvent has time to dry and defects appear. Considering the research results the optimum (in this case there is a minimum amount of defects) voltage between the electrodes 67 kV is determined.

4. CONCLUSION

It is defined that the most reasonable concentration of chitosan (in the test interval) is 2.0 wt.%, in this case the process is stable, and nanofibres with a diameter up to 250 nm are formed.

Based on these results it was found the technological parameters of the electrospinning taken into account (interelectrode distance should be 166 mm, the voltage between the electrodes should not be higher than 67 kV) to manufacture high-quality uniform nanofiber coating. However, the use of different types of chitosan, substrates of differing nature and structure, may require adjustment of the electrospinning process parameters.

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