NANOFIBROUS MATERIALS PRODUCED BY AC BUBBLE SPINNING

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Abstract

Bubble spinning method is a broadly discussed topic in the production of nanofibers in last few years. Bubble spinning technology is the youngest of the current known spinning methods and therefore not all the possibilities of this method are explored in these days. The same case is spinning method which uses alternating current (AC). This study has investigated the combination of bubble spinning and AC spinning methods for producing submicron fibers. The study has evaluated the morphology of fibrous layers produced by combination of these technologies, and consequently its comparison to fibrous layers made separately by above mentioned methods. By using alternating spinning technology and novel bubble spinning technology we are able to achieve much more efficient production of polymeric fibers. Combination of these two methods simultaneously may bring promising possibilities in the future, for example in technical applications.

Keywords: Bubble spinning, AC Spinning, nanofibers, submicron fibres, spinning equipment

1. INTRODUCTION

Bubble spinning was mentioned in study of Ji-Huan He and his colleagues in 2007 for the first time [1]. This method utilizes electrostatic force for overcoming surface tension on surface of created bubbles. These bubbles are created on surface of polymer solution with the help of supplied air. Taylor´s cone, which is the source of spinning, is created on surface of bubbles thanks to this electrostatic force. Surface tension is dependent on geometry and size of a bubble. With the help of Young-Laplac equation we can express surface tension of a bubble [2]:

$$\sigma = \frac{1}{4} r \Delta P \tag{1}$$

Where σ is surface tension, r - radius of the bubble, and ΔP - pressure difference.

In the course of electrospinning a higher amount of bubbles is created on solution surface, this amount is very difficult to manage [1]. Nevertheless this phenomenon does not have a negative impact on industrial production of fibres as it would be the case of detailed scientific analysis of separate bubbles. Nowadays bubble spinning method belongs to modern technologies of electrospinning. Created nanofibers by this method can be used in massive production of fibres with lowered energy consumption in comparison to other spinning methods. Further advantage is the production of low diameter fibres [2], [3]. Fascinating process of this spinning method was the impulse for design of first spinning device in laboratory. This device was modified by connection to AC spinning device, created at Technical University of Liberec [4]. Combination of these two spinning methods could lead to higher efficiency of spinning by bubble spinning technology. The question is, whether AC voltage does not negatively influence final morphology of fibrous layer. To prove this hypothesis it has been necessary to analyse fibrous layer.

2. EXPERIMENT

2.1. Description of device

At the Technical University of Liberec there has been designed and built a construction of device for bubble electrospinning. This device consists of round metallic container of polymer and conductive tube. There is a hole for air supply, drilled at the bottom part of metallic container. This container is put into a plastic container and they are fixed to a conductive tube. Through this tube an air flow passes and it creates required effect (bubbles). At the same time this tube is connected to AC voltage source. Spinning is realized towards a flat collector, which can be positioned at optional distance. Scheme of device is described in the **Figure 1**.

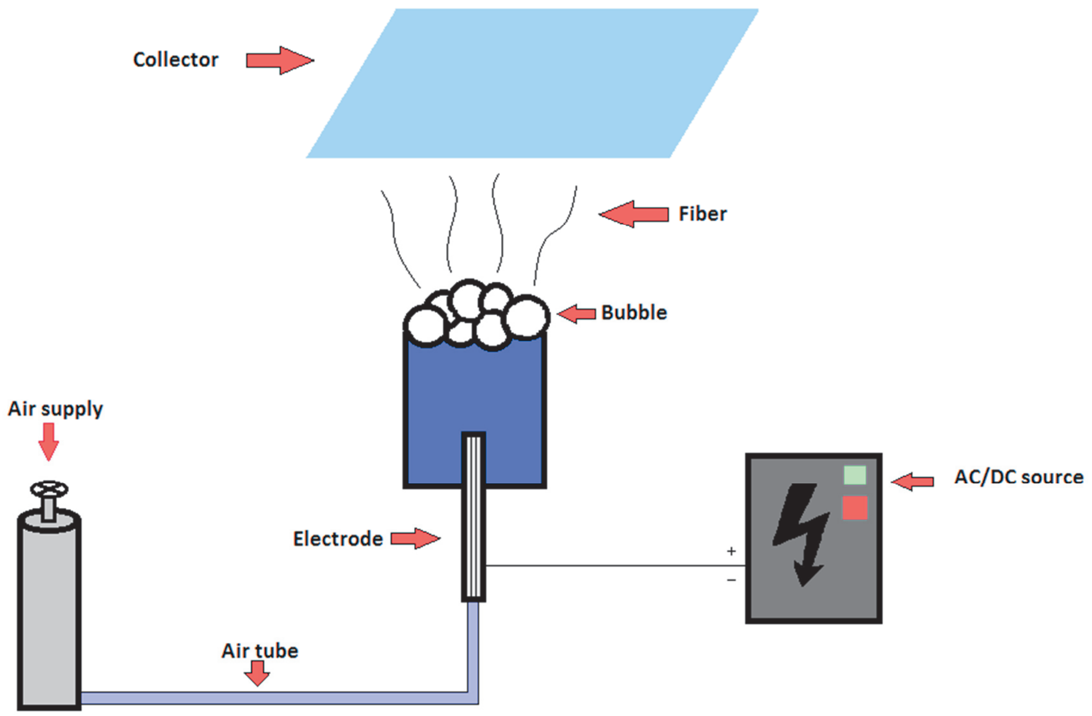

Figure 1 Scheme of device for AC or DC Bubble spinning

2.2. Experiment

AC Bubble spinning has been compared to AC needle electrostatic spinning and also to DC Bubble spinning. Average thickness of fibres and equivalent pore diameters have been analysed for all three technologies on the basis of this experiment. For spinning 12% wt polyvinyl alcohol (Mowiol 18-88, Mw 130 000, Sigma Aldrich) has been used. Distilled water has been used as a solvent. This solution has been stirred for 24 hours at the temperature of 100 °C. Concentration of 12% wt PVA has been chosen on the basis of best spinning process by bubble spinning technology and best final morphology of fibrous layer. Spinning has been realized onto a plate collector covered by spun bond, which has been positioned at the distance of 15 cm from spinning surface. The process has been realized at the temperature of 23.1 °C and relative air humidity of 61%. Within creating of fibres with the help of AC Spinning technology a flooding electrode with dosing 10 ml/h has been used. Images of fibrous layers have been analysed with the help of scanning electron microscope (SEM). 100 diameters of fibres have been measured and compared from images of each technology. Results of measurements have been statistically processed and analysed (**Figure 2**). Furthermore equivalent pore diameters of fibrous layer have been evaluated with the help of NIS software elements. Results of these measurements have been processed on the **Figure 3** and **4**.

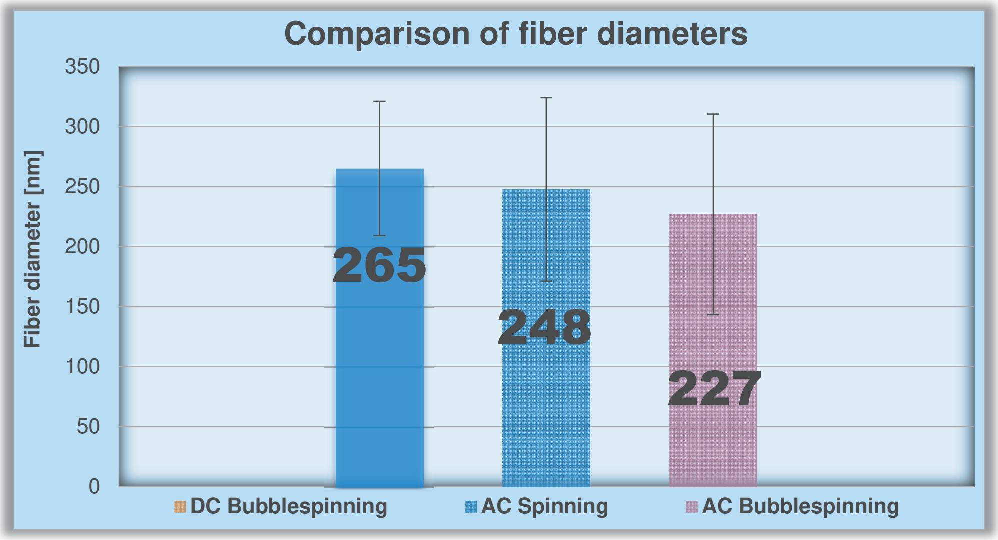

Figure 2 Comparison of fiber diameters

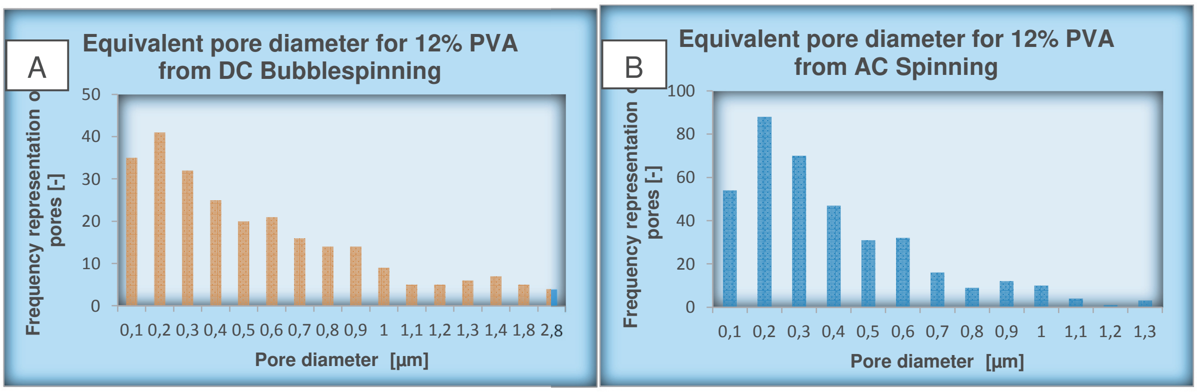

Figure 3 Equivalent pore diameter for 12 % wt PVA from: A) DC Bubble spinning B) AC Spinning

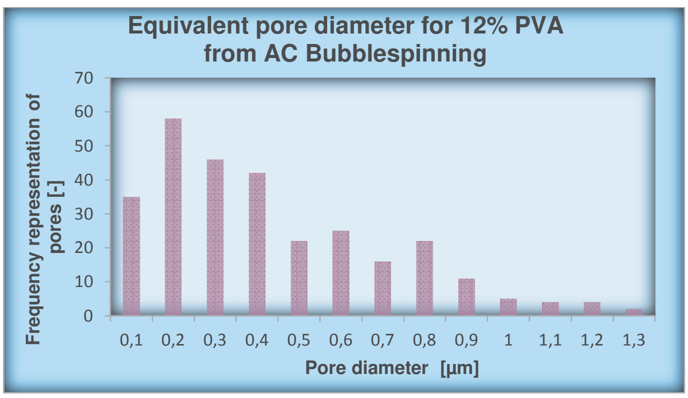

Figure 4 Equivalent pore diameters for 12 % wt PVA from AC Bubble spinning

3. RESULTS AND DISCUSSION

Figure 1 shows that bubble spinning method, with the help of AC voltage, is able to produce fibres with lower diameter than other two technologies. Average measured value has been 227 nm by AC Bubble spinning method; it has been 248 nm by AC Electrospinning technology. Average value (265 nm) has been highest within DC Bubble spinning technology. The lowest average value (0.44 ± 0.28 μm) has been within measuring of equivalent pore diameters of fibrous layer by AC Electrospinning technology. AC Bubble spinning technology has reached slightly higher value (0.48 ± 0.28 µm). Significantly higher average values have been measured by DC Bubble spinning technology (0.6 ± 0.5 µm).

4. CONCLUSION

This study has proven that AC Bubble spinning technology is able to produce lower diameter nanofibres with the use of 12 % wt polyvinyl alcohol solution than AC spinning and DC Bubble spinning technologies. At the same time this technology enables to produce nanofibrous layers with comparable equivalent pore diameter as AC Spinning technology. Thanks to this fact AC Bubble spinning technology could be applied in e.g. filter production, health care, but also in other sectors, where is suitable to utilize low fiber diameters.

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