THE EFFECT OF SUPPORTING MATERIAL TYPE ON THE NANOFIBER MORPHOLOGY

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Abstract

Nanofibers have the big potential to create absolutely new industries and application areas. In this study we demonstrated the effect of supporting material type on the fiber morphology such as diameter, diameter distribution and non-fibrous area. Poly (vinyl alcohol) (PVA), molecular weight of 88.000 g/mol was used as a polymer. Different supporting materials like polypropylene nonwoven antistatic material, black paper, various woven and knitting fabrics, carbon weaving and aluminium foil surface were used to collect the nanofibers. Nanofibrous materials were obtained using roller electrospinning method which has been known as Nanospider trade name. This method is one of the effective method to produce nanofibers at industrial scale which was invented by Jirsak et. al. from Technical University of Liberec. The same process parameters (solution concentration, voltage, distance between the electrodes, production time) were applied during the spinning process for all supporting materials. Then fiber morphology was analyzed using scanning electron microscope (SEM) and fiber diameter, diameter uniformity and non-fibrous area values were calculated. The best supporting material was determined after analysed the effect of supporting material type on the fiber morphology.

Keywords: PVA, roller electrospinning, supporting material, nanofiber.

1. INTRODUCTION

Electrospinning is the most popular and important nano-fabrication technology because of its advantages such as simple set up, spinning of wide range of polymers etc. Needle electrospinning was patented by Formhals firstly in 1930’ years [1]. In literature there are many studies about process parameters of needle electrospinning method to understand the mechanism and obtain optimum properties of nanofibers [2-5]. However there are only limited number of studies about process parameters of roller electrospinning [6-7]. Roller electrospinning method was invented by Jirsak et al. from Technical University of Liberec in 2005 [8]. This method is the unique to produce nanofibers at industrial scale and was commercialized by Elmarco under the Nanospider trade name. Nanospider can produce membranes collected fibers in a range from 100 to 600 nm of diameter. Such materials are widely utilized in many fields; as filtration, healthcare, building construction and many others [6]. The process parameters differ in some aspects from needle electrospinning method. In this study, we studied the type of supporting material on the collector which is independent process parameter of roller electrospinning method. In literature, there isn’t any study about this subject.

The aim of this study is analysing the effect of supporting material on the fiber properties such as diameter, diameter uniformity coefficient and non-fibrous area percentage. And also we aimed to determine the best supporting material on the collector for fiber properties.

2. EXPERIMENTAL

2.1. Material

In this work, poly(vinylalcohol) (PVA) polymer, molecular weight is 88.000 g/mol which was bought from Sigma Aldrich Company was used as a polymer and distilled water was used as a solvent. All solutions were prepared under the same conditions such as polymer concentration (10 wt % PVA), stirring time etc. Various
supporting materials such as polypropylene nonwoven antistatic material, black paper, plain weaving, twill weaving, carbon weaving, suprem knitting, lacoste knitting and aluminium foil were used to collect nanofibers during the spinning process.

2.2. Method

Roller electrospinning method which has been known as Nanospider trade name was used to obtain nanofibrous structures. The schematic diagram of this method was given in Fig 1.

Fig 1. Roller electrospinning system

Roller electrospinning method consists of three main part; rotating roller, high voltage supplier and collector electrode. A slowly rotating roller partially immersed into the polymer solution tank. Collector is usually grounded and polymer solution is connected to a high voltage supplier. During the spinning process, polymer solution is taken to the surface of the roller because of its rotation. After switched on the high voltage supplier, electrical field occurs between roller and collector electrode. And many Taylor cones [9] are created on the roller surface. The nanofibers are then transported towards the collector.

The same spinning conditions were provided during the spinning process. These spinning conditions such as voltage, distance between the electrodes, roller diameter, roller length and roller speed were given in Table 1.

Table 1: Spinning Conditions

<table>
<thead>
<tr>
<th>Voltage (kv)</th>
<th>Distance between collector and roller (cm)</th>
<th>Roller diameter (cm)</th>
<th>Roller length (cm)</th>
<th>Roller Speed (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>16</td>
<td>1</td>
<td>11.3</td>
<td>5</td>
</tr>
</tbody>
</table>

All spinning experiments were achieved under the room temperature and humidity and production time 6-8 minute for each sample.

The produced nanofibers were collected on different supporting materials such as aluminium foil, plain weaving, twill weaving, suprem knitting, carbon weaving, black paper, lacoste knitting and polypropylene nonwoven antistatic material. Then fiber morphology was investigated using a Scanning Electron Microscope (SEM). Fiber diameter, diameter uniformity and non-fibrous area percentage were calculated using Lucia 32G image analyse program.
3. RESULTS AND DISCUSSIONS

Up to now, generally polypropylene nonwoven antistatic material was used as a supporting material on the collector during the roller electrospinning process [10]. Fig 2 shows, SEM images of nanofibers which were collected on different supporting materials.

![SEM images of nanofibers collected on different supporting materials](image)

According to the SEM images of nanofibers, supporting material type has an important effect on fiber morphology. The best fiber morphology was obtained from suprem knitting and nonwoven fabric supporting materials. Figure 3 shows the effect of supporting material type on the fiber diameter. Generally fine and uniform nanofibers were obtained.

![Bar chart showing the effect of supporting material type on fiber diameter](image)

The lowest average fiber diameter value was obtained from polypropylene nonwoven fabric (303 nm). Coarse fibers were obtained from black paper (461 nm), carbon weaving (461 nm), suprem knitting (457 nm) and...
lacoste knitting (451 nm). It was also given in Figure 4, the effect of supporting material type on the fiber diameter uniformity coefficient.

![Graph showing the effect of supporting material type on the fiber diameter uniformity coefficient.](image)

**Fig 4.** The effect of supporting material type on the fiber diameter uniformity coefficient.

The most uniform nanofibers (uniformity coefficient is 0.97) were obtained from suprem knitting fabric as a supporting material.

Non-fibrous area percentage demonstrates the fiber density and refers to the quality of the spinning process. Therefore we also analysed the effect of supporting material type on the non-fibrous area percentage (Fig 5).

![Graph showing the effect of supporting material type on the non-fibrous area percentage.](image)

**Fig 5.** The effect of supporting material type on the non-fibrous area percentage

The lowest non-fibrous area percentage was obtained from suprem knitting (1.4 %) and nonwoven fabric (3.1). The highest non-fibrous area percentage was obtained from carbon weaving (25.5 %) and lacoste knitting fabric (27 %). Therefore fiber density is lower collected on these supporting materials and not useful to produce nanofibrous structures for high quality of the spinning process. It was also determined, the effect of supporting material type on the fiber diameter, diameter uniformity and non-fibrous area percentage is important statistically.

Another result from the experimental observations is about spinning rate increased using aliminium foil because of high conductivity of material. Fiber diameter is 420 nm, fiber diameter uniformity is 0.957 and non-
fibrous area percentage is 7.8 % with aluminium foil. It was also seen in literature, generally aluminium foil was preferred as a supporting material with needle electrospinning because of its good electric properties [11].

4. CONCLUSION
Roller electrospinning method depends on a wide range of independent and dependent parameters. Type of supporting material is one of the independent process parameter and in this study effect of supporting material type on fiber morphology was investigated. Generally nanofibers were collected on the nonwoven material showed good properties in terms of diameter, uniformity and non-fibrous area. The lowest average fiber diameter (303 nm) was obtained from nonwoven fabric, the most uniform nanofibers (0.970) were obtained using suprem knitting fabric and also the highest fiber density as well lowest non-fibrous area percentage (1.4) was also obtained using suprem knitting fabric.

Therefore we can say, type of supporting material has an important effect on fiber morphology obtained from roller electrospinning. The most useful supporting material in terms of fiber properties such as diameter, uniformity and non-fibrous area is suprema knitting and polypropylene nonwoven material to collect nanofibers during spinning process via roller electrospinning. On the other hand; carbon weaving, black paper and lacoste knitting fabrics are not useful supporting materials to collect nanofibers.

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REFERENCES