Applied Mechanics and Materials
ISSN: 1662-7482, Vol. 866, pp 244-247
doi:10.4028/www.scientific.net/AMM.866.244
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Submitted: 2016-07-26
Revised: 2017-01-13
Accepted: 2017-01-16
Online: 2017-06-06

The Development of Electrospinning Apparatus to Fabricate Nanofiber for Future Material Applications

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Keywords: electrospinning, apparatus, nanofibers, inexpensive

Abstract. This research examines the development of a low cost mobile electrospinning system for fabricating nanofiber. The electrospinning system developed in this study consists of a horizontal needle arrangement and a motor which supports the working system that controls the solution flow rate without an external syringe pump. In order to discover the equipment operating conditions for nanofiber fabrication, the distance from the needle to the target was studied. A PVA solution of 8wt% was used and voltage was applied at 13 kV. The needle to target distances were varied from 8-18 cm. At a distance of 10 cm, the SEM images showed that the smallest diameter of the fiber was 119 nm. The average diameter was in the range of 119-240 nm. Concentrations of the 3 different solutions of PVA, PEO and PCL with the variation of voltage at each concentration were studied. The results show the diameter of PVA at 8 wt% and 12%wt are in the range of 127-197 nm and 222-402 nm, respectively. The diameter of PCL solution at a 20 wt% concentration is in the range of 32-60 nm. PEO at 2 wt% and 4wt% was not able to form as a fiber.

Introduction

Electrospinning is a popular technique for producing nanofibers. The technique can be applied to generate fibers for a wide range of polymer applications such as biomedical engineering [1], filtration [2], electronics [3], batteries [4] and sensor technology [5]. Electrospinning has become the preferred technique in the production of nanofibers since it is cost effective, and requires simple tooling that is relatively easy to set up and use. In general, electrospinning apparatus consist of a syringe, a grounded collector and a high voltage power supply. In a typical fiber spinning process, a syringe is filled with a blended polymer solution and a high voltage is applied between the syringe nozzle and a collector. Nowadays, commercial electrospinning apparatus are too expensive for electrospinning researchers. Furthermore, commercial apparatus are costly to maintain and difficult to move. Many researchers attempt to design electrospinning apparatus that fit their workplace and applications. [6]

In this study, the apparatus was designed to be convenient for moving, space saving and inexpensive to set up. The electrospinning system developed in this study consists of a horizontal needle arrangement and motor which supports the working system that controls the solution flow rate without an external syringe pump. The apparatus was tested by using 3 base solutions of PVA, PEO and PCL and with different voltages and distances between tip and target.

Experimental Procedure

The electrospinning system developed in this study comprises of a horizontal needle arrangement with a steel structure and motor to support the working system that controls the solution flow rate (see Fig. 1). The use of a DC 10 rpm motor to power an internal syringe pump has been found to be more convenient than adding an external syringe to the system. In regards to the ground collector, a DC 12V 400 rpm was used to rotate the 304 stainless steel collector drum.

The rotating speed of the drum can be controlled through the switch controls. It was noticed from the detector that the drum and pump system ran smoothly.

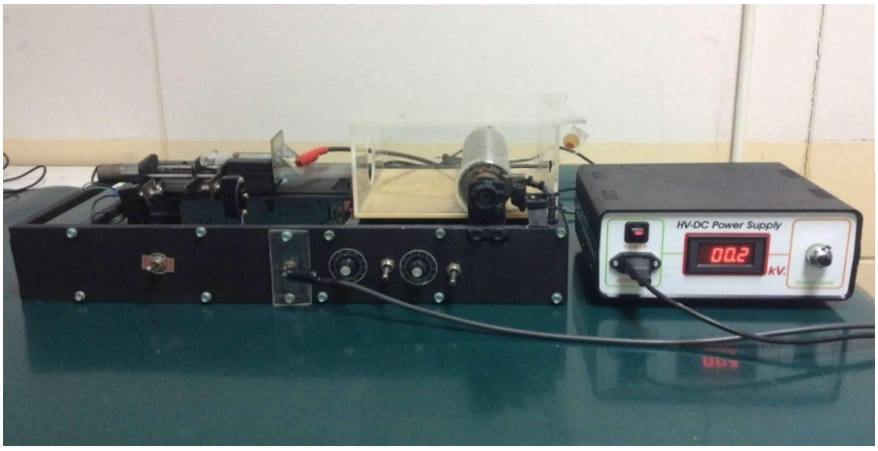

Figure 1. Shows the electrospinning set up used in this experiment.

PVA (Poly (vinyl alcohol), PEO (Polyethylene oxide) and PLC (Poly ε-caprolactone) solutions were used at various concentrations and voltage and distance between tip to target were adjusted in this experiment in order to gain an understanding of the operating system. Differences were observed from the SEM images.

Table 1. Show the studied parameter.

solutions	Distance from tip to target	Concentration	Voltage
	(cm)	(wt%)	(kV)
PVA	8, 10, 12, 14, 16, 18	8	13
PVA	10	12	10 -20
PCL	10	20	10 -20
PEO	10	2	6 - 10
PEO	10	4	6 - 10

Results and Discussion

Diameter of 8wt% PVA fibers applied at 13 kV with varying of the needle to target distances from 8 to 18 cm is shown in Fig. 2. A SEM image of 8wt% in PVA fibers at the distance of 10 cm was also shown in Fig. 2. Diameter of 8wt% PVA fibers were about 130, 119, 121, 129, 128 and 204 nm with the needle to target distances of 8-18 cm, respectively. The results indicated that diameter of 8wt% PVA fibers decreased as distances of the needle to target were increased.

The increase of distances from the needle to the target directly resulted on the longer duration for fiber elongation and more complete evaporation of the solvent. Therefore, the diameter of fibers decreased. An increase of the distance may cause a drop in the voltage intensity in the solution. This may result in less elongation of the fibers. It was discovered that the appropriate distance for this system was 10 cm. Thus, using a distance of 10 cm for different solutions would be reasonable.

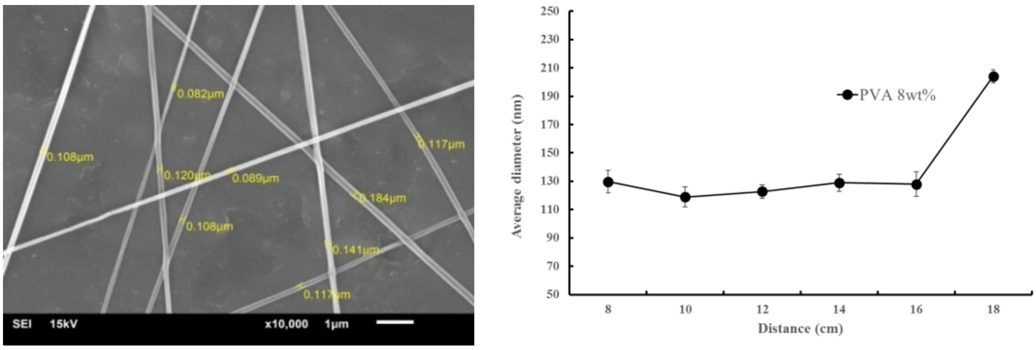

Figure 2. Diameters of 8wt% PVA fibers with varying distances.

To investigate the effect of voltage, 8wt% and 12wt% PVA fibers were fabricated by varying the voltage between 10-20 kV and with the fixed distance of needle to target at 10 cm. Their diameters were shown in Fig. 3. An SEM image of 8wt% PVA fibers fabricated at a distance of 10 cm is shown in Figure 3. Diameters of 8wt% PVA fibers were found to be approximately 192, 127, 197, 240, 172, 169, 161 and 158 nm at voltages at 10, 11,12, 13,15, 17 and 20 kV, respectively. Diameters of 12wt% PVA fibers were found to be approximately 352, 343, 392, 402, 362, 349, 315 and 222 nm at voltages of 10, 11,12, 13,15, 17 and 20 kV, respectively. Increasing the viscosity created higher surface tension of the solution, resulting in the decreased elongation of the fibers. Therefore, the diameter of the fiber increased. Furthermore, increased voltage resulted in the diameter of the fiber decreasing because there was more electrical force to extend the solution into fibers. This resulted in smaller fibers. The voltage was seen as stable from visual evidence taken from the fiber.

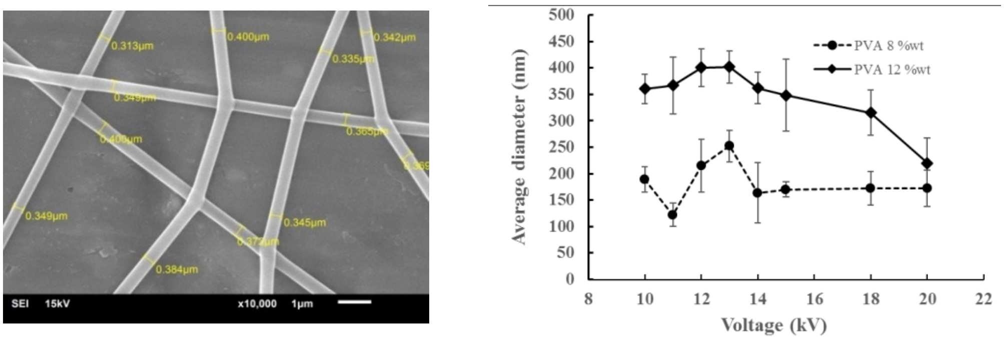

Figure 3. Diameters of 8wt% and 12 wt% PVA fibers with varying voltage.

Further investigation of the effect of voltage, found diameters of 20wt% PCL fibers were in the range of 32-60 nm at voltages between 10-20 kV with the fixed distance of 10 cm as shown in Fig. 4. Diameters of 20wt% PCL fibers appeared to decrease as the voltage increased. The results agree with those from S.A. Theron at al. [7]

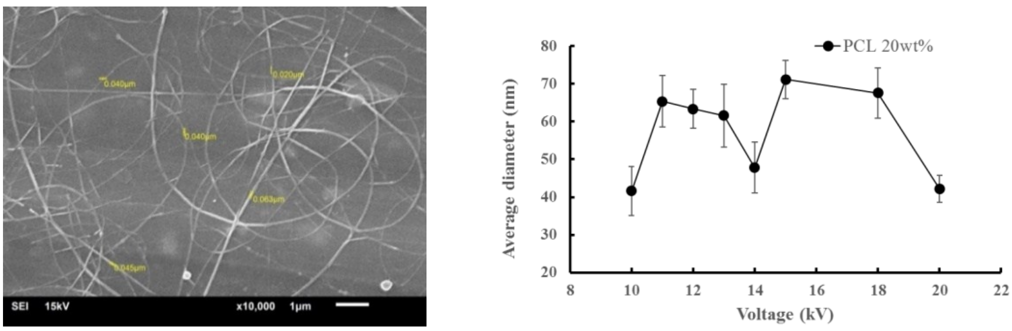

Figure 4. Diameters of 20 wt% PCL fibers with varying voltage.

SEM image of PEO at 2 wt% and 4wt% is shown in Fig. 5. It was not able to form as a fiber.

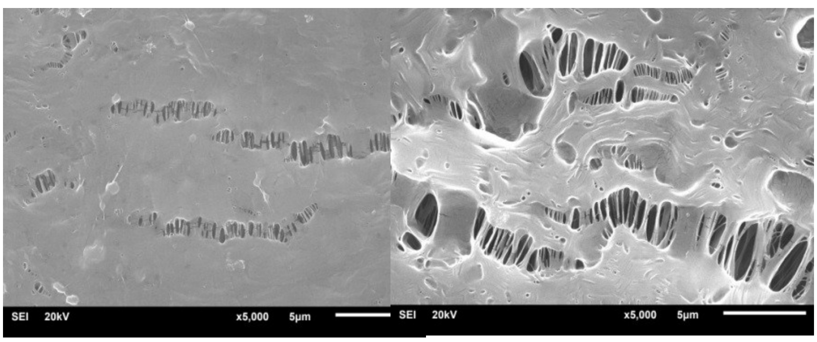

Figure 5. SEM image of PEO at 2 wt% and 4wt%.

Conclusion

This study discovered that the electrospinning apparatus used in this study could be produced at a lower cost than commercially available units. The apparatus was relatively simple to set up and use and produced fiber in the range of the nano scale. It can therefore be suggested that non-commercial, custom built electrospinning apparatus offer a cheap alternative for researchers with limited budgets. Further research should focus on producing a more adaptable version of the apparatus that can be used for greater applications.

Acknowledgement

This research was partially supported by Rajamangala University of Technology Krungthep (RMUTK). We thank Alan R. White from the Liberal Arts Department (RMUTK) and our colleagues who provided insight and expertise that greatly assisted the research.

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