ELECTROSPINNING PREPARATION AND CHARACTERIZATION OF SILVER FIBERS

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ABSTRACT

Electrospinning process is a technology which it was impulse the polymer jet solution in form of fuzzy nonwoven when the electrical charge was over than the surface tension. The valuable filler were adding in the solution for improving the properties. Also, Silver ion (Ag+)would add and prepare for bacteria protection fibers. The obtained fibers were continuous, anduniform. The preparation and fiber morphology were described in the following. This research was studied the behavior of fiber preparation then verified the morphology of electrospun fiber via scanning electron microscope (SEM). The relationship between the ratios of i-propanal to water as co-solvent was investigated. The appropriate ratio was 50%wt i-propanal what achieves the good performance fiber morphology. The voltage supplied was 6, 9, 12, 15, and 18 kilovolts (KV). The jet solution was droplet and gradually stretched to fiber form when the voltage was growth and completely at 18 KV. Finally, the length was 6, 7, 8, 9, and 10 centimeters. The fiber was packed form at 6 cm then uniform and continuous at 7 cm, after that the fibers were discontinuous. Finally, the silver fibers had 183.3 nanometer diameters. They were available for bacteria protection via AATCC test method 147-1998 (Quality).

Keywords:electrospinning process, co-solvent, polyvinyl alcohol, silver fibers, bacteria protection

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1. Introduction

Electrospinning process is not a new technology for polymer fiber production. It has been known since the 1930's to produce ultra-fibers from polymer, cellulose, and metal oxide by electrostatic force.The filament spun from the transforming was forming from sphere solution drop to elliptical from by driving force between electricity and solution viscosity. The electrospun fiber was extremely large surface to volume ratio. The diameter and the morphology of the fibers are influenced by the solution concentration, viscosity, conductivity, the solvent surface tension, and the strength of the applied electric field [1]. The electrospinning process may be modified so as to yield electrospun fiber with the desired morphology and properties.Thus it is important to have a basic understanding of the different group of materials before selecting the most appropriate electrospun fibers for specific applications.The electrospunfiber can be used in various applications asmembrane, filter media, tissue scaffolds, wound dressing, drug release, chemical & biology protective clothing, reinforcement, and energy&electrical applications. [2-6]

So, this research was aimed to study the behavior and morphology of spinning fibers via the factor inputs as lengths, viscosity then identified using for bacteria protection.

2. Experimental

2.1 Materials:1%w/w of Ag^{++} G100 Pdr powder from DKSH (Thailand) Limited, 20%w/w Polyvinyl alcohol ($(CH_2CHOH)_n$, Mw 30,000-70,000, 95 %) from Aldrich Chemicals and Propyl alcohol (i-Propanol), 99.5% from Fisher chemical. They were used without further purification.

*2.2 Fiber preparation:*The electrospun fiber was prepared form the viscous solution of dissolved Silver powder in co solvent solution. Silver power 1 wt% was dissolved and stirred continuously inco-solvent of water and i-propanol as 0, 10, 20, 30, 40, and 50 wt % of i-propanol presented. Then, itwasstirring vigorously until the viscous and clear solution was obtained. The solution was placed into a glass syringe with a metal needle size as0.55 x 25 mm. The tip was connected to a DC high voltage generator Model ES20P-20W from Gamma Voltage Research. A grounded aluminum sheet was used as a collector. The electrospun fiber was ejected in a fuzzy web form on the collectorthen dried at 80 ºC for 1 hour.

2.3 Solution viscosity: Theco-solvent solution between water and i-propanaolwas prepared and measured. They were observed the dissolving behavior and measured the viscosity by Rheometer Brookfield, Model DV-II.

2.4 Fiber morphology: The viscosity of the solution was using a viscometer. The fiber morphology was determined byHitachi S-510 with 20-30 kV energy.

2.5 Anti-bacteria test: The obtained fiber was verified the antibacterial protection for 2 methods as AATCC Test Method 100-1999 for quantitativeanalysis and AATCC Test Method 147-1998 for quality analysis.

3. Results and Conclusion

3.1 Solutionviscosity

The co-solvent is a solution that is formed by mixing more one solvent together. The mixed solvent becomes greatly enhancing the solvent power due to their synergism. In this study, i-propanol was used with water to form a mixed solvent for dissolving Ag^{++} powder and PVA. The varying i-propanol was 0, 10, 20, 30, 40, and 50 wt %, respectively. The viscosity of the mixture was measured and presented in Table 1.

Table 1 The effects of co-solvent ratio on solution viscosity

H_2O:i-propanol(wt.%)	Viscosity(Pa.s)
100:0	1
90:10	10.8
70:30	20.7
50:50	50.5
i-propanol> 50	N/A*(high viscosity for using)*

From Table 1, it wasevidently seen the wt% i-propanol influent on the solution viscosity. The solution viscosity was improved when increasing i-propanolwt% in co-solvent.The viscous solution was played from PVA solubility into co-solvent mixture. The main dissolving factor

was explained by the dielectric constant of a solvent. The dielectric constant is a relative measure of polarity. Water has a dielectric constant of 80 as high polarity, while i-propanol has a dielectric constant of 20 as semi-polar, and PVA has a dielectric constant of 2 (low polarity) at 20^{o}C [7]. It proposes that PVA can be run into i-propanol better than in water. There were two stages when a polymer dissolved in the solvent [1]. Firstly, solvent molecules diffused slowly into the polymer bulk to produce a swollen gel. Moreover, the polymer bonds were broke and formed true solution. Therefore, the addition of i-propanol as the co-solvent would enhance the solubility of the PVA and increase the viscosity of the solution as shown in Table 1. However, if the ratio of i-propanol is greater than 50wt%, the solution will stick. It was problematic to draw the fibers due to the cohesion effect on the metal needle tip. Hence, the 50 wt% i-propanol was an appropriated mixing solution and was chosen for further experimental.

3.2 fiber morphology

In this work were investigated the effect of applied voltage and the gap between ground collector and the needle tip that were taken to fiber morphology. Firstly, the voltage applied was varied from 6 – 18 kilovolts at 7 centimeters gab between of the needle tip and ground collector. A high voltage was a crucial element in the electrospinning process. It would induce the essential charge on the solution and the external electric field together. The electrostatic force must be higherthan surface tension to pulse the solution drop to distort into the shape of a Taylor cone. The fiber morphology was shown in Figure 1.

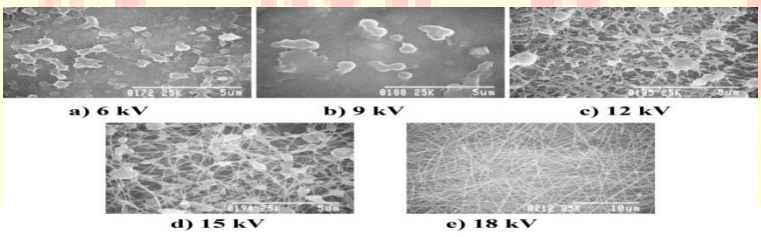

Figure 1 The effect of voltage supplied to fiber morphology

At the low voltage, the electrostatic force was not higher than the surface tension of the solution then the solution drop was not distorted into the Taylor cone and remained as a droplet

seen in Figure 1a) and b. Then, the higher voltage was supplied into the mixture solution. The great columbic force jet incident and the beads would change from spherical to spindle shape. An 18 kV electrical supplywas selected for fabrication the electrospun fiber. Not only electrical supply but also the gap between tip and collector was indicated the fiber morphology. It was relatedwith the flight time and the electric field strength. The electospun jet must have enough time for evaporating its solvents. This factor was a key role for controlling the fiber diameter. In this work was observedlength as 6 to 10 cm at 18 kV electrical supplies.

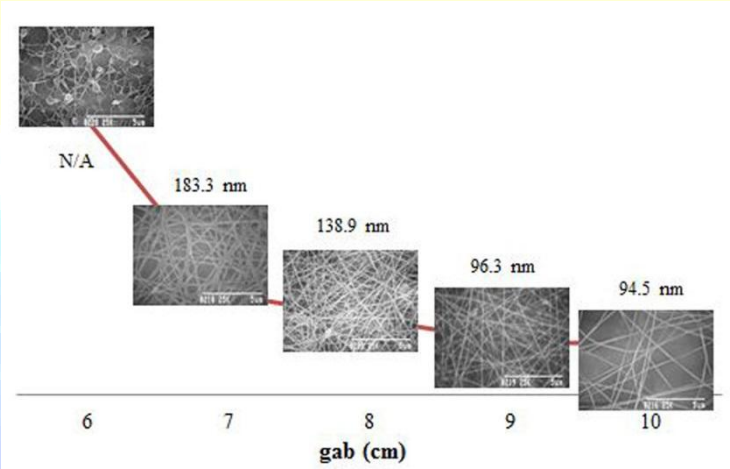

Figure 2 The effect of gap to fiber morphology

So, the lowest gab was 6 cm that the short time for fiber drawing. The fiber was connected by accumulated solvent as seen as Figure 2. Conversely, the spun fiber did not fall completely on the observed collectorat thelong distance.However, the greater elongation force on the electrospinning jet caused the more mobile smaller ions then it gavesmaller diameter fiber. Finally, 8 cm distance and 18 kV electric field were chosen for making silver fibers.

3.3 Anti-bacteria properties

Moreover, the electrospun fiber wasinvestigated for antibacterial test methods. It didn't found *Staphylococcus Aureus* Bacteria on sample by quality method via 147-1998 AATCC Test method. However, it could not against Bacteria along growing viaAATCC Test Method 100-1999. Hence, it was enhanced for bacteria protective than bacteria inhibitor.

Summary

This study found the silver electrospun fiber was prepared in 50 wt% of i-propanalto water as the good precursor. It could draw and achieve a good shape by using an 18-kV electrical supply. Also, the fiber morphology wasobviously and good performanceat 8 centimeters length of needle tip and aluminum ground collector. Moreover, the silver fiber was ability for *Staphylococcus Aureus* Bacteria protector.

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References

- Ramakrishna S., FujiharaK., TeoW.E., Lim T.C.and MaZ. 2005,***An introduction to electrospinning and nanofibers*.**World scientific publishing Co.Pte.Ltd, Singapore. pp 90-116.
- XueyuanTang, and Yuxi Yu. 2015. Electrospinning preparation and characterization of alumina nanofibers with high aspect ratio,***Ceramics International***, 41, pp 9232-9238.
- 3.RonariddhNakhowong. 2015. Fabrication and characterization of $MnTiO_3$ nanofibers by sol–gel assisted electrospinning,***Materials Letters,*** 161(15), pp 468–470.
- Attila Balogh, RichárdCselkó, BalázsDémuth, and *et.al.* 2015. Alternating current electrospinning for preparation of fibrous drug delivery systems,*International Journal of Pharmaceutics*, 495(1), pp 75-80.
- A.M. EL-Rafeim. Optimization of the electrospinning parameters of Mn_2O_3 and Mn_3O_4 nanofibers.***Ceramics International***, 41(9), pp 12065-12072.
- Rui Xu, Xiaofeng Zhang, Rita Chamoun, and *et.al.*Enhanced rate performance of $LiNi0.5Mn1.5O_4$ fibers synthesized by electrospinning.***Nano Energy***, 15, pp 616-624.
- Clipper Controls Inc. 2005. ***Dielectric Constant ReferenceGuide***. San Francisco, USA.