Synthesis of Nanofiber Polyvinyl Alcohol (PVA) with Electrospinning Method

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Abstract. PVA nanofibers are PVA solution-based nanofibers. PVA solution is a synthetic polymer that is non-toxic, soluble in air, and has excellent thermal, gas permeability, and chemical resistance qualities. Nanofibers were synthesized using PVA (Polyvinyl alcohol) solutions at concentrations of 8%, 10%, and 12%. The electrospinning method is used in this investigation, with input voltages of 17 kV and 20 kV, needle distances of 7 cm, 10 cm, and 15 cm from the collector, and a flow rate of 5 ml/hour for each concentration. An optical microscope was used to examine the nanofiber synthesis results in order to assess the morphology and diameter of the fiber. PVA nanofiber with the best fiber from electrospinning has a diameter of 1.06 µm and homogeneous fiber without beads is synthesized nanofiber with a variation of 10% PVA solution concentration, 15 cm distance from the syringe needle to drum collector, and 20 kV voltage.

1. Introduction

Nanotechnology is one of the most important and interesting fields of physics, chemistry, biology and engineering in recent years. One of the nanotechnology developments is nanoparticles. Nanoparticle research is growing rapidly because it can be widely applied in the fields of environment, electronics, optics and biomedicine [1]. Nanotechnology is a scope for study of nanosized materials ranging in size from 1–100 nm. These nanosized materials include nanofibers, nanowires, nanorods, nanocrystals, nanofoams, and nanotubes [2]. Currently, nanofibers are becoming the most desirable material because their applications in various fields such as drug delivery, catalysis, textiles, tissue engineering, filter media, cosmetics, and sensors [3].

Fabrication methods for nanofibers are various, such as electrospinning, centrifugal spinning, meltblown technology, phase separation, and template synthesis [2]. But the electrospinning method is most extensively used and most widely accepted [4]. This method has the potential to create infinite and continuous nanofibers [5]. This method can also make nanofibers with various surface topography and morphology from solution parameters, operational parameters, and environmental conditions [6]. The solution parameters consist of concentration, molecular weight, elasticity, viscosity, surface tension, and conductivity. The operational parameters are the pressure of the syringe pump, high electric voltage, and the spinning distance between the needle tip of syringe and collector drum. Parameters of environmental conditions are temperature and humidity [7].

The electrospinning process in which a polymer solution is charged by an electric field. The polymer solution is flowed at high voltage through a syringe. The polymer solution is removed from the tip of
the needle to form nanofibers continuously due to the high voltage. At that point, the droplets of the polymer solution at the tip of the needle form a cone called a Taylor cone [8].

Various synthetic polymers are used to produce nanofibers including poly glycolic acid (PGA), polyvinyl alcohol (PVA), polyurethane (PU), poly lactic acid (PLA), polylactic-co-glycolic acid (PLGA), and polyvinyl pyrrolidone (PVP), as well as natural biopolymers such as chitosan, collagen, gelatin and cellulose [9]. Of the many synthetic polymers, in this research using PVA due to the characteristics of PVA which is very soluble in liquids, in this case distilled water, non-toxic, has good thermal characteristics and chemical stability. PVA is also easy to obtain and can form fibers with small diameters, is homogeneous and can be used in various applications. [10]. Nanofibers with small and homogeneous diameters can be obtained by varying the synthesis process (electrospinning). According to research by Ewa et al. [11], the parameters that affect the fiber formed from the electrospinning process are voltage, flow rate, needle distance to collector, concentration, and solution viscosity, conductivity, temperature and humidity. To obtain the desired fiber, it can be done by adjusting the variation during the electrospinning process. Variations made in the manufacture of PVA fiber by electrospinning method include solution concentration, voltage, flow rate, and the distance of the needle tip to the collector drum.

2. Method

The research was initiated by making PVA solutions in various concentrations which can form fibers (8%, 10%, and 12%). The PVA solution was put into a syringe and put into an electrospinning device. At the time of fiber manufacture, variations are also made to the tension and distance of the needle to the collector drum. The diameter of the resulting nanofiber was measured and its morphology and homogeneity were observed with an Optical Microscope (Microscope Metalurgy BX53M Olympus).

2.1. Materials and Tools

The tools used in this study were 250 ml pyrex beaker, 5 ml pyrex measuring cup, dropper pipette, spatula, thermometer, aluminum foil, digital balance, magnetic stirrer, glass slide, 10 ml syringe, and Nachriebe 601 Electrospinning and for characterization using Microscope Metalurgy BX53M Olympus. While the materials used in this study were polyvinyl alcohol 72,000 g/mol (Merck) and distilled water.

2.2. Electrospinning Method

The electrospinning method is a technique for creating fiber used electric field. The electrospinning process is broken down into three steps, each of which is described as a jet model. The first stage is the initiation phase, which involves the creation of solution droplets at the needle end until the solution radiates towards the collector, causing the fiber's diameter to shrink. The second stage involves thinning the fiber diameter. The diameter of the fiber decreases as the distance between the tip of needle and the collector increases. Meanwhile, the third stage is the process of solvent evaporation and fiber freezing (jet solidification) [12]. The formed fiber is placed on a glass slide attached to the collector drum, so that it is easier to pick up and characterize it with an optical microscope to determine the diameter of fiber and its morphology formed.
2.3. Preparation of PVA Nanofibers
The basis material is PVA, which has a molecular weight of 72,000 g/mol. The PVA was used in the form of a PVA solution with concentrations of 8%, 10%, and 12%. Eight percent PVA solution was made by adding 8 grams of PVA into 100 ml of distilled water. Eight grams of PVA were mixed with 100 ml of distilled water to get an eight percent PVA solution. Ten grams of PVA were mixed with 100 ml of distilled water to make a 10% PVA solution. Twelve grams of PVA were mixed with 100 ml of distilled water to get a 12 percent PVA solution. The mixture was then agitated at 100°C until it was totally homogenous. Because PVA is hydrophilic, it may dissolve in water, adding aquadest to a PVA solution tries to dissolve it.

The resultant solution was then electrospinning at 17 kV and 20 kV, with a distance of 7 cm, 10 cm, and 15 cm between the needle tip of syringe and the collector drum, and a flow rate of 5 ml/hour and the electrospinning process time is 1 hour.

2.4. Nanofibers characterization method
The fibers generated as a result of the electrospinning process was characterized using an optical microscope (Microscope Metallurgy BX53M Olympus). It was used to examine the morphology of samples and determine the fibers diameter. It will be able to determine the best variation of voltage, distance between the needle tip and collector, and concentration of solution.

3. Results and Discussion
PVA solution with three different concentrations can produce fiber after electrospinning process. Overall, the resulting fiber has a diameter of less than 2 µm, where the largest fiber has a diameter of 1.45 µm and the smallest fiber is 0.42 µm. The diameter of the fiber produced with variations in voltage, concentration of PVA solution and the needle distance to the collector as shown in Table 1. Fiber diameter and fiber morphology were observed using an optical microscope, so that the accuracy of the diameter measurement results is still in micro units, so that higher accuracy needs to be measured with another characterization tool.

PVA nanofibers with a voltage variation of 17 kV mostly have smaller diameters than nanofibers with a voltage of 20 kV, this is contrary to research from Ewa et al [11], where the higher the voltage, the smaller the fiber diameter. However, the sample with a voltage of 20 kV is much more homogeneous than the sample with a voltage variation of 17 kV.

PVA nanofiber with a voltage of 20 kV has a fiber shape that looks neater, tighter, and stronger (Figures 2, 3, and 4). The nanofibers formed at a voltage variation of 20 kV also did not appear to have beads at all, unlike the nanofibers that used a voltage of 17 kV, where beads still formed on some parts.
of the nanofibers. In addition, although the diameter of the fiber in the 20 kV PVA nanofiber is larger than that of the 17 kV PVA nanofiber, the fiber with a strong morphology is more likely to be applied according to the PVA function in the process of forming fibers using the electrospinning method, namely as a polymer carrier material to be formed into nanofibers. Thus, the voltage variation that produces PVA nanofibers with the best morphological properties is at a voltage of 20 kV.

Table 1. Variations in solution concentration, needle distance to the collector, and voltage were used to test the synthesis of PVA nanofibers

| Concentration of PVA solution (%) | Needle distance to collector(cm) | Nanofiber diameter on 17 kV (µm) | Nanofiber diameter on 20 kV (µm) |
|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| 8                                | 7                                | 0.89                             | 0.90                             |
| 8                                | 10                               | 1.13                             | 1.45                             |
| 8                                | 15                               | 1.26                             | 1.11                             |
| 10                               | 7                                | 0.57                             | 0.42                             |
| 10                               | 10                               | 0.95                             | 1.17                             |
| 10                               | 15                               | 1.07                             | 1.06                             |
| 12                               | 7                                | 0.63                             | 0.83                             |
| 12                               | 10                               | 1.15                             | 1.35                             |
| 12                               | 15                               | 0.75                             | 1.04                             |

Figure 2. 10% PVA nanofibers with 7 cm needle distance to collector, (a) 17 kV voltage and (b) 20 kV voltage

Figure 3. 10% PVA nanofibers with 10 cm needle distance to collector, (a) 17 kV voltage and (b) 20 kV voltage
Figure 4. 10% PVA nanofibers with 15 cm needle distance to collector, (a) 17 kV voltage and (b) 20 kV voltage

According to research, homogeneity of nanofibers depends on the concentration percentage of PVA solution, the higher concentration will produce more homogenous PVA nanofiber. However, the diameter of the nanofiber was bigger at the greatest solution concentration, 12 %, than it was at a solution concentration of 10%. (Figure 5). The concentration of 10% nanofiber generated at a voltage of 20 kV was quite homogeneous (Figures 6, 7, and 8). So, in terms of solution concentration variations, a concentration of 10% is the best nanofiber.

Figure 5. Effect of solution concentration variation on PVA nanofiber diameter

Figure 6. 20 kV PVA nanofiber with 7 cm needle distance to collector, (a) 8 % concentration, (b) 10 % concentration, and (c) 12 % concentration
Figure 7. 20 kV PVA nanofiber with 10 cm needle distance to collector, (a) 8% concentration, (b) 10 % concentration, and (c) 12 % concentration

Figure 8. 20 kV PVA nanofiber with 15 cm needle distance to collector, (a) 8% concentration, (b) 10 % concentration, and (c) 12% concentration

PVA nanofiber diameter with 7 cm needle to collector distance creates nanofibers with the smallest diameter than 10 cm and 15 cm distance, but 7 cm needle to collector distance produces inhomogeneous nanofibers, according to the modification of needle to collector distance (Figure 9). In this investigation, the best fiber morphology with variations in needle distance occurred when the distance was set to 15 cm. This is because the diameter of the nanofiber is less at a distance of 15 cm than it is at the distance of 10 cm. Furthermore, fiber morphology is more homogenous, stronger, and neat at a distance of 15 cm than at a distance of 10 cm (Figure 10).

Figure 9. Effect needle distance to collector variation on PVA nanofiber diameter
Variations in voltage, concentration of PVA solution, and the distance between the needle and the collector all have an impact on the shape of the resultant fiber, as seen above. When the voltage variation is 20 kV, the concentration of PVA solution is 10%, and the distance between the needle and the collector is 15 cm, the results of the research on manufacturing PVA nanofibers in terms of morphology are the best.

4. Conclusion

Variations in the voltage used, the solution concentration, and the distance between the needle and the collector could all affect the condition of the nanofiber formed. The generated PVA nanofibers had the optimum morphological circumstances at a voltage of 20 kV, a concentration of 10% PVA solution, and a distance of 15 cm from the needle to the collector, according to the study's findings. The nanofibers in this version feature were strong, neat, homogenous fibers with a diameter of around 1.06 μm.

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