Conference Paper

Synthesis of Electrospun Nanofibers Membrane and Its Optimization for Aerosol Filter Application

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Abstract

Nanofibers membranes were synthesized using electrospinning method for air filtration application. Polyacrylonitrile (PAN) with three different concentrations as the polymeric matrix of the nanofibers membrane is used. In the aerosol filtration, the pressure drop is one of the most important parameters, which is determined by the membrane characteristics. One of the parameters that influence the characteristics of membrane is concentration of polymer solution, in which it will determine the diameter of fiber. In this study, the relation between the PAN concentration and the pressure drop in air filtration test was examined. Three different concentrations of PAN solution (6, 9, and 12 wt.%) were employed under the same process parameters of electrospinning. The fiber diameter distribution of each membrane was measured from its scanning electron microscope (SEM) image. The three concentrations resulted in significant different effect to the pressure drop that proved the existing correlation between the polymer concentration and the air pressure drop.

Keywords: nanofiber membrane, electrospinning, concentration, pressure drop

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1. Introduction

Air pollution is caused by the presence of other material substances in air such as dust, smoke, and others, which are harmful and contaminated in large quantities. Nowadays, air pollution happens more frequently along with the rapid population growth. Polluted air contains toxic substances which are fine particles with diameters ranging from 0.1 to 2.5 μm (PM2.5) [1]. Fine particles in air, which is called as aerosol, are the major cause of respiratory disorders. Separation between air and its pollutant is one way to solve the pollution problem. Researches regarding the air pollution problem are thus related to the finding of media that can separate the air and its pollutant. A filtration method by means of nanofibers materials is believed to answer the air pollution problem. Nanofibers membrane can capture fine particles from the aerosol flow through pile of fibers and pass the clean air through the pores [2-4]. Good distribution of membrane porosity can then increase the filtration efficiency [5,6].

There are diversely wide range of techniques to produce nanofibers and electrospinning is one of the simplest techniques [7,8]. The nanofibers obtained via electrospinning technique can be applied to various fields such as filters, biomedical tools, energy and sensor [9-10]. The morphology of nanofibers depends on various factors such as viscosity, conductivity, surface tension, flow rate, rate of solvent evaporation, voltage, and electric current [11]. In filter application, the efficiency of membrane can be optimized by adjusting the morphology and structure.

Recently, we have successfully synthesized nanofibers membrane from polyacrylonitrile (PAN) material for antibacterial activity in water filtration application [12]. Some researchers have tried to use PAN in air filtration application [4,5,13]. However, they did not discuss in detail about pressure drop and its relation to the concentration of polymer solution. Excellent air filters have special characteristics such as high particle collection efficiency, low pressure drop, and long lifetime [14]. Pressure drop is a very important parameter in air filter testing, because it is related to pressure or energy being applied in filtration process. Moreover, pressure drop is greatly affected by the shape and morphology of the membrane such as thickness and porosity [5]. The membrane porosity is also influenced by fibers diameter that can be controlled by adjusting the concentration of polymer solution [11]. In this study, PAN membranes were produced by employing different concentrations for air filtration application. The effect of each concentration to the pressure drop was then analyzed.

2. Experimental

2.1. Materials

The materials used in this experiment included polyacrylonitrile (PAN) with molecular weight of 150,000 g/mol and N,N-dimethylformamide (DMF) solvent; both were obtained from Sigma Aldrich. The PAN was dissolved in DMF to produce a suitable concentration of the polymer solution. The calculation of polymer (solute) weight concentration and solvent is calculated by weight percentage (wt.%) using Eq. 1.

$$C = \left(\frac{X}{X+Y} \times 100\right)\ wt.\% \tag{1}$$

where X is the weight of solute and Y is the weight of solvent. In this experiment, three concentrations of PAN solution were made, i.e., 6, 9, and 12 wt.%.

2.2. Electrospinning

Figure 1 shows the schematic of a Nachriebe 600 electrospinning system that we have developed. The system uses a high-voltage power supply with a high voltage flyback transformer (HVFBT). A syringe, where the polymer solution is contained, is placed on a syringe pump with controllable flow rate. A metal drum collector that can be rotated with controllable speed is used. The system is also equipped with a camera with a high magnification to observe the shape of jet at the tip of the syringe in real time. To

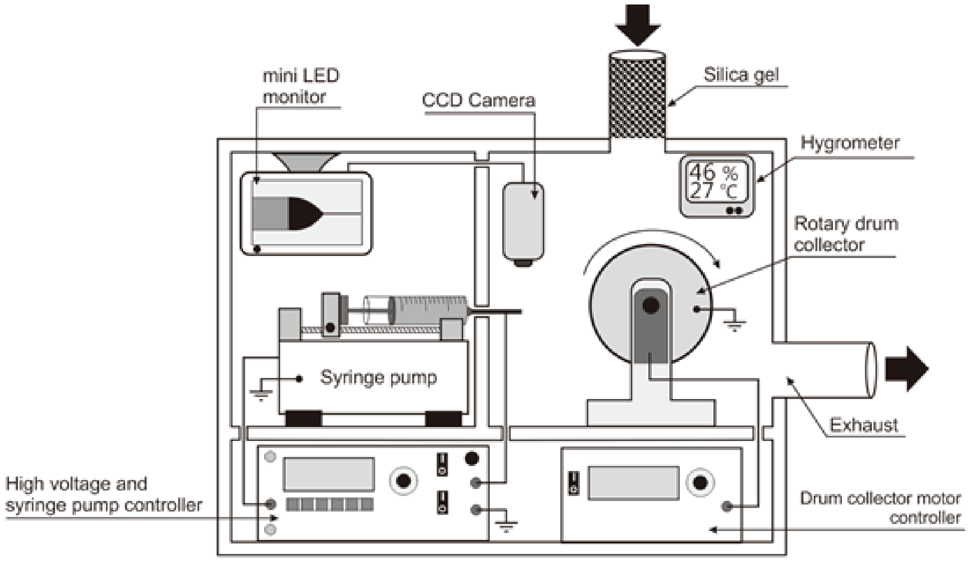

Figure 1: A schematic diagram of Nachriebe 600 electrospinning system.

control the relative humidity, silica gel and the exhaust is used to circulate the dry air into chamber.

2.3. Membrane Filter Test

Figure 2 shows the schematic of developed air filter test system. Air is pumped to undergo an initial filtration in the foam filter and then flowed through a buffer to collect the air. The collected air is subsequently dried in the diffusion dryer using silica gel. After dehumidification, the air is filtered again using a HEPA filter. The dehumidified air is then flowed with controllable flow rate through the membrane filter under test. The pressure drop, which is the pressure difference of two sides of the membrane filter, is measured using Sensirion SDP600. The pressure drop in this condition was controlled by changing the air flow in the flowmeter 2 while keeping the air flow in the flowmeter 1 constant. As the pressure drop sensor Sensirion SDP600 output is digital, a microcontroller system was employed to process the data.

3. Results and Discussion

3.1. Electrospun fibers

A sheet of cloth was used as a wrapper to the metal drum collector to ensure easy removal of the obtained fibers membrane. In order to produce a desired thick membrane, the electrospinning process lasted for 4 hours. Figure 3 shows a photograph of the obtained membrane on the cloth collector. SEM images of the obtained membranes for different concentrations are presented in Fig. 4. It is shown that the PAN membranes obtained from the concentrations of 6, 9, and 12 wt.% have different fibers diameter distributions with average diameters of 0.6, 0.8, and 1.2 μm, respectively. In

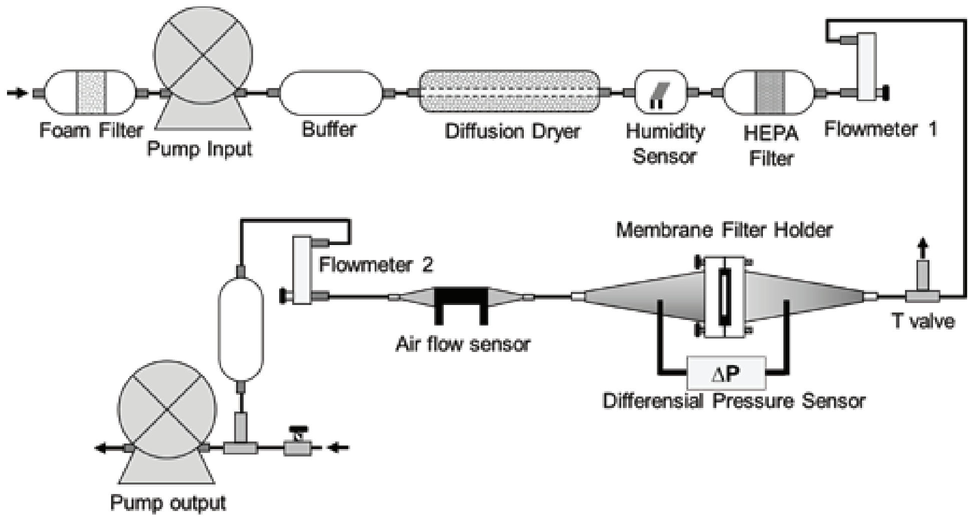

Figure 2: A schematic diagram of the aerosol filter test for pressure drop measurement.

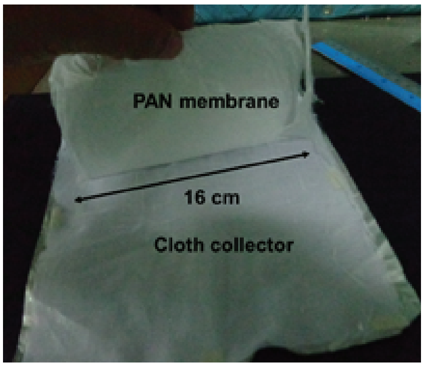

Figure 3: A photograph of PAN nanofibers membrane exfoliated from the cloth collector.

addition, as given in Fig. 4(c), the fibers membrane obtained from 12 wt.% in concentration is more uniformity fiber than the others. This result is similar to those have been reported by Munir, et al. and Zhang, et al. [11,15]. Note that uniform fibers has good characteristic in porosity, and it thus increases the efficiency of filtration.

3.2. Aerosol Filtration Test

Figure 5 shows the pressure drop measurement as a function of air flow. The pressure drop rises with the increase of air flow as described by the Darcy's law stating that the air flow or debit Q is given by Eq. 2.

$$Q = \frac{KA}{L}\Delta p \quad (2)$$

where Q is the air flow or debit, K is the Darcy constant, A is the area of membrane, L is the thickness of membrane, and Δp is the pressure drop.

Moreover, it has been found that the pressure drop increases with increasing the concentration of polymer solution. It can be explained by looking at Fig. 4 in which the

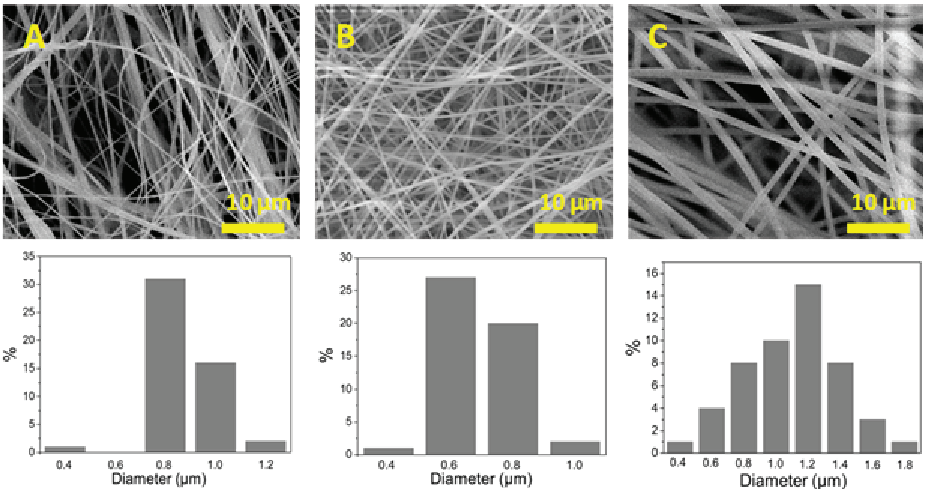

Figure 4: SEM images of PAN membranes obtained from the polymer solution concentrations of (a) 6, (b) 9, and (c) 12 wt.%.

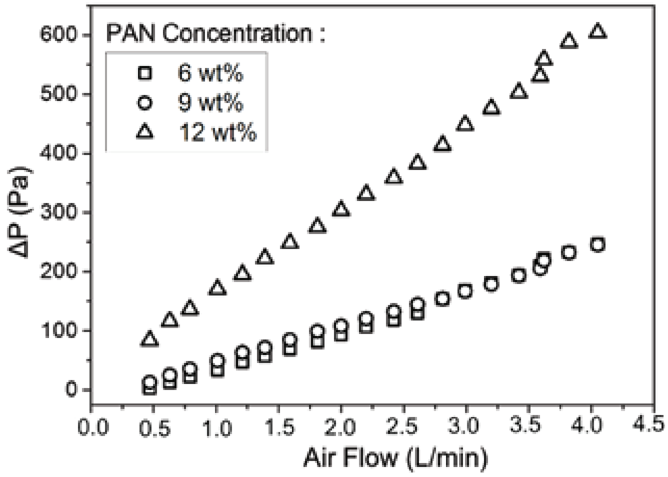

Figure 5: Pressure drop characteristics from each membrane.

average fiber diameter increases with the increase of polymer solution concentration. Larger fiber diameter will make the pores of membrane become smaller and it causes air difficult to flow through the membrane so that the pressure drop increases.

4. Conclusion

Nanofibers membranes of polyacrilonitrille (PAN) has been prepared by using electrospinning with three concentrations (6, 9, and 12 wt.%) of PAN solution. It has been found that the increase of polymer concentration caused the fibers diameter increases and its fibers diameter distribution became more uniform. The membrane obtained from the PAN solution concentration of 12 wt.% had the best morphology because of its homogeneity in fiber diameter, but the highest pressure drop as compared to the concentrations of 6 and 9 wt.%.

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