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The effect of solvent ratio on polystyrene and nylon 6,6 nanofibers membrane

Hassaneltrabi Tajuddin Alssir Ahmaydy, Abdull Rahim Mohd Yusoff
Department of Chemistry, Faculty of Science, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia
Corresponding Author: h.ahmaydy@outlook.com

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ABSTRACT

Synthesizing nonofibers with certain physical, chemical and mechanical criteria for different application is highly demanded nowadays. To obtain these properties, field emission scanning electron microscope (FESEM), contact angle and tensile strength measurement can be used to characteriz it. Thus, this study is about synthesizing nonofibers using binary solvent system at different volume ratios which can provide information about the properties of the nanofibers. In this project, two polymes were electrospinned i.e Polystyrene (PS) and Nylon 6.6 with DMF/THF and Acetic Acid/Formic Acid two solvent systems respectively. The ratio of the solvent for each polymer were as follows: (50:50, 75:25, 25:75, 100:0 and 0:100). The average size of the three nonofibers membrane for PS is 0.91, 1.32, 1.42, 1.26 and 6.02 µm respectively. For Nylon 6.6 only three membrane were obtained due the insolubility of some of the solvents ratio and the average size were obtained 66.45, 71.77 and 58.96 nm corresponding to the ratios of (50:50), (25:75) and (0:100) Also, the tensile strength for PS membrane 0.3402, 1.1959, 1.2778, 0.5241 and 1.2069 MPa according to the following ratios; (50:50), (75:25), (25:75), (100:0) and (0:100). Moreover, tensile strength for Nylon 6.6 were 3.7957, 3.4867 and 3.6769 MPa corresponding to the following solvent ratio; (50:50), (25:75) and (0:100). Also the contact angle 124.58°, 112.70°, 124.78°, 112.27° and 137.53° according to the following sequence; (50:50), (75:25), (75:25), (100:0) and (0:100). Also, the contact angle of Nylon 6.6 with the following ratio (50:50), (25:75) and (0:100) were found to be 42.58°, 43.62° and 52.53°. The effect of the solvent concentration dose play a role in changing the properties of the fiber such as the morphology diameter and contact angle.

Keywords: nanofiber membrane, Polystyrene (PS), Nylon 6.6, solvent ratio, physico properties.

1. INTRODUCTION

Electrospinning is an interesting process for producing non-woven fibers with the average diameters in the range of micro to nanometers. In this process, a continuous filament is drawn from a polymer solution through a spinneret by high electrostatic forces to deposit on a grounded-metal collective screen [1]. The appearance of the collected fibers depends on many factors: (a) viscoelastic force which has been found to depend on solution concentration , molecular weight average of the polymer, and viscosity of the solution, (b) surface tension which has been found to depend on solution concentration, molecular weight average of the polymer, and surface tension of the solvent [2], [3] (c) gravitational force which is dependent on solution density, and (d) electrostatic force which has been found to depend on the applied electrostatic field (i.e. an applied electrostatic potential divided by a collection distance) and the conductivity of the solution [4]. (e) contact angle which depend about the hydrophobicity and hydrophilicity of the membrane itself.

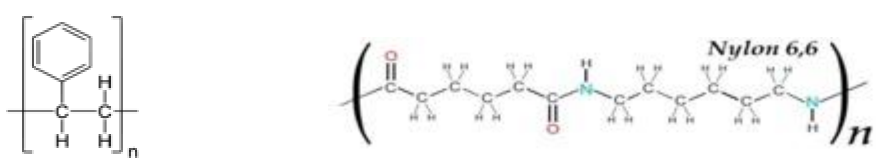


Figure 1 General chemical structures of PS and Nylon 6.6 accordingly

The scope of this study is to synthesis and characterizing of the membrane to determine the effect of the solvent ration in two system solvent. Two different polymers (PS and Nylon 6.6; see **Figure 1**) were used to synthesize the memranes with binary solvents system (DMF/THF) and (Acetic Acid/Formic Acid) for each polymer. For the characterization to determine the micro-structure and diameter of the fibers field emission scanning electron microscope (FESEM) imaging were obtained. Also, the data of tensile strength and contact angle were collected. The significant of this study to provide data about nanofiber membrane for further studies or for specific application since single nanofiber membrane cold take up to 50 laboratory hours. Therefore this study will save a lot of time for other researchers.

2. EXPERIMENTAL

The experiment was divided into two main parts. The first part was about the synthesis of the nonofibers memrane of both polymers with different solvent ratio. In addition, the second part was focused about obtaining the physical properties of the membrane . In order to synthesize PS and Nylon 6.6 electrospun the polymer must be dissolved in solvent (DMF/THF and Acetic Acid/Formic Acid) of 20% and 14% (w/v) respectively with five different ratio (50:50, 75:25, 25:75, 100:0 and 0:100). Moreover, the electrospinning machine parameters were, Injection flow rate = 1.60 mL/h, needle size = 0.6 μm, drum speed = 504 rpm at the working distance = 150 mm for PS. On the other hand for Nylon6.6 Injection flow rate = 1.50 mL/h [5], needle size = 0.6 μm, drum speed = 504 rpm at the working distance = 150 mm with applied voltage of 15.0-15.1 kV and 26.0 kV; see **Figure 2** for PS and Nylon 6.6 respectively. After finishing the first part, FESEM, tensile strength and contact angle was conducted [6]. For FESEM, small square with diameter of 0.5 cm. Then, the sample will be introduced to the machine with display screen to show the magnified image with controlling it with certain tools to zoom in or out. Also, the tensile strength test need specific diameter of (7cm x 1.5 cm). After that, the membrane will be taped at the top and bottom starting from its edge to 2 cm height from both edge to be hold by the machine clips to be stretched to record its tensile strength. Moreover, contact angle were obtained by introducing drops of treated water onto surface of the membrane with diameter of (100mm x 0.5 mm).

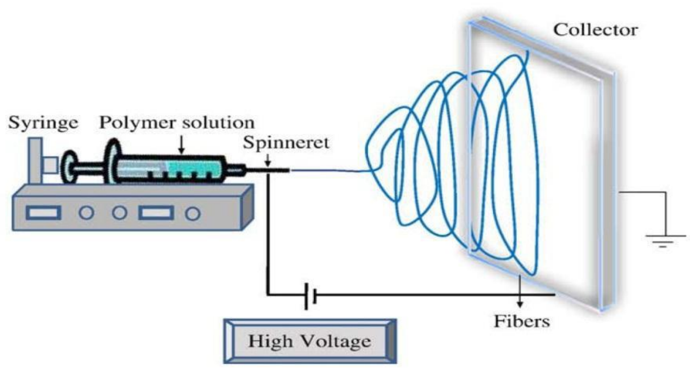


Figure 2 Electrospinning setup

3. RESULTS AND DISCUSSION

3.1. Polymer Fabrication of PS and Nylon 6.6

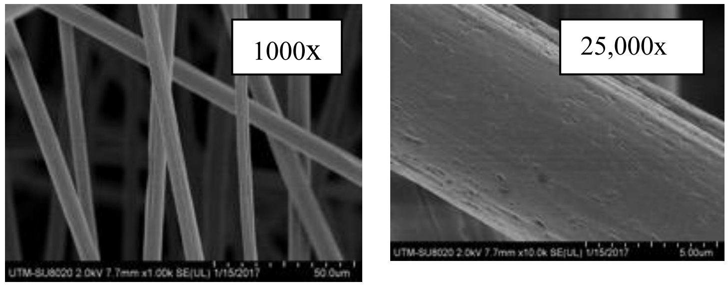
The synthesis of the membranes of PS was successful for all the solvent ratio of DMF/THF. Unlike Nylon 6.6 which could not be dissolved when the ratio of Acetic acid (75:25, 100:0). The reason is that Acetic Acid is not preferred as solvent for Nylon 6.6 in one solvent system but it will help to dissolve if it was a part of two solvent ratio as minority in the solution.

3.2. Characterization of Fibers Diameter of FS and Nylon 6.6

Characterization of **PS** FESEM image showed that the average diameter of fibers were 0.91, 1.32, 1.42 1.26 and 6.02 (μm) corresponding to the solvent (DMF/THF) as shown in **Figure 3** with the ratio of (50:50, 75:25, 25:75, 100:0 and 0:100). The images with magnification of 1000x and 25,000x for each sample shows different surface roughness due different boiling point of solvents in the system. DMF has boiling point of 115℃ and THF 66℃. This could be the reason behind morphology of the surface since the different time taken of the jet to reach the collector from the spinnrete will give different morphology.

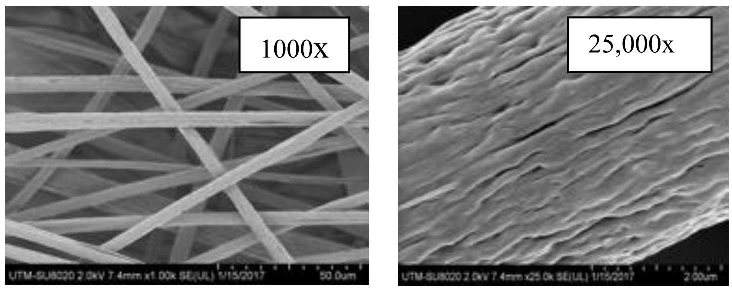
Characterization of **Nylone 6.6** FESEM image showed that the average diameter of fibers were 66.45, 71.77 and 58.96 nm for the ratio of (50:50, (25:75) and (0:100) respectively as shown in **Figure 4**. The maximum magnification of FESEM were obtained to study the morphology. Unfortunately, the image were not clear or distinguished due the small size (diameter of 58-72 nm) of the fibers. The maximum magnification with good resolution (not blur image) can be obtain by the machine is (100,000x) while the magnification of the image taken is 25,000x and 100,000x for each sample. More magnification than 100,000x will give unclear image.

a)



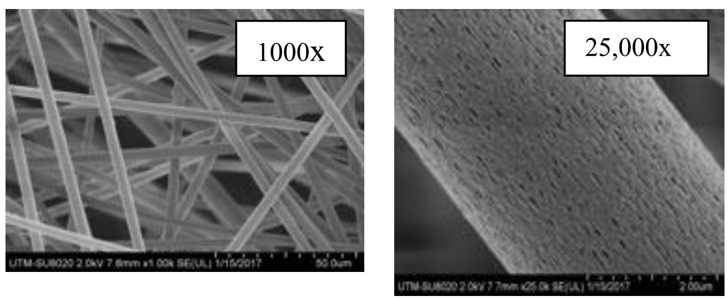
Diameter: 1.26 µm

b)



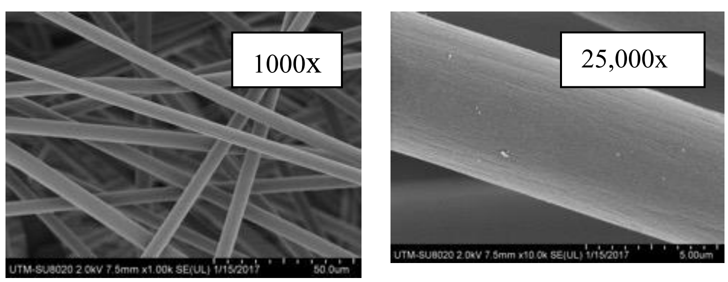
Diameter: 1.32 µm

c)



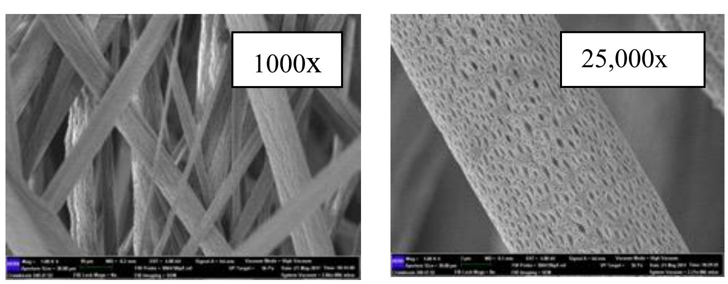
Diameter 0.91 µm

d)



Diameter: 1.42 µm

e)



Diameter: 6.02 µm

Figure 3 FESEM image of PS in solvent DMF/THF in the ratio of (a) 100:0, (b) 75:25, (c) 50:50, (d) 25:75 and (e) 0:100

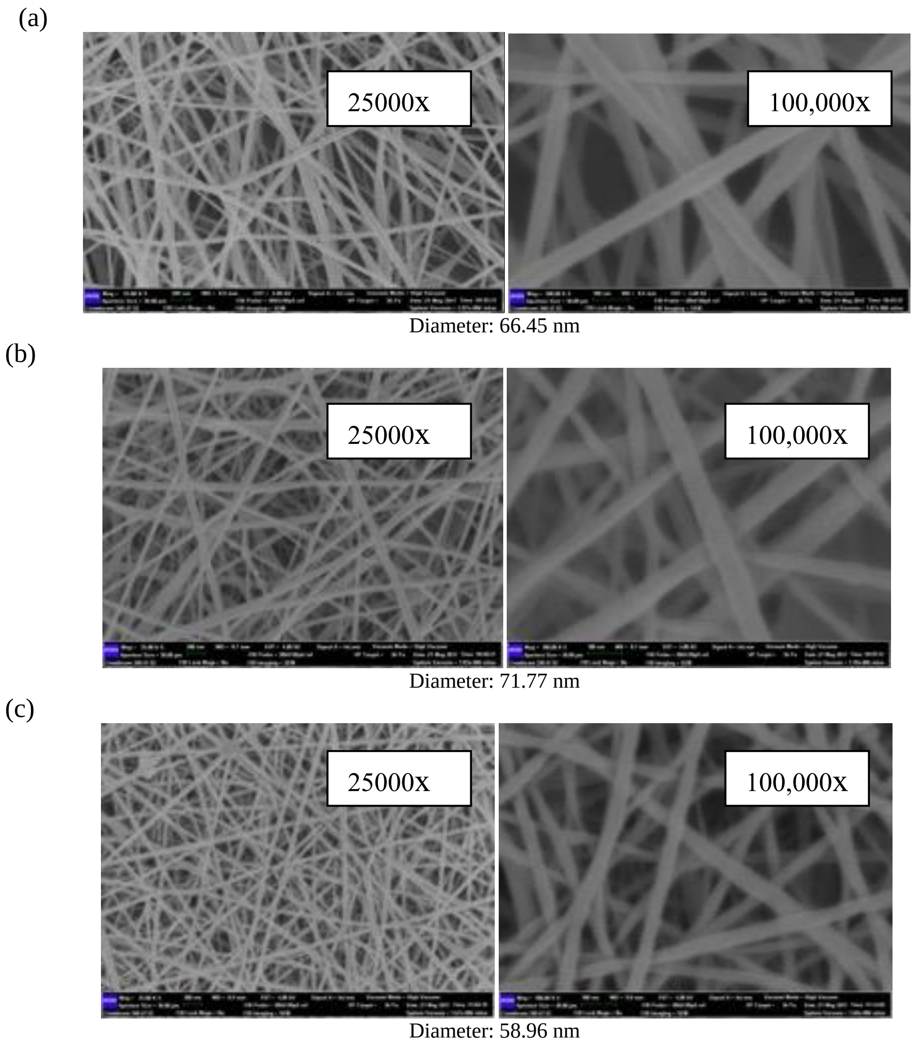


Figure 4 FESEM image of Nylon 6.6 in solvent Acetic Acid/Formic Acid in the ratio of (a) 50:50, (b) 25:75 (c) 0:100

3.2. Characterization of tensile strength of the fibers

The membrane tensile strength were tested. The average tensile strength for PS were 0.3402, 1.1959, 1.2778, 0.5241 and 1.2069 MPa according to the following ratios; (50:50), (75:25), (25:75), (100:0) and (0:100) respectively. On the other hand, the average tensile strength of Nylon 6.6 were 3.7957, 3.4867 and 3.6769 corresponding to the following solvent ratio; (50:50), (25:75) and (0:100). It express no liner relationship between increscent of Formic Acid concentration in the solution and the increscent of tensile strength. The tensile strength values for PS were lower than Nylon 6,6 the reason behind that could be due to cottony form of PS unlike Nylon 6,6 which is not cottony at all.

3.3. Characterization of Contact Angle for The Synthesised membranes

The contact angle test of PS was easy to be carried out due its hydrophibicity properties; see **Figure 5** [7]. The average contact angle of Polystyrene were 124.58°, 112.70°, 124.78°, 112.27° and 137.53° according to the following sequence; (50:50), (75:25), (25:75), (100:0) and (0:100). It shows the increscent of contact angle when concentration of THF increase in the polymer solution Also, the contact angle of Nylon 6.6 with the following ratio (50:50), (25:75) and (0:100) were found to be 42.58°, 43.62° and 52.53°. It shows direct relation of increscent of Formic Acid ratio in polymer solution with increscent of contact angle. These information is important to determine the usage of nanofiber membrane in water purification of certain pollutant.

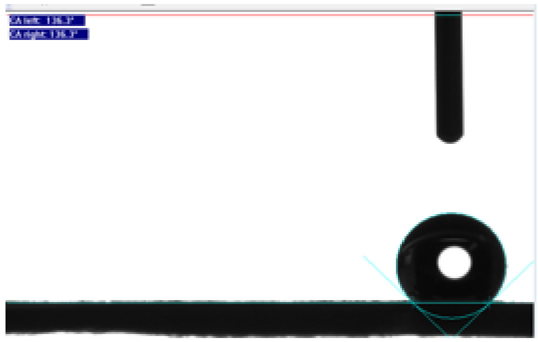


Figure 5 One image of contact angle testing

4. CONCLUSION

The synthesis of nonofibers of PS with 5 different solvent ratios were successfully carried out. Unlike Nylon 6.6 were only 3 solvent ratios synthesised. Since Nylon 6.6 were not able to dissolve in Acetic Acid/Formic Acid (75:25) and (100:0). The FESEM images shows different surface morphology for different solvent ratios. For Nylon 6.6 the diameter of the fiber has no relationship with increscent of Formic Acid. For the tensile strength, it was found that PS (25:75) had the highest value and the lowest was for PS (50:50). Furthermore, Nylon 6.6 (50:50) had the highest value and Nylon 6.6 (25:75) have the lowest. On the other hand, contact angle of PS (0:100) and (100:0) were the highest and lowest respectively. Unlike Nylon 6.6 which show a liner increscent of contact angle with increscent of Formic Acid in the polymer solution. It can be conclude that different ratio of solvent in binary solvent system have a significant effect in the properties of nanofiber membrane.

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