NANOFIBROUS COMPOSITE MEMBRANES FOR MICROFILTRATION

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Abstract

Wastewater treatment is one of the urgent need because of increasing water pollution. Polymeric nanofibrous composite membranes have been developed for the purpose of wastewater filtration due to small pore size and highly porous structure. In this work, various nanofibrous composite membranes were prepared, and flux performance was compared using a custom-built cross-flow unit. Membranes were prepared according to area weight of electrospun nanofiber mat, supporting layers and lamination methods.

Keywords: Microfiltration, wastewater, nanofiber, polyamide

1. INTRODUCTION

The application of nanofibers for membrane technologies has become very attractive for their high flux and performance due to highly porous structure and small pore size. Polyvinylidene fluoride (PVDF) and polyamide 6 (PA6) nanofibers are mostly used in water filtration process. PVDF and PA6 are thermally and chemically stable, and membranes from PVDF and PA6 can be easily formed nanofibers. PVDF nanofibers tend to be more hydrophobic surface than PA6 nanofibers. Hydrophobicity is a function of surface and roughness which can be increased by increasing surface roughness. Hydrophobicity limits the functionality of membranes which feed solution is passing through. On the other hand, highly hydrophilic membranes tend to foul during the filtration process.

Many researches have studied on improving the hydrophilicity or anti-fouling performance of PVDF and PA6 membranes [1-5]. The most of the work focused on chemical treatment. Preparation of non-fouling porous membrane is one of the biggest challenges for membrane producers. Reducing the pore size might help to decrease the fouling but this time permeability of membrane decreases. One of the biggest disadvantages of using nanofibers is their poor mechanical properties.

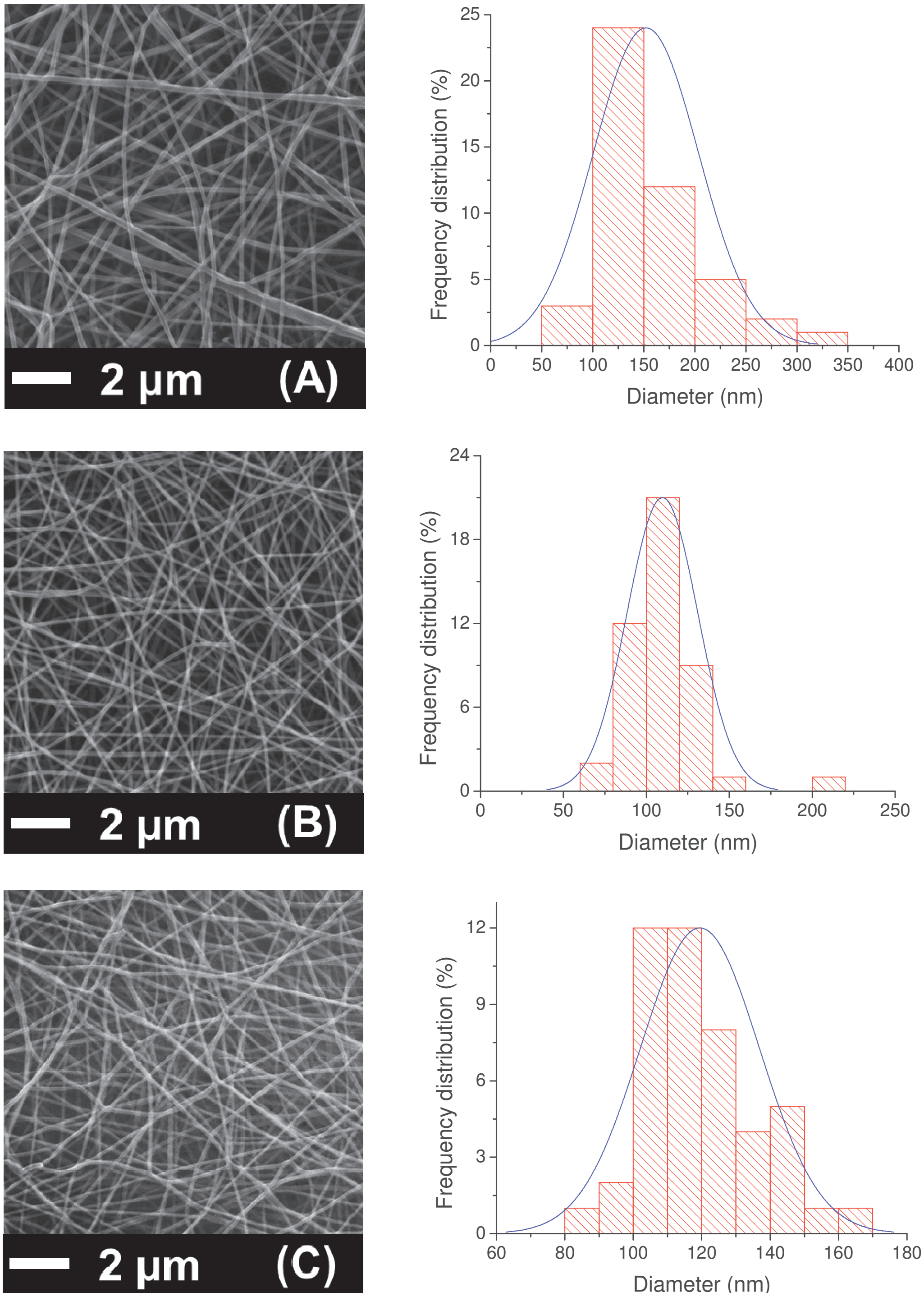
To the best of our knowledge, high tensile properties nanofiber composite membranes were prepared. Mechanical properties of the nanofibers were improved by a various lamination method. In this work, we have designed, fabricated, laminated and measured various nanofiber membranes for wastewater treatment and compared the permeability.

2. EXPERIMENTAL

Polyvinylidene fluoride (PVDF) with a trade name 761A was donated from Kynar, Arkema Slovakia; N, N-dimethylformamide (DMF), 99.8 % acetic acid (AA) and 98 % formic acid (FA) were purchased from Penta s.r.o; polyamide 6 (PA6) was purchased from BASF-Ultramid B24 N 02. The supporting layers polyethylene terephthalate (PET) spun bond nonwoven membrane with 17 and 120 g/m^2, and the 20 g/m^2 polyethylene/polypropylene (20/80) spun bond nonwoven bicomponent were used. 12 % wt. PVDF was dissolved in DMF, 8 % PA6 was dissolved in FA/AA (1/2) mixture. An NS 1S500U Nanospider unit was used for electrospinning. All of the process conditions were kept stable. The working mechanism of Nanospider unit was explained in previous work [6]. The samples were code as the name of sample and the area weight of supporting layer such as PVDF-17, PA6-120. The SEM images were analyzed using a scanning electron microscope (SEM, Tescan Vega3 SB). The contact angle was measured at different places of the samples at room temperature using a Kruss Drop Shape Analyzer DS4. A custom-made cross-flow laboratory module equipped with a constant water flow velocity through the cell (70 L/min) and pressure (0.04 bar) were used to filtrate the wastewater. Wastewater was supplied from industry which produces pitch and tar oils.

3. RESULTS AND DISCUSSION

The area weight of prepared nanofibers for PVDF and PA6 is 0.88 g/m^2 and 1.11 g/m^2, respectively. The surface of the laminated nanofibers has been analyzed using SEM images as shown in **Figure 1**.



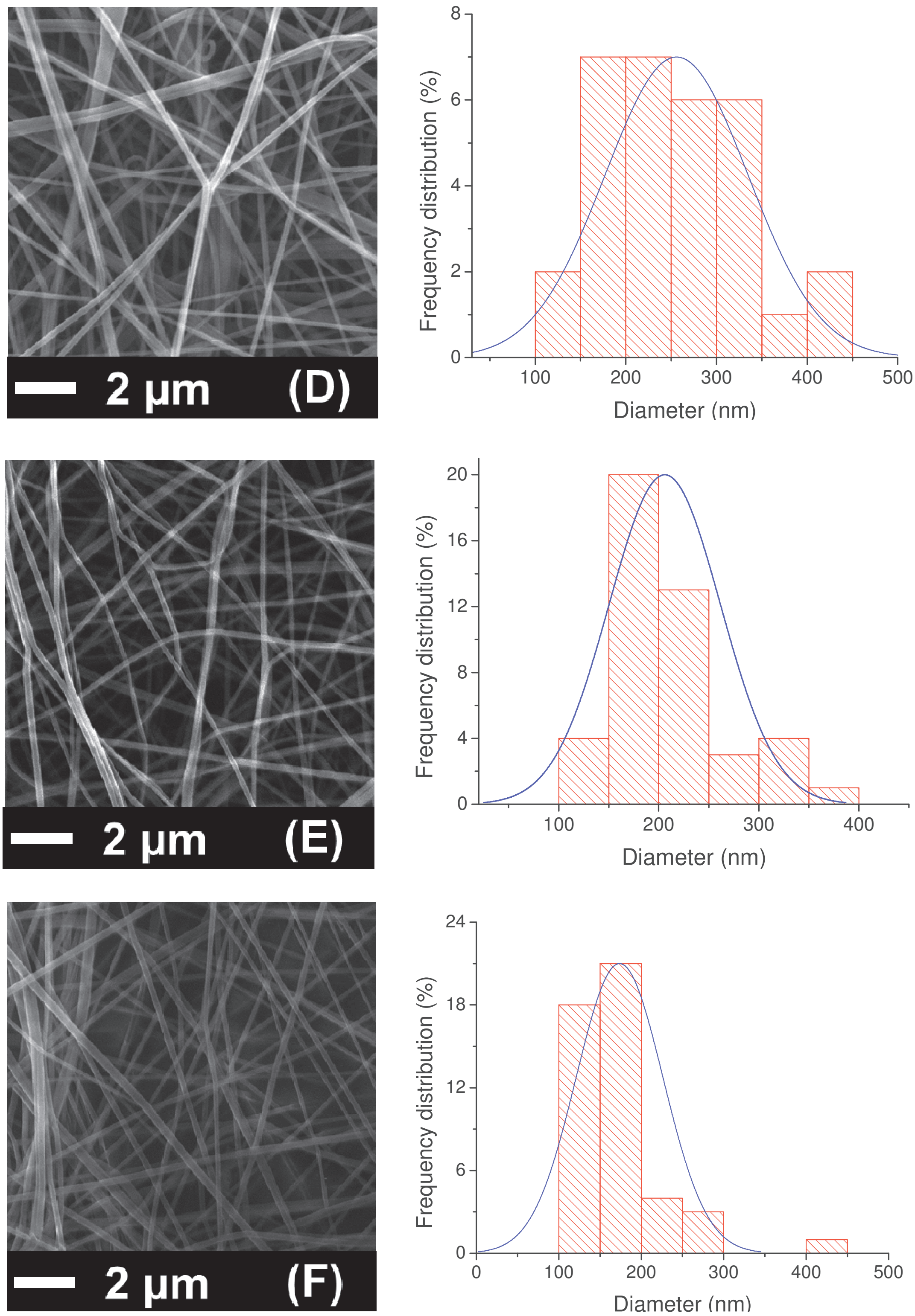


Figure 1 SEM images of the membranes, (A) PA6-17, (B) PA6-20, (C) PA6-120, (D) PVDF-17, (E) PVDF-20, (F) PVDF-120

PVDF nanofibers have twice fiber diameter than PA6 nanofibers. The pore size of PA6 is lower than PVDF nanofibers. The anti-fouling effect of PA6 might be higher than PVDF nanofibers. The lamination results indicate that there is no damage on the fiber surface. The pore size and porosity has a significant influence on the permeability of membranes. Another critical parameters those affect the permeabilities are the hydrophilicity and hydrophobicity. The contact angle of the membranes was analyzed and shown in **Figure 2**.

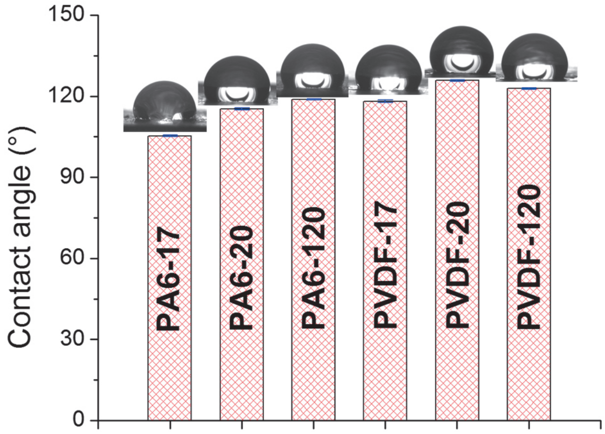


Figure 2 Contact angle of laminated membranes

Figure 2 revealed that each lamination method and supporting layer affected the hydrophilicity of membranes. All the membranes found in different hydrophobicity. Based on polymers, the lamination method, and the supporting layers, the permeability of the membranes was measured and compared using a cross-flow filtration unit. The results are shown in **Figure 3**.

The results of **Figure 3** showed the permeability of PA6 nanofibrous composite membranes is much higher to compare the PVDF nanofibrous composite membranes. The main reason is the hydrophobic structure of PVDF. PA6 is more polar and has an affinity to water absorption. The results indicate that nanofiber is not the only effective criteria on the flux and permeability but also the supporting membrane has importance. Although the PA6-17 has the lowest contact angle, PA6-120 has better permeability. The reason could be either due to lamination method and fouling of the pores. During the lamination, it is crucial not to block all the pores of nanofibers. The PA6-20, PVDF-20, and PVDF-120 showed stable permeability during 15 hours operation time. On the contrary of PA6-17, PVDF-17 has high permeability among the other PVDF membranes. The fouling mechanism for both PVDF and PA6 nanofibrous composite materials work in differently.

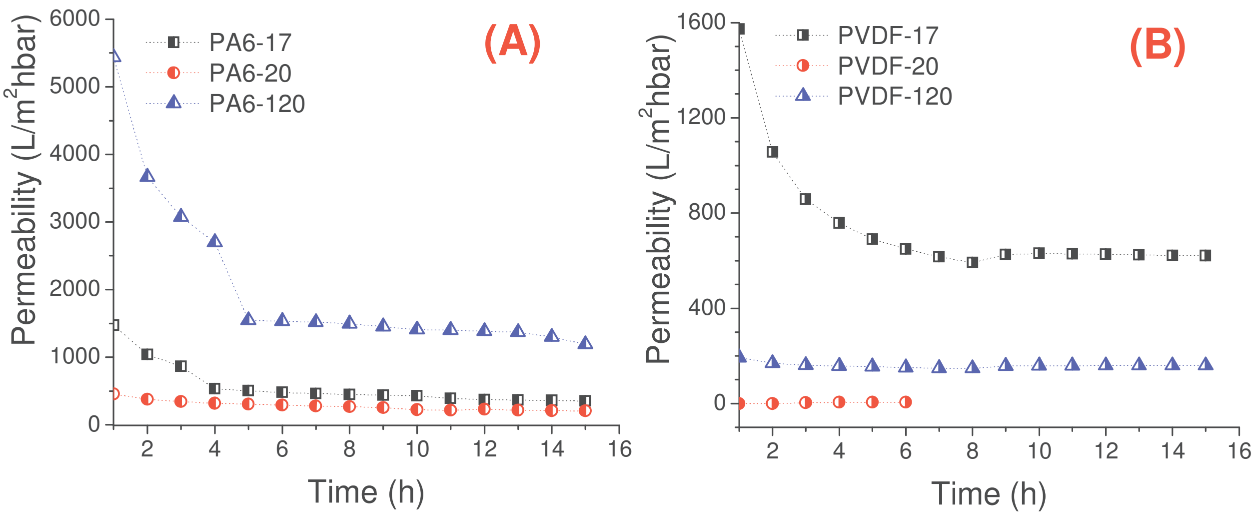


Figure 3 The permeability results of the membranes (A) PA6 membranes, (B) PVDF membranes

Figure 4 The feed and permeate solution after microfiltration

A qualitative measurement was done by observation of the feed and permeate solution. The difference between feed and permeate water is illustrated in **Figure 4**. **Figure 4** shows that the nanofiber composite membrane caught solid black compounds.

4. CONCLUSION

The results indicate that nanofibers are an excellent candidate for the wastewater treatment. The permeability of the membranes mainly depends on the type of material, the lamination method, and the supporting layer. The results can be concluded that PA6 nanofibers have better performance than that PVDF one. Even tough using the same nanofiber layer, the influence of supporting layer on the permeability of the membrane is considerable. Using various supporting layer, the permeability of PA6 and PVDF nanofibrous composite membranes were increased over than 3 times.

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