Journal of Fiber Bioengineering and Informatics 10:4 (2017) 223–230
doi:10.3993/jfbim00272

Fabrication and Characterization of Electrospun Nanofibrous Composite Membrane for Air Filtration ⋆

Si Cheng [b], Yuan-Xiang Xiao [b], Lian-Ying Zhao [a,b], Lv-Tao Zhu [b]
Ren-Long Li [b], Guo-Cheng Zhu [a,b,c,*]

[a] *Key Laboratory of Advanced Textile Materials and Manufacturing Technology, Ministry of Education Zhejiang Sci-Tech University, Xiasha, Hangzhou 310018, China*

[b] *College of Materials and Textiles, Zhejiang Sci-Tech University, Xiasha, Hangzhou 310018, China*

[c] *Hubei Key Laboratory of Advanced Textile Materials & Application, Wuhan Textile University Wuhan 430200, China*

Abstract

One kind of composite membrane by combining electrospun nanofibrous membrane with fiberglass mesh was developed for air filtration. The fiber diameter, morphology of membranes, pressure drop and filtration efficiency of composite membrane were evaluated. The results revealed that the pressure drop and filtration efficiency of composite membrane decreased with the increase of winding speed (the higher winding speed is, the less of nanofibers are). The pressure drop of all samples at an airflow speed of 5 m/min was less than 25 Pa, which was much lower than the values from other reported work; and the highest filtration efficiency of sample in this work was more than 83% for particulate matters with 1.88 μm.

Keywords: Electrospinning; Nanofiber; Light Transmittance; Pressure Drop; Filtration Efficiency

1 Introduction

Many countries nowadays are suffering heavy air pollution, which has become a very serious problem in affecting environment, public health and people's living quality. PM2.5 represents the particulate matters with a diameter of 2.5 microns, which is the most harmful part of polluted air for people since it can penetrate and lodge deep inside the lungs. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer [1-5]. Around 3.7 million premature deaths worldwide caused by air pollution and the

⋆Project supported by Zhejiang Sci-Tech University (Project Number: 16012168-Y), The Young Researchers Foundation of Key Laboratory of Advanced Textile Materials and Manufacturing Technology, Ministry of Education, Zhejiang Sci-Tech University (Project Number: 2016QN05), and Hubei Key Laboratory of Advanced Textile Materials & Application, Wuhan Textile University (Project Number: Fzxcl2017006).

*Corresponding author.
Email address: zgc100100@hotmail.com (Guo-Cheng Zhu).

Dec. 2017

greatest number was in the Western Pacific and South-East Asia regions according to WHO record in 2012 [6]. PM2.5 has successfully attracted much attention of researchers, governments and industries. The Chinese government unveiled its action plan for air pollution control (2013-2017), which will dedicate 1.7 trillion RMB toward pollution control.

Nanofibrous membrane has been taken as the most promising air filter for its unique features, i.e. superfine and uniform fiber diameter, very large specific surface area, very high porosity, very small and uniform pore size. Khalid had applied Polyacrylonitrile (PAN), Poly (vinyl pyridine) (PVP), Poly (methyl methacrylate) (PMMA), and Nylon-66 nano-fibrous membrane onto metallic mesh and nylon mesh to capture PM2.5 [7]. Their samples had good transparency and very high filtration efficiency. However, the pressure drop of sample was very high which strongly influence the air exchange rate. Besides, the protection of nanofibers onto mesh was not taken into consideration, which means the lifetime of nanofibers or such a same product could be very short.

Poly (vinylidene fluoride) (PVDF) has been widely used as a membrane material thanks to its good chemical resistance, great mechanical properties and high thermal stability [8-10]. It is broadly applied in ultrafiltration, microfiltration, membrane distillation and other membrane processes [11, 12]. Therefore, in this work the PVDF nano-fibrous membrane was prepared by electrospinning technology and applied onto fiberglass mesh. The fiber diameter and morphology of membranes were evaluated, and the effect of winding speed of nanofibrous membrane on pressure drop and filtration efficiency of composite membrane was discussed.

2 Materials and Methods

2.1 Materials

PVDF powder provided by Arkema Group, Dimethylacetamide (DMAc) supplied by PENTA Chemicals, Tetraethylammonium bromide (TEAB) obtained from Sigma Aldrich, fiberglass mesh provided by Jinwu Glass Fiber CO., LTD., were used in this work.

PVDF was dissolved in DMAc with concentration of 12% in w/w. Before electrospinning process, 2% TEAB was added into the PVDF solution. Nanofibers were electrospun from PVDF solution by Nanospider^{TM} NS-500. The temperature and humidity during electrospinning process were controlled at 23±0.5 °C and 18±1%. The applied voltages were −10/+50 kV, electrode distance was 180 mm, the slit diameter was 0.5 mm, rotating wire speed was 80 mm/min, cartridge speed was 300 mm/s, and winding speed were from 620 mm/min to 1150 mm/min, which is given in Table 1 in details.

2.2 Methods

The conductivity of solution was measured by SCHOTT instruments (Model: k00090-L), the solution viscosity was measured by HAAKE Viscotester E from Thermos Scientific Company. The fiber morphology and nano-fibrous window screen was observed under scanning electron microscope (SEM). The pressure drop of samples was evaluated according to ASTM D737-1996 by air permeability tester FX3300, which measures the airflow rate under constant air pressure drop, or measures the pressure drop under constant airflow rate. Six measurements for each