Journal of Fiber Bioengineering and Informatics 9:3 (2016) 167–176
doi:10.3993/jfbim00243

Air Permeability and Moisture Management Properties of Electrospun Nanofiber Membranes ⋆

Vinod Kadam, Amit Jadhav, Rajkishore Nayak
Lijing Wang, Rajiv Padhye*

School of Fashion & Textiles, RMIT University, VIC–3056, Australia

Abstract

Recently, electrospun nanofiber membranes (ENMs) have been received an increased attention in personal protective clothing owing to their excellent filtration efficiency and low basis weight as filtering materials. However, high resistance to air flow is a major drawback of ENMs which in turn effect on comfort. In addition, comfort properties such as moisture management of ENMs need to be evaluated for practical applications. It is argued that air permeability and moisture management influenced by selection of electrospinning process parameters. This research studied the effect of collector speed and deposition time on the air permeability of ENMs. Polyacrylonitrile nanofibers that had the diameter in the range of 291—877 nm were fabricated. The deposition time significantly influenced air permeability, unlike collector speed. Hence a short deposition time is desirable. A good correlation was found between the theoretical porosity and experimental air permeability of ENM. Furthermore, it was found that moisture management properties of ENM require improvements for personal protective clothing.

Keywords: Electrospinning; Air Permeability; Moisture Management; Porosity; Nanofiber Membrane

1 Introduction

Electrospinning (E/S) has gained a tremendous increase in research and commercial interest since the technology was developed [1]. Electrospinning is a simple, easy and versatile process to produce polymeric nanofibers [2-5]. In a typical electrospinning process, a viscoelastic polymer fluid is electrically charged with high voltage. The fluid then overcomes its surface tension and elongates in a jet form to deposit as nanofibers onto a collector [6, 7]. The continuous nanofiber membranes have been prepared using a rotating collector drum. ENMs possess high surface area to volume ratio (specific surface area) and low pore size compared to microfiber membranes. These superior properties of ENMs have led them to use for variety of applications including filtration [6], tissue engineering, drug delivery [8], and protective textiles [9, 10].

⋆Project supported by RMIT University international PhD scholarship foundation and Indian Council of Agricultural Research for granting the study leave.

*Corresponding author.
Email address: rajiv.padhye@rmit.edu.au (Rajiv Padhye).

More attention has been given on optimizing the electrospinning process to achieve uniform fiber diameter [6, 7, 11]. The nanofiber diameter is largely influenced by polymer fluid characteristics and electrospinning process parameters. The polymer fluid characteristics include molecular weight, solution viscosity and electrical conductivity, whereas the electrospinning process parameters include applied voltage, flow rate, needle gauge, needle to collector distance, collector speed and deposition time [12]. However, the optimization of electrospinning for the properties such as air permeability and moisture management is still in infancy.

Air permeability is the important parameters of ENM, especially for air filtration applications [13]. Air permeability is defined as the rate of air flow through a porous material under a specified differential pressure across the material, usually 0.5 inches of water [14]. Porosity is the ratio of volume of void in the ENM to volume of fiber and void [2]. ENMs have good air filtration efficiency due to small fiber diameter and small pore size [15, 16]. High porosity ENM should give high air permeability. However, attaining high filtration efficiency adversely effects on air permeability and porosity. One major challenge in developing protective materials is to maintain low pressure drop and high air permeability while increasing the filtration efficiency. Many filtration media provide high efficiency by sacrificing air permeability [17]. Optimized ENM can be effective in resolving the problem. Additionally, good moisture management properties can improve comfort in the personal protective clothing. Relatively fewer studies focused on air permeability and moisture management properties of nanofiber membranes.

In this study, PAN ENMs produced by using a laboratory scale electrospinning apparatus with an indigenously designed collector assembly. Air permeability, porosity and moisture management properties of ENMSs were evaluated following standard procedures. The effect of collector speed and deposition time on nanofiber diameter, fiber distribution, air permeability, and moisture management properties was analyzed. The correlation between porosity, air permeability and nanomembrane thickness was established statistically.

2 Experimental

2.1 Materials

Polyacrylonitrile polymer (Mw 110 000 g/mol) was purchased from Goodfellow Cambridge Limited, England. N, N-dimethylformamide (DMF) was obtained from Merck, Australia. Both polymer and solvent were used without further purification. Wool/nylon fabric (control) was used as a support to nanofiber membrane.

2.2 Methods

2.2.1 Preparation of Solution

Polyacrylonitrile, 8% (w/w) dissolved in DMF under continuous stirring at 70 °C for 3 hours to obtain homogenous solution. The solution was stored at room temperature.