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Short Communication

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Water Purification by Polyvinyl Chloride Nanofibers Membrane Filter

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Abstract

The objective of this work was to purify wastewater of preparing Polyvinyl Chloride (PVC) nanofibrous membranes by electrospinning with single solvent and their potential applying as affinity membrane. The PVC solutions in dichloromethane (DCM), formic acid and acetic acid were electrospun into nonwoven fiber membranes, respectively. The field emission scanning electron microscope (FEEM) results showed that the as-spun PVC nanofibers using DCM as solvent were continuous and smooth with the fiber diameter ranging from 50-500nm. Furthermore, their properties such as specific surface area, fiber diameter and porosity were investigated. The nanofibrous membranes exhibited high surface area and high porosity compared with commercial filter paper like as patron filter and displayed very high water permeability.

Keywords: Poly(vinyl Chloride), Nanofibrous membranes, Electrospinning, Formic Acid, Dichloromethane, acetic acid, Trifluoroacetic acid, Field Emission Scanning Electron Microscope

Introduction

Electrospinning is a process that produces continuous ultrafine polymer fibres through the action of an external electric field imposed on a polymer solution or molten solution. Recently, polymer nanofibres have been attractive materials for a wide range of applications because of their large surface area to volume ratio and the unique nanometer scale architecture built by them. Among the most successful methods for producing nanofibres is the electrospinning. One of the possible applications of nanofibres is water filtration.

For this application a nanofibres flat-sheet membrane can be produced that can be used as a water filtration membrane. More specifically, this can be used in ultra-filtration. Due to their higher porosities and interconnected pore structures, nanofibres offer a good permeability to water filtration than conventional materials currently in use [3]. This study aims at assessing the possible use of electrospun nanofibres filters in water filtration. Firstly, synthesis of polyvinyl chloride nanofibers by electrospinning setup was determined. Secondly, character-rization of the structural condition and surface morphologies of nanofibers (functionalized or non-functionalized) by using field emission scanning electron microscope (FESEM) were investigated. Thirdly, the application of the electrospun membranes for raw water filtration in the laboratory was investigated and raw water source and filtrated water were characterized by XRF(X-Ray Fluorescence) for the comparison of particles concentration [1].

Most microfiltration(MF), Ultrafiltration(UF), Nanofilt-Ration(NF) and reverse osmosis(RO) membranes are synthetic by organic polymers. MF and UF membranes are often made from the same materials, but they are prepared under different membrane formation conditions, so that different pore sizes are produced. The water permeability was successfully tested for a lot of filter samples include some samples with PA, PVA or PI nanofibers. Typical MF and UF polymers include poly(vinylidenefluoride), polysulfone, poly(acrylonitrile) and poly(acrylonitrile)-poly(vinylchloride) copolymers. Poly(ethersulfone) is also commonly used for UF membranes. MF membranes also include cellulose acetate-cellulose nitrate blends, nylons, and poly(tetrafluoro ethylene). Nevertheless the PVC nanofiber layer was different. When the water flow through the PVC nanofibers started the value of pressure drop didn´t stabilized after 10 second but after 30 minutes and the value increased two times against the initial value. It looked that the filter was clogged by captured particles. The pressure drop was similar to initial value from the former experiment. The effect of slow increasing of the pressure drop has been observed again (Figure 1).

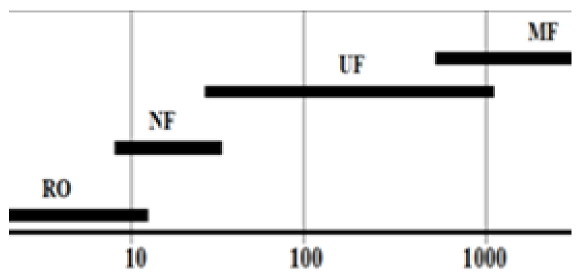

Figure 1: Range of Nominal Pore Diameter (nm scale).

Materials and Methods

A Preparation for PVC Solution

For the electrospinning, the PVC powder (Sigma-aldrich Co,)and dichloromethane (DCM)(1:4 v/v) were sonicated by ultra-sonicator (Qsonicar Q-700 Misonic sonicator Co,Ltd) at 200 ± 10°C for ½ h and 1h respectively. In that case, the solution of PVC/DCM was started boiling and evaporation, when the temperature reached at 120°C. To control and maintain the lack of molecules by evaporation, 5 wt% of trifluoroacetic acid was added in this mixture. And then, 5 wt% of formic acid was added by using magnetic stirring at 200°C for 24 h. The PVC/DCM solutions for electrospinning were exited as homogeneous stability without any precipitates and air bubbles. Before electrospinning, PVC solution were characterized for their viscosity and conductivity by using NDJ-79 rotary viscosity meter and DDS-11A conductivity meter at room temperature, respectively [2].

Electrospinning System Configuration and Setup

Figure (2) illustrates the electrospinning setup (NF -103A MECC Co. Ltd from Japan.) and this configuration is the same as the conventional electrospinning system[8].

Then, each spinning solution was placed in a 10 ml syringe with a stainless steel syringe needle (inner diameter of 0.75mm) as an electrode which connected to Direct Current (DC) high-voltage generator.

The syringe was loaded in a syringe pump to control a flow rate accurately. A piece of aluminum foil was used as a collector for obtaining sheet type nanofiber assemblies and grounded.

There are many kinds of collectors such as drum, disk, plate and others in electrospinning used as required fiber formation. The electrospinning experiments were performed at room temperature and to prevent the electric shock there was no more than 60% humidity.

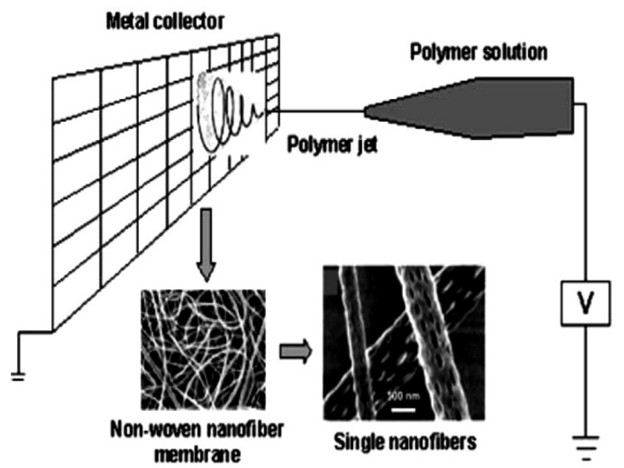

Figure 2: Schematic diagram of the electrospinning setup.

Membrane Fabrication

In the electrospinning setup, the polymer solution is continuously feds through the three syringes pump. A high voltage of 17-22 kV is applied using a high voltage power supply(MECC1HP-101).

Electric potential and distance between the source and collector were fixed at 15-20 kV and 75-00mm, respectively. The polymer solution was fed through the device at the feed rate of 1.2-3 ml/min and nanofibers of PVC were collected on the drum collector (Figure 3).

Figure 3: PVC filter membrane collected from the drum collector.

E. Water Filtration Process by Using the PVC Nano- fibers Membrane Filters

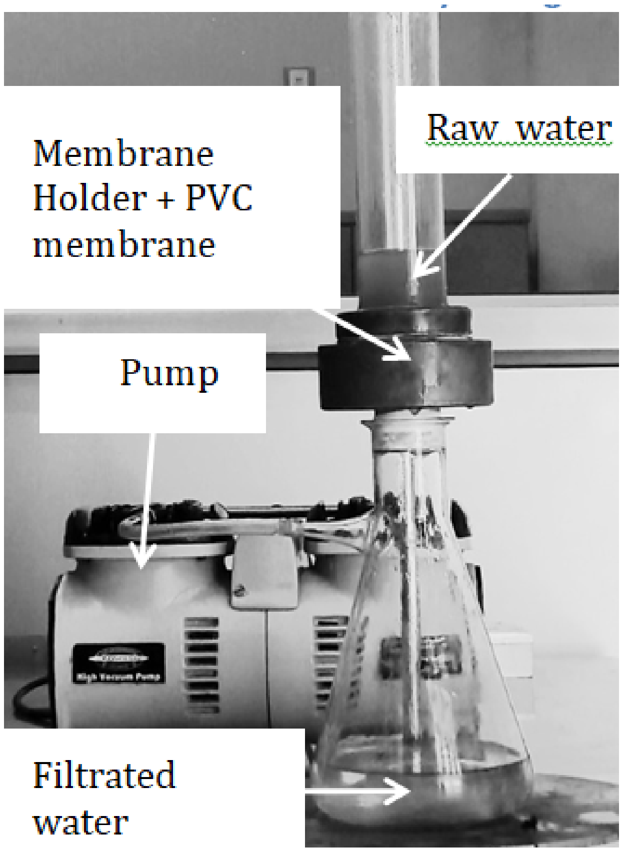

Figure 4: Water filtration setup.

- Water permeability and pressure drop of the filter is very important attribute of the filtration process. The procedure of the filtration process is following:
- Firstly, the pump is connected with the vacuum flask.
- Then, the PVC nanofibrous membrane is placed into the holder and griped using sealed tape to prevent any air leakage.
- When the vacuum pump is turned on with low pressure rate, the required value ofwater flow is set.

- After the stabilization of the pressure at 0.2 MPa, the water flow is measured aslit/m (typical time of the stabilization is 60 seconds).

Results and Discussions

Membrane Characterization

Morphological structures of the electrospun PVC nanofibers with DCM solvent were observed by using scanning electron microscope (FE-SEM) (Agilent Co., USA) after sample preparation and the diameter of the nanofibers were measured by the image processing software [3].

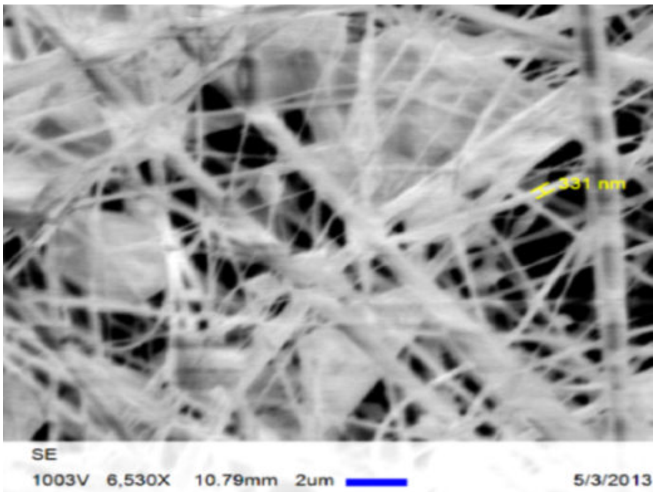

Figure 5(a): Contaminations contain on the surface of PVC nanofibers membrane.

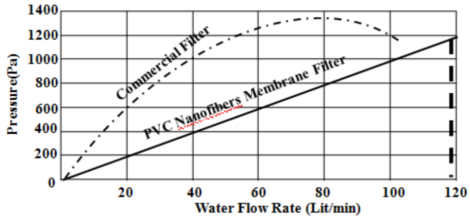

Figure 5(b): Ultra-fine PVC nanofibers membrane

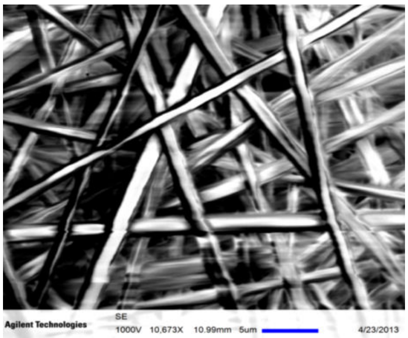

Figure 5(c): FESEM Images of high magnification of the PVC nanofibers membrane.

B. XRF (X-Ray Fluorescence) Results

The raw water source and filtrated clean water were characterized by XRF (X-Ray Fluorescence) and their results were shown in Tab. I and II respectively. Very important fact is the diameter of nanofibers and membrane holder. That is called patron filter, which is the most common used for liquid filtration.

Formula	Net int.(kCps)	Calc.conc (%)
Mg	0.2891	0.107
Al	1.13	0.315
Si	2.894	0.443
K	1.199	0.1453
Ca	13.85	0.426
Ti	1.345	0.0269
Fe	52.96	0.2307

Table 1: Particles Concentration Before Filtration Process

Formula	**Net. Int(kCps)**	**Calc. conc (%)**
Ca	0.2596	0.008

Table 2: Particles Concentration After Filtration Process.

Wastewater Porosity of PVC Nanofibers Membrane Filters.

Electrospinning of PVC nanofibers membrane was widely applied on wastewater filtration process. The results of our experimental study showed that one of the most effective schemes to alter the fiber diameter was to change the solution concentration. Although, there are many parameters in electrospinning(e.g. flow rate, applied electric field, and distance between spinneret and collecting drum) that can be used to control the fibers diameter [4]. This finding was also confirmed in the references. By changing the PVC concentration from 1 to 5v/v while keeping other processing parameters were constant, the average fiber diameter could be varied from 124 to 720 nm. Furthermore, the fiber diameters at higher concentrations (i.e. more than 5 v/v) appeared to approach a constant value (i.e. 750 nm) under our experimental conditions. The corresponding of FESEM images of the PVC fibers electrospun at different concentrations, clearly illustrating that all the fabricated fibers showed fairly good uniformity.

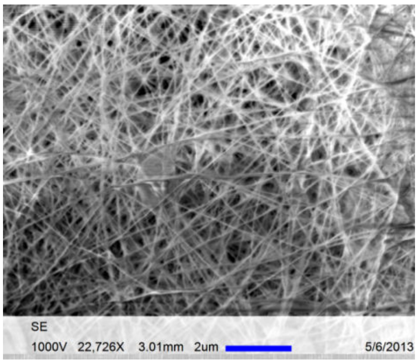

Figure 6: Observation of water flow rate.

The liquid filtration efficiency is very important depend on fibers density. Particles are usually captured on the surface and creates so-called “filter cake” so it is suitable to clean filter after sometime. During the filtration process it is necessary to have dense structure with small pores and high pressure drop. The effect of the change of pressure drop was repeated for different water flow. From the test results we can name three main facts:

- The relation between the pressure drop and water flow is not linear, which is assumption for the most common D´Arcy´s law. It looks, that the Hagen-Dupuit-Darcy´s law is more suitable.
- The pressure drop for the same water flow is changing during the time and the stable value we obtain roughly after 25 minutes. Bigger difference was observed for higher values of water flow.
- The change of the pressure drop during the time is repeatable, it means that the pressure drop increase is not caused by the filter clogging [5].

Conclusion

The PVC/DCM nanofibers membrane filter can use in the field of water filtration process. This nanofibers membrane filter had smoothly structure and ultra-fine fibers network. Compared with commercial filter paper, the nanofibrous membranes exhibited high surface area and high porosity. Also, the nanofibers membranes filter exhibited very high water permeability and hydrolytic stability. Electrospinning of the PVC nanofibrous membranes gave the possibility of producing new materials for potential filter. We will observe the specific possibilities of the application of nanofibrous membrane filter in the field of wastewater treatment as further study.

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