Fabrication of environmentally friendly high performance membrane via electrospinning and its application

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전기방사를 이용한 친환경 고성능 멤브레인의 제조와 응용

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Abstract

Electrospinning has been recognized as an efficient technique for the fabrication of polymer nanofibers. Various environmentally friendly nano membrane have been successfully electrospun into ultrafine fibers in recent years. In this study, the environment-friendly polyvinyl alcohol (PVA) nanofiber membrane successfully fabricated by electrospinning technology.

1. Introduction

With the development of industry, people are faced with the problem of a worsening environment. For example, air, water and soil pollution are still serious problems in many countries. Air pollution can cause asthma, skin irritation, nausea, cancer, braindamage, birthdefects, respiratory and heart problems due to gaseous pollutants and particulate matter (PM) [1,2]. In recent decades, the use of nanotechnology to treat pollutants has become a hot research topic. Because nanofibrous webs have a large surface area to volume, high porosity, tight pore size and high permeability that make them an appropriate candidate for filtration applications. Therefore, nanofibers have received increased attention in pollutant treatment applications [2].

The fabrication of polymer nanofibers mainly includes drawing [3], template synthesis [4], phase separation [5], self-assembly [6], electrospinning [7] and other techniques. Among these technologies, the electrospinning has become the most popular nanotechnology for the production of nanofibers in recent decades, based on its simple equipment, easy manipulation and low energy consumption, it can produce fibers with diameters ranging from tens of nanometers to several micrometers, even less than 1 nanometer [8]; the electrospun nanofiber membrane also has a large specific surface area and high porosity, which directly translates to a large number of adsorption sites and high adsorption capacity [9]; moreover, the as-spun nanofibers can also be modified by physicochemical methods to obtain desired porosity, pore size and related functional groups [10]. Therefore, the electrospun fibers are widely used in filtration, ultrafiltration, affinity membrane, protective clothing, scaffolds in tissue engineering, enzyme immobilization, drug delivery, energy generation, biomedical/wound healing and other fields [11].

On the other hand, waste oils emanating from the automobile industry such as spent engine oil, lubricating oil and grease from mechanical workshops are important because they contain a mixture of hydrocarbons (n-alkanes, polycyclic aromatic hydrocarbons), engine additives such as amines and organometals. These hydrocarbons and engine additives are toxic to plants, animals, humans and the environment [12]. Oil pollution resulting from petrochemical, textile, and food industries, as well as the frequent oil spill accidents during offshore oil production or marine transportation, has caused a great loss of energy sources and long-term damaging effects on the ecological environment [13]. Membrane technique has been proved to be one of the best methods for pollutant treatment from air, water oil and so on [14]. Therefore, there is a need to find efficient, affordable and more environment-friendly methods of waste engine oil treatment. In this study, the environmentally friendly polyvinyl alcohol (PVA) nanofiber membranes were prepared by electrospinning technology, and the concentration of PVA and the adsorption capacity of new and waste engine oil were optimized.

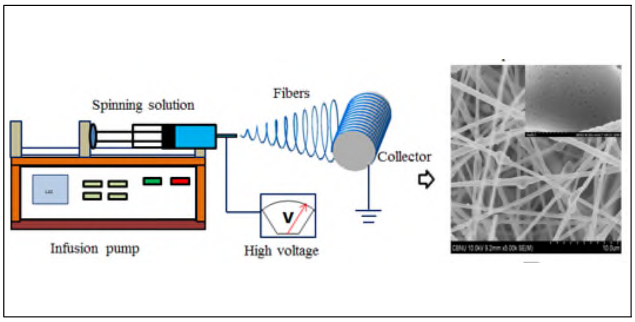
2. Materials and Methods

2.1 Materials

Polyvinyl alcohol (PVA) with 80,000 g/mol of weight molecular weights (Mw) was used the main material for fabricating environment-friendly fiber membrane, which was obtained from Hefei Sipin Technology Co., Ltd., China. Pure water (conductivity: Max. 2.0 μs/cm; resistivity: Min. 0.5 MΩ) was used as the solvent and procured from Samchun Pure Chemical Co., Ltd., Korea.

2.2 Fabrication of PVA nanofiber membrane

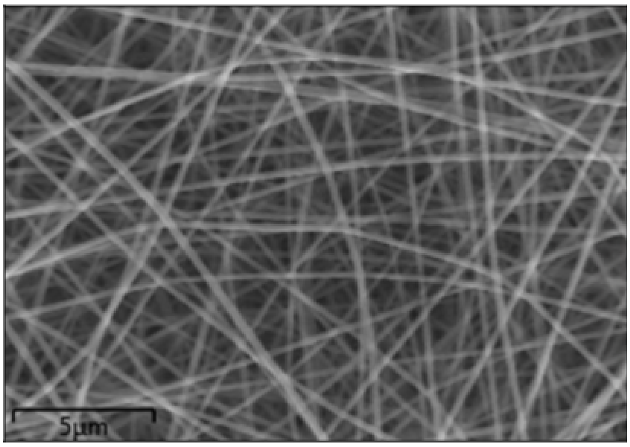
In order to observe the membrane forming characteristics of PVA fiber and obtain the best mixing ratio, a variety of PVA/water electrospinning solutions (8 wt%, 9 wt%, 10 wt%, 11 wt%, 12 wt%, 13wt%, 14 wt% and 15 wt%) were prepared. The details are as follows: First, eight different weight PVA powders were respectively dissolved in the prepared pure water by using a magnetic stirrer dissolved for 24 h at room temperature. Then, to further ensure that the PVA powder was uniformly dispersion in the pure water, these PVA solutions were treated with ultrasonication for 2 hours. Finally, the prepared PVA electrospinning solutions were injected into a 12 ml syringe with a 0.5 mm inner diameter needle (21G) to prepare for spinning. All as-prepared spinning solutions were electrospun at 20 kV of high-voltage electricity with an 100 mm tip-to-collector distance, and the solution feed rate was 0.5 mL/h. The process of electrospinning is shown in Figure 1. After electrospinning, the PVA membranes were dried for 24 h at 80 ℃ in a vacuum oven.



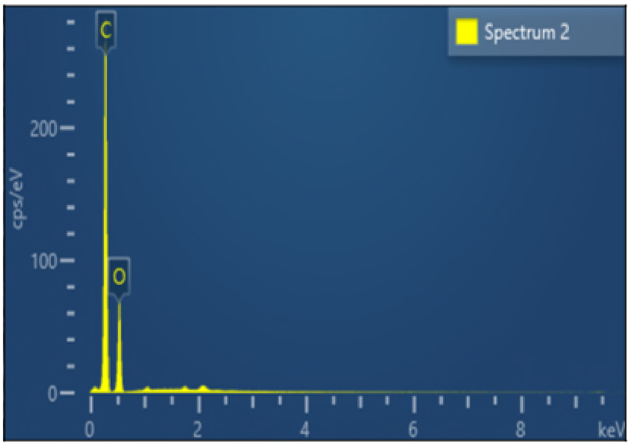
[Fig. 1] Schematic diagram of the PVA nanofiber membrane electrospinning system.

3. Results and discussion

The morphology of electrospun ultrafine fibers is affected by the applied voltage, solution flow rate, distance between the capillary and the collector, etc., especially the polymer solution concentration, surface tension and solvent properties [15,16]. Figures 2a and 2b show the SEM micrograph and EDX of PVA fibers from a 10% PVA solution in pure water, respectively. It can be seen from Fig. 2a that the 10% PVA fibers have a smooth surface, are nonporous, and have uniform diameter. This may be due to the fact that the viscosity of PVA with 10% concentration exceeds the critical value, so that the charged jet can fully withstand the columbic stretching force and produce uniform and smooth fibers [17].



(a) 10%



(b)

[Fig. 2] FE-SEM image and EDX of 10% PVA membrane.

4. Conclusions

Environmentally friendly PVA nano membranes with different concentrations were successfully prepared by electrospinning technology. The PVA nanofibres with uniform and smooth morphology with a narrow diameter distribution. PVA fiber membrane has great potential in ultra-filtration of waste oil.

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