Preparation of Antibacterial Polyethersulfone/Silver Nanoparticle Ultrafiltration Membrane

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\textbf{Abstract.} Antibacterial polyethersulfone/silver nanoparticle ultrafiltration membrane was prepared. The result revealed that the membrane exhibited the excellent property by showing bovine serum albumin (BSA) rejection of 73.6 % with no significant change in water flux when the n-Ag content was 0.5 wt\% and the blending temperature was 80\(^\circ\)C. The membranes surface contact angle was also reported to increase significantly.

\textbf{Introduction}

Recently, membrane technology especially ultrafiltration membrane have been generally accepted for the application in wastewater treatment. Polyethersulfone (PES) is one of the most widely used polymers for ultrafiltration membrane due to its solvent resistance high chemical and thermal stabilities, good oxidation resistance and chlorine resistant. However, the lifespan of PES membranes is mainly limited by surface fouling. Inorganic additives added to polymeric membranes has been proven to successfully reduce membrane fouling. In the last decade, much attention was focused on the application of silver nanoparticle (nAg) in improving the antifouling performance of membrane due to its practical importance in bacteriostatic and bactericidal properties. nAg were added to cellulose acetate, polyimide, and other membrane materials. The objectives of the paper is to synthesize a kind of novel antibacterial nanocomposite ultrafiltration membranes and characterize the membrane surface properties and anti-fouling.

\textbf{Experimental}

\textbf{Materials}

Polyethersulfone (PES, P-6020) was purchased from BASF company. Polyethylene glycol-400 (PEG400, \(\geq 99.5\%\)) and N,N-dimethylacetamide (DMAc, \(\geq 99.7\%\)) were purchased from Tianjin Damao Chemical Reagent Corporation and Beijing Yili fine Corporation, China, respective. NAg (25nm) and ovalbumin were obtained from Aladdin reagent Co., Ltd. Escherichia coli (E. Coli) was prepared by Biology Institute of Shandong Academy of Science. Sinopharm Chemical Reagent Co., Ltd. Provided other chemicals including Bovine serum albumin (BSA) and Tween-80.

\textbf{Synthesis of Ultrafiltration Membrane}

Flat-sheet membranes were prepared by phase inversion. For preparing the casting solution, poured certain amount of DMAc, PEG and Tween-80 into a 3-neck boiling flask. Then nAg were added
and dispersed under ultrasonication for 40 min. PES was dissolved in the solution. Subsequently, the solution was cast onto a clean glass plate. After partial evaporation, the glass plate was immersed smoothly in a precipitation bath.

**Ultrafiltration Performance**

The water flux was determined from the weight change of the draw solution using a digital mass balance as Eq.1:

$$J = \frac{V}{At} \cdot$$

where \(V\) is the volumetric flow rate of permeate (L) in a predetermined time interval \(t\) (h), \(A\) is the membrane effective membrane area.

The BSA rejection (Re) of membrane was defined as Eq.2:

$$R_e = \left(1 - \frac{E_n}{E_0}\right) \times 100\% \cdot$$

where \(E_n\) and \(E_0\) represented absorbance of BSA concentrations in permeate and feed solutions, respectively.

**Characterization of Membranes**

**Contact Angle and Scanning Electron Microscopy (SEM).** Contact angle of PES/nAg flat membrane was measured by the sessile drop method at room temperature using contact angle meter (Dataphysics Model OCA40, Germany). The surface and cross-section of membrane morphology were characterized by SEM (JEOL Model S4800, Japan).

**Membrane Anti-bacterial and Anti-biofouling Characteristics.** Membrane anti-bacterial tests were conducted with pure cultures of E. Coli in a static state.

The flux recovery ratio (FRR) was calculated to evaluate the membrane anti-fouling capability. The steady state pure water flux \((J_1)\) of the prepared membranes was measured first. Then, the feed of ovalbumin solution was introduced. Then the water flux was re-evaluated and the value was defined as \(J_2\) after washing the membrane and immersing in distilled water for 20 min. The FRR was calculated using the Eq. 3.

$$FRR = \frac{J_2}{J_1} \cdot$$

**Results and Discussion**

**Membrane Performance**

Figure 1(a) presents the water flux and rejection of ultrafiltration membrane as a function of blending temperature. With respect to water flux, an optimum temperature which contributed to the maximum water flux was observed. However, increase of blending temperature from 50 °C to 70 °C produced a negative effect on the rejection and a positive form was found at the temperature from 70 °C to 90 °C. Considering water flux and rejection together, the optimum blending temperature is 80 °C.

From Figure 1(b) we can see that nAg content caused negative effect on BSA rejection at the beginning of the experiment. By contrast, nAg content caused no significant effect on the water flux. However, the repeated addition of nAg content caused different effect. Considering water flux and rejection together, the optimum nAg content of PES/nAg membrane was about 0.5 wt%.
Characteristics of Ultrafiltration Membrane

**Contact angle and SEM.** The morphological studies of the various sections of ultrafiltration membrane were made using SEM (Figure 2). It is recognized that the PES ultrafiltration membrane and PES/nAg ultrafiltration membrane have the similar asymmetric structures with a nanoporous top surface and a fully porous bottom layer. The image for the PES/nAg ultrafiltration membrane (Figure 2d) show a number of scattered deposits on the membrane holes.

![SEM images of PES and PES/nAg ultrafiltration membrane.](image)

The contact angles values of the control PES ultrafiltration membrane and PES/Ag ultrafiltration membrane were measured. The contact angle of the membranes decreased from 95.3° to 76.1° with the addition of nAg. It should be noted that the incorporation of nAg has led to the significantly impact of contact angle.

**Antibacterial properties.** In order to assess the effectiveness of nAg, a blank control group was set to avoid the action of other factors such as temperature. The data of experiments showed in Figure 3 demonstrated that PES/nAg ultrafiltration membrane exhibit outstanding potent bactericidal properties against E. Coli since microorganisms were less likely to attach within the present of PES/nAg membrane. However, the antibacterial property of PES ultrafiltration membrane was inconspicuous.

![Graphs showing the influence of blending temperature and nAg content on membrane performance.](image)
Figure 3. Antibacterial test of E.coli dilution $10^{-2}$ (a), (b), (c) and dilution $10^{-3}$ (d), (e), (f).

**Anti-biofouling characteristics.** The FRR values is increased from 0.48 to 0.58 after the addition of nAg. The results obtained with the figure showed that the hydraulic cleaning and anti-biofouling of membranes may be enhanced since the FRR of PES/nAg ultrafiltration membrane was higher compared to the control PES membrane.

**Conclusion**

In this paper, the antibacterial PES/nAg ultrafiltration membrane was prepared. The results showed that the optimal ultrafiltration membrane was obtained when silver content was 0.5wt % and blending temperature was 80 °C. Its pure water flux was 350.1 L/ m²·h with the BSA rejection rate of 73.6 %. SEM images depicted the asymmetric structure of membranes and the presence of nAg. NAg played a crucial role in improving the anti-biofouling properties of ultrafiltration membrane.

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**References**


