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ZnO Nanocomposite Membranes for Desalination

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ABSTRACT

Severe drinking water scarcity is a major problem around the world and pressure driven membrane processes are gaining importance in the field of water purification. This work mainly focuses on improving membrane performance in terms of hydrophilicity, solute rejection, etc. It emphasizes on the preparation of polysulfone (PSf) based blend membranes via phase inversion method. PSf membrane is modified by the addition of zinc oxide (ZnO) nanoparticle at various compositions and the resultant membrane performances were studied. The PSf-ZnO membranes were characterized by ATR-IR and SEM. These membranes showed much better salt rejection performance.

Keywords: ZnO Nanoparticles, PSf membrane, desalination, blend, nanofiltration

1.0 INTRODUCTION

The shortage of pure drinking water is increasing every day due to human activities. Inorder to overcome this one has to find out a suitable process for water purification. Among the various methods of water purification, membrane filtration is more attractive due to its simplicity, relatively high effiency and low cost [1]. Hydrophilicity, porous structure, antifouling property and chemical resistance of the feed solution are the key membrane characteristics that influence the performance of the membrane separation.

Polysulfone (PSf) is a common polymer for the manufacturing of memberanes due to its chemical stability and thermal resistance [2]. There are many research is taking place around the world to increase its mechanical properties. PSf based composite membranes are extensively used in various separation techniques [3]. But, hydrophobic nature of PSf polymer limits its use as a membrane material for desalination purpose [4]. Diverse methodologies have been developed by many researchers to enhance its hydrophilic character such as, chemical surface treatment and the addition of hydrophilic additives [5].

Addition of nano particle is one of the recent development in the membrane technology, which improves the performances of the membranes filtration [6-8]. The water permeability of the psf membranes was enhanced under high pressure in reverse osmosis (RO) [9-11]. Thus, in this work, being a beginner in the field of membrane research, we mixed zinc oxide (ZnO) nanoparticles with PSf in various compositions hoping that it will increase the hydrophilic nature of the synthesized composite membranes. Membranes were synthesized via phase inversion method and its

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characterization was performed. The salt rejection performance was studied by using electrolyte solution of NaCl. Results of such studies were discussed in this paper.

2.0 METHODS

2.1 Materials

Low molecular weight PSf with molecular weight 35,000 g/mol was purchased from the Sigma Aldrich Company. 1-methyl-2-pyrrolidone (NMP) was purchased from Merk India, Ltd. Commercially available ZnO nano powder (Sigma Aldrich) were used for the membrane preparation. NaCl was used as feed solutions for rejection studies.

2.2 Synthesis of Polysulfone membrane

PSf (2 g) was dissolved in 8 mL of NMP by constant stirring and heating at 60^{o}C. The mixture kept under continuous stirring for 7 h to obtain a homogeneous solution. Resulting solution is cooled, and degassed in an ultrasonic bath to remove any bubbles. The resultant viscus PSf/NMP solution was casted to the form of a thin membrane using a glass plate and a doctor's blade via phase inversion technique. The solvent was allowed to evapourate for 30 s and it was immersed in coagulation bath containing distilled water for 24 h, washed with distilled water followed by drying under vacuum [12].

2.3 Synthesis of PSf/ZnO Blend Membranes

Required quantity of PSf was dissolved in NMP under constant stirring at 60^{o}C. The solution is stirred constantly for 2 h to ensure the uniformity of the solution. A uniform solution of ZnO-nanoparticles were prepared separately by dissolving pre weighed ZnO pwder in NMP under constant stirring and heating. Later both these solutions were mixed by keeping the temperature at 60^{o}C and stirring at a constant rate for 7 h in order to obtain a homogeneous solution. The resultant solution is then sonicated and then casted on a glass plate using doctor's blade. The solvent was allowed to evapourate for 30 s and it was immersed in distilled water for 24 h followed by drying under vacuum. Table 1 shows the formulation of the PSf membranes.

Table 1 Dope formulation of PSf membranes

Membranes	ZnO (g)	PSf (g)
M1	0.0	1.0
M2	0.02	0.98
M3	0.04	0.96
M4	0.06	0.94

2.4 Characterization of PSf/ZnO blend membranes

The morphology of the membranes was examined by using Scanning Electron Microscopy (SEM) analysis. FTIR of the membranes were also recorded to ensure the formation of the required type.

2.5 Salt Rejection Studies

All dried membranes were soaked in distilled water for 24 h before taking them for filtration performance analysis. Dead end filtration cell was used for performing filtration experiments. Filtration experiments were performed on 5 cm diameter circular membranes discs which provides total filtration area of about

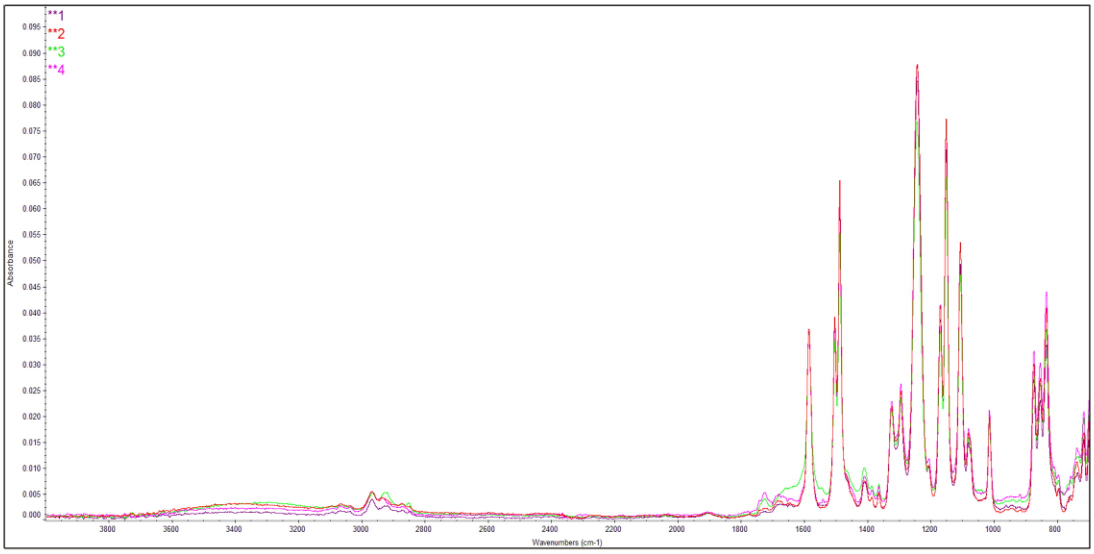

Figure 1 FTIR spectrums of pure PSf membrane, and at different loading of ZnO nano particles

19.6 cm^2. In order to give mechanical support to the membrane, these circular membrane samples were placed over porous stone support. The feed tank was filled with test solution and pressurized as per requirement.

The experimental setup was maintained at room temperature and constant stirring to minimize the effect of concentration polarization. Before taking any reading, permeate was allowed to attain equilibrium flow for atleast 15min. The concentration of feed and permeate solutions were measured using EQ-660A conductivity meter (Equip-tronics, India).

3.0 RESULTS AND DISCUSSION

3.1 Fourier Transform Infrared Spectroscopy (FTIR)

The chemical structures of the PSf/ZnO blend membranes were characterized by FTIR, and its infrared spectrum was compared to that of a pure PSf membrane in Figure 1.

3.2 Scanning Electron Microscopy (SEM)

Figure 2 presents the SEM images of the membranes embedded with different mass fractions of ZnO-PSf. The increased composition of ZnO in casting solution resulted in a highly porous membrane structure. Highly porous and hydrophilic nature of PSf/ZnO membranes contributed to the enhanced flux. Figure 3 shows the succesfull incorporation of ZnO in the PSf membrane matrix.

3.3 Salt Rejection Performance

Figure 4 shows the salt rejection results of synthesized membranes against NaCl. Performance of the membrane increases as the weight percentage of the ZnO nanoparticles increases. ZnO nano particles makes the membrane more hydrophilic which is accounted for the increased performance.

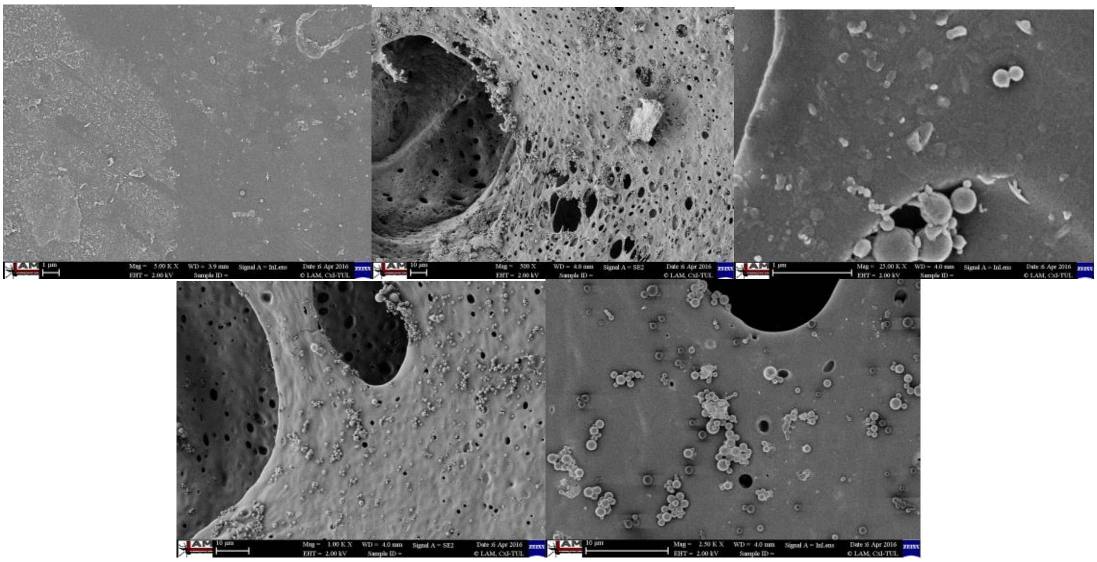

Figure 2 SEM images of top surface of the membranes M-1 (top left), M-2 (top middle and right) and M-3(bottom left and right)

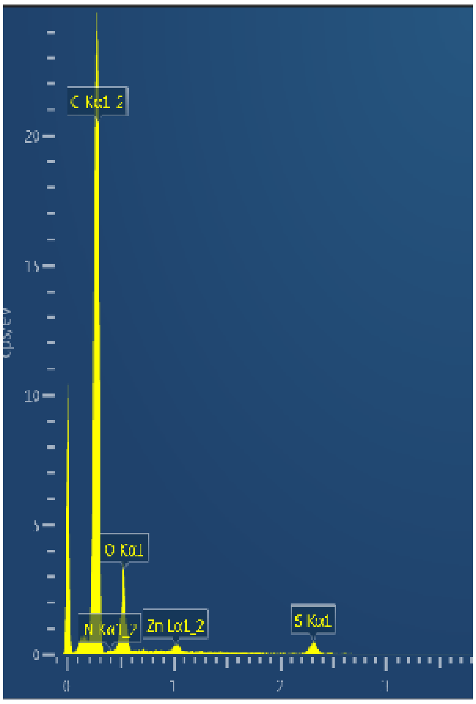

Figure 3 EDX analysis PSf-ZnO blend membrane M2

3.4 Water Uptake of the Membrane

In order to understand the water uptake properties, dry membranes were cut into pieces of abour 2 sizes, dry weight was noted and then these samples were immersed in distillaed water for 24 h. After than, the membrane were taken out of water and surface water was removed using blotting paper, after which the wet membrane weight was noted. The percent water uptake was calculated using equation,

$$\text{Water uptake (\%)} = \frac{W_w - W_d}{W_w} * 100 \quad (1)$$

where w_w and w_d are the weight(g) of wet and dry membranes respectively.

The results are presented in Figure 5. It can be noticed that, uppermost water uptake observed was 81% and the minimum was 45%. The membrane with highest percentage of ZnO exhibited maximum water uptake which provides an evidence for the fact that, the increase in the percentage of ZnO nano particles enhances the hydrophilic nature of the membrane.

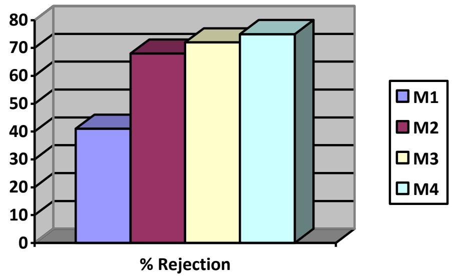

Figure 4 The NaCl electrolyte rejection study of membranes at 2 bar pressure

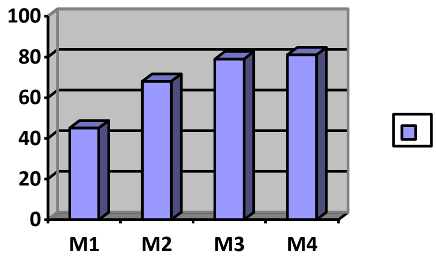

Figure 5 Water uptake of the membranes

4.0 CONCLUSION

In summary, PSf-ZnO blend membranes were synthesized by phase inversion method by mixing PSf and ZnO with NMP at 60°C. Depending on the amount of ZnO added, the resultant membranes achieve different removal efficiency against NaCl.

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