Preparation and characterization of PVC/GO membranes

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Abstract

the membrane pure water flux increased with increasing graphene oxide content as a result of hydrophilicity**.** In this study, polyvinyl chloride/graphene oxide membranes were fabricated via a non-solvent induced phase separation method. The membranes were then characterized using a set of analyses including FESEM, Contact angle and pure water flux. The results of FESEM showed all membranes are spongy and asymmetric in structure and as the content of graphene oxide increased, the number and size of the pores increase. The results of the contact angle analysis showed a decrease in the contact angle of all the nanocomposite membranes in comparison to the neat membrane, which resulted in increased membrane hydrophilicity.

Keywords: Membrane, PVC, GO.

Introduction

Today, increasing population rates and industrialization have led to a decline in available water resources, and in addition to the introduction of domestic and municipal wastewater into the water, it has exacerbated the crisis of water pollution[1]. This vital material is the most important strategic resource on Earth that is essential for urban, industrial and agricultural needs[2]. Among the wastewater treatment technologies and water recycling processes, membrane bioreactor (MBR) is the most feasible one and has already been employed in real applications[3]. In the last few years, membrane technology has inchmeal gained a lot of attention due to its numerous advantages in industrial processes. The main benefits of membrane separation is efficient and ease of exploitation, low energy consumption due to no phase change, environmentally friendly, ability to combine with other separation processes, high flexibility in system design and very high separation efficiency[4]. Polyvinyl chloride (PVC) is one of the most used organic polymers in filtration processes. PVC is a linear hydrocarbon polymer that is produced by polymerization from vinyl chloride and is made up of repeating units of $-(C_2H_3Cl)_n$ which possess a semi-crystalline structure[5]. It has excellent mechanical, thermal and chemical properties and dissolved in various solvents[6].

However, the phenomenon of membrane fouling is a controversial challenge in industrial processes [7]. Membrane fouling results in increased operating pressure resulting in increased costs and repeated washing, reducing the lifetime of the membranes[8]. Increasing membrane hydrophilicity is a reasonable method for counteracting the fouling phenomenon [9-10]. There are various methods for modification of polymer membranes that are generally divided into two main categories: surface modification and membrane bulk modification method. The surface modification includes coating[11] plasma technique [11-12] and ozone treatment[13]. The bulk modification involves compounding, bonding, surface chemical reaction, and dispersion of inorganic nanoparticles[14]. One of the most common methods for modification is the use of nanoparticles on the membrane surface. Graphene oxide nanoparticles are among the carbon nanoparticles that have been added to the polymer membranes due to their advantages such as hydrophilicity, their interaction with different polymers, high antibacterial activity, and high specific surface area [15-16]. In this study, GO nanoparticles were embedded into PVC membranes to increase their hydrophilicity and antifouling properties.

Experimental

Materials

PVC (MW=90000) was supplied by Arvand Petrochemical Company, Iran. Polyethylene glycol (PEG 400), N,N-dimethylacetamide (DAMc), Graphene oxide nanopowder (3.4-7 nm) were purchased from Merck.

Preparation of PVC UF membranes

The PVC and PVC/GO composite membranes were prepared by the phase inversion method. First, GO with varying amounts (0–0.2% by wt.) was dispersed and sonicated in DAMc solvent for at least 30 min. Then PEG was added to the dispersion and stirred for about 15 min. After adding PVC solution, the final mixture continued to be stirred for 24 h until a homogenous solution was formed. The homogeneous solution was then allowed to degas overnight. Table 1 shows the composition of each casting solution. The solution was cast onto a glass plate using an automatic casting knife. The plate and film were immediately immersed in distilled water to induce phase separation until the formed membranes were freely separated from the plate. After removing the membranes from the plate, the membranes were placed in another distilled water bath and left for about 24 hours to get rid of the residual solvent.

Table 1:Compositions of the casting solutions for PVC and PVC/GO nanocomposite membranes.

Membrane ID	PVC (wt%)	PEG (wt%)	DAMc (wt%)	GO (wt%)
M0	15	6	79	0
M1	15	6	78.95	0.05
M2	15	6	78.9	0.1
M3	15	6	78.85	0.15
M4	15	6	78.8	0.2

Characterization of membranes

Contact angle

The angle between water and membrane surface was measured with contact angle meter. To minimize experimental error, was measured 5 times and the average was reported.

Pure water flux

The pure water flux of the membranes was measured using dead-end filtration system. The membranes were compact at a pressure of 3 bar. Then we reduced the pressure to 1 bar. After reaching steady state, the pure water flux was calculated using the following equation:

$$J_0 = \frac{M}{A\,t}$$

where J_0 is pure water flux (PWF), M is collected mass of water, A is membrane area and t is the time

Morphology

The morphology of the prepared membranes was visualized with a field emission scanning microscope. For cross-sectional imaging, the membranes were fractured in liquid nitrogen and then coated with gold.

Results and discussion

1) Hydrophilicity of the PVC and PVC-GO membrane:

Table 2 showes contact angles of prepared membrane. It can be seen that contact angle of membranes decreased by increasing graphen oxide nanosheets content which indicates that the htdrophilicity of the membranes increased at the presence of GO.

Table 2. Contact angle of prepared membranes.

Membrane	Contact angle
PVC	80.00
PVC-0.05%GO	75.5
PVC-0.1%GO	74.5
PVC-0.15%GO	72.25
PVC-0.2%GO	70

2) Morphology of membranes:

Fig. 1 presents the FESEM image of PVC and PVC-GO membranes. These images shows increase in membranes porosity by increasing hydrophilicity, and also voids structure of modified membranes changed to finger-like structure.

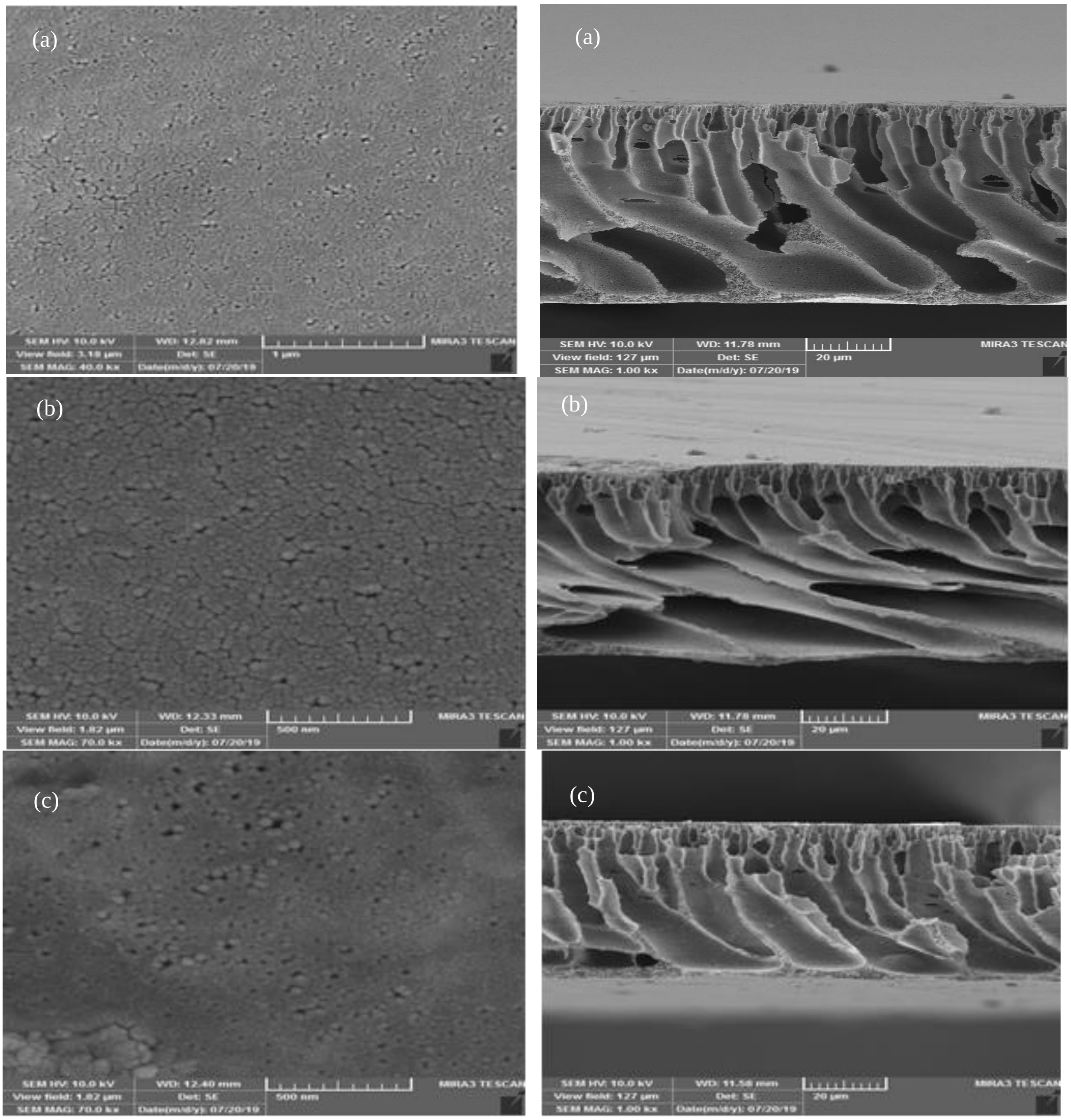

Fig1: Surface (left) and cross section (right) FESEM of prepared membranes.(a) Neat PVC, (b) 0.1 wt.% GO, (c) 0.2 wt.% GO.

3) Pure water flux

Pure water flux of prepared membranes are shown in Fig. 2. It can be seen that composite membranes showed a higher pure water permeation flux than the pure PVC membrane except PVC-0.2% GO. This can be due to the hydrophilicity effect as well as morphological difference of the membranes. As shown, the hydrophilicity of the membranes was increased at the presence of GO nanoparticles. Moreover, the namber of surface pores increased at the presence of GO nanoparticles. Therefore, pure water flux of PVC/GO membranes increased.

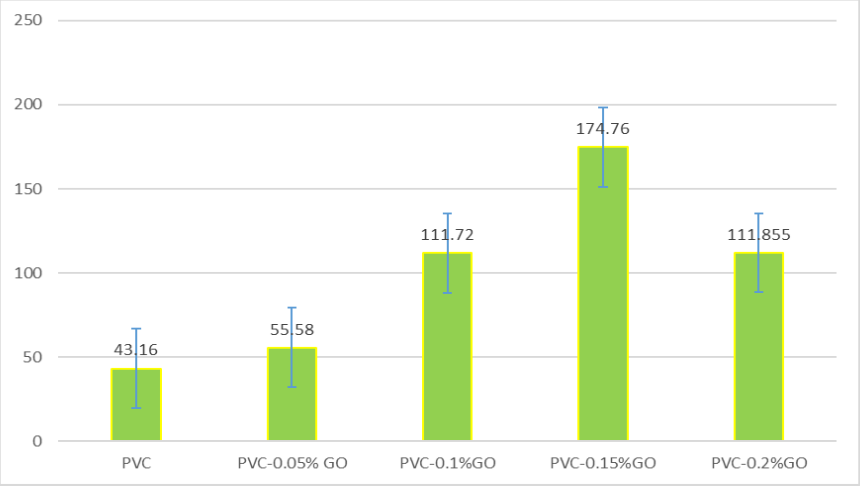

Fig2: Pure water flux of neat and GO embedded PVC membranes.

Conclusions

PVC/GO nanocomposite membranes were prepared via nonsolvent induced phase separation method. The results from this study showed that the pure water flux and hydrophilicity of 0.15%w PVC/GO membrane was considerably higher than the other membranes. The SEM images showed significant changes in the morphology of the PVC/GO as compared with pristine PVC particularly in the membrane surface. Pure water flux of PVC/GO membranes was higher than that of neat PVC membrane due to the difference in the hydrophilicity and morphology. These results indicate that PVC/GO can be potentially used as ultrafiltration membrane.

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