Fouling Characterization of Polysulfone-Grafted-Methyl Methacrylate Membrane

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Abstract. This study investigates the effects of different grafting time on the polysulfone grafted methyl methacrylate (PSf-g-MMA) membrane performance. PSf-g-MMA was successfully prepared via UV radiation method. Methyl methacrylate (MMA) and benzophenon (BP) were used as a monomer and initiator respectively. Membrane performances were measured based on permeation and rejection of bovine serum albumin (BSA). Degree of grafting was found to increase as grafting time increases and the optimum time was found at 100 minutes. The results revealed that the pure water flux and rejection were significantly improved with the addition of grafting time. The present of MMA also were found to improve fouling properties of the membrane.

Introduction

Membrane fouling can occur in two ways: cake formation and absorption of foulants. Cake fouling is generally reversible by water flushing or backwashing. However, fouling due to the adsorption of foulants is essentially irreversible and can only be counteracted to a certain extent by aggressive chemical cleaning. Fouulant adsorption can occur both on the membrane surface and in the pores. The foulant will reduce the flux of membrane and resulted in decreased water permeate through membranes [1].

Membrane organic fouling is always associated with restriction of membrane pores or pore blockage and cake layer formed on the membrane surface due to the adsorption and deposition of natural organic matters (NOM). In order to avoid membrane fouling, it is very important to understand the chemical composition of the feed water, membrane properties and hydrodynamic condition of largely dissolved NOM. Morphology membrane, charge and hydrophilic been known to reduce membrane fouling.

Thus several studies have attempted to improve the formulation of the membrane with the addition of hydrophilic polymer on membrane via various method and techniques such as grafting, crosslinking, blending etc [2–6] . Grafting method is one of the most common methods to make modifications of polymer material. In principle, the method of polymerization provides multiple functions in combining a group of polymers. Grafting polymerization can be done by treatment of chemical, UV irradiation and gamma radiation techniques. There are many factors in controlling the grafting techniques in example, the nature of the backbone, the effect of a monomer, solvent effects, the roles of additives in the grafting process and the effect of temperature [7]. In past years, the emphasis has been raised about the use of polymer grafting [8]. Modification of polymers by grafting method has a bright future and it was developed with practical ways without limitation. Thus in this study, grafting technique was used to modify the membrane surface of polysulfone (PSf).
Methodology

Synthesis of PSf-graft-MMA copolymers. PSf-g-MMA copolymers membranes were prepared by irradiating homogeneous solutions of PSf, MMA monomer and BP photoinitiator with UV light. Predetermined amounts of PSf and MMA were dissolved in N-methyl-2-pyrrolidone (NMP) and the concentrated solution was stirred for a few minutes. After that the concentrated solution was irradiated with UV light at room temperature. Distilled water was bubbled into the solution for 10 min to remove the dissolved oxygen from the solution. The suspension obtained was filtered and then the solid product was vacuum dried to constant weight. The product was purified by dissolution and precipitated in distilled water. This purification procedure was repeated twice.

Membrane casting. PSf-g-MMA flat sheet membrane was prepared by the phase inversion method uses Flat Sheet Membrane Casting System machine [5]. The dope solution was poured onto a clean glass plate at room temperature and it was cast on a glass plate using a casting knife. Immediately after casting, the glass plate with the cast film was dipped into the distilled water at room temperature. Phase inversion starts and after a few minutes a thin polymeric film separated out from the glass. The membrane was washed with distilled water and kept in the water bath until it is ready for evaluation. All flat sheet membranes were visually inspected for defects and good areas were chosen for membrane evaluation.

Permeation water flux (PWF) and Rejection. The permeation fluxes of the prepared membranes were measured by a UF cross flow filtration experimental setup feed with distilled water at a transmembrane pressure of 2 bar [6], [10]. Rejection was characterized with distilled water solution after the membrane was previously filtered with distilled water mixed BSA until flux was steady. Experiments were performed using a Membrane Permeation Testing Unit at a pressure of 2 bar. Around 15 ml of permeate was collected and concentration of the permeate was measured using UV-vis (Thermo Scientific).

Fouling investigation. Fouling investigation is to measure flux reduction of the membrane by using 2 liter distilled water mixed with 0.2 g bovine serum albumin (BSA). Experiments were performed using a Membrane Permeation Testing Unit at a pressure of 2 bar. For every 10 minutes, water measurements will be recorded for 2 hours for pure PSF and PSF-g-MMA.

Results and Discussions

Figure 1 shows the effect of UV radiation time with respect to degree of grafting. The graph shows that percentage of MMA onto PSf at 30 minutes increased progressively with UV irradiation time up to 90 minutes, then decreased at 120 minutes. The increase percentage of grafting is due to polymerization of MMA on the surface of PSf. However, after 90 minutes percentage of grafting reduces due to PSF structure received too much energy from UV that allowed PSf chain backbone to break apart [8].

The pure water flux of prepared membrane at various grafting time is shown in Figure 2. The graph shows that the flux increased significantly with the time increases from 0 minutes to 120 minutes. The maximum value of the flux is 47.21 \( \text{lm}^{-2} \text{h}^{-1} \) at 120 minutes of PSF-g-MMA membrane, followed by 32 \( \text{lm}^{-2} \text{h}^{-1} \) at 90 minutes, 25.68 \( \text{lm}^{-2} \text{h}^{-1} \) at 60 minutes and 22.57 \( \text{lm}^{-2} \text{h}^{-1} \) at 30 minutes. While the lowest value of the flux is 19.71 \( \text{lm}^{-2} \text{h}^{-1} \) at 0 minutes of pure PSF membrane (without grafting). At 120 minutes, the flux increased significantly as compared to others. This is probably due to surface crack formation on PSf membrane when exposed to UV light. The cracks which form during chain scission of PSf molecule were allowed water to pass through the membrane and increase water permeability [11].
Figure 1: Effect of grafting time on degree of membrane grafting

Figure 2: Pure water flux of membrane at different grafting time

Figure 3: BSA membrane rejection at different grafting time

Figure 4: Fouling analysis between pure PSf membrane and the UV-initiated grafting membrane

Figure 3 shows humic acid rejection performance of prepared membrane. In this rejection test, Bovine serum albumin (BSA) was used as rejection model. The graph shows that the rejection increased when the grafting time increases and significant change when the time increases up to 120 minutes. Even though at this time degree of grafting decreases, the formation of crack supposed to allow the more radical structure on the surface of the membrane. Hence, narrowing the membrane pores and increased membrane rejection.

Fouling analysis between pure PSf membrane and the UV-initiated grafting membrane is shown in Figure 4. The highest fouling result of this study is a pure PSf membrane while for the lowest
fouling result is PSf membrane grafted for 120 minutes. Due to the antifouling property of MMA therefore with increased grafting time and even with reduction porosity the fouling is reduced. Overall the fouling effect shows the reduction value in all grafted samples. Figure 5 shows the volume of water acquired during fouling tests performed. Volume of water was taken at every 10 minutes up to 120 minutes for each sample. The result shows the rate of water flow through the membrane of the ungrafted membrane is lower than grafted membrane [12].

![Figure 4: Fouling percentage at different grafting time](image)

![Figure 5: Volume permeate versus temperature at different grafting time](image)

**Summary**
PSf-g-MMA membrane was successfully prepared via UV radiation method. The optimum degree of grafting obtained was at 100 minutes. The PSf-g-MMA induced UV radiation for 120 minutes was observed show higher water flux and all grafted membrane has a better pure water flux (47.22 L/m²hr) compare to ungrafted membrane. Due to the reduction of pore when increased grafted membrane therefore the rejection of grafted membrane obviously increased compared to ungrafted membrane. Meanwhile in fouling investigation, the reduction value of fouling is decreases as grafting time increases.

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References


