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Flat Sheet Membrane Using Silica from Sugarcane Bagasse as Additive: Effect of Morphology

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Abstract- The work describes is primarily concerned with the fabrication and testing of flat sheet membrane. The aim of this research is to investigate the morphology of flat sheet membrane that uses silica from sugarcane bagasse as an additive. Six flat sheet membranes were then fabricated by varying the dope formulation. Membrane surface and cross-section area were analyse by scanning electron microscope (SEM). The analysis of SEM shows that the addition of silica from sugarcane bagasse changed the surface structure of the membrane especially at top layer and sub layer. The performance of flat sheet membrane were determine based on flux of pure water permeate, rejection sodium chloride solution and molecular weight cut off. The results indicate that the addition of 3% of silica give the best rejection and highest flux where successfully do rejection of 75.35 % and 42.65 L/m2hr water flux. The molecular weight cut off results shows that the membrane having solute rejection beyond 70% and categorized on their nominal molecular weight cut off.

Index Terms- Additive, Flat sheet, Membrane, Morphology, Sugarcane bagasse

I. INTRODUCTION

Membrane has gained an important place in chemical technology and are used in a wide range of applications. Technologies of membrane has become a better solution in the process of water purification, component of important procedure and apparatus in most medical sector, food industry, cosmetic industry and other industries. Nowadays, modifications of materials used in the formulation of membrane via phase inversion and processing parameters that involve in the preparation have been intensively studied [1]. The thermodynamic and kinetics properties of the membrane during the formulation process may alter the membrane structure and performance. One method that commonly used to improve the performance of membrane is addition of additive into membrane formulation. Study by [2, 3] stated that small quantity of additive being added into the formulation may cause significant changes to the characteristics of membrane. Previous study by [4] used glycerol as organic additive for blended polymer of polyvinyl alcohol and polyethylene glycol stated that the additive may acts as anti-fouling mechanism. The presence of the glycerol on the top layer of thin film composite membrane had increased the hydrophilicity of the membrane's surface [4]. Other studies by [5], found that by addition of SiO_2 in the membrane formulation will enhances fouling resistance ability, molecular weight cut off, pore radius, pore density, and surface porosity of the membrane. However, different types of silica produce different effects on membrane properties. Therefore in this study, silica extracted from sugarcane bagasse was used as an additive for flat sheet membrane fabrication.

II. EXPERIMENTAL PROCEDURES

A. Extraction of Silica

Sugarcane bagasse will be collected from nearby plantation. The sugarcane bagasse samples were undergoes hydrolysis, refluxing, precipitation and washing process to extract the pure silica. Silica was used as an additive in membrane preparation.

B. Preparation of flat sheet Membrane

The PSf were dried by temperature 50°C for 24h before use in casting formulation. Then, casting formulations were prepared by dissolving the ratio between Psf: DMAc: PVP: Silica. The six dope composition formulae for membrane formulation involve constants amount of Psf, 21% and DMaC, 71%. The PVP: Silica ratio is 7:1, 6:2, 5:3, 4:4, 3:5 and 2:6 respectively. Psf was added into the vessel containing the solvent DMAc and stirred continuously by using a magnetic stirrer to make sure the polymer is well mixed. This procedure was repeated until all the required amount of polymer is added. This process was controlled at desired range 60°C temperature and 400 rpm speed. The solution was stirred until it become homogeneous. Next, the additive, PVP was added in the solution and followed by additive silica from sugarcane bagasse. Then, the mixing process was continued until a homogeneous solution is obtained. After that, the dope solution was poured and cooled in a clean one liter storage glass bottle. The above steps is surface treatment of membrane fabrication process which involved evaporating the solvent on the membrane surface by allowing air being sucking out of the air hood. Later on, the dope solution undergo coagulation steps where the membrane sheets were immersed into appropriate liquid at appropriate temperature so that the membrane will harden and detach from the casting plate. The dope solution was cast using casting knife with range thickness 100-125 μm and immersed into coagulation bath containing distilled water under room temperature. The flat sheet membrane was air-dried for 24 hour at room temperature (27ºC). Finally, the membranes then were cut in ring shape about 6 cm diameters before placed in the cell.

C. Membrane Analysis

Membrane morphology was examined using a scanning electron microscope (SEM). Membrane were immersed in liquid nitrogen, fractured carefully then coated with gold prior to SEM analysis [6]. The performance of flat sheet membrane was evaluated based on pure water permeation fluxes (PWP) and solute rejection rates (SR) [7]. Molecular weight cut off of the flat sheet membrane was determined by identifying an inert solute rejection SR of 70-100% in steady state of experiment [6]. The concentration of solute the feed and permeate were determined by UV Spectrophotometer.

III. Results and discussion

A. Membrane Morphology

Table I shows the summarization results of morphology based on surface and cross-sections area and performance in terms of pure water flux, NaCl rejection and molecular weight cut off. The SEM image indicates that the membrane were found dense skin layer at top of surface. SEM image shows macrovoids on the membrane surface that forming spongy microstructures. Basically, the SEM image of cross section describes an asymmetric structure consisting of dense top layer, a porous sub-layer and a small portion of spongy-like structure between bottom surface layers. The top layer acts as a separation layer whereas the sub-layer provides the mechanical strength for membrane. The finger-like structure beneath the top surface layer becomes large void near the bottom surface layer. The result was similar to the previous work by [6, 8, 9] showed the membranes consist of a dense skin layer at top surface and short finger-like structure. This relates to high rejection due to the effective rejection that flow through dense skin layer and finger-like structure explaining the high water flux obtained [8].

From the cross section area images, the membrane structure was changed in terms of finger like, pore size at top and bottom layers and interconnectivity by adding silica to the casting solution. By increasing percentage of silica from 1% to 3%, it is significant that the finger like structure at the sub-layers and middle layers become longer and the spongy structure at bottom layer tend to be a finger like structure with bigger size. However, as the percentage of silica increase from 4% to 6 %, the finger like structure decreases. This is due to the separation of membrane with DMAc solvent solution is decreases and slow precipitation inside membrane layer. Principally, the precipitation started from the outer surface due to thermodynamic instability between dope and water in coagulation tank. Then, it is followed by dispersion of solvent into the coagulation bath and non-solvent into the cast film [1]. Thus, the result indicate that the straight and longest finger like structure was at dope S3 which give the best permeation compared to short finger like structure. In fact, the pore size at the top layer of membrane for dope S3 is the smallest hence lead to the better rejection.

B. Pure water permeation fluxes and solute rejection rates

From Table I, the flux is increase when the percentage of silica increases up to 3%. The PWF of 1% silica is 28.90% L/m2hr, 2% silica is 33.62 L/m2hr and 3% silica is 42.65 L/m2hr, this increases trend might due to the increased of hydrophilicity properties of membrane. The PWF were slightly similar after addition of 4% to 6% silica. In this study, the optimum flux rate can be considered at membrane which contains 3% of silica which indicate more hydrophilicity and attracts water molecules into the membrane. Moreover hydrophilicity properties also may facilitate water penetration through the membrane thus enhancing the flux [1]. In terms of salt rejection, the results indicated that at the first 3% of SCBN, the salt rejection were slightly similar approximately 75.33 % rejection. Then, the salt rejection shows gradually decreased from 75.35 % to 71.18 % with addition of 4% to 6% silica. According to the results, the 3% silica show the highest NaCl rejection of 75.35% due to the optimal mixture of silica that result in good hydrophilic properties. The high hydrophilicity membrane may reduce interaction between hydrophobic contaminants and the membrane surface; hence, the rejection properties were improved effectively [1]. This is clearly show by the rejection properties when silica is added as additive in nanofiltration membrane. However, with more addition of silica, it is result to low NaCl rejection. This may be due to crystalline effect of the silica that has low compatibility when mixed with polymer. Therefore, the small particles can be a small defect and this surely will affect the rejection value.

C. Molecular Weight Cut Off (MWCO)

In this study, the MWCO of the membrane were investigated using different reference solutions which are 1000 Da and 400 Da. Molecules having a molecular weight larger than the MWCO of a membrane will not pass through the membrane. Figure 1 shows the percentage of solute rejection for six dope formulation of flat sheet membrane. The result indicates that, the MWCO of all six dope formulation membrane having solute rejection beyond 70%. An increase in silica content from 4% to 6% for decreases the percentage of solute rejection from 92.53% to 92.38% for 1000 Da and from 76.93% to 76.79% for 400 Da respectively.

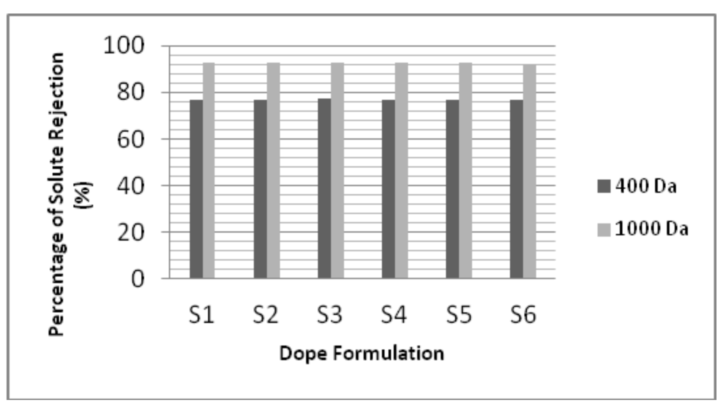
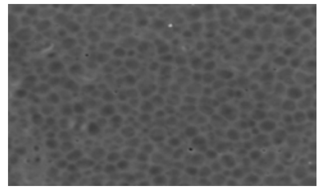
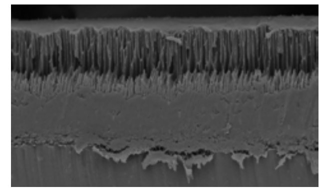
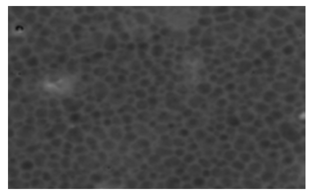
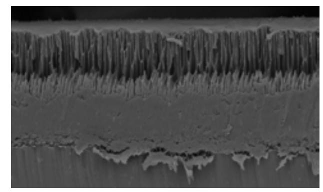
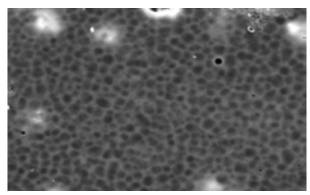
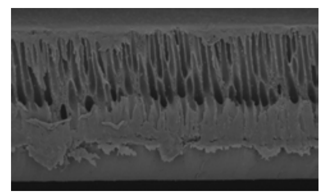
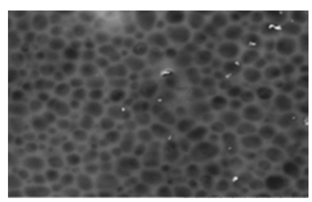
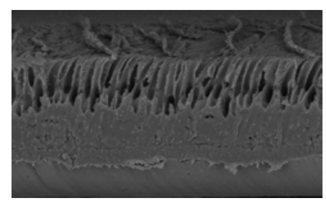
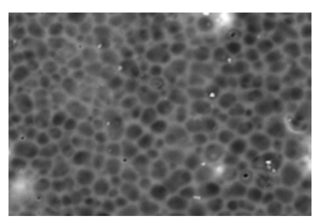
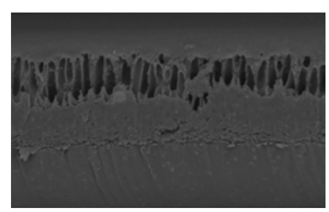
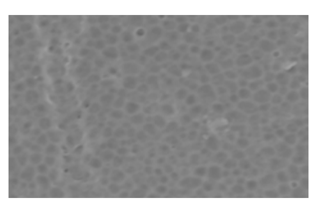
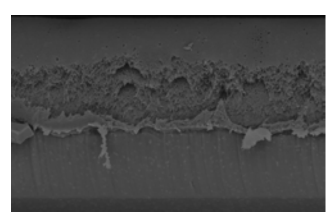


Figure 1: Molecular Weight Cut Off Test

Table I: Result on Morphology, Flux, Rejection and MWCO

Membrane	Pure water Flux (L/m^{2}hr)	NaCl Rejection (%)	Molecular Weight Cut Off test (%)		Scanning Electron Microscopy	
			400 Da	1000 Da	Surface	Cross-section
S1	28.90	75.40	76.93	92.47		
S2	33.62	75.23	77.00	92.5		
S3	42.65	75.35	77.14	92.6		
S4	41.96	74.40	76.93	92.53		
S5	42.90	73.49	76.79	92.49		
S6	42.64	71.18	76.91	92.38		

IV. CONCLUSION

In conclusion, the morphology and performance of prepared flat sheet membranes using silica as additive were successfully investigated. The best formulation of flat sheet membranes was dope S3. From the results and analyses, it found that the membrane performance of dope S3 with addition of 3% silica give the best rejection of 75.35 % and 42.65 L/m2hr water flux. From the observation using SEM, the membranes consist of a dense skin layer at top surface, it relates with the results which have higher rejection due to the effective rejection that flow through dense skin layer. The result indicates that dope S3 has straight and longest finger like structure, smallest pore and good interconnectivity which give the best permeation.

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