RESEARCH ARTICLE | FEBRUARY 05 2019

Enhanced performance of celluloce acetate/polyethylene glycol (CA/PEG) with the addition of functionalized carbon nanotube (CNT) prepared by wet-dry method FREE

Siti Nurkhamidah ✉; Yeni Rahmawati; Rizal Andhika Gumilang; Moch. Ilham Riswanda; Yusril Eka Fahrizal; Irham Hikmawan Ramadhan

AIP Conf. Proc. 2065, 030031 (2019)
https://doi.org/10.1063/1.5088289

Enhanced Performance of Celluloce Acetate/Polyethylene Glycol (CA/PEG) with the Addition of Functionalized Carbon Nanotube (CNT) Prepared by Wet-Dry Method

Siti Nurkhamidah*, Yeni Rahmawati, Rizal Andhika Gumilang, Moch. Ilham Riswanda, Yusril Eka Fahrizal, Irham Hikmawan Ramadhan

Department of Chemical Engineering, Faculty of Industrial Technology,
Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo, Surabaya 60111, Indonesia
**Corresponding author: nurkhamidah@chem-eng.its.ac.id*

Abstract. The addition of carbon nanotube (CNT) on cellulose acetate/polyethylene glycol (CA/PEG) membranes is observed to show the effect of CNT to the performance of CA/PEG membranes. Before added into CA/PEG membrane, CNT has been functionalized first by using wet-dry method. Membranes are characterized for their hydrophilicity, surface and fractured morphology, and their performance for desalination process. The performance of membranes shows by their flux permeates, permeability and salt rejection. The hydrophilicity is determined by Fourier-Transformed Infra-Red (FTIR) spectra. Surface and fractured morphology are identified by using Scanning Electron Microscopy (SEM). The experiment results show that hydrophilicity of CA/PEG membrane increases with the addition and the increasing of CNT contents. Flux permeates and permeability of membrane increases with the increasing of CNT content. Salt rejection of membrane also increases with the increasing of CNT content; however, it decreases with further increasing of CNT content. The highest value of permeate flux, salt rejection, and permability of CA/PEG/CNT membrane is 1233.333 $L/m^2.h$, 49.303%, and 10.802 $L/m^2.h.kPa$, respectively.

Keywords: cellulose; PEG; desalination; CNT; hydrophilicity; salt rejection
PACS:

INTRODUCTION

Membrane technology has become increasingly use for clean water production. How to fabricate membrane with a good performance must be done to fulfill it. Cellulose is a common material that used for membrane desalination. Ahmad et al. have observed that cellulose acetate/polyethylene glycol (CA/PEG) membrane with composition 80/20 shows the best results of salt rejection and flux permeate [1]. PEG is hydrophilic material and it increase flux permeate because it can increase pore number in the membrane [2]. However, with the increasing flux permeate, salt rejection decreases. To overcome this problem, material which can increase salt rejection need to be added. Chakrabarty, Ghoshal, and Purkait have analyze that CA can increase salt rejection [3].

Recently, several attempts have been made to increase membrane performance using nanomaterials. Effect of silica on CA/PEG membrane has been observed in the previous study [4]. The results show that hydrofilicity of membrane increases with the decreasing of silica particle size. Another nanoparticles that have been used to modified membrane are silica [4], silicon dioxide (SiO_2) [5], zinc oxide (ZnO) [6], titanium dioxide (TiO_2) [7-8], alumina (Al_2O_3) [9], zeolite [10], and carbon nanotube (CNT) [11]. In the previous study, polysulfone (PSf) membrane with the addition of 4% of multi-walled carbon nanotubes (MWNTs) has higher flux and salt rejection than PSf membrane without MWNTs [12]. In this study, CA/PEG membrane is modified with the addition of CNT nanoparticles to increase its performance.

MATERIALS AND METHODS

Cellulose acetate (CA, Mw 3000 Da, acetyl content 39%), polyethylene glycol-200 (PEG, Mw 200 Da) was purchased from Sigma Aldrich. Multi wall carbon nanotube (MWCNT) with outer diameter of 8-15 nm, length of 10-50 µm and purity > 95wt% particle size: 0.007 and 0.2µm) were purchased from Cheap Tubes Inc. Aceton was used as solvent and water as non-solvent.

Proceedings of PPS-34
AIP Conf. Proc. 2065, 030031-1–030031-4; https://doi.org/10.1063/1.5088289
Published by AIP Publishing. 978-0-7354-1793-9/$30.00

CNT were first treated with a mixed acid solution (H_2SO_4/HNO_3 = 3/1) at 70°C for 6 h and then filtered to get bulk CNT. The bulk CNT were rinsed with deionized water repeatedly until there was no more trace of acid. CNT were dried in a vacuum drying oven at 70°C then lighted with UV light for 30 minutes resulting functionalized CNT. Two gram of CA and 0.5 gram of PEG were dissolved in 17 mL of acetone. Functionalized CNT was added into that solution and its weight was varied: 0; 0.0125; 0.025; 0.0375; 0.05 gram and named as CPCU0; CPCU1; CPCU2; CPCU3; CPCU4, respectively. This solution was heated at 130°C up to homogen. Solution was cast at room temperature and dip into water for 15 min. After immersion process in water, membrane was removed at room temperature from the mold.

The permeate flux (J) represents the amount of pure water collected per unit time and per unit area at variable pressures. It was calculated by: $J = Q/t \times A$, where J is the permeate flux (mL/h.m^2), Q is the amount of permeate (mL), t is the time and A is the area (m^2). Percentage of salt rejection is the efficiency of membrane and its ability to remove contaminates and calculate by using this equation: $R=(1 - C_p/C_f) \times 100\%$, where R is the percentage of salt rejection, C_p (in ppm) is the salt concentration of the permeate, C_f (in ppm) is the salt concentration in the feed water.

RESULTS AND DISCUSSION

CNT is hydrophobic material; thus, it needs to be treated to change hydrophobic to hydrophilic. It can be hydrophilic by adding hydroxyl group (-OH group) on the surface of CNT with the addition of strong acid, H_2SO_4 dan HNO_3 [12]. The presence of –OH group is shown by the appearance of peak at wavenumber 3330 cm^{-1}, –CH group at wavenumber 2858 – 2921 cm^{-1}, C=O group at wavenumber 1716 cm^{-1}, C=C group at wavenumber 1596 cm^{-1}, and C-O group at wavenumber 1081– 1182 cm^{-1}. Figure 1 shows the increasing of –OH group in CA/PEG membranes with the addition of CNT. It means that the hydrophilicity of CA/PEG membrane increases with the increasing of CNT content. FTIR results show that the hydrophilicity of CPCU4 is the highest proved by measuring the area of –OH group, it shows that CPCU4 has higher –OH are compare to others. The morphology of membranes were analyzed by using SEM and showed in Figure 2. It shows that the morphology of membrane is asymmetry and consists of sponge and finger-liked structure.

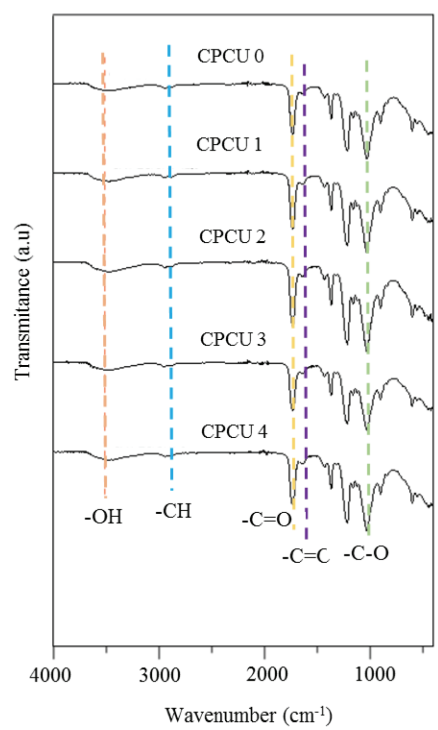

FIGURE 1 FTIR results of CA/PEG membrane with the addition of CNT

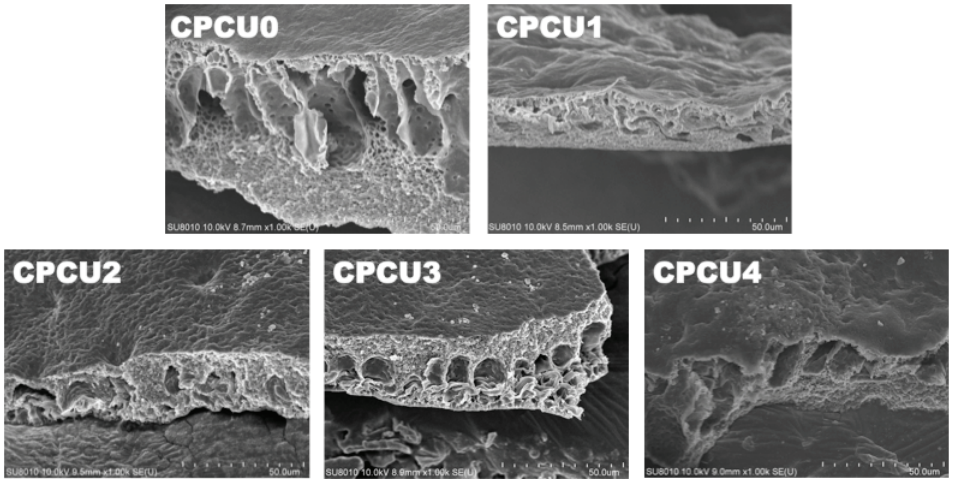

FIGURE 2 SEM micrograph of CA/PEG membrane with the addition of CNT

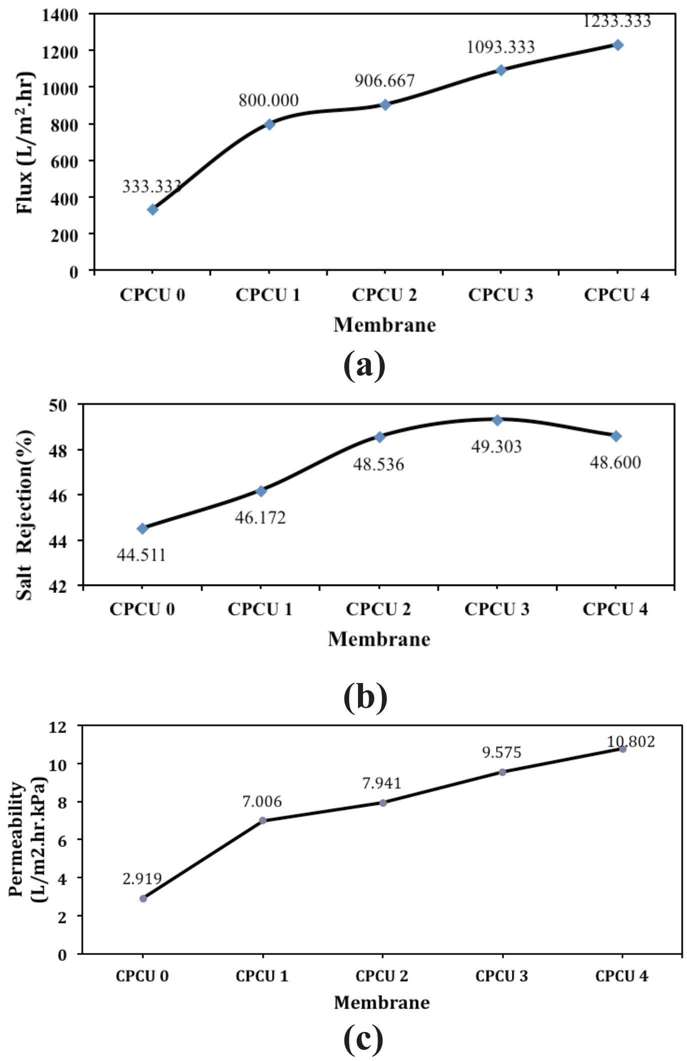

FIGURE 3 (a) Permeate flux, (b) salt rejection and (c) permeability of CA/PEG membrane with the addition of CNT

Membrane performance was analyzed from flux, salt rejection and permeability value and showed on Figure 3. Figure 3a shows flux permeates of membrane CPCU0 is 333.333 L/m^2.h then increases with the increasing of CNT. CPCU4 has the highest permeate flux, 1233.333 L/m^2.h. This result is in agreement with FTIR results. Hydrophilicity of CA/PEG membrane increases with the increasing of CNT content; thus, flux of permeate is also increased with the increasing of CNT content. Figure 3b shows that the salt rejection of CA/PEG membrane increases with the addition of CNT; however it decreases with further increasing of CNT content. The highest salt rejection is 49.303% for CPCU3. The addition of 0.0375 gram CNT could increase salt rejection of CA/PEG membrane of 10.76%. Salt rejection decreases with the increasing of membrane's pore size due to the agglomeration of CNT as reported by Kim et al. [13]. Permeability of CA/PEG/CNT membrane showed in Figure 3c. Membrane permeability shows the ability of membrane from hydrophilic pressure. Figure 3c shows that permeability of CPCU0 is 2.919 L/m^2.h.kPa and its increase with the increasing of CNT content. The highest permeability is for CPCU4, 10.802 L/m^2.h.kPa. The increasing of permeability with the increasing of CNT content is in the same trend with permeate flux.

CONCLUSIONS

Hydrophilicity of CA/PEG membrane increases with the addition and the increasing of CNT contents as shown by FTIR results. Membrane performance shows by permeate flux, salt rejection, and permeability of membranes. The results show that permeates flux and permeability increases with the increasing of CNT content. For salt rejection, it also increases with the increasing of CNT content; however, it decreases with further increasing of CNT content. Membrane with the highest value of permeates flux and permeability is CPCU4 and the value is 1233.333 L/m^2.h and 10.802 L/m^2.h.kPa, respectively. CPCU3 has the highest salt rejection of 49.303 %.

ACKNOWLEDGMENTS

This work has been financially supported by Ministry of Research, Technology and Higher Education of the Republic of Indonesia with contract's number 128/SP2H/PTNBH/DRPM/2018 (926/PKS/ITS/2018) to which the authors express their sincerest gratitude.

REFERENCES

1. A. Ahmad, S. Waheed, S. M. Khan, S. e-Gul, M. Shafiq, M. Farooq, K. Sanaullah, T. Jamil. Effect of silica on the properties of cellulose acetate/polyethylene glycol membranes for reverse osmosis. *Desalination* **355**, 1-10 (2015).
2. G. Arthanareeswaran, D. Mohan, M. Raajenthiren. Preparation, characterization and performance studies of ultrafiltration membranes with polymeric additive. *Journal of Membrane Science* **350**, 130-138 (2010).
3. B. Chakrabarty, A. K. Ghoshal, M. K. Purkait. Effect of molecular weight of PEG on membrane morphology and transport properties. *Journal of Membrane Science* **309**, 209-221 (2008).
4. S. Nurkhamidah, Y. Rahmawati, F. Taufany, I. M. P. A. Merta, D. D. D. Putra, E. M. Woo. Effect of Silica Particle Size in Cellulose Membrane for Desalination Process. *AIP Conference Proceeding*, 1699 (2015)
5. H. Wu, J. Mansouri, V. Chena. Silica nanoparticles as carriers of antifouling ligands for PVDF ultrafiltration membranes. *Journal of Membrane Science* **433**,135-151(2013).
6. S. Balta, A. Sotto, P. Luis, L. Benea, B. Van der Bruggen, J. Kim. A new outlook on membrane enhancement with nanoparticles: The alternative of ZnO. *Journal of Membrane Science* **389**, 155-161(2010).
7. H. S. Lee, , S. J. Im, J. H. Kim, H. J. Kim, J. P. Kim, B. R. Min. Polyamide thin-film nanofiltration membranes containing TiO_2 nanoparticles. *Desalination* **219**, 48-56(2008).
8. S. Nurkhamidah, Y. Rahmawati,I. Gunardi, A. Pitsyah, Priambodo, K. D., Zaim, R. L., Muqni, W. E. Enhancing Properties and Performance of Cellulose Acetate/Polyethylene Glycol (CA/PEG) Membrane with the addition of Titanium Dioxide (TiO_2) by Using Surface Coating Method. *Matec Web of Conferences* **156**, 08016 (2018).
9. X. Wang, X. Li, K. Shih. In situ embedment and growth of anhydrous and hydrated aluminum oxide particles on polyvinylidene fluoride (PVDF) membranes. *Journal of Membrane Science* **368**, 134-143(2011).
10. C. P. Leo, N. H. Ahmad Kamil, M. U. M. Junaidi, S. N. M. Kamal, A. L. Ahmad. The potential of SAPO-44 zeolite filler in fouling mitigation of polysulfone ultrafiltration membrane. *Separation and Purification Technology* **103**, 84-91(2013).
11. H. Zhao, S. Qiu, L. Wu, L. Zhang, H. Chen, C. Gao. Improving the performance of polyamide reverse osmosis membrane by incorporation of modified multi-walled carbon nanotubes. *Journal of Membrane Science* **450**, 249-256(2014).
12. J. Choi, J. Jegal, W. Kim. Fabrication and Characterization of Multi-Walled Carbon Nanotubes/Polymer Blend Membranes. *Journal of Membrane Science* **284**, 406-415 (2006).
13. H. J. Kim, K. Choi, Y. Baek. High Performance Reverse Osmosis CNT/Polyamide Nanocomposite Membrane by Controlled Interfacial Interactions. *ACS Publication of Applied Materials and Interfaces*, 2819 – 2829 (2013).