CURRICULUM VITAE

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Academic Qualifications

Doctor of Philosophy (October-2020)	**Department of Chemical Engineering,** National Institute of Technology- Tiruchirappalli, Tamilnadu, India. **Thesis Title:** "Quorum sensing inhibitors embedded polyethersulfone membranes for enhancement of biofouling resistance in wastewater treatment"
Master of Engineering. (2009-11)	**Environmental Engineering**, Alagappa Chettiar College of Engineering& Technology, Karaikudi. (Govt. of Tamilnadu) Affiliated to Anna University, Tiruchirappalli, Tamilnadu.
Bachelor of Technology (2005-09)	**Biotechnology** P.R Engineering College, Vallam, Thanjavur. Affiliated to Anna University, Chennai, Tamilnadu.

Professional Experience

Research Associate (Sep, 2013 – Jun, 2016)	Department of Chemical Engineering, National Institute of Technology- Tiruchirappalli, Tamilnadu.
Assistant Professor (June, 2012- April, 2013)	Department Civil Engineering, Dhanalakshmi Srinivasan Engineering College, Perambalur, Tamilnadu.
Assistant Professor (Jan, 2012- May,2012)	Department Civil Engineering, M.N.S.K. College of Engineering, Pudukkottai, Tamilnadu.
Shift Engineer (May, 2011-Dec, 2011)	ETP treatment plant (Chennai Petro chemical Limited-Site,Manali, Chennai), Pure Enviro Engg. Pvt Ltd, Chennai.

Research Summary

- Fabrication and characterization of UF, MF and RO Membranes.
- Expert in development of biofouling resistant membrane.
- Design of membrane modules for water filtration, gas separation and distillation process.
- Optimization of membrane process conditions for water treatment.

Awards & Fellowship

- Qualified to final stage of Carbon Zero Challege-2019 conducted by IIT-Madras, India and received Rs. 500,000 for the development of Membrane desalination (MD) prototype.
- DST Project Research Associate Fellowship, Indo-Korea Research Project (INT-Korea P-20/2013), National Institute of Technology- Tiruchirappalli, Tamilnadu.
- Best Oral Presentation Award- during 'ICMHCEE2019' Conference, NIT-Tiruchirappalli (2019).

HONORS

June 2015	Visiting Student, Advanced Membrane Technology Research Centre (AMTEC), Universiti Teknologi Malaysia (UTM), Malaysia.
March 2014	Visiting Student, Department of Environmental Engineering, Konkuk University, Seoul, 143-701, South Korea.

Publications in Referred Journals

1. **<u>Sathish Kumar R.,</u>** Arthanareeswaran G., Ismail A.F., Jihyang Kweon, (2020), Enhanced performance of Mindel membranes by incorporating conductive polymer and inorganic modifier for application in direct methanol fuel cells (DMFCs), *Asia-Pac J Chem Eng.* (Article in press) https://doi.org/10.1002/apj.2473. **John Wiley & Sons, Ltd, Impact factor: 1.06 (Q2 Journal)**
2. Anirudh Singh, **<u>Sathish Kumar R.,</u>** Gumpu M. B., Zsuzsanna L., Veréb. G., Kertész S., Arthanareeswaran G. (2020) Titanium dioxide doped hydroxyapatite incorporated photocatalytic membranes for the degradation of chloramphenicol antibiotic in water, *J. Chem. Technol. Biotechnol.* https://doi.org/10.1002/jctb.6617 **John Wiley & Sons, Ltd, Impact factor: 2.75 (Q1 Journal)**
3. Lukka Thuyavan, Y., Arthanareeswaran, G., Ismail, A. F., Goh , P. S., Shankar, M. V., Ng, B. C., **<u>Sathish Kumar, R.,</u>** Venkatesh, K. (2020) Binary metal oxides incorporated polyethersulfone ultrafiltration mixed matrix membranes for the pretreatment of seawater desalination, *J. App. Poly. Sci.* (Article in press) https://doi.org/10.1002/app.49883 **John Wiley & Sons, Ltd, Impact factor: 2.52, (Q2 Journal)**
4. **<u>Sathish Kumar, R.,</u>** Arthanareeswaran, G. (2019). Nano-curcumin incorporated polyethersulfone membranes for enhanced anti-biofouling in treatment of sewage plant effluent. *Mater. Sci. Eng. C.*, **94**, 258–269. **Elsevier, Impact factor: 5.880 (Q1 Journal)**
5. **<u>Sathish Kumar, R.,</u>** Arthanareeswaran, G. (2018). Reduction of chemical oxygen demand and colour from the rice mill wastewater by chitosan/2(5 H)-furanone-incorporated ultrafiltration membrane system. *Sep. Sci. Technol.*, **6395**, 1–17. **Taylor & Francis, Impact factor:** 1.718 **(Q2 Journal)**
6. **<u>Sathish Kumar, R.,</u>** Arthanareeswaran, G., Lukka Thuyavan, Y., Ismail., A.F. (2017). Enhancement of permeability and antibiofouling properties of polyethersulfone (PES) membrane through incorporation of quorum sensing inhibition (QSI) compound. *J. Taiwan Inst. Chem. Eng.*, **72**, 200–212. **Elsevier, Impact factor: 4.794 (Q1 Journal)**
7. **<u>Sathish Kumar, R.,</u>** Arthanareeswaran, G., Paul, D., Kweon, J.H. (2015). Modification methods of polyethersulfone membranes for minimizing fouling - Review. *Membr. Water Treat.*, **6**, 323–337. **Techno-Press, Impact factor:0.975 (Q3 Journal)**
8. **<u>Sathish Kumar, R.,</u>** Arthanareeswaran, G., Paul, D., Kweon, J.H., (2015). Effective removal of humic acid using xanthan gum incorporated polyethersulfone membranes. *Ecotoxicol. Environ. Saf.*, 121, 223–228. **Elsevier, Impact factor: 4.527 (Q1 Journal)**

Book Chapters

1. **<u>Sathish Kumar, R.,</u>** Arthanareeswaran, G., 2018, Biofouling in a Membrane System: Mechanisms, Monitoring and Controlling Publisher: Nova Science Publishers, Inc. Book: Membrane Bioreactors and Fouling: A Review and Directions for Research Editor: Jose King, PP 71-101 (ISBN: 978-1-53614-363-8).
2. **<u>Sathish Kumar R.,</u>** Arthanareeswaran G., Ahmad Fauzi Ismail, Muhammad Sihwan Abdullah, Be Cheer Ng, 2018, Chapter 4, Nuclear Magnetic Resonance (NMR) Spectroscopy, Book: Membrane Characterization, Publisher: Elsevier, Editors: Nidal Hilal, Ahmad Fauzi Ismail, Takeshi Matsuura, Darren Oatley-Radcliffe, pp.69-79 (ISBN: 978-0-444-63776-5).

Conference Publications

1. **<u>Sathish Kumar R.,</u>** Arthanareeswaran G., 2020 "Acylase-I enzyme immobilized polyethersulfone nanofiltration membrane to prevent biofouling based on quorum sensing inhibition" Chemicals & Materials for Emerging Technologies (CheMET-2020) e-conference, Qatar University, Qatar

2. **<u>Sathish Kumar R.,</u>** Arthanareeswaran G., 2019 "Quorum sensing inhibitors embedded Polyethersulfone membranes for enhanced wastewater treatment", Young Scientist Conference, India International Science Festival (IISF-2019), Kolkatta.
3. Anirudh Singh, **<u>Sathish Kumar R.,</u>** Arthanareeswaran G., 2018, Performance evaluation of photocatalytic membranes for the treatment of pharmaceutical wastewater, International Conference on Desalination (InDACON-2018), at National Institute of Technology-Tiruchirappalli, Tamilnadu.
4. **<u>Sathish Kumar R.,</u>** Arthanareeswaran G., 2017, "Development antibiofouling polyethersulfone/furanone loaded nanochitosan membranes for treatment of rice mill effluent"National conference on Recent trends on Membrane and Separation Technology, CSIR-CSMCRI, Gujarat.
5. **<u>Sathish Kumar R.,</u>** Arthanareeswaran G., 2014 "Biopolymer incorporated polyethersulfone (PES) membranes for enhanced ultrafiltration performance and improved hydrophilicity" national conference on "Application of the Derivatives of Chitin and Chitosan (ADCC)", at The Gandhigram Rural Institute-Deemed University, Dindigul, Tamil Nadu.
6. **<u>Sathish Kumar R.,</u>** Arthanareeswaran G., Ismail A.F. 2014 "Removal of residual pesticide from rice mill effluent by novel polymer-enhanced ultrafiltration technique" Proceedings of the International conference on Green Technology for Environmental Prevention and Control (ICGTEPC-2014), at National Institute of Technology- Tiruchirappalli, Tamilnadu.

Membership in Scientific Societies

1. Life member -International Association of Engineers (IAENG) (Membership Number: 158782)
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Reference

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Declaration

I hereby declare that all the information provided by me in this document is factual and correct to the best of my knowledge and belief.

Date: <u>24.01.2021.</u>
Place: <u>Pudukkottai.</u>

Yours Sincerely,

(SATHISH KUMAR R)

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Nano-curcumin incorporated polyethersulfone membranes for enhanced anti-biofouling in treatment of sewage plant effluent

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ABSTRACT

Biofouling is a severe problem in membrane systems which hampers their broad applications because it requires regular chemical cleaning, reduces membrane life, and also decreases product quality. In this study, nano-curcumin (CCM) was prepared by sonication-assisted wet-milling technique and then incorporated in polyethersulfone (PES) membrane to enhance the anti-biofouling property. TEM analysis of the curcumin showed that nanomaterials are spherical. FTIR studies confirmed that the presence of CCM nanomaterial in PES membrane. Zone inhibition studies revealed that PES/CCM nanocomposite membranes exhibited the better anti-biofouling propensity against *Escherichia coli* and *Pseudomonas aeruginosa*. Static adhesion studies also showed that PES/CCM nanocomposite membranes prevented the attachment and proliferation of *E. coli* cells. Also, PES/2 wt% CCM nanocomposite membrane had a high thermal degradation temperature of 575.62 °C and tensile strength of 1.87 MPa. Moreover, addition of CCM nanomaterial in casting solution altered the membrane morphology and hydrophilicity. Further, pure water flux was increased up to 64.48 $L \cdot m^{-2} \cdot h^{-1}$ for PES/2 wt% CCM nanocomposite membrane. Filtration of raw sewage treatment plant effluent was also carried out. The incorporation of curcumin in membranes was effectively improved the antifouling tendency without compromised affecting the chemical oxygen demand reduction. This study highlights the anti-biofouling potential of CCM incorporated PES nanocomposite membranes, which could be utilized for various filtration applications.

1. Introduction

Biofouling is defined as the undesirable attachment and growth of the microorganisms on the membrane surface, and attached microorganisms produce the biopolymer matrix, i.e. biofilm. Biofouling causes pore blocking and formation of a cake layer on the membrane surface and then leads to decrease in membrane performance. It requires adequate cleaning, which increases the operational and maintenance cost of the membrane process as well as, reduces the lifespan of the membranes [1–3]. Recent research was focused on fabricating the novel membranes to enhance the membrane selectivity and mitigate the biofouling.

In this study, polyethersulfone (PES) was used for membrane synthesis owing to its high mechanical and thermal stability properties [4,5]. It also possesses the better chemical stability and film-forming properties [6]. However, PES membranes tend organic fouling and biofouling due to their undesired hydrophobic property [7,8]. Thus, various modification techniques such as coating [9], grafting [10,11], blending [12,13] etc. were developed to overcome the fouling. Among the modification techniques, blending is a facile method, and it is widely preferred [14,15].

To prevent the biofouling, antimicrobial nanomaterials such as graphene oxide (GO), silver (Ag), hydrous manganese dioxide (HMO) and titanium dioxide (TiO_2) were directly incorporated into the membrane matrix [12,16–18]. M Zhang et al. [12] fabricated bio-Ag^0/PES nanocomposite membranes and reported that excellent antibacterial property. Duan et al. [19] fabricated graphene immobilized enzyme/polyethersulfone mixed matrix membrane for enhanced anti-bacterial properties. Nowadays, natural products or derivatives of natural compounds were used as biofouling preventers, and they were listed in Table 1. In this study, we focused on the utilization of the commercially available natural compound curcumin as an antibiofouling enhancer.

Curcumin (diferuloylmethane), isolated from the rhizome, *Curcuma longa* Linn, has broad pharmacological properties such as antioxidant, antitumor, anti-inflammatory, antibacterial, antiviral and anticoagulant activities [29–32]. Curcumin has extensive anti-biofilm properties against the Gram-positive microorganisms such as *Staphylococcus aureus* [33], *Pseudomonas aeruginosa* [34] and uropathogens [35]. Curcumin has also been used to fabricate the antimicrobial polymers [36,37], polymer blend films [38], nanofibers [39,40] for various biomedical

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Reduction of chemical oxygen demand and color from the rice mill wastewater by chitosan/2(5*H*)-furanone-incorporated ultrafiltration membrane system

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ABSTRACT

Improper disposal of high organic load rice mill effluent may cause adverse impact to the environment. In the present study, we fabricated anti-biofouling polyethersulfone (PES) membrane by incorporating chitosan (CH) and 2(5*H*)-furanone loaded chitosan (FCH) nanoparticles for the effective treatment of rice mill effluent. As prepared, membranes were characterized by Fourier transform infrared spectroscopy, scanning electron microscope, and atomic force microscopy. Membrane performance was evaluated by rice mill effluent filtration studies. PES/1.5 wt.% FCH membrane showed the higher flux rate with lesser fouling reduction ratio of 32%, chemical oxygen demand rejection of 63%, and color reduction of 67%. Moreover, it exhibited the better anti-biofouling resistance than the neat PES membrane.

Abbreviations: CH: Chitosan nanoparticles; FCH: Furanone loaded chitosan nanoparticles; COD: Chemical oxygen demand; DMSO: Dimethyl sulfoxide; PES: Polyethersulfone; QSI: Quorum sensing inhibition; PVC: Polyvinyl chloride; BSA: Bovine serum albumin; TPP: Sodium tripolyphosphate; NMP: N-methyl pyrrolidone; MA: MacConkey agar; HA: Humic acid; OD: Optical density; TEM: Transmission electron microscopy; NIPS: Non-solvent induced phase separation; FESEM: Field emission scanning electron microscope; AFM: Atomic force microscopy; PWF: Pure water flux

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Introduction

Rice is an essential food, and it is consumed by more than a third of the world's population.[1] Rice milling is a practice of removing the husk from the rice paddy. Parboiling process is the most common method to remove the husk from the rice paddy in rice milling industries. Parboiling process requires large quantities of water for soaking the paddy and generates 1–1.2 l of wastewater per unit weight (kg) of paddy.[2] Rice mill effluent contains a high concentration of organic and inorganic substances.[3,4] Discharge of rice mill effluent into soil or water bodies on a continuous basis causes an adverse impact on the ecosystem. Therefore, adequate treatment is needed to fulfill the stringent environmental regulations and prevent the environmental pollution.

Nowadays, membrane filtration systems were widely used for wastewater treatment owing to their advantages such as energy-efficient and easy to scale up.[5] Among the various polymeric materials, polyethersulfone (PES) is the well-renowned polymer for the fabrication of microfiltration and ultrafiltration membranes due to its excellent chemical resistance property, thermal stability, and high mechanical strength.[6] However, the hydrophobicity of the PES membrane is usually susceptible to fouling, which can reduce the productivity and also shorten the lifespan of the membrane.[7] Fouling is caused by the undesired deposition of organic matters, inorganic particles, salts, and colloids and also by biological growth. Among other fouling, biofouling is a severe problem for the membrane systems, and it is complicated to clean because of the microorganisms' self-replicating nature.[8]

In general, membrane modifications are highly pronounced to enhance hydrophilicity, as well as to endow antimicrobial property to the polymeric membranes.[8–14] Recent studies also reported that quorum sensing inhibition (QSI) received the considerable attention and QSI inhibitors such as garlic extract, ginger extract, vanillin, *Piper betle* extract, furanone derivatives, etc. can effectively mitigate the biofouling on the membrane surface.[15–21]

Among them, 2(5*H*)-furanone was broadly utilized as a QS inhibitor owing to its broad spectrum of antimicrobial and antifungal property.[22–24] It has a QS inhibition activity against gram-negative bacteria such as *Aeromonas hydrophila*,[24] *Chromobacterium violaceum*,[25] and

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/lsst.

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Enhancement of permeability and antibiofouling properties of polyethersulfone (PES) membrane through incorporation of quorum sensing inhibition (QSI) compound

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ABSTRACT

The increasing incidence of accumulation of microorganisms on polymeric membrane surfaces has motivated the present study to develop novel biofouling resistant membranes. Hydrophilic and quorum sensing inhibition properties of vanillin (4-hydroxy-3-methoxybenzaldehyde) have propelled the current investigation of employing it as a modifier for the fabrication of fouling resistant polyethersulfone (PES) membrane. The concentration of vanillin varied from 0.5 to 2 wt. % and *N*-methyl-2-pyrrolidone (NMP) was used as solvent. ATR-FTIR and thermogravimetry analysis showed that vanillin had a good compatibility with the PES membrane. The contact angle value of the neat PES membrane was 74.3° and it decreased up to 61.5° for 2 wt. % vanillin incorporated PES membrane. Moreover, the water flux also significantly improved up to 27.41×10^{-6} L/m^2 s kPa. Antifouling propensity of the prepared membranes was evaluated by protein static adsorption and filtration of alginic acid solution. Among the membranes, PES (98 wt. %)/vanillin (2 wt. %) membrane exhibited the lowest flux reduction ratio of 26%. In addition, antibiofouling property of the membranes was assessed by disk diffusion assay technique and it showed that PES (98 wt. %)/vanillin (2 wt. %) membrane displayed the higher inhibition zone value of 3.10 ± 0.21 mm and 2.60 ± 0.18 mm for *E. coli* and *P. aeruginosa* respectively.

1. Introduction

In recent decades, membrane systems have received considerable attention in water treatment, desalination of seawater and wastewater reclamation to meet the stringent environmental regulation, potable water demand [1]. In addition, membrane systems have advantages such as energy efficiency and easy scaling up. However, membrane systems confront the challenge of fouling. Fouling is caused by accumulation of organic materials (organic fouling), deposition of clay and silt (colloidal fouling) and also due to biomolecules (extracellular polymeric substances) secreted by bacteria and which lead to adherence and consequent growth of microorganisms on the membrane surface (biofouling) [2,3]. Fouling shortens the lifetime as well as productivity of the membrane systems and also increases the maintenance cost [3]. Under these circumstances, membrane modifications were widely pronounced to mitigate fouling. Among the various modification techniques, blending is commonly used to fabricate membranes with desired properties in an efficient manner [4].

Literature studies reveal that hydrophilic polymers [5], inorganic salts [6], hydrophilic nanomaterials [7–11], and hydrophilic monomers [12] were blended with the base polymer to enhance hydrophilicity, selectivity of the membranes and also to minimize the fouling [6]. However, biofouling still remains as a major obstacle for the wide usage of membrane systems. Hence, the important aspect of controlling biofouling represents one of the most persistent challenges in membrane systems [13,14]. Biofouling is in general initiated through the following steps. (a) Attachment of bacteria to the membrane surface, (b) Communication between bacteria, *i.e*. quorum sensing (QS) leading to colony /biofilm formations [15]. In biofilms, bacterial colonies are enclosed by extracellular polymeric substances (EPS). EPS are mainly composed of polymeric compounds, proteins and polysaccharides and are also referred as major foulants in membrane operations [16].

Plant extracts from piper betle [17] and *Vanilla planifolia* [18] and natural products like 2(5H)-Furanone have been reported to prevent biofouling on membrane surfaces [19]. These natural compounds inhibit quorum sensing and reduce the formation of biofilms.(ref) Vanillin is a plant derivative and a well-known

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Effective removal of humic acid using xanthan gum incorporated polyethersulfone membranes

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ABSTRACT

In this study, xanthan gum (XA) was used as a hydrophilic biopolymer additive for the modification of polyethersulfone (PES) membrane to removal of humic acid (HA). The membranes are prepared using phase inversion technique and the concentration of XA was varied from 0.5 to 1.5 wt%. The prepared membranes are characterized as a function of hydrophilicity, equilibrium water content (EWC), porosity studies and functional group analysis. Membrane surface and cross-sectional morphology was studied using scanning electron microscope. The lower contact angle value 64.2° was exhibited, when 1.5 wt% of XA incorporated in PES membrane and this ensures that increase of hydrophilicity in pristine PES membrane. Further, higher water permeability (PWP) of 68.9^{-9} m/s kPa was observed for 1.5 wt% of XA/PES membrane. The effect of pH on HA removal was studied for neat PES and XA/PES membranes. The rejection performance of XA incorporated in PES membranes were compared with commercial available PES membrane.

1. Introduction

Surface water is being intensively polluted by various industrial activities, modern agricultural practices, and a natural accumulation of dead leaves, fish and bird faeces, and anthropogenic activities. Moreover, dead leaves degradation and in situ anaerobic digestion of algal or microbial biomass generate humic substances in the surface water streams. Humic acid (HA) is an organic matter. Presence of HA in surface water, can cause the following adverse effects. There are, (a) Impart unpleasant the odour, (b) Changes the colour, (c) Absorbs the metals and (d) Increase the microbial population (Kilduff et al., 1996; Chen et al., 2003; Thurman, 1985). Hence, HA has to be properly treated to provide the portable water to the Public. It is difficult to treat by the conventional water treatment methods. Because, during the conventional water treatment process like coagulation and clarification, it may react with coagulants, forms by-products and hinders the treatment process. Moreover, during the disinfection process, phenolic hydroxyl groups of HA reacts with chlorine and forms trihalomethanes (THMs) as disinfection by-product (Krasner et al., 2006; Zularisam et al., 2006).

Membrane treatment are widely recognized alternative water treatment process to conventional treatment methods for removal the pollutants and meet the stringent environmental regulations (Katsoufidou et al., 2005; Susanto and Ulbricht, 2008; Shao et al., 2011; You et al., 2013). The selection of suitable membrane materials for removal the pollutants with desired properties is important task. Polyethersulfone (PES) is widely used membrane materials because it has good mechanical strength, high thermal stability, better chemical resistance and film-forming property. However, the major bottleneck of usage of PES is hydrophobic property. Hydrophobic surfaces are more prone to fouling (Wang et al., 2011; Wang et al., 2006; Rahimpour et al., 2010; Rahimpour, et al., 2012). Fouling hinders productivity, affects permeation of ions, transport of pollutants and also the lifetime of the membrane. Hydrophobic polymeric membranes have been modified by using additives to enhance permeability and increase their hydrophilicity to prevent the fouling. The work reported the influence of hydrophilic polymeric additives such as Polyethylene glycol (PEG) (Xu et al., 1999b), Polyvinylpyrrolidone (PVP) (Xu et al., 1999a; Marchese et al., 2003) and poly sulfoxide amide (Rahimpour et al., 2009) that increase the hydrophilic property of the modified membrane. Hydrophilic biopolymers are also a potential material for modification of hydrophobic polymers. There had also been reports on novel membranes synthesised by blending cellulose acetate (CA) with hydrophilic biopolymer carboxymethyl cellulose acetate (CMC) which shows enhanced hydrophilic characteristics and higher pure water flux (PWF) (Han et al., 2013). Lakra et al. (2013) reported Chitosan blend membranes such as PES and PES/CA with improved flux and without compromising

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SPECIAL THEME RESEARCH ARTICLE

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Enhanced performance of Mindel membranes by incorporating conductive polymer and inorganic modifier for application in direct methanol fuel cells

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Abstract

Sulfonated polyethersulfone (SPES), polyaniline (PANI), and Cloisite 15 A® were used as modifiers for the fabrication of Mindel composite polymer electrolyte membranes (PEMs). Pristine Mindel and Mindel composite PEMs were fabricated by the solution intercalation technique. The presence of modifiers in the Mindel membrane matrix was confirmed by Fourier transform infrared (FTIR) studies. The primary characteristics of pristine Mindel and Mindel PEMs such as water uptake, methanol uptake, proton conductivity ion-exchange capacity (IEC), and chemical and mechanical stability were evaluated. The pore size of Mindel/SPES/Cloisite 15 composite PEM was increased owing to the addition of SPES and Cloisite 15. The higher proton conductivity of 4.323 × 10^{-4} S cm^{-1}, enhanced IEC of 0.482 mequiv. g^{-1}, and maximum water uptake (%) of 38.12 were noted for Mindel/SPES/Cloisite membrane. Membrane selectivity of all Mindel PEMs was enhanced by the addition of modifiers. The results of this study indicate that Mindel composite membranes could be utilized as PEMs for direct methanol fuel cell (DMFC).

KEYWORDS

Cloisite 15 A®, direct methanol fuel cell, membrane selectivity, Mindel, proton conductivity, sulfonated polyethersulfone

1 | INTRODUCTION

In the recent past, development of polymer electrolyte membranes (PEMs) for direct methanol fuel cells (DMFCs) has received substantial consideration owing to their low cost, high energy density, and easy handling.[1,2] In general, perfluorinated ionomers (PFIs) such as Nafion and Nafion-like polymers were widely used as solid polymer electrolyte materials in DMFC. However, usage of existing PFI membranes was limited owing to very high cost, operation temperature that is restricted to 70–80°C, and high methanol crossover.[3] In recent decades, researchers devoted their attention to the development of low-cost, high-performance PEMs for fuel cell applications.[3–7] Sulfonated polyethersulfone (SPES),[4,5] sulfonated poly(ether ether ketone) (SPEEK),[6–9] sulfonated polysulfone,[3,10,11] sulfonated poly(aryl ether ether ketone ketone)s,[12] sulfonated poly(ether ketone ketone),[13] and so on have been utilized for the preparation of PEMs owing to their outstanding mechanical

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Binary metal oxides incorporated polyethersulfone ultrafiltration mixed matrix membranes for the pretreatment of seawater desalination

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Abstract
In this study, an attempt was made to pretreat seawater using polyethersulfone (PES) mixed matrix membranes (MMMs) incorporated with titania-based binary metal oxides. Two different titania-based binary metal oxides were prepared, namely titania-zirconia (TiZr) and titania-zinc oxide (TiZn). The influence of hydrophilic and negatively charged sulfonated poly(ether ether ketone) (SPEEK) polymer as additive of PES MMMs was also studied. Morphological and elemental analysis revealed that both ZrO_2 and ZnO were well dispersed in the as-prepared binary metal oxide TiZr and TiZn, respectively. Thermogravimetry analysis indicated the good compatibility of TiZr and TiZn with the SPEEK/PES polymer. The binary metal oxide incorporated SPEEK/PES MMMs exhibited improved hydrophilic properties with a low water contact angle of $57^\circ \pm (0.6)$. SPEEK/PES MMMs incorporated with 0.5 wt% TiZr exhibited the highest permeability of $3.11 \times 10^{-7} \pm (0.2)$ m/s·kPa. Seawater pretreatment performance of membranes evaluated using natural organic matters containing high salinity feed water. TiZr and TiZn incorporated SPEEK/PES MMMs exhibited 95% rejection for humic acid. SPEEK/PES MMMs loaded with 0.5 wt% TiZr also showed the highest water flux and 87% water recovery within 90 min of seawater filtration. Both PES/SPEEK/TiZr and PES/SPEEK/TiZn MMMs exhibited superior antibacterial activity.

KEYWORDS
Binary metal oxides, Fouling, Mixed matrix membranes, Seawater desalination

1 | INTRODUCTION

Seawater reverse osmosis (SWRO) is a reliable and sustainable desalination technology to produce high-quality potable water. However, the performance of RO membranes is hindered during longer operation duration by the attachment of various foulants such as natural organic matter (NOM), extracellular polymer substances, and inorganic salts and microbes.[1] Fouling causes reduction in water permeability and salt retention capability of the membrane. Biofouling is also associated with high-energy consumption and shortened membrane shelf life.[2] To reduce the fouling tendency of RO membrane, seawater is preferably pretreated via conventional unit operations such as coagulation, sedimentation and flocculation. However, such conventional pretreatment techniques do not produce quality influent that can be treated with RO process to produce satisfactory

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Modification methods of polyethersulfone membranes for minimizing fouling – Review

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Abstract. Membrane Fouling was considered as major drawback in various industrial applications. Thus, this paper reviews the surface modification of polyethersulfone (PES) membranes for antifouling performance. Various modification techniques clearly indicate that hydrophilicity has to improve on the PES membrane surface. Moreover, the mechanism of fouling reduction with corresponds to various modification methods is widely discussed. Incorporation of hydrophilic functional groups on PES membrane surface enhances the surface free energy thereby which reduces the fouling. Characterization techniques adopted for the surface modified membranes was also discussed. These studies might be useful for the other researchers to utilize the modification technique for the applications of waste water treatment, chemical process industry and food industry.

Keywords: surface modifications; fouling; hydrophilic modifiers; polymer additives; flux decline

1. Introduction

Membrane technology is a novel separation technique. In recent days lot of research is going on to develop new polymeric synthetic membranes. Based on very specific properties, originating from structural factors and the final application of the membrane, the membrane material has to be chosen. Normally, organic or inorganic polymer materials are used for fabrication of ultrafiltration membranes. Commonly, PES is used as a membrane material for various industrial applications as given below.

- Dairy industry for protein separation and whey protein recovery
- Pharmaceuticals
- Beverage filtration and concentration
- Haemodialysis
- wastewater treatment (Maximous *et al*. 2010)
- Gas separation
- Bacteria and particulate removal (Yadav 2009)

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A Review and Directions for Research

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Chapter 3

BIOFOULING IN A MEMBRANE SYSTEM: MECHANISMS, MONITORING AND CONTROLLING

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ABSTRACT

Biofouling is defined as adherence and undesired growth of microorganisms on membrane surfaces, and it can result in loss of productivity, increase in transmembrane pressure (TMP) and reduction in lifespan. It is the most persistent challenging issue for membrane development and applications. In this book chapter, the mechanism of biofilm formation is discussed along with the factors influencing the attachment and consequent growth of microorganisms on the surface of the membrane. The common biofouling mitigation methods such as feed pre-treatment, membrane cleaning and membrane modification for

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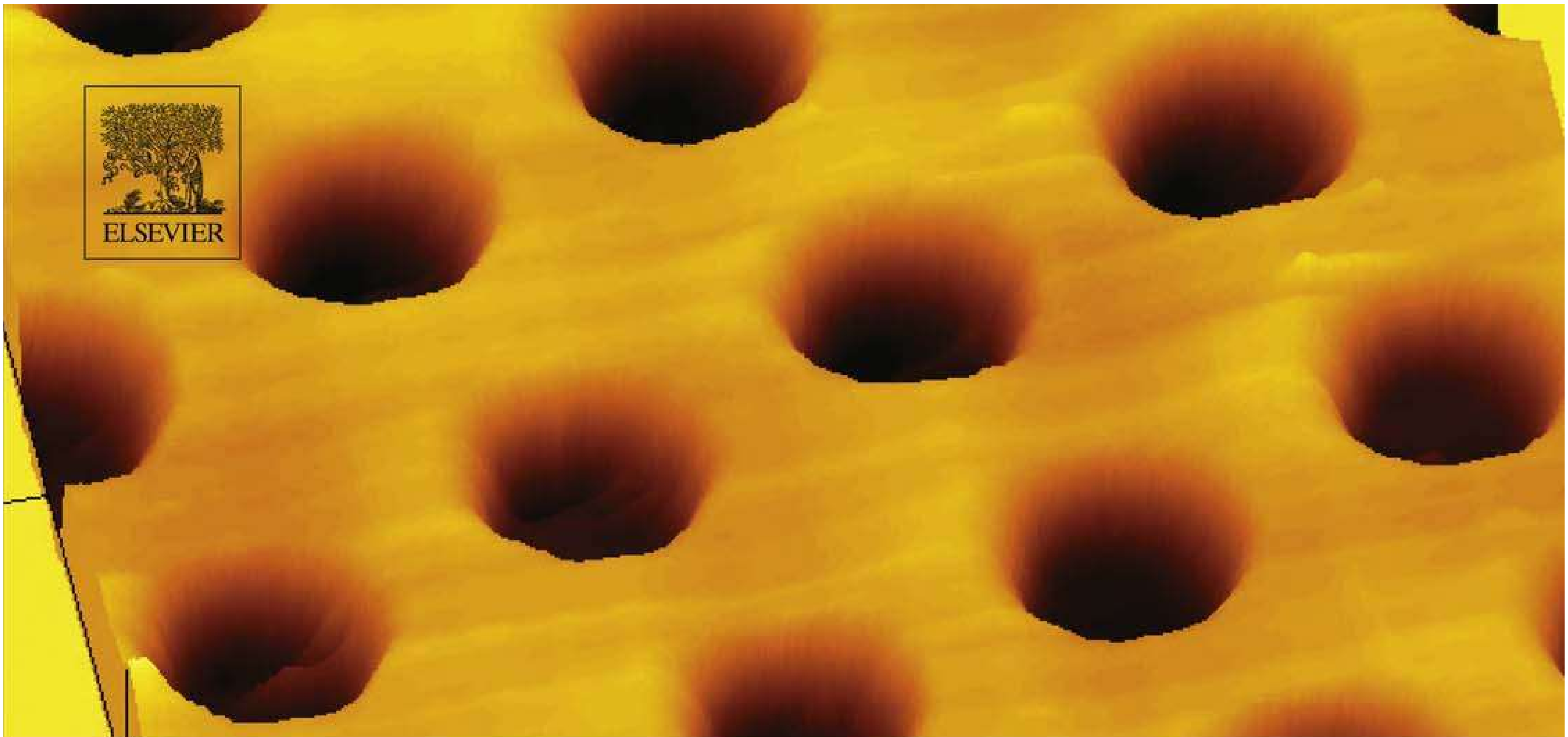

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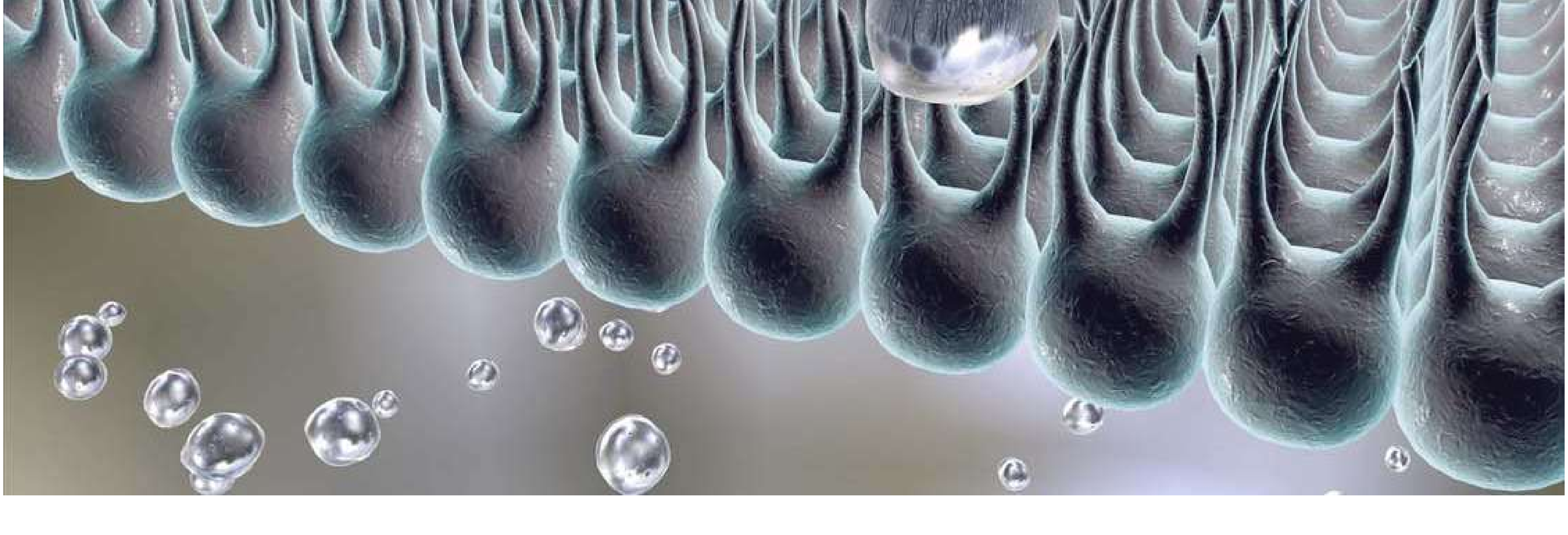

CHAPTER 4

Nuclear Magnetic Resonance (NMR) Spectroscopy

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Chapter Outline

1. Introduction

Nowadays, nuclear magnetic resonance (NMR) spectroscopy is one of the most essential research tools in material science and engineering. It received a considerable interest in membrane technology that offers structural information [1], blend miscibility [2], blend phase morphology [3], and purity of polymers [4]. It provides details about the stability and degradation of the polymers such as degree of acetylation, degree of amination, and degree of sulfonation [5–8]. It is also used to predict the pore size distributions (PSDs) of the polymer matrix [9]. The main objective of this book chapter is to increase our knowledge of using NMR spectroscopy on membrane technology. In addition, the chemical nature and the surface features of polymeric membranes, and their proton conductivity properties were correlated.

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