

Novel sulfonated polyamide thin-film composite nanofiltration membranes with improved water flux and anti-fouling properties

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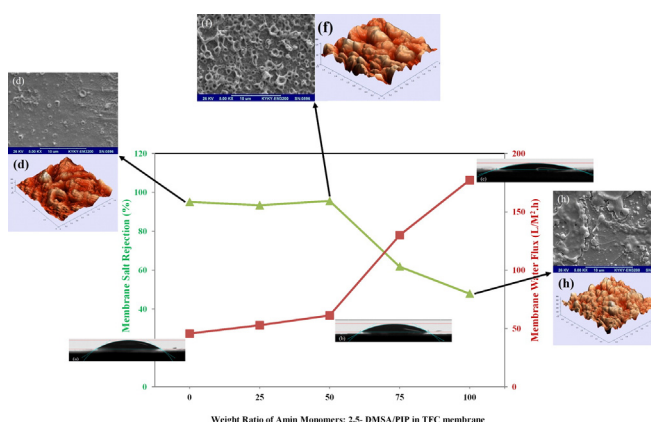
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HIGHLIGHTS

- A novel sulfonated TFC NF membrane was synthesized via interfacial polymerization.
- Effect on amine monomer type on membrane structure and performance was evaluated.
- A combination of sulfonated amine and usual amine was used in membrane top layer.
- Sulfonated amine improved membrane PWF, hydrophilicity, and antifouling property.
- Membranes prepared by 50% of sulfonated amine showed the best separation performance.

GRAPHICAL ABSTRACT



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ABSTRACT

A novel sulfonated aromatic diamine monomer is used to provide thin-film composite (TFC) nanofiltration (NF) membranes with excellent performance and anti-fouling properties. A sulfonated TFC NF membrane was prepared through an interfacial polymerization reaction between amine agents in the aqueous phase and trimesoyl chloride (TMC) in the organic phase. Aqueous phase contained 2,5-diaminobenzene sulfonic acid (2,5-DABSA) as a sulfonated amine and piperazine (PIP) as a routine amine. The membrane performance results indicated that at 50% 2,5-DABSA, water flux reached $61.2 \text{ L/m}^2 \cdot \text{h}$ demonstrating 34.2% higher water flux compared to membrane prepared by PIP without a significant change in salt rejection. The membrane was characterized using FT-IR, SEM, AFM, and contact angle methods. The results of contact angle and anti-fouling experiments proved that hydrophilicity of the membrane surface improved in the presence of 2,5-DABSA monomer. The high water flux was attributed to the presence of strong hydrophilic sulfonic groups at new polyamide layers leading to improved membrane anti-fouling properties.

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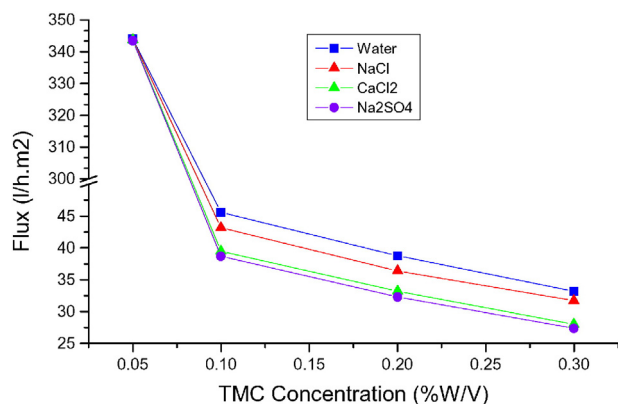


Fig. 1. The effects of TMC concentration on the water flux and salt solution flux.

1. Introduction

NF membrane filtration technology is one of the most promising techniques to be employed in water and wastewater treatment systems and plays an important role in the separation technology; because it is cheap, fast, more selective, and flexible to be integrated with other processes [1,2]. Most NF membranes are a kind of TFC polyamide membrane prepared by interfacial polymerization method, an important technique in the field of NF membrane production first put forward in 1965 by P.W. Morgan [3]. An asymmetric microporous membrane (usually polyethersulfone, polysulfone, and PAN) usually made by a phase inversion process is applied to a supporting polyamide active top layer [4,5]. In the interfacial polymerization method, reactive monomers (usually diamine and acyl chloride) are dissolved in two insoluble phases (such as water and n-hexane), where polymerization of the two monomers occurs on the surface of the microporous support [6]. As a result, a dense ultra-thin active layer is formed separately onto a microporous support that can have a major role in determination of the water flux and selectivity of the membrane surface.

However, as approved by membrane researchers, fouling is one of the major obstacles greatly limiting the practical application of NF membrane technologies in water and waste water treatment [7,8]. Several physicochemical membrane surface properties have been identified as major factors affecting the membrane fouling property. These factors include electrostatic charge, roughness, and hydrophilicity [9]. Fouling in water and wastewater that lead to TFC membrane fouling are mainly categorized into four types: inorganic, organic, colloidal, and biological agents [10]. Membrane surface roughness is directly related to colloidal fouling of NF membranes. Indeed, colloidal particles can be plugged into the valleys of the membrane rough surface and can increase the membrane resistance against feed molecules transport [11].

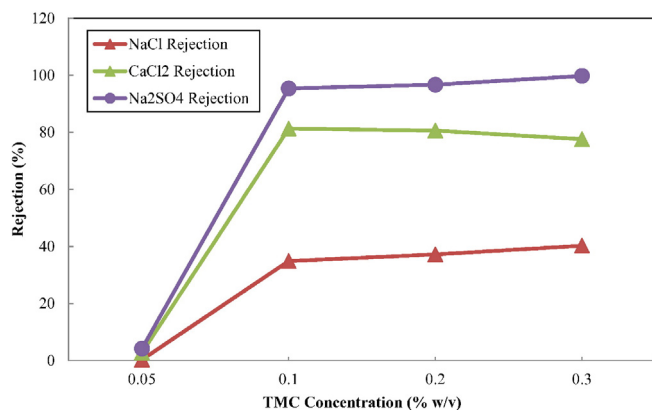


Fig. 2. The effect of TMC concentration on the NaCl (Δ), CaCl₂ (Δ) and Na₂SO₄ (○) salt rejections.

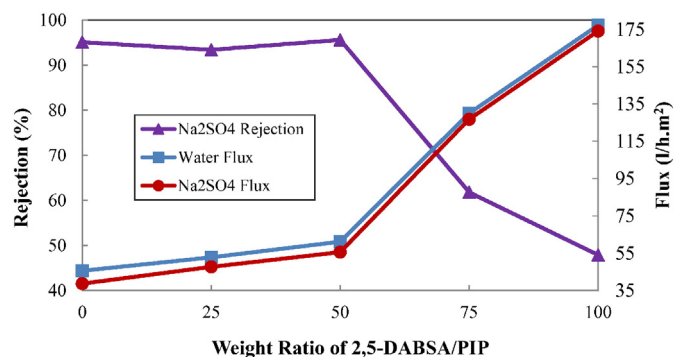


Fig. 3. The effect of 2,5-DABSA/PIP weight ratio on the water flux (□), Na₂SO₄ (○) flux and Na₂SO₄ (Δ) salt rejection.

Electrostatic charges of membrane surface and foulants have a great effect on the anti-fouling characteristics, where interactions between them can be reduced by increasing the electrostatic repulsion through promoting the membrane surface charge [9]. The hydrophobic interaction between foulants and membrane surface affects the membrane fouling. This interaction depends on the nature of foulants and membrane surface [13,14]. Moreover, an increase in hydrophilicity yields better anti-fouling properties because many foulants in the feed solution are hydrophobic in nature. Furthermore, a water layer is easily formed on the highly hydrophilic membrane surface leading to prevention from the adsorption and deposition of foulants on the membrane surface, thereby increasing fouling resistance.

Several research have been carried out to provide an anti-fouling TFC membrane with improved hydrophilic properties of the membrane surface using new monomers or interfacial polymerization process and second modification using hydrophilic agents such as polymers or nanoparticles. The new monomers used in interfacial polymerization usually contain a higher number of polar properties or functional groups bringing about smoother surface roughness or better hydrophilicity and

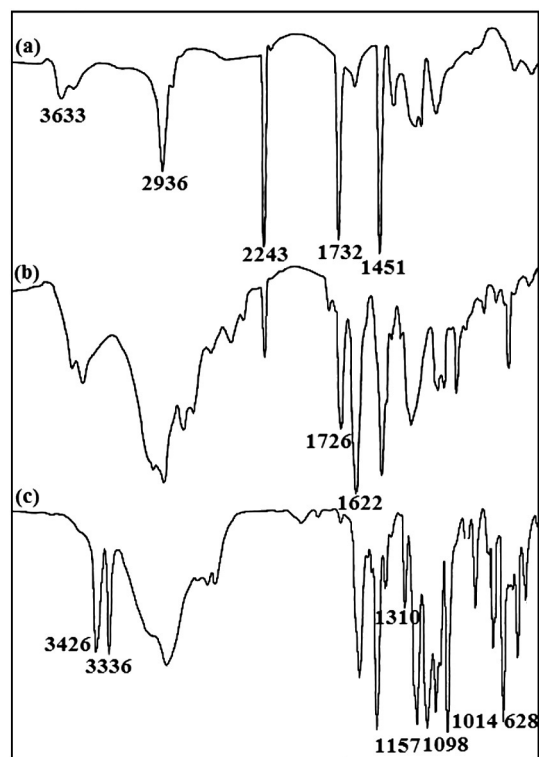


Fig. 4. FT-IR spectra of the PAN support membrane (a), polyamide TFC membrane with PIP (b), and 50% 2,5-DABSA/PIP (c).

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