

Membrane Materials for Sustainable Water Desalination

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ABSTRACT

Reverse osmosis produces most of the world's desalinated water, and its energy use is set by how permeable and how selective its membranes are. Polyamide thin-film composite membranes have improved slowly, trading permeability against salt rejection. This dissertation investigates two routes past that trade-off. It incorporates aligned graphene-oxide nanosheets into the polyamide layer to create fast water channels, and it tunes interfacial polymerization to produce thinner, crumpled selective layers with more surface area. Membranes combining both reached a water permeance of 5.1 litres per square metre per hour per bar with 99.6% sodium chloride rejection, nearly double the permeance of a commercial seawater membrane tested under the same conditions.

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TABLE OF CONTENTS

ABSTRACT	2
ACKNOWLEDGMENTS	3
LIST OF ABBREVIATIONS	5
1 Introduction	7
2 Background	8
3 Nanosheet-Reinforced Polyamide Layers	9
4 Results	10
5 Conclusion	11
A Test Conditions	13

LIST OF ABBREVIATIONS

GO	graphene oxide
NaCl	sodium chloride
RO	reverse osmosis
TFC	thin-film composite

LIST OF FIGURES

3.1	Fabrication of the nanosheet-reinforced membrane.	9
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LIST OF TABLES

4.1	Permeance and salt rejection under seawater test conditions.	10
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Chapter 1

Introduction

Freshwater scarcity affects billions of people, and in arid coastal regions desalination is a primary source of drinking water. Reverse osmosis dominates because it uses far less energy than thermal distillation [1]. Its remaining energy cost depends on the membrane: a more permeable membrane of equal selectivity needs less pressure for the same output.

Chapter 2

Background

Water flux through a reverse-osmosis membrane follows the solution-diffusion model,

$$J_w = A (\Delta P - \Delta \pi), \quad (2.1)$$

where A is the water permeance, ΔP the applied pressure and $\Delta \pi$ the osmotic pressure difference. Increasing A without increasing salt passage has proved difficult, reflecting a permeability-selectivity trade-off observed across membrane materials [2].

Chapter 3

Nanosheet-Reinforced Polyamide Layers

Graphene-oxide nanosheets were dispersed in the aqueous amine phase and aligned by a shear flow before interfacial polymerization with trimesoyl chloride. A sacrificial nanoparticle interlayer produced a crumpled polyamide film with a larger effective area.

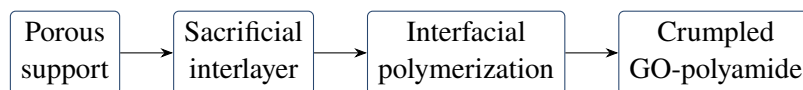


Figure 3.1: Fabrication of the nanosheet-reinforced membrane.

Chapter 4

Results

Table 4.1 compares the membranes under seawater test conditions.

Table 4.1: Permeance and salt rejection under seawater test conditions.

Membrane	Permeance ($\text{L m}^{-2} \text{h}^{-1} \text{bar}^{-1}$)	NaCl rejection (%)
Commercial seawater TFC	2.6	99.7
Crumpled polyamide	4.0	99.6
Crumpled GO-polyamide	5.1	99.6

Chapter 5

Conclusion

Aligned nanosheets and a crumpled selective layer together nearly double membrane permeance without sacrificing salt rejection. Long-term fouling and chlorine resistance must be established before the membranes can be used at scale.

Bibliography

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- [2] Ho Bum Park, Jovan Kamcev, Lloyd M. Robeson, Menachem Elimelech, and Benny D. Freeman. Maximizing the right stuff: The trade-off between membrane permeability and selectivity. *Science*, 356:eaab0530, 2017.

Appendix A

Test Conditions

Membranes were tested in cross-flow at 55 bar with a 32 g/L sodium chloride feed at 25 °C after 24 hours of compaction.