IChemE
Institution of Chemical Engineers

Membrane Technology

A Practical Guide to Membrane Technology and Applications in Food and Bioprocessing

Z. F. Cui
R. S. Muralidhara

B
H

Membrane Technology

A Practical Guide to Membrane Technology and Applications in Food and Bioprocessing

Edited by

Z.F. Cui and H.S. Muralidhara

常州大学山书馆
藏书章

ELSEVIER

AMSTERDAM • BOSTON • HEIDELBERG • LONDON • NEW YORK • OXFORD
PARIS • SAN DIEGO • SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO

Butterworth-Heinemann is an imprint of Elsevier

BH

Butterworth-Heinemann is an imprint of Elsevier
The Boulevard, Langford Lane, Oxford OX5 1GB, UK
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA

First edition 2010

Copyright © 2010 Elsevier Ltd. All rights reserved

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the publisher's permissions policies and our arrangements with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions.

The book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices
Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for the injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data Control Number
A catalog record for this book is available from the Library of Congress

ISBN: 978-1-85617-632-3

For information on all Butterworth-Heinemann publications visit our website at elsevierdirect.com

Typeset by MPS Limited, a Macmillan Company, Chennai, India
www.macmillansolutions.com

Printed and bound in the United States of America

10 11 12 13 10 9 8 7 6 5 4 3 2 1

Working together to grow libraries in developing countries
www.elsevier.com | www.bookaid.org | www.sabre.org
ELSEVIER BOOK AID International Sabre Foundation

Membrane Technology

Preface

Separation and purification are key to many manufacturing processes in the food, bioprocessing and pharmaceutical industries. Furthermore, these processes are becoming increasingly important for the growth of industries such as bioenergy, biotechnology and nanotechnology. The multiple steps involved in separation/purification processing often require substantial up-front capital and significant operating costs. Thus the efficiency and productivity of separation technology can be critical to both the profitability and sustainability of an enterprise.

Recent developments in membrane technology, especially the development of novel membrane processes, are the most growing areas of process technology. There are several excellent books published in the general areas of membrane science and membrane technology, but there is minimal focus on the applications of membrane technology in food and pharma areas, even though they have grown steadily during the last two decades. For example, one of the major applications in the food industry is the use of reverse osmosis membranes to extend the evaporation capacity and reduce the overall energy costs, thus lowering the carbon footprint for the overall process.

The idea for this book, which focuses on the practical applications of membranes in food and bioprocessing, came out of a North American Membrane Society (NAMS) meeting in Chicago, Illinois, USA, in 2006, when both editors held a workshop on "Fundamentals and Applications of Membrane Technology in Food/Bio-processing". With our combined experience in food technology and bioprocessing, we felt that a book dedicated to the practical aspects and challenges of utilizing membranes effectively in an industrial setting would be an extremely useful tool for any one in membrane processing and practice. The idea gained even more momentum when Elsevier conducted a market study and subsequently expressed its interest in publishing a book on the topic.

In many ways editing this book has been a privilege and a unique experience. Thanks firstly to our excellent contributors without whose support, this book would not have materialized. It is most fitting that this technological work is published from contributors around the globe and is founded on the spirit of free enquiry coupled with hard work and imagination. It has indeed been a great pleasure to be in touch with all contributors during the last 3 to 4 years. Thanks also for their patience and understanding.

We would be utterly remiss if we did not acknowledge those people who have provided us with the inspiration, motivation and never-ending encouragement throughout the course of this work.

Dr Murali would like to acknowledge Mr Ronald Christenson, former Chief Technology Officer, Cargill Inc; his wife Ponnamma; his children Shubha and Shilesh, their spouses Chuck Harris and Nupur Parikh and his two lovely grandchildren Reya and Azad; all his teachers and mentors during his entire career; and his parents who would have been both excited and extremely proud to see this book published.

此为试读,需要完整PDF请访问: www.ertongbook.com

Dr Cui wishes to thank his wife, Dr Jing Yu, for her unreserved support over decades, his mother for her love, and his children, Jenny and Michael, for "keeping him happy". He would like to thank those who inspired and encouraged him to embark on a career in the "membrane world". Such a list would be long, and here just name a few: Tony Fane, John Howell, Norman Li and Bill Eykamp.

In setting our goal of bringing this book to fruition, we kept in mind these words from Robert Frost in The Road Not Taken:

"Two roads diverged in a wood and I-
I took the one less travelled by,
And that has made all the difference"

ZFC and HSM

About the Editors

Zhanfeng Cui is the Donald Pollock Professor of Chemical Engineering, University of Oxford since the Chair was established in 2000. He is the founding Director of the Oxford Centre for Tissue Engineering and Bioprocessing (OCTEB).

He was educated in China and got his BSc from Inner Mongolia University of Technology (1982) and MSc (1984) and PhD (1987) from Dalian University of Technology. After a postdoctoral experience in Strathclyde University in Scotland, he joined Edinburgh University as a Lecturer in Chemical Engineering (1991). He then held academic appointments at Oxford Engineering Science Department as University Lecturer (1994–1998) and Reader (1999–2000). He was a Visiting Professor of Georgia Institute of Technology, USA (1999), the Brown Intertec Visiting Professor to University of Minnesota, USA (2004), and a Chang-Jiang Visiting Professor to Dalian University of Technology, China (2005). He is a Chartered Engineer, a Chartered Scientist, and a Fellow of the Institution of Chemical Engineers. In 2009 he was award a Doctor of Science (DSc) by Oxford University to recognise his research achievement in membrane science and technology. Apart from membrane research, he also works on tissue engineering and stem cell technologies, and bioprocessing. He published widely and is also the academic founder of Zyoxel Limited, an Oxford University spin-off in 2009.

H.S. Muralidhara Ph.D is a Chemical Engineer. He retired from Cargill Inc. in Minneapolis, USA in Oct 2009 as a Vice President, Manager Process Technology, Corporate Plant Operation after 20 years of service. Prior to that he was a Research Leader at Battelle Memorial Institute in Columbus, Ohio, USA for 10 years. He is currently an industrial consultant.

He has over 30 years of industrial experience in separation purification process technologies including application of membranes in food and bioprocessing. He is a coinventor of 27 US patents and 15 patents pending. He has edited two books and has served as a key note speaker in many major international conferences.

About the Contributors

Vicki Chen is the director of the UNESCO Centre for Membrane Science and Technology at The University of New South Wales, Australia.

Jim Davies is a biochemical engineer with a PhD from UCL and is currently a Principal Group Leader in Purification Development at Lonza Biologics UK.

R.W. Field is a Reader in Engineering Science at Oxford University and has many years of experience in membrane technologies.

Val D. Frenkel, PhD, PE, DWRE, Director Membrane Technologies with Kennedy/Jenks Consultants, is the company-wide leader for Membrane Technologies. Dr. Frenkel formed and leads the firm's Membrane Technology Group and has 25 years of experience in engineering, with expertise in water and wastewater treatment, water reuse, and membrane technologies, including desalination.

Yu Jiang was awarded her DPhil in 2009 from Oxford University. Her DPhil thesis was entitled "Emergency drinking water device based on gravity driven ultrafiltration".

Bassam Jirjis is a Principal Chemical Engineer at Cargill Inc., in Minneapolis, Minnesota. He has more than 25 years of experience in the area of separation technologies and food processing.

N.S. Krishna Kumar, PhD, is a Senior Chemical Engineer at Cargill Inc., Minneapolis, Minnesota, USA. His research interest is focused on application of membranes in food, bioprocessing and water treatment. He is currently involved with vegetable oil process development research work concentrated towards process improvement.

Abhay R. Ladhe is a Research Chemical Engineer at Cargill Inc., Minneapolis, Minnesota, USA. He graduated from University of Kentucky with a Ph.D. in Chemical Engineering. His research interests include membrane functionalization and membrane based separation. He is currently working in the area of vegetable oil processing for process improvement and process development.

Hongyu Li is a Research Fellow in the UNESCO Centre for Membrane Science and Technology, The University of New South Wales, Australia.

Frank Lipnizki, PhD, is currently with Alfa Laval – Business Centre Membranes (previously Danish Separation Systems), Denmark. Since 2010 also Docent at the University of Lund, Sweden. His main research interests are the integration and optimization of membrane process for the food, biotech and process industry.

Jianquan Luo, MEng, Institute of Process Engineering, Chinese Academy of Sciences. Mr Luo is an experienced engineer specializing in membrane applications in bioseparation and wastewater treatment.

Susana Luque is a Full Professor in Chemical Engineering at the University of Oviedo in Spain. Her main interests are in applied membrane research and membrane-based hybrid processes.

Alan Merry has a PhD in Chemical Engineering. He has 30 years' experience at ITT-PCI Membranes Ltd, working with all aspects of membranes including membrane development, applications and production.

Joseph Scimeca, PhD, currently holds the position of Director of Global Regulatory Affairs, in the department of Corporate Food Safety and Regulatory Affairs, at Cargill, Incorporated, where he has responsibility for ensuring that the company's food and feed products and processes are safe, including being protected against intentional acts of adulteration and bioterrorism, and are compliant with the appropriate food/feed regulations.

Martin Smith, also a Biochemical Engineer from UCL, is currently a Bio-Process Consultant at eXmoor Pharma Concepts in the fields of Biopharmaceuticals and Regenerative Medicine.

Yinhua Wan, DPhil, is a Professor of Biochemical Engineering at Institute of Process Engineering, Chinese Academy of Sciences. He has published more than 80 papers in refereed journals and holds a number of patents in membrane separation technologies.

Contents

此为试读,需要完整PDF请访问: www.ertongbook.com

Chapter 1

Fundamentals of Pressure-Driven Membrane Separation Processes

Z.F. Cui, Y. Jiang and R.W. Field
Department of Engineering Science, Oxford University, Oxford, UK

Table of Contents

1.1 INTRODUCTION

Membrane processes are one of the fastest growing and fascinating fields in separation technology. Even though membrane processes are a relatively new type of separation technology, several membrane processes, particularly pressure-driven membrane processes including reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF), are already applied on an industrial scale to food and bioproduct processing.

The concept of membrane processes is relatively simple but nevertheless often unknown. Membranes (*lat.: membrana = thin skin*) might be described as conventional filters (like a coffee filter) but with much finer mesh or much smaller pores to enable the separation of tiny particles, even molecules! In

Membrane Technology. DOI: 10.1016/B978-1-85617-632-3.00001-X
© 2010 Elsevier Ltd. All rights reserved.

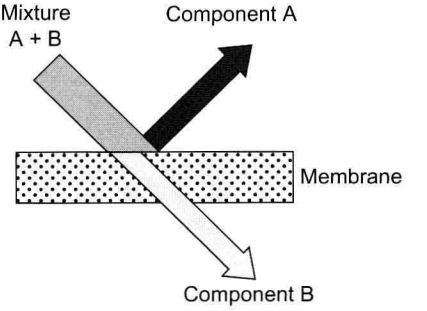

FIGURE 1.1 Basic principle of porous membrane processes. (Above is idealized; complete separation is not achieved in practice.)

general, one can divide membranes into two groups: porous and nonporous. The former group is similar to classical filtration with pressure as the driving force; the separation of a mixture is achieved by the rejection of at least one component by the membrane and passing of the other components through the membrane (see Fig. 1.1). However, it is important to note that nonporous membranes do *not* operate on a size exclusion mechanism. It should be pointed out that this chapter focuses on pressure-driven membrane processes using porous membranes for its close relevance to food and bioproduct processing.

Membrane separation processes can be used for a wide range of applications and can often offer significant advantages over conventional separation such as distillation and adsorption since the separation is based on a physical mechanism. Compared to conventional processes, therefore, no chemical, biological, or thermal change of the component is involved for most membrane processes. Hence membrane separation is particularly attractive to the processing of food, beverage, and bioproducts where the processed products can be sensitive to temperature (vs. distillation) and solvents (vs. extraction).

1.2 PROCESSES

1.2.1 Process Classification

There are four major pressure-driven membrane processes that can be divided by the pore sizes of membranes and the required transmembrane pressure (TMP): MF (0.1–5 μm, 1–10 bar), UF (500–100,000 Da, 1–100 nm, 1–10 bar), NF (100–500 Da, 0.5–10 nm, 10–30 bar), and RO (<0.5 nm, 35–100 bar). Figure 1.2 presents a classification on the applicability of different membrane separation processes based on particle or molecular sizes. RO process is often used for desalination and pure water production, but it is the UF and MF that are widely used in food and bioprocessing.

此为试读,需要完整PDF请访问: www.ertongbook.com