Edited by Enrico Drioli
and Lidietta Giorno

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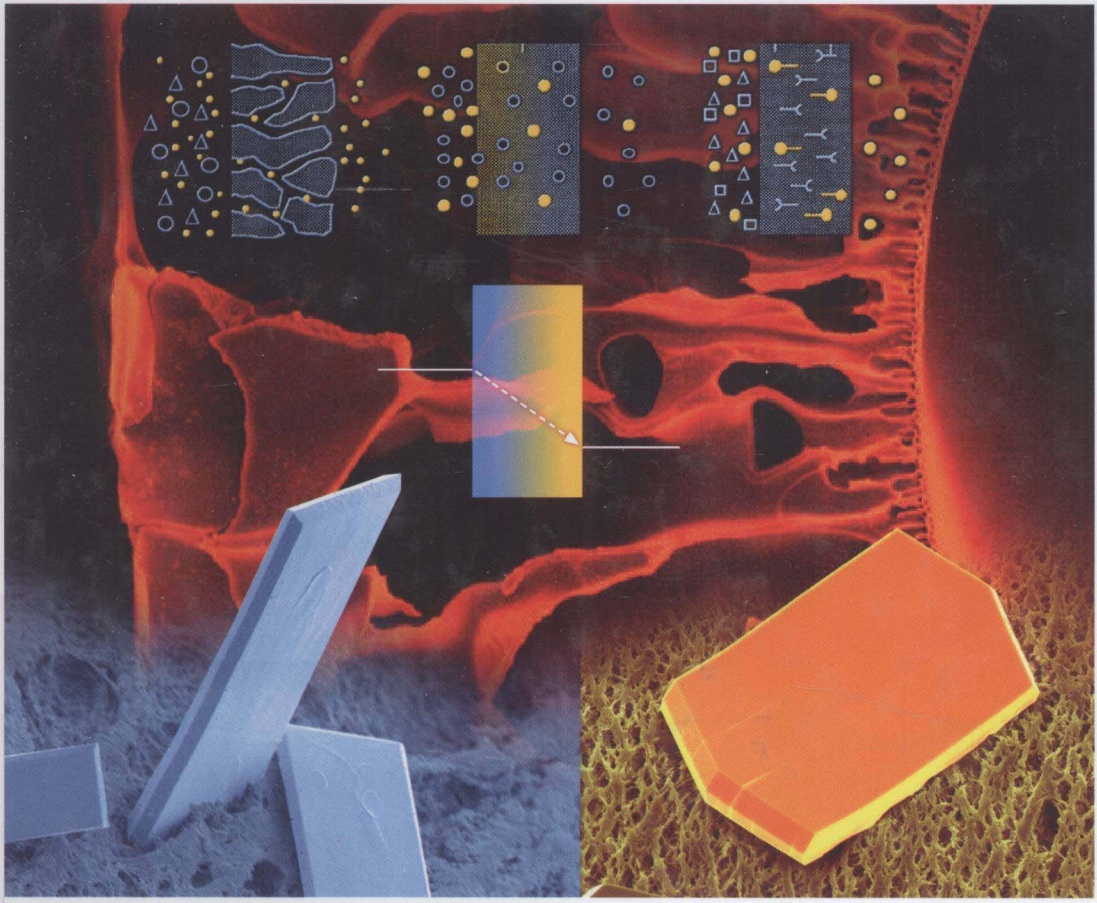
Membrane Operations

Innovative Separations and Transformations



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Innovative Separations and Transformations

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Enrico Drioli and Lidietta Giorno

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Introduction

Membrane processes are state of the art technologies in various industrial sectors, including gas separation, wastewater treatment, food processing and medical applications.

Modelling methodologies are contributing significantly to the knowledge-based development of membrane materials and engineering.

Micro-ultrafiltration and reverse osmosis are mature technologies for separations based on molecular exclusion and solution-diffusion mechanisms, respectively. Cleaning and maintenance procedures able to control fouling to an acceptable extent have made these processes commercially suitable.

Some of the largest plants for seawater desalination, wastewater treatment and gas separation are already based on membrane engineering. For example, the Ashkelon Desalination Plant for seawater reverse osmosis (SWRO), in Israel, has been fully operational since December 2005 and produces more than 100 million m^3 of desalinated water per year. One of the largest submerged membrane bioreactor unit in the world was recently built in Porto Marghera (Italy) to treat tertiary water. The growth in membrane installations for water treatment in the past decade has resulted in a decreased cost of desalination facilities, with the consequence that the cost of the reclaimed water for membrane plants has also been reduced.

Membranes are growing significantly also in gas separation, for example, the current market size of carbon-dioxide separation from natural gas is more than 70 million Euro/year.

Medical applications are among the most important in the membrane market, with hemodialysis, blood oxygenators, plasma separation and fractionation being the traditional areas of applications, while artificial and bioartificial organs and regenerative medicine represent emerging areas in the field.

Nanofiltration has achieved a good stage of development, gaining attention in various applications for separations based on both molecular exclusion and charge interaction as well as on the solution-diffusion mechanism. In particular, nanofiltration is considered among the most suitable technologies for solvent separation. More recent processes such as membrane reactors, membrane contactors, and membranes in life science are also developing very rapidly. The optimal design of

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chemical transformation processes with control of reagent supply and/or product removal through catalytic membranes and membrane reactors is one of the most attractive solutions in process intensification. The catalytic action of biocatalysts is extremely efficient, selective and highly stereospecific when compared to conventional chemical catalysts. Membrane bioreactors are particularly attractive in terms of ecocompatibility, because they do not require additives, are able to operate at moderate temperature and pressure, reduce the formation of by-products, while permitting the production of high valuable coproducts. This may allow challenges in developing new production lines moving towards zero discharge to be faced. The development of catalytic membrane reactors for high-temperature applications became realistic more recently, with the development of high-temperature-resistant membranes.

The major market for membrane bioreactors is represented by wastewater treatment with the use of submerged modules configuration. These are considered among the best available technologies by the European Directives on Environment. Membrane bioreactors are also applied in food, red and white biotechnology. In these cases, the external loop configuration is used.

Membrane contactors, including membrane crystallizers and membrane emulsifiers, are among the most recent membrane operations with growing interest in various industrial sectors. For example, membrane emulsification has grown from the 1990s, when it was first developed in Japan, to nowadays with applications in food, chemical, pharmaceutical and cosmetic fields. In Europe, the research at the academic level has achieved a thorough knowledge both from experimental and theoretical points of view. This is fuelling the industrial interest towards the membrane emulsification technology, especially for those productions that involve labile bioactive molecules.

In general, nowadays the attention towards membrane science and technology is increasing significantly. Drivers of this interest include the need for technologies to enable sustainable production, directives and regulations about the use of eco-friendly technologies, consumer demand for high-quality and safe products, public concern about environment, and stakeholder confidence in and acceptance of advanced technologies.

Current initiatives recognize that a sustainable solution to the increasing demand of goods and energy is in the rational integration and implementation of new technologies able to achieve concrete benefits for manufacturing and processing, substantially increasing process precision, reducing equipment size, saving energy, reducing costs, and minimizing environmental impact.

Membranes and membrane processes are best suited in this context as their basic aspects well satisfy the requirements of process intensification for a sustainable industrial production. In fact, they are precise and flexible processing techniques, able to maximize phase contact, integrate conversion and separation processes, with improved efficiency and with significantly lower energy requirements compared to conventional techniques.

This multiauthor book highlights the current state and advances in membranes and membrane operations referring to three major roles of the membrane: mole-

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cular separation, (bio)chemical transformation and phase contactors. Each topic includes fundamentals and applications of membranes and membrane operations.

The largest section is constituted by membranes in molecular separation, which is the most traditional application of membranes. Significant advances of membrane science and technologies are expected in transformation processes and membrane contactors for conventional and innovative applications.

Contents

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