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Book review

MEMBRANE TECHNOLOGY IN THE CHEMICAL INDUSTRY
Second, Revised and Extended Edition

Suzana Pereira Nunes, Klaus-Viktor Peinemann (Editors)
Wiley-VCH Verlag GmbH& Co. KGaA, Weinheim, Germany
ISBN: 978-3-527-31316-7, 2006, XIV+340 pages.

Membrane processes and membrane technologies have started to have an increasing role in the chemical industry since this domain of engineering has experienced major developments in the last ten years. Consequently, there is a greater need for accurate and updated information in this field and, in this respect the second edition of the *Membrane Technology in the Chemical Industry* edited by Suzana Pereira Nunes and Klaus-Viktor Peinemann represents a very useful compendium of reviews on the available membranes on the market and on the membrane processes employed by the chemical industry. The merit of the two editors is that they have succeeded in gathering reviews and articles from well-known researchers and membrane scientists with recognized experience in the separation technologies for the chemical industry in which they supply thoroughly analyses of the membrane applications. The book is structured into two distinctive parts which make it very easy to navigate and use: the first part deals with membrane materials and membrane preparation technologies, while the second one is focused on current applications and perspectives of the membrane technologies.

The first part begins with a short introduction and then follows a chapter entitled *Membrane Market* in which the authors present recent situations of world expenditure on different types of membranes and membrane applications. Furthermore, they show that the world market for membranes and modules has increased from 4.4 billion US $ in 1998 to 6.8 US$ in 2005 and that in 2008 the world market volume for membranes will reach 9 billion US$, and the greatest increase will be that of RO membranes due to increasing demand for reliable municipal water supply in major cities in China.

Chapter 3 *Membrane Preparation* begins with a classification of the membranes according to their morphology. The authors show that the breakthrough of membrane technology came in 1960's with the development of asymmetric membranes which became the most common membranes due to their high fluxes and good mechanical resistance and stability. This is why they have chosen to present in detail the phase inversion method for asymmetric membrane preparation, which consists in forming the porous structure in a polymer solution either by temperature changes, either by using a non-solvent solution.

The next chapter, *Presently Available Membranes for Liquid Separation* presents the most common membranes for reverse osmosis, nanofiltration, ultrafiltration and microfiltration. Special attention is given to membrane materials and to their chemical and physical properties, as well as to their hydrodynamic characteristics. This chapter also includes valuable information on NF and UF membranes that operate into harsh conditions (extreme pH ranges and solvent media) as seen very often in the chemical industry.

Chapter 5 presents four methods for the modification of membrane surface in order to increase their performances in terms of permeate flux and selectivity. Chemical oxidation is the simplest way to increase the hydrophicility, plasma treatment is used to reduce the surface pore size, to introduce functional groups in the surface layer of the membrane or to deposit a thin layer on the membrane support in order to increase selectivity. Classical organic reactions are used to increase hydophicility, while polymer grafting has been reporting as a useful method to decrease the susceptibility to fouling. The next chapter describes four types of membranes especially designed for the fuel cells for automotive and mobile applications: perfluorinated membranes, non-fluorinated (polymeric) membranes, membranes for high temperature operation and organic-inorganic

membranes. The most promising fuel cells for low temperature applications, make use of a polymeric membrane separating the anode and cathode of an electrochemical cell. The requirements for this type of membranes are quite high: good chemical stability, high proton permeability, low fuel and oxygen permeability, high electronic resistance and low costs.

The last chapter of the first part of the book is dedicated to gas separation with membranes because it has been one of the most significant new unit operations developed in the chemical industry in the last 25 years. Membranes are employed at industrial scale to separate gaseous phases in applications like: nitrogen generation, refinery hydrogen recovery, acid gas treating, natural gas dehydration, pollution control and organic solvent recovery. The state-of-the art of the emerging applications in this field, and the materials for these membranes are discussed. Also, some key features of integral asymmetric and composite membranes for gas separation are presented and finally the influences of basic process parameters are explained.

The second part of the book which presents current applications and perspectives of membrane technology in chemical industry begins with an article written by K. Ohlrogge and K. Sturken. They present the separation of organic vapors from gas streams by means of membranes, foregone by a historical background of membrane usage for gaseous streams and show that the main driver for developments in this field of VOC abatement by membrane means was the adoption of new clean air acts and more stringent emission standards. Special attention is given to the applications: off-gas and process gas treatment, gasoline vapor recovery and polyolefin production processes. The article ends with the presentation of future directions of development of membrane processes to be emplyed in gaseous streams separations like: emission control at petrol stations, natural gas treatment or hydrogen / hydrocarbon separations.

D.J. Stookey presents in the next chapter the methodology for the implementation of industrial scale gas-separation polymeric membranes processes, with a focus on design consideration and limitations of the new applications for gas-separation membranes. The authors present in detail the separation of hydrogen, helium, nitrogen, acid-gas mixtures, and the gas dehydration. The next chapter, written by H.E.A. Bruscke, reveals the state-of-the-art in pervaporation processes in the chemical industry. The chapter covers the theoretical aspects of vapor and gas permeation, as well as the principles of pervaporation and the transfer phenomena that occur during these processes. Also, the membranes and modules used in pervaporation are presented together with two examples: removal of water from reaction mixtures and organic-organic separations.

Chapter 4 of the second part, *Organic solvent nanofiltration,* is written by A.G.Livingston, l.G. Peeva and P. Silva. They present the current applications and the potential for further development in nanofiltration, but also the theoretical background and transport processes and problems that occur during nanofiltration: concentration-polarization and osmotic pressure increase.

Chapter 5, written by M.F. Kemmere and J.T.F. Keurentjes, presents the combined reaction – membrane separation processes and the associated membrane reactors used on industrial scale. The authors discuss the potential of the membrane reactors, with an emphasis on the three functions that membranes can have in these systems: selective and non-selective addition of reactants, selective and non-selective removal of reaction products and retention of catalysts. Finally, the authors present some examples of development in this field that have led to scaling-up the process at industrial level.

T.A. Davis, V.D. Grebenyuc and O. Grebenyuc present in the next chapter the electromembrane processes. In the first two sections of the chapter the authors present the ion-exchange membranes and their properties important for the electro-separation processes, while in the next section the electromembrane processes are described in detail. The last part of the chapter is dedicated to industrial processes that make use of ion-exchange membranes: electrochemistry, chlor-alkaly industry, fuel cells or electroorganic synthesis.

In the last chapter of the book, R.W. Baker presents the future directions of membrane technologies applied in the chemical industry. His predictions are based on an in-depht analysis of the past and current state of the membrane materials, membrane properties and performances and processes application. The author covers in his analysis almost all of the membrane processes employed in separations in chemical industry, focusing on the gas-separation processes that will face in the near future a rapid growth in terms of market share, but also in terms of technological developments. In the last part of this chapter, R.W. Baker makes predictions for the development of liquid and gas separation by membrane processes for the next 15 years.

Membrane Technology in the Chemical Industry edited by Suzana Pereira Nunes and Klaus-Viktor Peinemann outlines several established applications within the chemical industry, reviews the available membranes and membrane processes for this field and discusses the great potential for this technology in chemical processes. Most of the contributors to this second edition are renowned leaders in the field of membrane science and applications and the result of their efforts is an updated and practice-oriented overview of membrane processes addressed to process engineers, material scientists and to environmental specialists working in the chemical industry.

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