AASCIT Communications
Volume 2, Issue 3
April 20, 2015 online
ISSN: 2375-3803

New Technologies in Membrane Separation Field: A Brief Survey

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Keywords

Polymer Membrane, Water Desalination, Chiral Separation, Algae Separation, Gas Separation, Energy Production

The main purpose of this short article was to introduce a membrane technology for diverse application including water desalination, algae separation, chiral separation, energy production and gas separation. A wonderful period for membrane investigation and development started at the beginning of the seventies. The membranes and related modules for reverse osmosis (RO), electrodialysis (ED), ultrafiltration (UF) and microfiltration (MF) had mostly been developed in this period. A great success in the membrane field was achieved in the decade 1980 concerning the development of new membrane processes such as seawater and brackish water desalination, pure and ultrapure water production, separation, purification and concentration of various liquids by membrane technology were applied on medium and large scale. At the same decades, gas separation (GS) membrane development also started. Studies on membrane distillation (MD), pervaporation (PV), membrane extraction (MEx), membrane phase separation (MPS), inorganic membranes (IM) and membrane reactors (MR), membrane bioreactors (MBR) were also started. In 1990s, composite membranes for RO and NF (nanofiltration) were manufactured on pilot scale. At present, new technologies and new processing techniques on membrane production are constantly being revealed and invented. Membrane separation replaces or supplements these techniques by the use of selectively permeable barriers, with pores sized to permit the passage of water molecules, chiral drugs, micro-algae but small enough to retain a wide range of particulate and dissolved compounds, depending on their nature. The membranes are made from materials such as thin organic polymer films, thin film coating monomer materials, bioinspired materials for coating, depending on the applications. Membranes are manufactured in different forms such as hollow fibers or flat sheets. The studies of these membranes along with their diverse application briefly explain in this brief survey.

Introduction

As we know the polymer membranes shows diverse applications like water desalination, algae separation, chiral separation, energy production and gas separation and the schematic diagram of membrane separation technology for diverse applications is shown as Figure 1. Since its early beginnings in the 1950's, ink-jet printing has been developed to accurately deliver pico-liter quantities of ink, or other substances onto numerous types of surfaces. Ink-jet technology is rapidly progressing and the number of industrial and laboratory applications is increasing: In 2006 alone there were more than 3500 patent applications involving ink-jet technology, with far reaching implications in many diverse fields and industrial applications [1]. Apart from the obvious application of graphics, this technology is currently employed in the laboratory and industry for many diverse applications including life sciences applications such as proteomics, protein and nucleic acid arrays, DNA sequencing, and printed scaffolding for the growth of live tissues [2]. High-resolution printers can precisely deliver droplets of many types of materials including nanoparticles for many other applications including printed electronics [3,4], (including sensors, solar panels, fuel cells, batteries, and circuits) ceramics, and polymers [5]. Despite the impact ink-jet technology has made in other fields, it has not yet been applied to the functionalization of membranes in the context of separation membranes, water research and desalination.

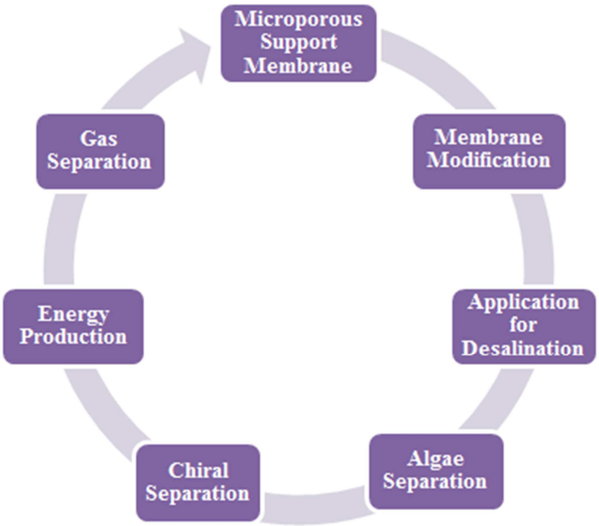

Fig. 1. *Schematic diagram of membrane separation technology for diverse applications.*

Separation of chiral compounds, enantioselective composite polymer membrane was prepared by using co-polymerizing interfacially a mixture of different chiral compounds (amino acids, and drugs) and chiral monomer with acyl chloride in-situ on polysulfone/polyethersulfone ultrafiltration membrane. Ingole et al., research shows the chemical composition of composite membrane was determined by ATR-FTIR, scanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM) and X-ray fluorescence spectroscopy. For the product analysis the high-performance liquid chromatography analysis was carried out using a chiral HPLC apparatus equipped with Chiral Chrompak column. The optical resolutions of α-amino acids, chiral alcohols were performed in pressure driven membrane processes. The effect of membrane preparation conditions, operating pressure, permeation time and feed concentration on the performance of membrane were studied. These works shows a new concept of excipient, which are not only inert ingredients but they have eligibility to separate different enantiomers. Keeping in view the pharmacological and chemical aspects of a specific enantiomer there is great need for efficient separation process. These studies will be fruitful in the area of separation of enantiomer by using polymer composite material as support and its more functional in the pharmaceutical field [6-10].

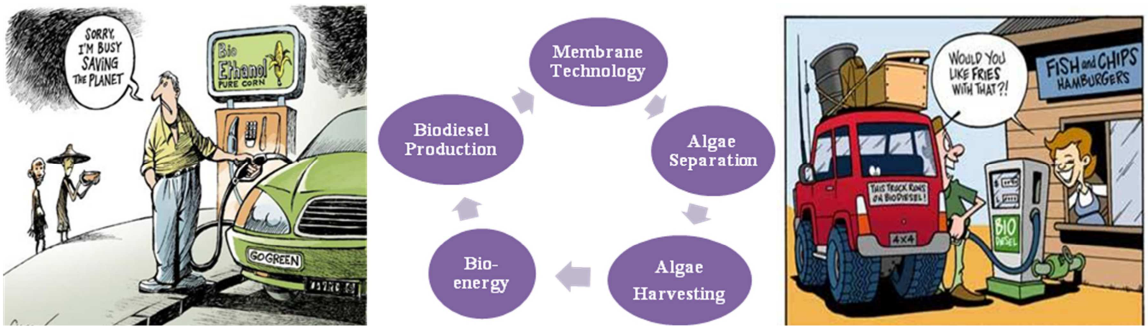

Fig. 2. *Schematic diagram of membrane separation technology for biodiesel production.*

As increasing world population and industrialization demand more energy leading to scarcity of fossil fuels. The schematic diagram of membrane separation technology for biodiesel production is shown in Figure 2. Algae with the potential of high oil productivity together with significant sequestering of carbon dioxide from the atmosphere can solve both the problems of depletion of fossil fuels and environment pollution. This report shows the current developments in the field of algae harvesting, algae separation, and application as biodiesel production [11,12]. In bio-economy, particularly, bio-refining and bio-energy production, have received significant interest in recent years as a shift to renewable bio-resources to produce similar energy and chemicals derived from fossil energy sources. Membrane technologies have been shown to play a key role in process escalation and products recovery and purification in bio-energy production processes. Among the various separation technologies, membrane technologies provide excellent fractionation and separation capabilities, low chemical consumption, and reduced energy requirements [13-15]. The advantages and limitations of membrane technologies for their applications are discussed and new membrane-based integrated processes are proposed. Finally, challenges and opportunities of membrane technologies for bio-refining and bio-energy production in the coming years are addressed. The performance of ultrafiltration (UF) and microfiltration (MF) membranes was compared for this application. The interesting finding of our work is that microfiltration and ultrafiltration showed very similar performance in terms of permeate flux under the same operation conditions at low trans-membrane pressure. More than 98% of micro-algae were eliminated. Overall, this work presented foundation toward the potential use of bacterial biomass for algal harvesting from water. The spacious report on attractive algae product applications are shown in Figure 3.

Fig. 3. *Spacious report on attractive algae product applications.*

Hollow fiber (HF)/flat sheet (FS) polyethersulfone (PES) membranes have been prepared using the phase inversion technique for diverse applications like, gas separation, energy production etc. On this PES HF/FS membranes thin film composite polymer membranes were prepared by interfacial polymerization of different aqueous phase monomers, like *m*-phenylenediamine (MPD), piperazine (PIP), with organic phase monomer, trimesoyl chloride (TMC) produce a polyamide thin film on the surface of HF/FS membranes, these polyamides are capable for gas separation [16], and energy production [17]. By controlling the aqueous/organic monomer ratio we were able to obtain a uniformly interfacial polymerized layer. To achieve a highly cross-linked layer, three reactive groups in both the aqueous and organic phase monomers are required; however, if the monomers were arranged in a planar structure, the probability of structural defects also increased. On the contrary, linear polymers are less likely to result in structural defects, and can also produce polymer layers with moderate selectivity.

With oil price increasing rapidly and urgency of reducing the global CO_2 emission, the hydrogen has emerged as an important and interesting synthetic fuel from natural gas. Gas separation using membrane is an rising technology indicating strong marketable potential in assorted industrial applications including hydrogen/CO separations, $SO_2/CO_2/N_2$ separation, and natural gas promotion [18,19]. Among the different methods discussed for CO_2 capture, membrane processes have received increased attention due to their advantages such as low cost, high energy efficiency, environmental sustainability and easy to scale up [20]. Even though all the research and study, polymeric membrane separation is still restricted by the famous trade-off between gas permeability and selectivity [21]. To study the feasible separation performance through polymer membrane that could reach the techno-economical requirement of CO_2 captures have been made by many researcher [22-25]. Recent pilot plant study [26] showed that removal efficiency of CO_2 and concentration of CH_4 in the retentate flow rate are increased by post-treatment. HFM module performance reached to 88.0% of CH_4 concentration and CO_2 removal efficiency was 86.7% according to the operating pressure. Also, the feed flow rate was influenced to CO_2 removal efficiency due to permeate driving force difference. The permeability of a membrane for a specific gas is a product of its diffusivity and solubility. Diffusivity contribution to permeability is typically small; however, a significant increase in permeability can be expected from the improvements in solubility [27].

Conclusion

The above research work shows new concept of separation, which are not only inert ingredients but they have eligibility to water desalination, chiral separation, algae separation, gas separation, energy productions etc. Keeping in view the chemical aspects of a specific membrane there is great need for efficient separation process. Above studies will be fruitful in the area of separation science by using polymer composite material as support.

Future Research

Our plans for future works are having following purposes.

1. One is to determine whether the results achieved in the laboratory can be repeated on a pilot scale.

2. The second one is to determine the performance of the system under real industrial conditions.

3. Devolvement of polymeric composite membranes by using different novel coating materials.

4. Applications by using these prepared materials as par our research requirements.■

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