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Polymer Nano-Composite Membranes

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Abstract

Nanoscale materials are of fundamental interest to the material scientists. The property of bulk polymeric material which can change by molecular manipulation in the nano scale region in contrast to the structural modification by chemical reaction or physical means could have excellent potential for advanced membrane separation applications.

Keywords: Nano-filler; Polymer nano-composite; Membrane; Interface; Performance

Introduction

As a green technology, membrane based separation is likely to play an important role in many industrial applications. There are many advantages of using membranes for industrial processes such as no phase changes, easy to scale up, simple in operation, relatively low energy consumption, low labor cost, less space requirement etc. [1]. Separation through membranes is usually based on the selective transport phenomenon of the molecules through the membrane matrix. The significance of this phenomenon has led to the development of novel membrane materials to enhance the molecular fluxes in the membrane matrix while separating the molecules of interest [2]. Two or more materials with dissimilar properties in a certain proportion are mixed together to form a composite. The individual components in composites are remaining bonded together by certain physical or chemical interactions, while, retaining their physical or chemical identities. Generally, properties of the composite materials are superior in many respects to those of the individual pure components. Most of the composites are made with synthetic polymer (as matrix phase), and synthetic, metallic, silica or glass filler (as dispersed phase). Nano-particles are interesting nano scale fillers to improve the functional performance of bulk polymeric material at very low concentration (typically a fraction compared to the matrix polymer) [3]. Polymer nano-composites continue to receive tremendous attention for potential in advanced material applications including in the novel membrane science and technology.

Current State-of-the-Art

Polymeric membranes are widely used in membrane separation processes for the advantages of their ability to form good membrane, flexibility, toughness, economical, and excellent separation properties; whereas, they have few pitfall such as limited mechanical, chemical, and thermal resistance, low mass transport (for dense polymeric membrane) as well as a poor anti-fouling ability induced by their surface properties. Preparation of novel composite polymeric membrane by structural modification of the existing matrix of polymer membrane materials to improve their permeability, permselectivity and strength and other functional properties would play an important role in membrane science and technology. Polymeric nano-composite membranes are prepared by mixing of nano-sized fillers and polymer matrix to enhance performances such as high permselectivity, fluxes, favorable surface morphology as a result of excellent fouling resistance compared with the pure polymeric matrix membranes [4,5]. In the past few years, polymer nano-composite membrane has been dominating in its application for gas separation, water and wastewater treatment, desalination, fuel cell etc. The ultimate properties of a polymeric nano-composite membrane are very much dependent on the dispersion and distribution (Figure 1) of the reinforcing nano-filler in the continuous phase, as well as interfacial interaction between the surface of nano-scale filler and polymer matrix [3]. By incorporating nano-size fillers in the polymer solution prior to the membrane fabrication, one can change solution rheology, alter phase inversion and control membrane morphology. Prospective nano-fillers for polymer nano-composite membrane fabrication are carbon nanotubes, graphene oxide, TiO_2, SiO_2, $Mg(OH)_2$, Al_2O_3, ZnO, clay etc. Surprising enhancement of both membrane permeability, and selectivity for molecular species during separation could be achieved by reinforcing nanofillers in the polymer membrane matrix. The highly favorable property enhancement in terms of flux and selectivity for polymer nano-composite membrane in contrast to the conventional filler reinforced polymer membrane is most likely due to an extra region at the nanofillers polymer interface and/or disruption of polymer chain packing as a result of substantial increase of free volume size through which molecular transport would occurs in the dense nano-composite membrane matrix [6,7]. Thus, both gas separation as well as large-scale water treatment of commercial and environmental importance could be benefited by using polymer nano-composite membrane.

Conclusions: Challenges and Opportunities

With the rapid increase of global population and subsequent needs for energy, fresh water and waste water treatment, the application of

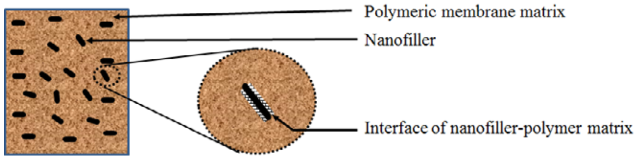

Figure 1: Schematic showing an example of good dispersion and distribution of nano-fillers in the polymeric nano-composite membrane matrix, and the interface between nanofiller-polymer matrixes.

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membranes will lead in many areas such as water treatment (viz. desalination, waste treatment), gas treatment and fuel cells are few fields of many to states. Research and development in the polymer nano-composite membrane is promising. However, further progress is needed as there are many challenges to overcome before nano-composite polymeric membrane can be considered in the industrial full phase applications. In order to meet the demand for novel applications, following will be challenging and interesting for researchers:

1) Finding novel nano-filler for specific applications of nano-composite membranes.

2) One of the major problems for nano-composite membrane is the proper dispersion and distribution of nano-fillers in the polymer nano-composite membrane matrix.

3) Surface modification of nano-fillers, hence, to improve the interfacial interaction between the dissimilar surface of nano-filler and polymer matrix.

4) Enhancing the flux through the nano-composite polymeric membrane matrix while separating the targeted component is challenging to the membrane scientists.

5) Membrane fouling is another obstacle for the membrane based separation where nano-fillers could be applicable to improve the membrane performance.

Nano-composite polymeric membrane could improve the membrane separation process which could be a key contributor for solving global fresh water supply, environment and energy.

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