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Material Behaviour

Permeation characteristics of tailored poly (*m*-phenylene isophthalamide) ultrafiltration membranes and probing its efficacy on bovine serum albumin separation

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ABSTRACT

Poly (*m*-phenylene isophthalamide) (PMIA) ultrafiltration (UF) membranes has been prepared using lithium chloride (LiCl) and poly (ethylene glycol) of average molecular weight 600 Da (PEG 600) as additives by phase inversion technique. Membranes were characterized by FTIR, TGA, DTG and UTM. Surface characteristics are probed by SEM, AFM and water contact Angle. It was evidenced from SEM analysis that all membranes have macrovoids in its structure and hence possess high water permeability. Accordingly, all membranes were highly hydrophilic in nature which can be predicted from water wettability and work of adhesion measurement using contact angle. Further, membranes were subjected for protein rejection study using bovine serum albumin (BSA) as a model foulant and its fouling ability was analyzed. It has been found that the 10 wt.% PMIA membrane with 2 wt% of PEG 600 and 4 wt.% of LiCl has high water permeability and better reversible and irreversible anti-fouling capability than any other prepared membranes. Flux recovery ratio (FRR) of 91% was obtained for the 10 wt.% PMIA also confirmed it is one of the promising UF membrane materials.

1. Introduction

Growing global demand for clean water and increasing environmental concerns make membrane separation process as the technology of choice for industries seeking to reuse their wastewater and reduce their water footprint. It helps in increasing the separation efficiency with budget friendly room temperature operation with increasingly stringent discharge regulations. UF is a pressure-driven process that removes emulsified oils, metal hydroxides, colloids, emulsions, dispersed material, suspended solids and other large molecular weight materials from water. The major opportunities for UF involve clarification of solutions containing suspended solids, removal of viruses and bacteria or high concentrations of macromolecules. It finds applications in various fields because of its high efficiency and low operating pressure [1].

Aromatic polyamides showed excellent thermal stability and mechanical resistance. Due to its aromatic structure and the presence of inter and intramolecular hydrogen bonds, the aromatic polyamides usually have a high level of cohesive energy that leads to high glass transition temperatures [2]. Poly (*m*-phenylene isophthalamide) (PMIA) is one of the most important aromatic polyamides and has been widely used because of its thermal stability and excellent mechanical properties. PMIA also known as *m*-aramid, has been used for industrial applications such as fire fighter's cloth, as a thermal filter in a power plant and as a membrane in an electric transformer. Furthermore, it is possible to take the advantage of PMIA self-charged characteristics to develop UF membranes directly without additional post-polymerization modifications [3]. Recently different commercial symmetric and asymmetric membranes are prepared by phase inversion method using synthetic polymers or copolymer or blends [4–7]. Poly (ethylene glycol) of average molecular weight 600 Da (PEG 600) which is non-toxic and highly soluble in water used as an additive to increase the hydrophilicity and porosity of the membrane [8,9]. LiCl used as another additive during membrane preparation interacts strongly to form complexes with solvents and this strong LiCl-solvent interaction increases the viscosity of the casting solution, resulting in favorable membrane morphology [10–12]. UF membranes were also found to be more effective in the separation of soluble proteins from aqueous

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solutions which is advantageous because it is non-destructive and the process limits denaturation of proteins [13]. These separations of protein studies have created a new dimension for the practicability of the UF process in the food and pharmaceutical industries.

For instance, Wang et al. [14,15] used PMIA hollow fiber nanofiltration membrane to study the effect of non-solvent additives on the morphology and separation performance. Huang and Zhang [16] prepared the high flux PMIA nanofiltration membrane for dye purification and desalination at low operation pressure. By far, no literature was found using PMIA as polymeric material to prepare UF membranes through 'non-solvent induced phase inversion' method using LiCl and PEG 600 additives for the rejection of proteins. In this work, asymmetrical PMIA UF membranes were prepared using phase inversion technique for BSA protein rejection at different operating conditions. All the prepared membranes were characterized using Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM) and atomic force microscopy (AFM), water contact angle (WCA), universal testing machine (UTM) analysis to find the strength of the membrane, thermogravimetric analysis (TGA) and differential thermogravimetric analysis (DTGA). Flux studies have been done to ensure the membrane permeability.

2. Experimental section

2.1. Materials

Commercial grade PMIA (M_w = 36.8 kDa; T_g = 274 °C) (Fig. 1) was purchased from Sigma-Aldrich, India. All the polymers were dried in a vacuum for 8 h prior to use. PEG 600 was obtained from Merck (I) Ltd., Analar grade N-methyl-2-pyrrolidone (NMP) from SRL Chemicals, India Ltd. was sieved through molecular sieves (Type 5A°) to remove moisture and stored in dry conditions prior to use. BSA (M_w = 69 kDa) was purchased from SRL Chemicals Ltd., India. Dextrans with different molecular weights 19, 40, 70 and 150 kDa were procured from Sigma Aldrich Inc., and stored at a suitable temperature before use. Anhydrous LiCl was purchased from Loba Chemie Pvt. Ltd., and used as such during membrane preparation.

2.2. Membrane preparation

Pure PMIA membrane was optimized in terms of physical properties such as thickness, smoothness and homogeneity. LiCl (4 wt.%) added during dope solution preparation was assists in the solubility of a PMIA polymer and PEG 600 was used as the organic pore former. The optimum compositions of dope solution for membrane preparation have been found to be PMIA (10 wt.%), LiCl (4 wt.%) and PEG 600 of different weight percentage in NMP solvent as shown in Table 1. Initially,

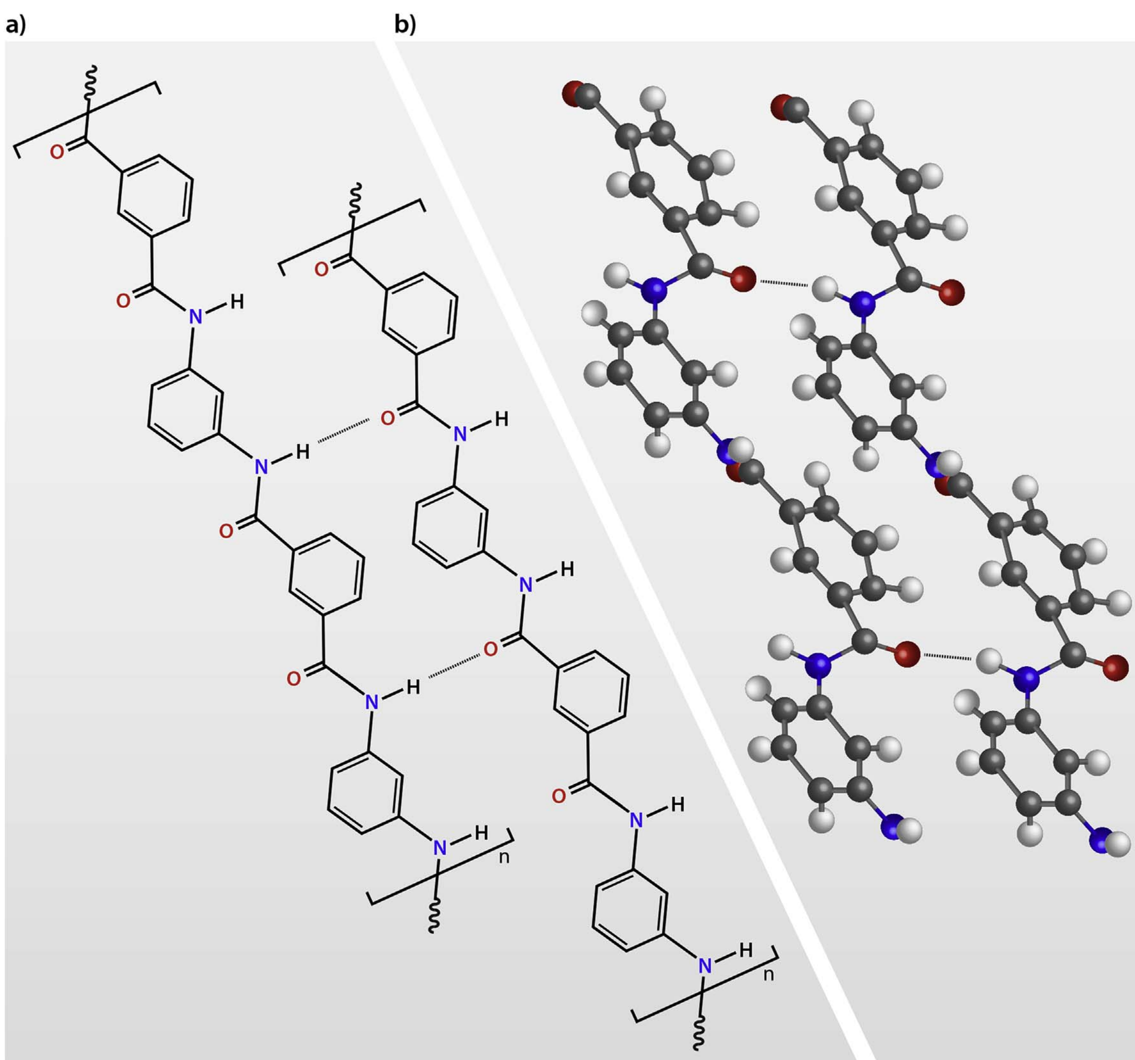

Fig. 1. Chemical structure (a) and three dimensional crystal structure (b) of PMIA.