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ORIGINAL RESEARCH

Temperature-sensitive poly(*N*-isopropylacrylamide)–reduced graphene oxide/polysulfone as smart separation membrane: structure and performance

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Abstract

N-Isopropylacrylamide (NIPAM) was successfully grafted on reduced graphene oxide (RGO) by free radical polymerization and characterized by attenuated total reflection Fourier transform infrared (ATR-FTIR) spectroscopy, transmission electron microscope (TEM) measurements, thermogravimetric analysis and ultraviolet–visible transmission spectroscopy. The synthesized poly(*N*-isopropylacrylamide)–reduced graphene oxide (PNIPAM–RGO) was used to improve the properties of polysulfone (PSF) membranes with different PNIPAM–RGO weight fractions. The structure and properties of PNIPAM–RGO/PSF membrane were characterized by X-ray photoelectron spectroscopy, scanning electron microscopy, atomic force microscope, contact angle and tensile testing. The water permeability, self-cleaning recovery rate and water flux decline factor were tested. The blend membrane with 0.4 wt% PNIPAM–RGO possessed the optimal rejection and exhibited an impressive self-cleaning recovery rate and fracture strain of 98.6 and 72.2%, showing a 67.4 and 76.5% enhancement compared to that of pure PSF membrane (58.9 and 40.9%), respectively. Meanwhile, the water flux decline factor decreased from 21.0 to 7.8%. The drastic change of permeability to aqueous solution, observed around lower critical solution temperature of PNIPAM–RGO, proved the thermal sensitivity of the blend membrane. The NIPAM grafted onto RGO by free radical polymerization and utilizing the advantages of both PNIPAM and RGO, which was used as an additive in the membrane, and very hard to lose during the membrane formation and application. The resulting membrane exhibited a significant increase in self-cleaning recovery rate, hydrophilicity, mechanical strength and thermosensitivity.

Keywords Thermosensitive · Poly(*N*-isopropylacrylamide) · Reduced graphene oxide · Polysulfone · Blend membrane

Introduction

Membrane separation technologies have received increasing attention due to low cost, low operating temperature and high production efficiency, which have a broad application prospect in diverse fields [1–3]. Polysulfone (PSF) is an outstanding polymer in UF membrane preparation for its excellent property. However, poor hydrophilic often results in grievous membrane fouling and decline of permeability. Therefore, the study of modified PSF membranes is meaningful. Based on the understanding and expectation of separation membrane, higher requirements for the membrane performance are discussed to meet diversified and multi-level needs, which promote the rapid development of the technology and products such as stimulation responsive, molecular recognition and affinity separation membrane. The stimulus-responsive separation membranes are sensitive to environmental stimuli and their property will change according to different external conditions such as temperature, pH, light, and electric field [4–6]. Developing effective, inexpensive and stable smart separation modified membranes is of great importance and desirability.

Poly(*N*-isopropylacrylamide) (PNIPAM) is a typical kind of thermosensitive polymer with a lower critical solution temperature (LCST) of 32 °C, which is most commonly used in the field of smart separation membrane [7, 8]. Due to the existence of hydrophilic amide groups and hydrophobic isopropyl groups, PNIPAM chains are hydrophilic and show an extended random coil conformation below LCST. However, when the temperature is increased above LCST,

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