Journal of Environmental Chemical Engineering 10 (2022) 107862

Contents lists available at ScienceDirect

Journal of Environmental Chemical Engineering

journal homepage: www.elsevier.com/locate/jece

E-beam induced grafting of binary monomer on polysulfone membrane for the separation of skim natural rubber latex

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ARTICLE INFO

Editor: Dr. Zhang Xiwang

Keywords:
Electron-beam irradiation
Hydrophilic modification
Natural rubber filtration
Antifouling
Binary monomer
Surface modification

ABSTRACT

Polysulfone (PSF) membranes containing TiO_2 were prepared by phase inversion. The membrane surfaces were modified by electron beam irradiation at energies of 3 and 10 MeV for irradiation doses of 10 and 50 kGy. Hydrophilic sulfonate groups were then introduced by single-step grafting using a binary monomer of acrylic acid (AAc) and sodium styrene-sulfonate (SSS). The surfaces of the modified membranes were characterized by analysis of water contact angles (WCA), surface energy (SE), Fourier transform infrared spectroscopy (FTIR), X-ray photoelectron spectroscopy (XPS), atomic force microscopy (AFM), and scanning electron microscopy (SEM). Filtration performances were evaluated using bovine serum albumin (BSA) and NR serum. A membrane irradiated at 10 MeV and 50 kGy showed the highest hydrophilicity after AAc/SSS grafting, with a WCA of 35.2 degrees and SE of 60.1 mJ/m^2. After 2nd cycle filtrations of BSA and NR serum, this membrane demonstrated flux recovery ratios of 97.8% and 95.9%, respectively. The rejection rates of total solid content (TSC) and total protein in NR serum were 72.1% and 91.5%, respectively.

1. Introduction

Thailand is the world's biggest producer and exporter of natural rubber (*Hevea brasiliensis*) [1]. Total rubber production in Thailand in 2018, 2019, and 2020 was 4.81, 4.77, and 4.24 million metric tons, respectively (Department of International Trade Promotion, Ministry of Commerce, Thailand, https://www.ditp.go.th.com, 2021) [2]. Unfortunately, latex production and rubber processing causes environmental issues from foul odors and wastewater [3]. Because the chemical processing of rubber extracts the usable rubber particles in natural rubber latex, the wastewater from the process contains the unusable components in the remaining fraction (NR serum) [4]. NR serum contains water, proteins, resins, sugars, ash, fats, residual rubber particles, and other compounds [5]. Value could be added to the large quantity of NR serum produced in several countries by treating the serum to extract amino acids, proteins and other elements [6].

Wastewater from rubber processing can be treated by organic separation techniques such as coagulation and activated sludge but the application of these treatments has been limited by costs, complicated separation equipment, low removal efficiency, and organic molecule degradation [7]. Consequently, membranes, which do not degrade organic molecules, present a more viable solution to the problem of separating NR serum from water. However, the membrane filtration of NR serum has proved challenging because NR serum contains small residual rubber particles that are sticky and tend to clog the membrane, obstructing pores and leading to irreversible fouling [8,9]. Fouling is a crucial factor in membrane performance and can be influenced by electrostatic interactions, hydrogen bonding effects, hydrophobicity, and Van der Waals forces [10]. One way to reduce the accumulation of hydrophobic rubber molecules is by improving the hydrophilic properties of the membrane surface [9,11], which is the most critical factor in anti-fouling.

Increasing the hydrophilicity of a membrane surface reduces the adsorption of hydrophobic molecules at the membrane [12] but unfortunately, most polymer membranes are naturally hydrophobic. Polysulfone (PSF), for instance has excellent mechanical stability, high chemical and thermal resistance but has a low surface energy and is therefore hydrophobic [13]. Since membrane substrates should be as

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https://doi.org/10.1016/j.jece.2022.107862
Received 16 February 2022; Received in revised form 4 April 2022; Accepted 4 May 2022
Available online 6 May 2022