

γ -Valerolactone (GVL) as a Next-Generation Platform Solvent for Sustainable PVDF Membrane Preparation

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Abstract

This study, conducted within the framework of the MEASURED project, investigated the use of green solvents in membrane preparation for applications in Membrane Distillation (MD). In particular, γ -valerolactone (GVL) was examined as a bio-based solvent for preparation of poly (vinylidene fluoride) (PVDF) membranes via phase inversion technique. The results demonstrated the feasibility of obtaining membranes with a wide range of pore sizes, from microfiltration (MF) to ultrafiltration (UF) applications and confirmed that GVL-based membranes maintained controlled morphology and properties comparable to commercial options, making them a promising choice for MD applications.

Keywords: sustainable membrane preparation, green solvents, γ -valerolactone (GVL), PVDF porous membrane, membrane distillation.

Introduction

The MEASURED project aims to drive a significant advancement in membrane technologies for pervaporation, gas separation, and membrane distillation, laying the foundation for the future commercialisation of more sustainable technological pathways across the entire value chain [1]. One of the goals of this project was to refine membrane materials and ensure efficient scalability. In this respect, the CNR-ITM is a leader in the MD process and a pioneer in the sustainable membrane preparation by using green and more sustainable solvents. Although MD follows the metrics of process intensification and it is widely recognized as a process that can be successfully used for the treatment of industrial wastewater, the membrane manufacturing is yet to embrace the use of harmful and toxic solvents, such as N-methyl-2-pyrrolidone (NMP), N, N-dimethylacetamide (DMA), and N, N-dimethylformamide (DMF) [2]. The developing of alternative solvents for membranes preparation follows the fifth principle of Green Chemistry, which encourages minimizing hazardous auxiliary substances and ensuring their safety when used [3]. This study explored the use of γ -valerolactone (GVL), a renewable and bio-based solvent derived from lignocellulosic biomass, for the preparation of PVDF membranes through phase inversion technique. GVL exhibits low toxicity, high biodegradability, and excellent solvation properties, making it an ideal candidate for sustainable membrane preparation.

Materials and Methods

PVDF-based membranes were produced by coupling vapor-induced phase separation (VIPS) and non-solvent-induced phase separation (NIPS) techniques. The formation mechanism of the developed membranes was preliminary studied in terms of thermodynamics, related to polymer precipitation behaviour (such as Hansen Solubility Parameters), and kinetics, related to the exchange rate of solvent/nonsolvent during phase separation (such as dope viscosity). The PVPK17 (polyvinylpyrrolidone) and polyethylene glycol (PEG200) as pore-formers were used for the fabrication of membranes with controlled pore sizes. The membranes were cast in the climatic chamber with 55Rh% of humidity for different times (0,2,5,5 minutes) Isopropanol and/or Ethanol with water were selected as coagulant baths and the effect of relative energy difference (RED) in different compositions was investigated. The membranes were fully characterized concerning morphology, pore size distribution, wettability, thickness, porosity and trans-membrane vapor flux in MD tests carried out using distilled water as feed.

Results

GVL proved to be a suitable green solvent for replacing conventional toxic solvents in PVDF membrane preparation, enabling the production of membranes with pore sizes ranging from 0.1 to 1 μm . The choice of preparation method (NIPS or VIPS-NIPS) and the use of specific coagulation baths (isopropanol and ethanol) significantly influenced membrane properties. The fabricated membranes exhibited porosities between 84% and 86% and thickness variations between 90 and 120 μm , depending on the dope solution composition and the presence of additives. Membranes prepared demonstrated a sponge-like morphology without the presence of macrovoids and resulted to be suitable for MD applications.

Discussion and Conclusions

The study demonstrated the use of GVL as a green solvent for PVDF membrane particularly for MD application. The research confirmed that replacing traditional toxic solvents with GVL enabled the production of PVDF membranes with desirable properties such as controlled pore size distribution and high porosity. The combination of phase inversion methods and coagulation conditions played a crucial role in determining membrane structure and efficiency. Membranes produced through VIPS-NIPS exhibited improved pore interconnectivity and maintained a uniform sponge-like morphology. This study reinforced the importance of sustainable membrane production and its potential applications in wastewater treatment. By adopting green solvents, industries could take a step towards reducing hazardous waste and promoting totally green membrane technology.

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Conflicts of Interest

The authors declare no conflict of interest.

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