ADVANCED ELECTROSPUN POLYMERIC MEMBRANES EMBEDDED WITH ZIF-8 AND ZIF-8@TiO_2 PARTICLES FOR INDUSTRIAL APPLICATIONS

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1. Introduction

Advanced electrospun polymeric membranes have emerged as promising materials for separation and purification processes due to their high surface area, interconnected porosity, and tunable fiber morphology. These structural characteristics contribute to improved mass transfer and permeability compared to conventional membrane systems, making electrospinning an attractive technique for industrial-scale applications. Recent studies have shown that the integration of electrospinning with other fabrication approaches enables the development of hierarchical and multifunctional membrane architectures with enhanced performance [1].

Recent research has explored the enhancement of photocatalytic AOPs by integrating metal-organic frameworks (MOFs), specially zeolitic imidazolate frameworks like ZIF-8, with conventional photocatalysts such as titanium dioxide [2], [3]. ZIF-8, with its high surface area and good chemical stability which facilitates pollutant adsorption while promoting electron transfer during photocatalysis [4]. The combination of TiO_2 with ZIF-8 can improve photocatalytic efficiency under UV or visible light irradiation.

This study proposes the development of electrospun nanofibrous membranes modified with photocatalytic materials, specifically ZIF-8 and ZIF-8@TiO_2 composites, to examine how different production methodologies influence structural morphology.

2. Methodology

ZIF-8 was synthesized by mixing zinc chloride (0.34 g) and 2-methylimidazole (1.64 g) in methanol (45 mL) under stirring (500 rpm) at room temperature for 30 min, followed by static aging overnight. ZIF-8C@TiO_2 was synthesized via in situ incorporation of TiO_2 (anatase, 20 nm). After 30 min stirring and overnight aging, the product was centrifuged, washed with methanol, and dried at 60 ºC for 12 h [5].

Two nanofibrous membranes were prepared using polyacrylonitrile (PAN) and ZIF-8-based materials. A bilayer membrane was obtained by first electrospinning a PAN support, followed by the deposition of a second layer containing 50 wt% PAN and 50 wt% ZIF-8. In contrast, a homogeneous membrane was produced by electrospinning a solution containing 50 wt% PAN and 50 wt% ZIF-8@TiO_2. All solutions were prepared in N,N-dimethylformamide (DMF) and stirred until complete homogenization prior to electrospinning under controlled conditions. The resulting membranes were dried at room temperature. Electrospinning process was performed at 25 kV, 0.8 mL/h, and a tip-to-collector distance of 20 cm. The resulting particles and membranes were analyzed by microscopy to identify differences at the morphology influences by the particles and the spray deposition.

3. Results and Discussions

Microscopy was employed to characterize the particle size and morphology of the produced materials, as well as to assess the spatial distribution of TiO_2. The particle size of ZIF-8 was approximately 1100 nm (Fig. 1), whereas ZIF-8@TiO_2 exhibited an average particle size of 380 nm (Fig. 2). In addition, smaller particles attributed to TiO_2 were observed, with an average size of 32.4 nm as confirmed by the lattice fringes. The microscopy shows clear morphological differences depending on the incorporation strategy and material. The membrane containing ZIF-8 (Fig. 1) exhibits a heterogeneous surface with visible particle agglomerates, likely due to the bilayer configuration and post-deposition onto the PAN support, which limits particle dispersion. In contrast, the membrane with ZIF-8@TiO_2 (Fig. 2) presents a more uniform and compact structure, indicating better dispersion

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when the composite is directly incorporated into the electrospinning solution. The surface appears more continuous and interconnected, suggesting improved integration between particles and the polymer matrix.

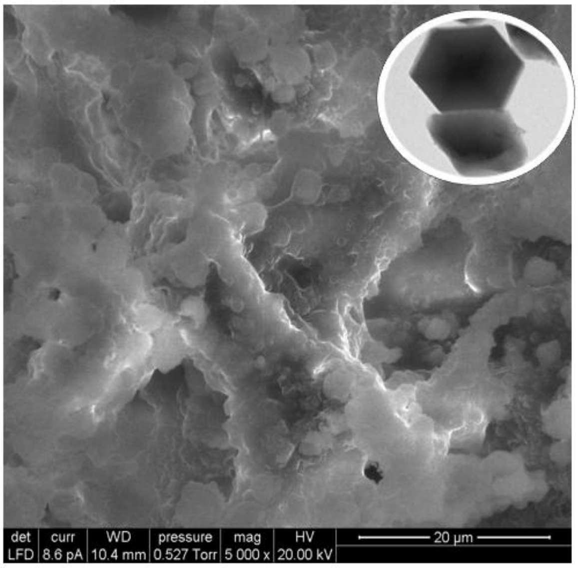

Fig. 1. *Membrane with PAN support and an electrospun layer composed of 50 wt% PAN and 50 wt% ZIF-8.*

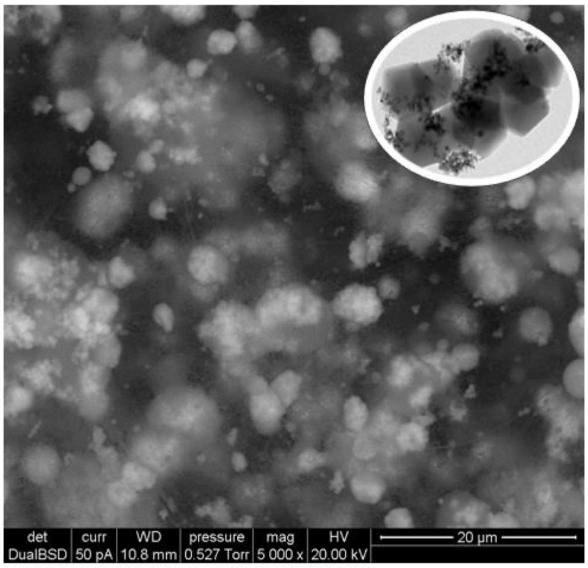

Fig. 2. *Electrospun membrane prepared from a solution containing 50 wt% PAN and 50 wt% ZIF-8@TiO_2*

Overall, direct incorporation promotes a more homogeneous morphology, while layer deposition leads to particle clustering, which may influence membrane performance. Future studies should investigate how these morphological differences affect photocatalytic activity and the general membrane performance to improve membrane stability and efficiency in industrial applications.

4. References (boldface Times New Roman 11 pt)

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Acknowledgments

The authors acknowledge the Università degli Studi di Padova for institutional support and the IILA (International Italo-Latin American Organization) for financial support.

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