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Improving the separation performance of the forward osmosis membrane based on the etched microstructure of the supporting layer

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HIGHLIGHTS

- ZnO nanoparticles as templates were used to prepare PVDF porous membranes.
- The microstructure of the supporting layer could be optimized by etching method.
- The optimized channels alleviated the concentration polarization in the FO membrane.

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ABSTRACT

The physical and chemical characteristics of the porous supporting layer play a key role in the separation efficiency and concentration polarization of the forward osmosis (FO) membranes. In this paper, the modified polyvinylidene fluoride (PVDF) porous membranes with high porosity and large amounts of surface membrane pores were prepared with zinc oxide (ZnO) nanoparticles as the template, and used as the supporting layer of the FO membrane. The modified FO membranes showed enhanced water permeability and separation selectivity. The increased water flux was based on the increase of the effective membrane area, and the decreased τ/ε (tortuosity factor/porosity) value obviously alleviated the concentration polarization phenomenon based on the optimization of the flow channel. The etching of the porous microstructure could reduce the limit of the supporting layer on the separation performance of the FO membrane, and provide a simple method to improve the separation efficiency of the thin film composite (TFC)-type FO membranes.

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1. Introduction

In recent years, more and more attention has been paid to the forward osmosis (FO) technology, which is an innovative means of separation used in the field of desalination and water treatment, with the characteristics of low energy consumption, reduced membrane fouling and high separation precision [1–3]. Nowadays, the application of the FO membranes is limited by the disadvantage of low separation efficiency. The previous studies have demonstrated that the thin film composite (TFC)-type FO membranes can enhance the separation efficiency, based on the thin active layer. However, the porous structure of the supporting layer always induces serious concentration polarization problems in the FO processes, especially the internal concentration polarization (ICP), resulting in the separation flux lower than the theoretical value [4–6].

In order to optimize the separation performance and ease the concentration polarization problem, much research work has been focused on the modification of the supporting layer of the FO membranes. Blending hydrophilic media and functional inorganic materials, or using novel supporting materials are the common methods for the improvement of the porous supporting layer. Xu et al. enhanced the permeability of the porous polyether sulfone (PES) membrane supporting layer and optimized the pore structure through the addition of the sulfonated polyether sulfone, and the prepared FO membranes showed higher separation efficiency [7]. Wang et al. prepared a nano-composite membrane supporting layer by dispersing carboxylated multi-walled carbon nanotubes into PES via non-solvent induced phase separation (NIPS) method, and the prepared hybrid PES membrane showed more open pore structures and higher water permeability coefficient than the neat PES membranes [8]. Wang et al. used another synthetic hydrophilic inorganic material, namely, reduced graphene oxide (rGO) modified graphitic carbon nitride (g-C3N4), as a modifier for the porous PES substrate to prepare the TFC-type FO membrane, and the water permeability of the prepared FO membrane was significantly improved due to the optimization of the pore structure and enhanced wettability [9]. Obaid et al. used SiO_2 nanoparticle-incorporated PVDF electrospun

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nanofiber membrane as the supporting layer, and the prepared FO membrane exhibited the highest water flux of 83 L/m^2 h, the constant salt rejection of 99.7% with 2 M NaCl as the draw solution, and the lowest structural parameter (S) value of 29.7 [10]. Kim et al. also used the crosslinked polyvinyl alcohol (PVA) nanofiber membrane as the supporting layer, and the prepared FO membrane was highly hydrophilic, with a high porosity of 93% and a decreased S value of 66 μm [11].

It is generally known that the matrix pores of the porous membranes are the filter channels, and reducing the tortuosity factor of the channel can accelerate the flow of the feed or draw solution within the membrane pores [12,13]. According to the separation mechanism of the TFC-type FO membranes, the supporting layer not only provides the supporting role and passing channels, but also acts as an effective region (near the active layer) for the osmotic pressure to work. The surface of the supporting layer, which is attached with and underneath the active layer of the TFC-type FO membrane, is the real acting area of the osmotic pressure. The more pores of the surface of the supporting layer, the more effective area of the FO process, which has direct positive effect

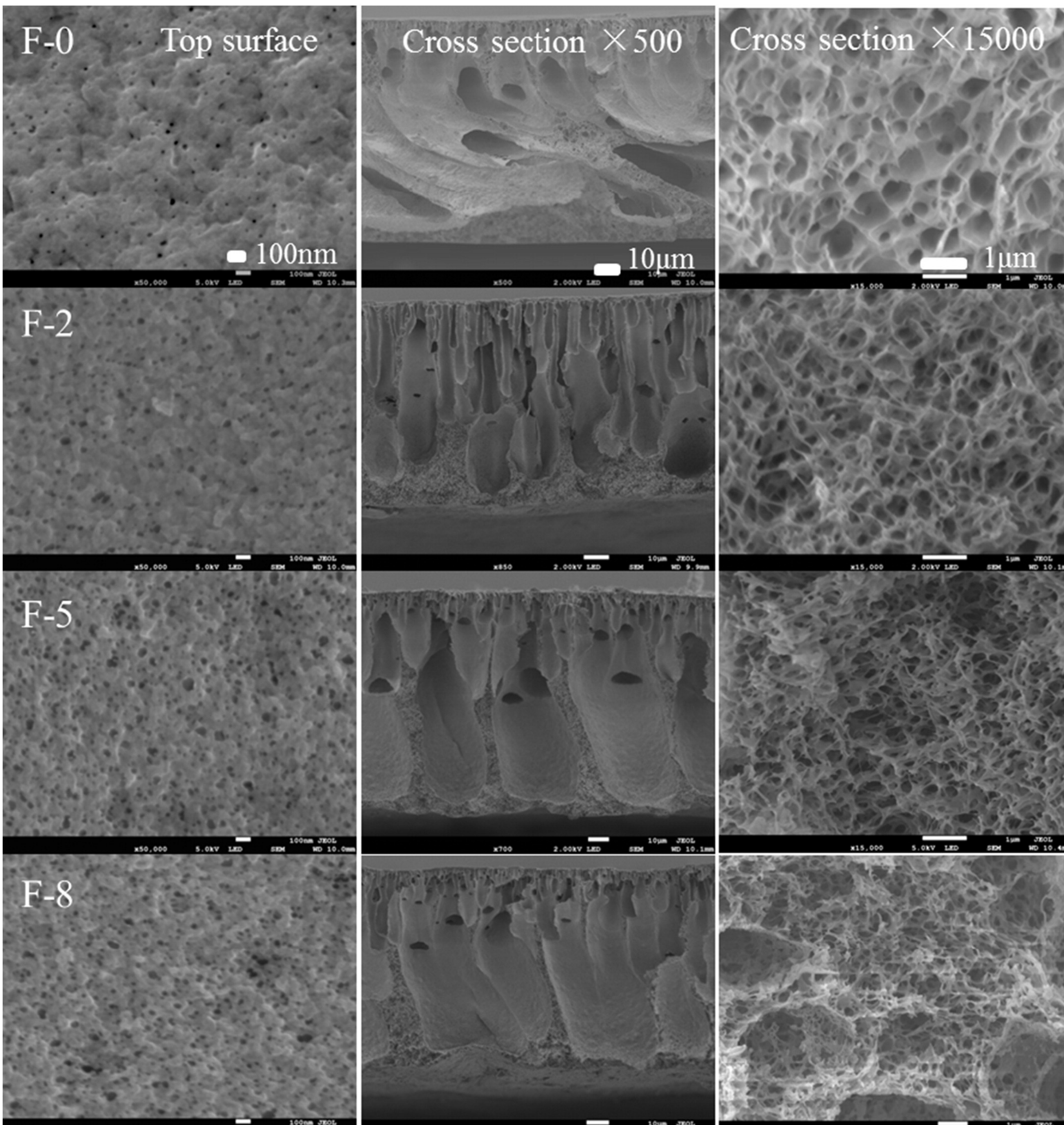

Fig. 1. SEM images of the neat and modified PVDF membranes prepared by the template method.

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