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Technology Offer

Hierarchically Structured Nanofilament-Based Coating for Enhanced Membrane Distillation Performance

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Abstract

The innovation involves nanofilament-based superhydrophobic coatings designed for membrane distillation (MD), specifically targeting brine desalination and wastewater treatment applications. By coating microporous membranes with polysiloxane nanofilaments, a multi-scale, hierarchical porous structure is achieved, enhancing the membrane's resistance to wetting and fouling without using fluorinated compounds. The membrane's superhydrophobic nature results from nanofilament coatings that establish a stable air cushion, supporting consistent vapor permeability while repelling contaminants. This nanofilament-based coating technology presents a valuable, environmentally friendly option for efficient and sustainable MD processes.

Background

Membrane distillation is an energy-efficient alternative for desalinating highly saline waters and reclaiming wastewater, relying on heat-driven water vapor transfer across hydrophobic membranes. Traditional membrane materials like PTFE or PVDF lack the robust antifouling capabilities necessary for long-term operation in challenging environments, often using environmentally harmful fluorinated compounds to enhance hydrophobicity. This technology addresses these limitations by employing a nanofilament-based coating to improve both fouling resistance and distillation flux.

Technology

This nanofilament-based coating combines a microporous polymer support with a superhydrophobic nanofilament layer to establish a hierarchical porous structure ideal for membrane distillation. The support membrane includes through-going pores with a nominal diameter ranging from 0.2 µm to 50 µm (Fig. 1) and the fluorine-free superhydrophobic layer features nanopores with diameters between 5 nm and 200 nm (Fig. 1). This nanofilament coating is created by depositing polysiloxane nanofilaments on the membrane surface through a controlled reaction. The process involves plasma activation of the membrane to introduce hydroxyl groups, followed by immersion in a solvent mixture containing trichloromethylsilane and trace water. This reaction forms a dense, interwoven nanofilament network that bonds securely to the surface. This structure facilitates high water contact angles (>150°), significantly reducing liquid penetration and allowing the coated membrane to repel water-borne contaminants, proteins, and surfactants effectively. The excellent liquid repellency is also reflected by the high liquid entry pressure of up to 11.5 bars. In tests, membranes coated with this nanofilament layer showed superior stability and a consistent flux over extended periods under both air gap (AGMD) and direct contact (DCMD) configurations, demonstrating antifouling properties with bovine serum albumin (BSA) (Fig. 2) and antiwetting with sodium dodecyl sulfate (SDS) solutions (Fig. 3).

Advantages

- Superior distillation flux: Improved vapor transport across the membrane surface compared to conventional membranes.
- Enhanced fouling resistance: Nanofilament coating minimizes protein and surfactant adhesion.
- High wettability resistance: Maintains superhydrophobicity without fluorinated compounds.
- Environmentally friendly: Fluorine-free formulation aligns with sustainable development goals.

Potential applications

- Brine desalination: Treatment of highly saline waters for freshwater recovery.
- Industrial wastewater treatment: Effective in recovering clean water from contaminated streams.
- Critical resource extraction: Used in processes for lithium and other mineral extraction from brine.
- Off-grid water purification: Suitable for solar-driven distillation systems in remote areas.
- Pharmaceutical and biotech: Removal of organic and biological contaminants from water supplies.

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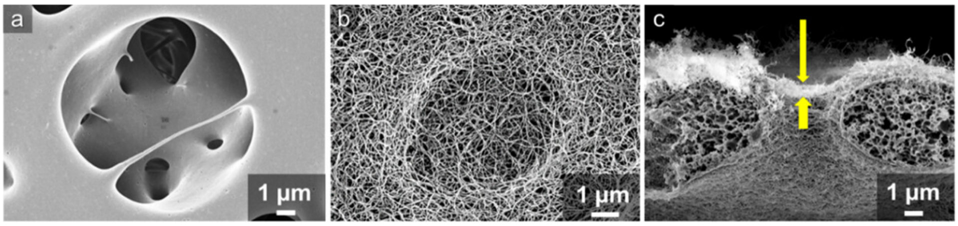

Figure 1: Scanning electron microscopy (SEM) images of the pristine hydrophilic poly(ether sulfone) membrane with a nominal pore size of 8 µm (PES-8) (a), nanofilament-coated PES-8 membrane (b), and cross-section of nanofilament-coated PES-8 with hierarchical porous structures. Yellow arrows in (c) denote the nanoporous outer layer on top of microporous structures (Shah, et al., 2023).

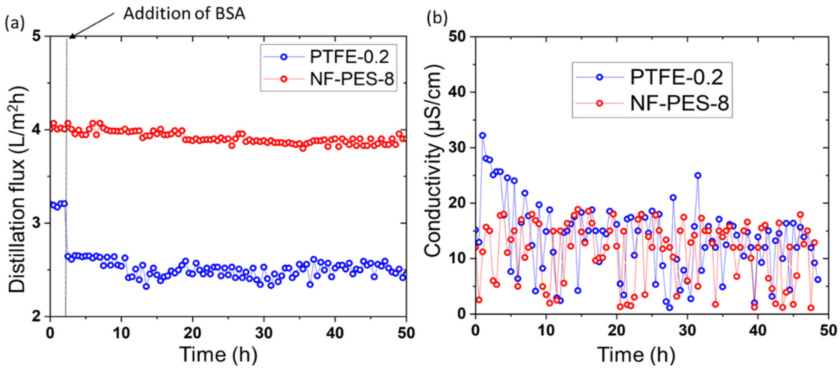

Figure 2: (a) AGMD distillation flux and (b) distillate conductivity as a function of time for original poly(tetrafluoroethylene) membranes with a nominal pore size of 0.2 µm (PTFE-0.2) and nanofilament coated poly(ether sulfone) membranes with a nominal pore size of 8 µm (NF-PES-8) (feed temperature Tf of 53 °C, distillate temperature Tc of 15 °C) with only 35 g/L salt and later with 1 g/L BSA and 35 g/L salt in the feed solution (Shah, et al., 2023).

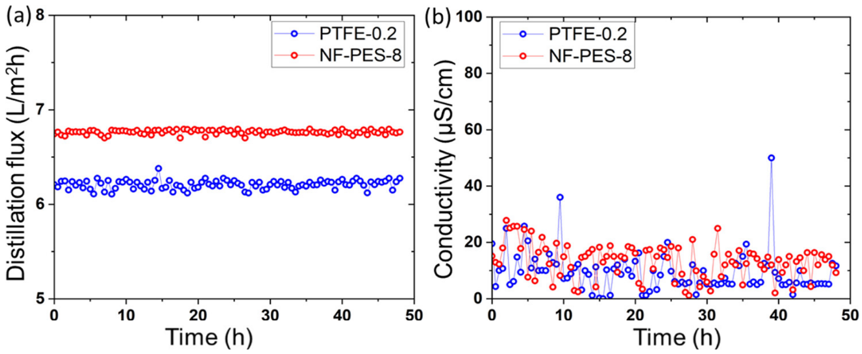

Figure 3: (a) AGMD distillation flux and (b) distillate conductivity as a function of time for original poly(tetrafluoroethylene) membranes with a nominal pore size of 0.2 µm (PTFE-0.2) and nanofilament coated poly(ether sulfone) membranes with a nominal pore size of 8 µm (NF-PES-8) with 2.8 mg/L SDS + 35 g/L salt at a Tf of 65 °C and Tc of 15 °C showing a stable flux for 48 h with no wetting (Shah, et al., 2023).

Patent Information

EP Priority application filed 07.01.2022,
WO2023131622 filed 04.01.2023, nationalized in EP and US

Publications

Shah, P.; Hou, Y.; Butt, H.-J.; Kappl, M. Nanofilament-Coated Superhydrophobic Membranes Show Enhanced Flux and Fouling Resistance in Membrane Distillation. *ACS Appl. Mater. Interfaces* **2023**, *15*, 55119–55128.

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