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A Facile Approach to Fabricate Superhydrophobic Membranes with Low Contact Angle Hysteresis

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Abstract

A robust superhydrophobic polyvinyldene fluoride-co-hexafluoropropylene (PVDF-HFP) electrospun membrane was fabricated by using a modest and versatile coating technique. Inspired by the natural phenomenon of thin layer formation of dust particles on the surfaces. Electrospun mats of PVDF-HFP were coated with tetrafluoroethylene oligomers (OTFE) particles. Dust of the OTFE was created in a closed chamber and used to form a thin layer of OTFE particles on the surface of the electrospun PVDF-HFP membranes. Hot pressing was used then to infuse the loose OTFE deposited layer on the surface of the PVDF-HFP membrane. Scanning electron microscopy images indicate that OTFE particles infused ~2-3 µm in the electrospun non-woven network. Static contact angle of water on the PVDF-HFP surface improved from 125°±2 to 156°±2 after OTFE coating. In addition, OTFE coating did not alter the pore size distribution of PVDF-HFP membrane and permeation flux, whereas it significantly helped in improving the water liquid entry pressure. The prepared membranes were tested in direct contact membrane distillation (DCMD) applied to desalination and reported to achieved 99.9% salt rejection with permeation flux of 13-14 kg/m^2 h. In addition to increasing the hydrophobicity of the membranes, OTFE coating significantly reduces the contact angle hysteresis from ~90°±2° to ~10°±2°. To show the significance of contact angle hysteresis on membrane performance, high fidelity modeling based on computational fluid dynamic in thermal coupled membrane flow was developed. Results of the temperature, polarization coefficient (TPC) and heat transfer coefficient (h) clearly show the favorable impact of the reduced value of hysteresis and its implication of inducing slip. Under total slip, considerable gain in the TCP is observed and reaching as high as 25%.

Keywords: Superhydrophobic membrane; membrane distillation; computational fluid dynamics; desalination

Introduction

Membrane distillation (MD) is an emerging technology for water desalination. It is considered a low energy desalination process compared to the commercially available RO technology[1]. In the MD process, a hot salt water stream and potable cold water stream are separated by a hydrophobic membrane. The temperature difference between the hot and cold stream creates a partial pressure difference between the two sides of the membrane. The vapors generated on the hot side passes through the membrane and is collected by the cold stream of water. The hydrophobic membrane does not allow the water in the liquid phase to pass through. The membrane controls the mass and heat transfer in this process and acts as a key component of the technology[2]. The MD membranes need to possess the basic properties for desalination including superhydrophobicity, porousity, minimal thermal conductivity and low cost. Currently, there is no commercial membrane is available in the market for MD technology.

Flourinated polymers Such as: Polyvinylidene fluoride (PVDF)[3], polyvinylidene fluoride-co-hexafluoropropylene (PVDF-HFP)[4], polytetrafluoroethylene (PTFE)[5] and polyvinylidenefluoride-co-tetrafluoroethylene (PVDF-TFE)[6] were commonly used for fabrication of hydrophobic membranes.