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LOW-COST, HIGH-PERFORMANCE MATERIALS FOR SOLAR-DRIVEN MEMBRANE DISTILLATION IN WATER TREATMENT AND DESALINATION

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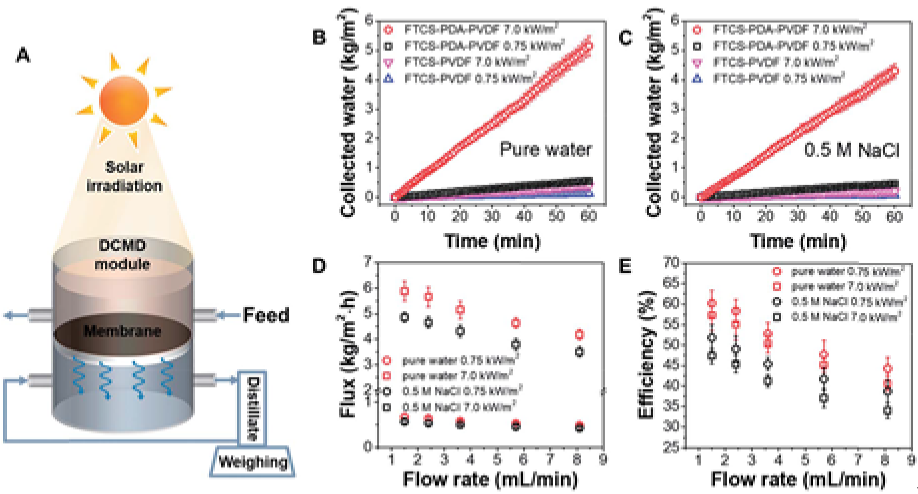
Technology Description

Engineers in Prof. Young-Shin Jun's laboratory and Prof. Singamaneni's laboratory have developed high performance, stable membrane materials that can be used for photothermal membrane distillation (PMD) to purify or desalinate water with minimal input of electricity. These environmentally-friendly membranes can be produced through low cost, scalable processes for energy efficient, solar-driven water treatment, particularly in low resource environments (e.g., developing countries, disaster relief).

PMD is a solar-driven process that has the potential to meet the global demands for clean or desalinated water, particularly in low resource environment. PMD reduces the energy consumption (i.e., electricity) than conventional membrane distillation; avoids the membrane fouling common in reverse osmosis; and is able to kill 100% of bacteria or remove all contaminants. However, to date, the materials utilized in PMD membranes have low photothermal conversion efficiency and low water flux; require expensive, complex synthesis; and are unstable. This technology offers different two high performance, low-cost, robust, environmentally-friendly membrane materials that address these shortcomings. These materials [PDA-coated polyvinylidene fluoride (PVDF) and PDA-bacterial nanocellulose (BNC) aerogel] utilize polydopamine (PDA) that has broad light absorption and outstanding photothermal conversion, driving effective local heating on membrane surface to facilitate vapor transport across membranes. Both materials have demonstrated high levels of energy efficiency and water flux with high salt rejection (>99.9%). In addition, PDA/BNC facilitates high vapor permeability and resists biofilm growth with self-disinfection properties. Furthermore, PVDF and BNC aerogel have been commercialized by industry with simple, scalable synthesis. This technology holds great promise for efficient, stable, scalable and sustainable water purification to alleviate water scarcity, especially in decentralized areas without a reliable source of electricity.



Schematic and results from solar-driven direct-contact membrane distillation (DCMD system) with FTCS-PDA-PVDF membrane

Proof of concept

The inventors demonstrated lab-scale performance of each of these materials:

- PDA-coated PVDF: energy efficiency = 45%; water flux = 0.49 kg m^{-2} h^{-1} under 0.75 kWm^{-2} solar irradiation (19-fold enhancement over membrane without PDA)
- PDA/BNC aerogel: energy efficiency = 68%; water flux = 1.0 kg m^{-2} h^{-1} under 1 sun irradiation
- PDA enables self-disinfection of membranes
- Fluorosilanization (FTCS) on both materials allows only vapor transport and high salt rejection (>99.9%)

Applications

- **Water purification and desalination** particularly for:
  - low resource areas and decentralized systems such as in developing countries (e.g., personal portable device, household roof top device), disaster relief zones or ships, or military installations
  - industrial wastewater treatment (e.g., flowback water from unconventional oil and gas recovery)

Key Advantages

- **High performance, environmentally-friendly, stable materials:**
  - 19-fold and 23-fold increase in permeate flux over materials without PDA
  - excellent solar energy efficiencies
  - >99.9% salt rejection
  - PDA and BNC are both biodegradable
  - PDA has excellent underwater adhesion, making PDA-coated PVDF material resistant to delamination
  - PDA/BNC aerogel has long term chemical and mechanical stability and resists biofilm growth
- **Easy, low-cost scalable production**
- **Advantages of photothermal membrane distillation over conventional membrane distillation and reverse osmosis:**
  - energy efficient with renewable energy source – solar-driven process requires minimal

electricity input because of low pressure, room temperature conditions (e.g., no energy needed to heat bulk feedwater)
    - efficient clean water collection because localized heating reduces influence of temperature polarization
    - minimal fouling or corrosion on membrane (unlike reverse osmosis, it is not a pressure driven process), therefore suitable for highly polluted wastewater
    - ensures 100% cleaning of bacteria from untreated water

Publications

- Wu, X., Jiang, Q., Ghim, D., Singamaneni, S., & Jun, Y. S. (2018). Localized heating with a photothermal polydopamine coating facilitates a novel membrane distillation process. *Journal of Materials Chemistry A*, 6(39), 18799-18807.
- Wu, X., Cao, S., Ghim, D., Jiang, Q., Singamaneni, S. and Jun, Y.-S.* A Thermally-Engineered Polydopamine-Bacterial Nanocellulose Bilayered Membrane for Photothermal Membrane Distillation, *in review*.

Patents – Application pending

Related Patent - Ultrafiltration membrane based on bacterial nanocellulose and graphene oxide (WUSTL Technology No. T-016682, U.S. Patent Publication No. US20190247793)

Related Web Links

- Jun Group (Environmental Nanochemistry Laboratory, ENCL)
- Singamaneni Group (Soft Nanomaterials Laboratory)