Enhanced Performances of Osmotic Energy Based Membrane Systems by Novel Approaches for Spacer Fabrication with 3D Printing

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1. INTRODUCTION

The desalination technologies have recently focused on the membrane treatment methods due to the relatively low cost and the more efficient performance behaviors. Between all membrane operations, salinity gradient based ones are taking high attention for the water-energy nexus. One of these operations, forward osmosis (FO) process has taken a lot of attention with its low energy consumption and relatively high water flux as well as its simplicity. Another one, pressure retarded osmosis (PRO) which provides energy harvesting by the application of extra pressure from the draw side still has problems related power density and membrane robustness to be applied in desalination plants.

For the osmotic energy based membrane systems, there are some critical issues to be solved. One of the critical issue, membrane fouling has increased the studies related to the membrane spacers since it has been observed for many times that fouling is reversely affected by the turbulence which can be controlled by the existence of membrane spacers. Another critical issue is the less viable power density of PRO systems which is caused by the surface damage of the membrane due to the high pressure at the draw side. Although, this problem is tried to be solved by fabrication of novel membranes, metal protector also known as metal spacer is also another approach.

Here, we use the de facto technology, polymer based and metal based 3D printing to produce the membrane spacers for FO and PRO system, which allows us practicality to test them in the laboratory, not just with staying dependent on computer modelling. Best of our knowledge, this is the first study in terms of 3D printing application for FO/PRO systems, spacer pattern effect on reverse solute flux, and metal printing application for membrane science.

2. MATERIALS AND METHODS

2.1. FO Spacers

2.1.1. Shape Effect

Novel designs were prepared by CAD modelling and printed by Polyjet type 3D printer which had the highest precision.

2.1.2. Material Effect

We focused on the material used for the spacers. We utilized acrylonitrile butadiene styrene (ABS), polypropylene (PP), and natural polylactic acid (PLA) as materials and by taking commercially available product as reference, we were able to produce spacers same pattern via 3D printing (Fig. 1) [1].

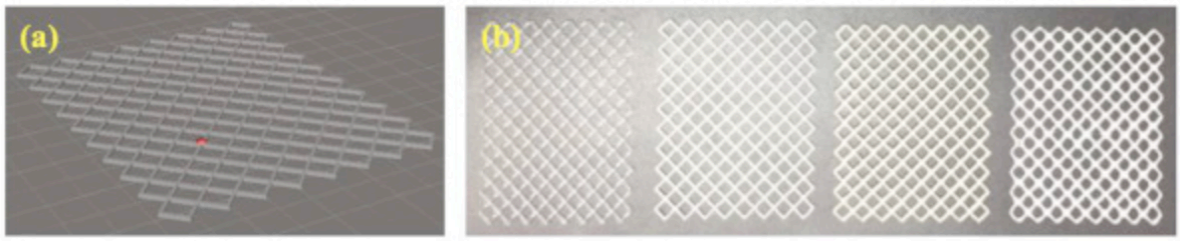


Figure 1. a) The CAD Model, screen picture from Autodesk Meshmixer. b) The Commercial Spacer (Com), PP spacer, ABS spacer, and PLA spacer from left to right, respectively (Figure is cited from our publication[1])

2.1.3. Performance Evaluation Tests

Water flux test. Shape and material effect on membrane spacers were tested by using engineered osmosis system in FO mode.

Fouling test. Alginate was used for our research as organic foulant to investigate the effects of shape and material change on membrane fouling. Atomic Force Microscopy (AFM) and Confocal Laser Scanning Microscopy (CLSM) were used fouling characterization.

Strength test. For measuring tensile strength of the 3D-printed spacers, Universal Testing Machine (UTM) was used.

2.2. PRO Spacers

Spacer part of the lab scale PRO test cell was redesigned by using Blender CAD modelling software (Fig. 2). After the redesign, modifications for the shape are done and fabricated via metal printing (SLM 280 2.0, Germany). Water flux and power density performances for of the spacers are evaluated by engineered osmosis system.

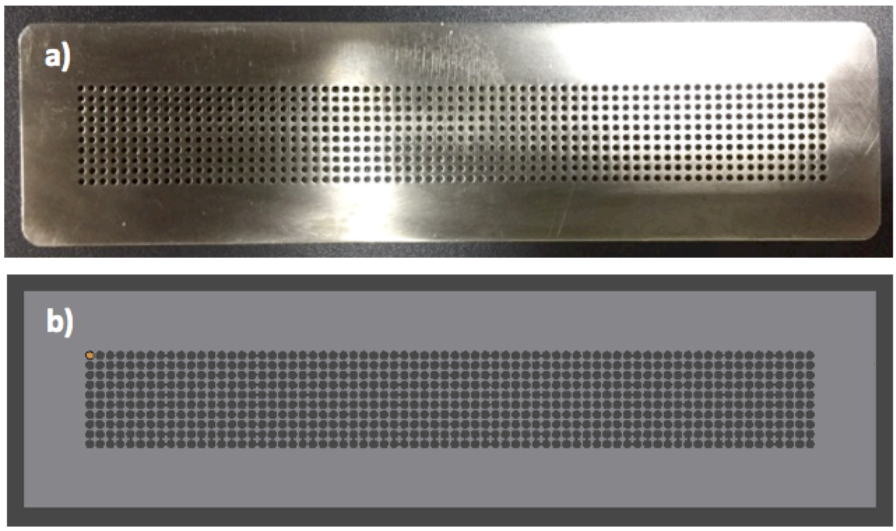


Figure 2: a) PRO spacer from the membrane test cell **b)** Modified design by CAD modelling

3. RESULTS AND DISCUSSION

Shape and material change of FO membrane spacers by utilizing 3D printing provided us relatively higher performances in terms of water flux, reverse solute flux (up to 40%) better performance and fouling resistance. We obtained higher fouling resistance and stronger structure by changing classical design. Fouling based water flux decrease by percentage under the effect of pattern change is given on Fig. 3.

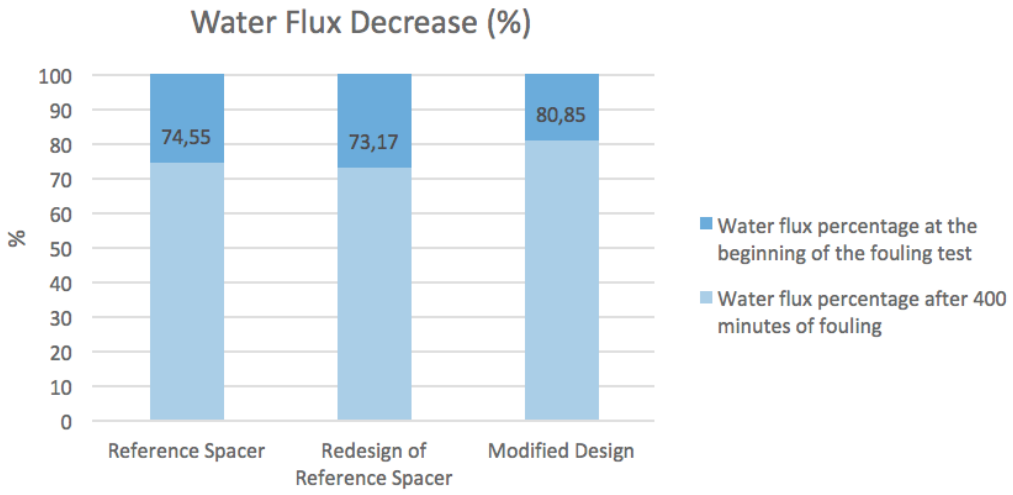


Figure 3: Water flux decrease caused by fouling of the membrane surface (In percentage)

Application of various materials for the fabrication of spacer also brought compatible performances. Especially, fouling layer was remarkably decreased (Fig. 4).

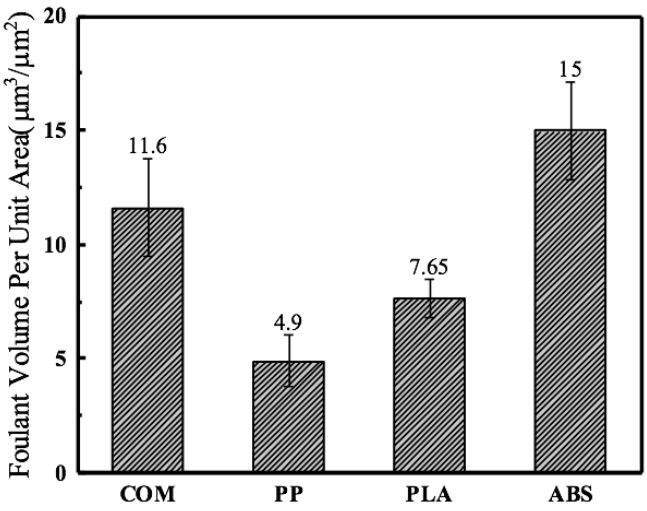


Fig. 4. Foulant volume per unit area from CLSM images of fouled membranes of Com, PP, ABS, and PLA. (The error bars give the deviations of 10 measurements based on two repeated experiments.) (Cited from our publication [1])

Usage of metal spacers brings confinement and protection to PRO spacers; however, it also results in relatively law water flux which decreases the power density. Therefore, by modifications of the designs, we managed to optimize membrane life and water flux as well as the power density.

CONCLUSIONS

3D printing technology allowed us to apply novel materials and pattern modifications for spacers. After designing, we had chance to have bespoke fabrications with higher fouling resistance and water flux for FO, and optimized power density for PRO.

REFERENCES

1) Yanar, N., Son, M., Yang, E., Kim, Y., Park, H., Nam, S.-E., Choi, H., Investigation of the performance behavior of a forward osmosis membrane system using various feed spacer materials fabricated by 3D printing technique, Chemosphere (2018), doi: 10.1016/ j.chemosphere.2018.03.147.