Electronic Supplementary Material (ESI) for RSC Advances.

Novel Strategy for Enhancing Electrospun PVDF Support layer of Thin-Film Composite Forward Osmosis Membrane

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3.1.1 Chemistry and structure of the membranes

The calculation method of β-phase content was explained as follow; the intensity of the absorbance peak at 840 cm^{-1} of the β-phase and at 762 cm^{-1} for the α-phase was calculated and used in the following equation to estimate the amount of β-phase[1, 2];

$$(\beta\ \%) = \frac{A_\beta}{\left(\frac{K_\beta}{K_\alpha}\right) * A_\alpha + A_\beta} * 100$$

Where, (β %) is the percent of β-phase content; the $\boldsymbol{A_\beta}$ and $\boldsymbol{A_\alpha}$ are the infrared absorbance at 840 and 762 cm−1, characteristics of the β-and α-phases, respectively; and Kβ (7.7 × 104 cm^2.mol^{-1}) and Kα (6.1 × 104 cm^2.mol^{-1}) are the absorption coefficient at the respective wavenumber.

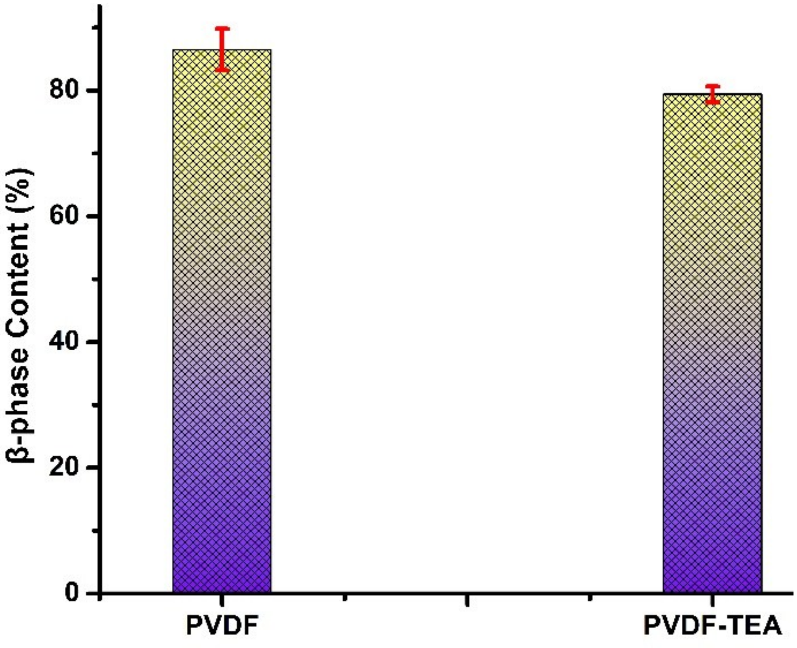
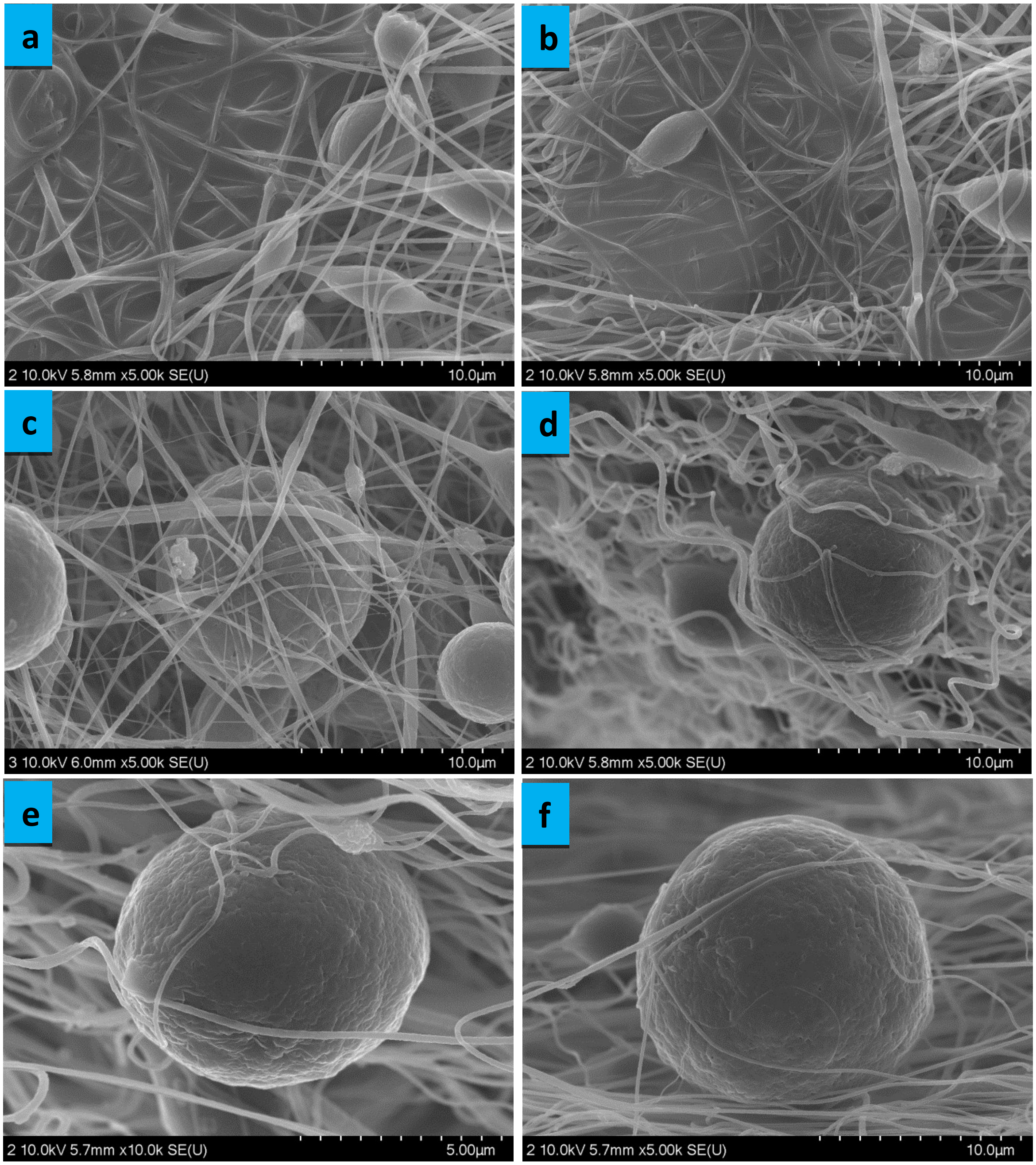


Fig.S1: the β-phase content for the support layer before and after treatment

Numerically, Fig. S1, the β-phase content decreased from 86.5±3.3% in the pristine PVDF to 79.4±1.25% for the treated membrane; owing to the decline in the absorbance intensity of the $\boldsymbol{\beta}$ at 840 cm^{-1} as shown in Fin.2B.

3.1.2 Morphology of the membranes



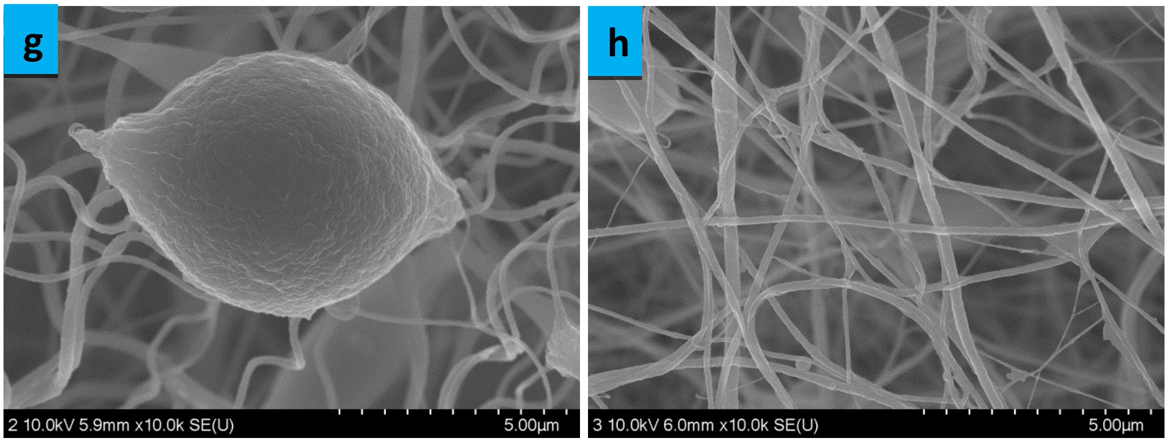


Fig.S2: FE-SEM images for the modified support layer (PVDF-TEA). (a and b) are the forming of the dense layer on the surface at some points, (c-f) the agglomeration of the short nanofibers and forming the balls having the dense layer, and (g and h) the ball and the cross linking of PVDF-TEA, respectively.

Moreover the big balls in Fig.S2 may be formed due to the agglomerating of the short electrospun nanofibers. In addition, the sample of PVDF-TEA was scanned (using FE-SEM) at different 8 positions as shown in Fig.S2 (a-h). From the results it can be claimed that, through the treatment process some of the short nanofibers may be agglomerate under the TEA solution, then the cross linking occurred on the surface of this part (ball) making a dense layer as formed on the flat surface Fig.S2a and b. Moreover, the balls with dense surface finally were formed as shown in Fig.S2 (c-f) and by focusing in these images it can be noticed that, the long nanofibers were partially covered and partially stuck to these balls. However, Fig.S2 (g and h) concluded the treatment process as a ball due agglomeration and the cross linking of the long nanofibers, respectively.

3.1.3 Wettability, work of adhesion and surface energy of TFC-FO membrane.

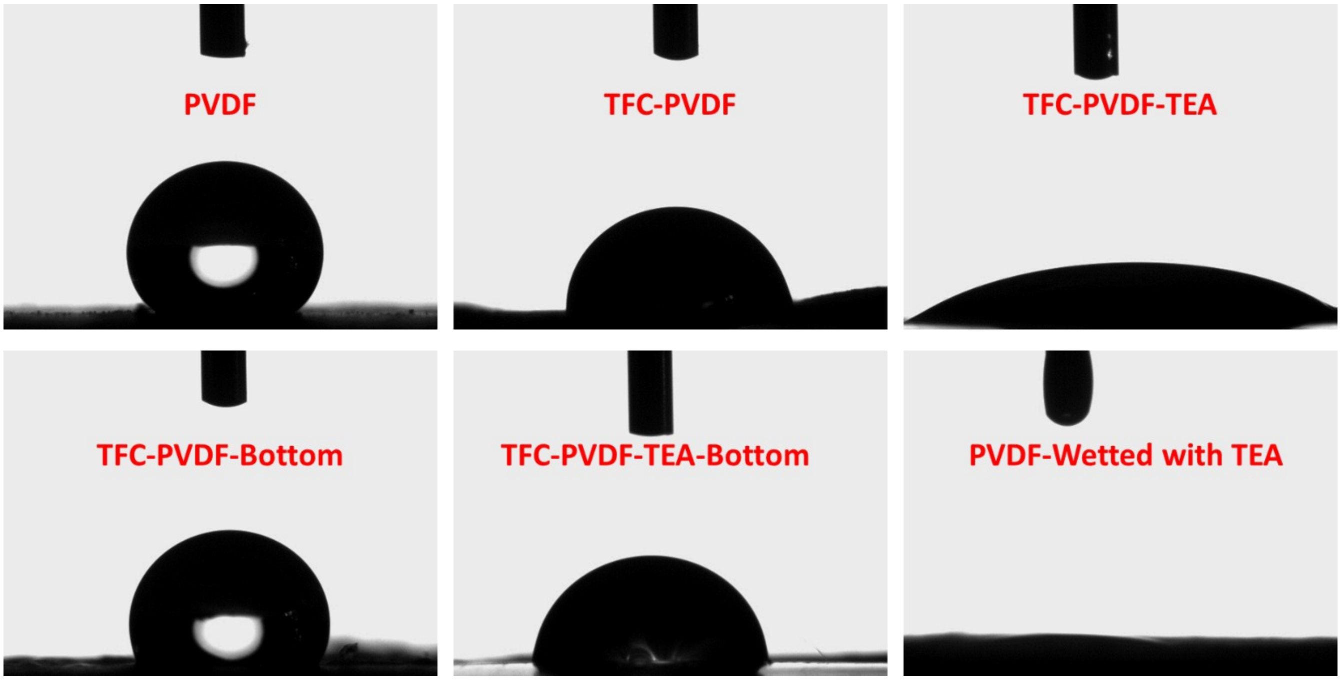


Fig. S3: the images of the water contact angle of the support layers and TFC membranes.

3.2 Estimation of the transport parameters of the membranes.

The transport parameters were estimated using an algorithm (Microsoft Visual Basic within Microsoft Excel) that developed by other researchers[3]. In brief, the experimental data of the water and reverse salt flux from FO experiment, under 4 different draw solution concentrations, were used to estimate the intrinsic transport parameters; A, B, and S. Furthermore, the different draw solution concentrations were used namely; 0.5, 1, 1.5, and 1.5M NaCl in the single FO experiment. Then the water and reverse salt flux were calculated based on eq.1 and eq.2. the results were used in the excel spreadsheet [3] where the input data are; the draw and feed concentrations, the water and the reverse salt flux at these concentrations, and the initial best guess of A, B, and S. Overall, the intrinsic transport parameters were calculated by performing a least-squares non-linear regression, using A, B, and S as regression parameters [3].

3.3 Influence of the modification on the CP.

The internatal concentration polyerization (ICP) and External concentration polyeraziation (ECP) were estimated based on Changwon Suh and Seockheon Lee model[4].

The C_i, C_{Dm} and C_{Fm} were estimated using eq.S1-eq.S3 based on the Suh and Seockheon report [4]. Sequentially, the drop in the osmotic pressure difference was calculated based on the difference in C_i and C_{Dm} divided by the theoretical osmotic pressure difference to estimate the ICP.

$$C_i = \frac{C_{Dm} + {}^{J_s}\!/_{J_w}}{exp(J_w K)} - \frac{J_s}{J_w}$$

eq.S1

$$C_{Dm} = \frac{C_{Db} + {}^{J_s}\!/_{J_w}}{exp(J_w / k_D)} - \frac{J_s}{J_w}$$

eq.S2

$$C_{Fm} = \left(C_{Fb} + \frac{J_s}{J_w} \right) exp\,(\frac{J_w}{J_F}) - \frac{J_s}{J_w}$$

eq.S3

Where, K and kD are the solute resistivity coefficient and the mass transfer coefficient, respectively; and D related to the draw solution.

Moreover, the numerical value by which the ECP was affected the pressure drop, was estimated based on the difference in C_{Db} and C_{Dm}, and in C_{Fm} and C_{Fb} the theoretical osmotic pressure difference to calculate the dilutive ECP and the concentrative ECP, respectively.

References

1. C. Ribeiro, V. Sencadas, J. L. G. Ribelles and S. Lanceros-Méndez, *Soft Materials*, 2010, 8, 274-287.
2. S. Lanceros-Mendez, J. Mano, A. Costa and V. Schmidt, *Journal of Macromolecular Science, Part B*, 2001, 40, 517-527.
3. A. Tiraferri, N. Y. Yip, A. P. Straub, S. R.-V. Castrillon and M. Elimelech, *Journal of Membrane Science*, 2013, 444, 523-538.
4. C. Suh and S. Lee, *Journal of Membrane Science*, 2013, 427, 365-374.