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A Facile Route to Enhance the Water Flux of Thin-Film Composite Reverse Osmosis Membrane: Incorporating Thickness-Controlled Graphene Oxide in Highly Porous Support Layer

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Experimental

Contact angle measurements

Contact angle measurement on the support layer was conducted using a contact angle analyzer (KRÜSS, DSA100, Germany) and, subsequently, solid–liquid interfacial free energy is calculated as described in the previous study.[S1]

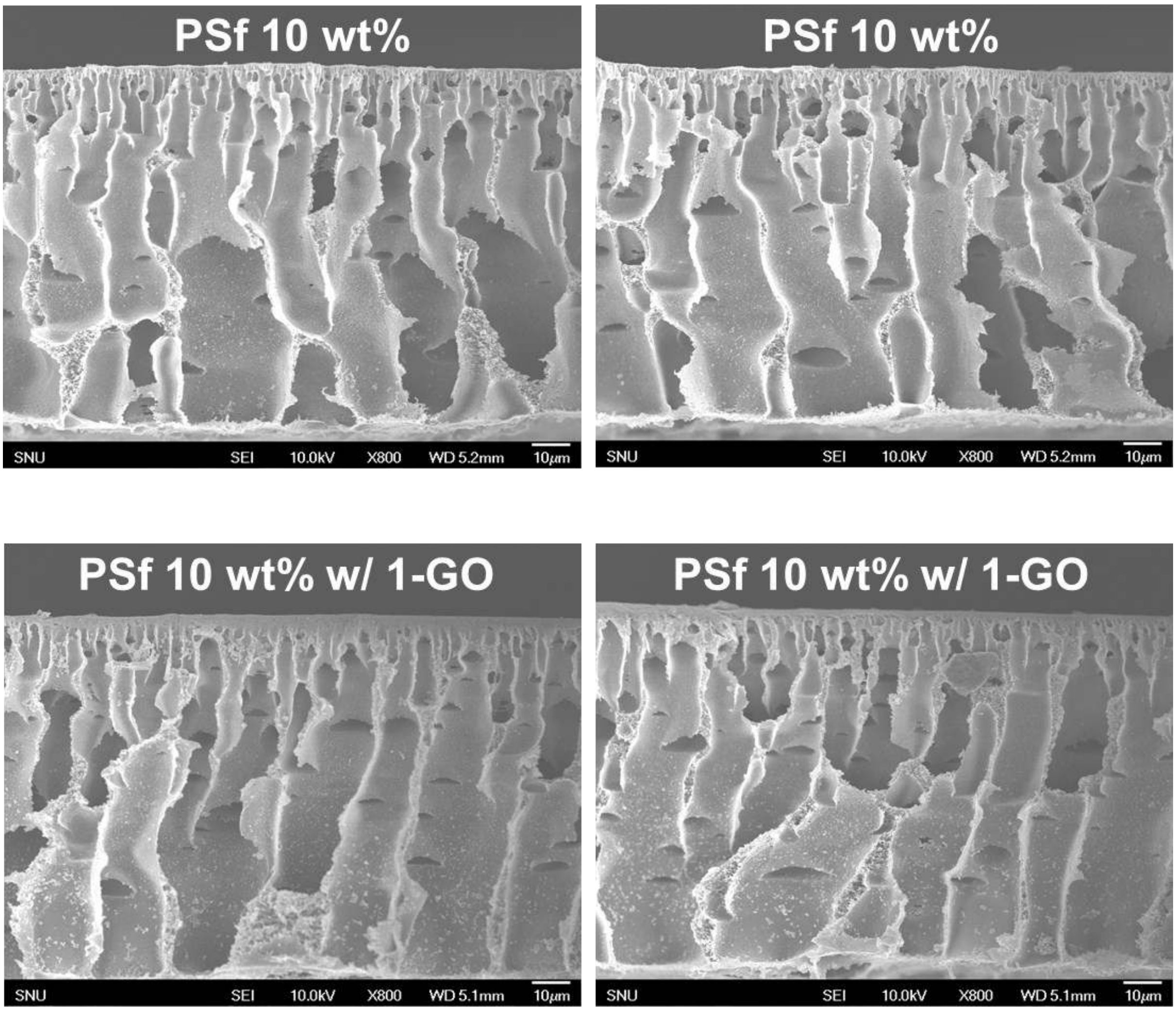

Fig. S1 The cross-sectional images of the 10 wt% support layers with and without 0.9 wt% 1-GO. The average thicknesses of the 10 wt% support layers with and without 0.9 wt% 1-GO were 93.4 (±0.7) μm and 92.6 (±1.6) μm, respectively (Number in parentheses: standard deviation (n=2)).

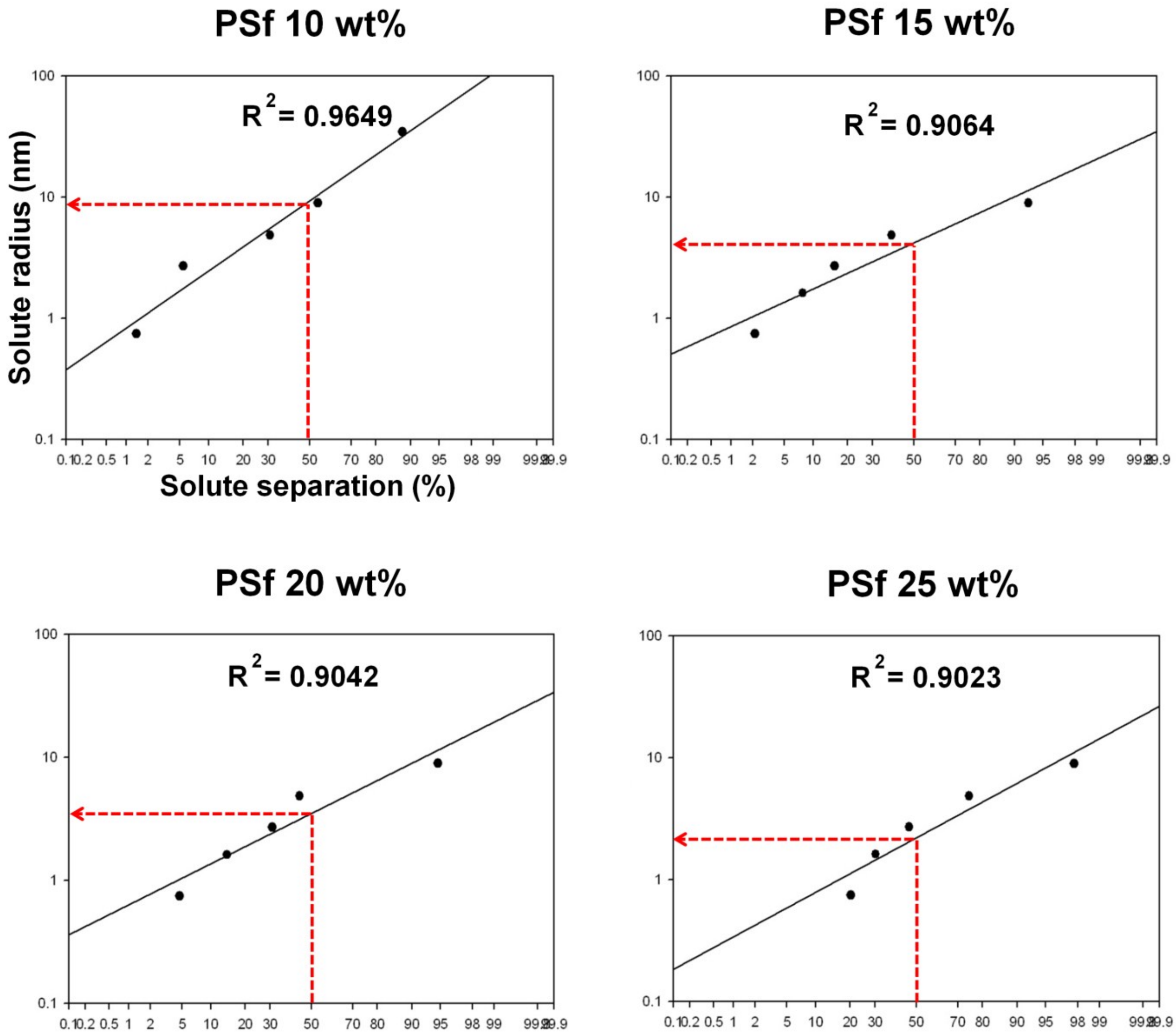

Fig. S2 Solute radius curves plotted on a log-normal probability paper for the support layers prepared with different polymer solution concentrations. Solute: Polyethylene glycol (PEG) or Polyethylne Oxide (PEO). Polymer solution: 10 wt%–25 wt% of PSf.

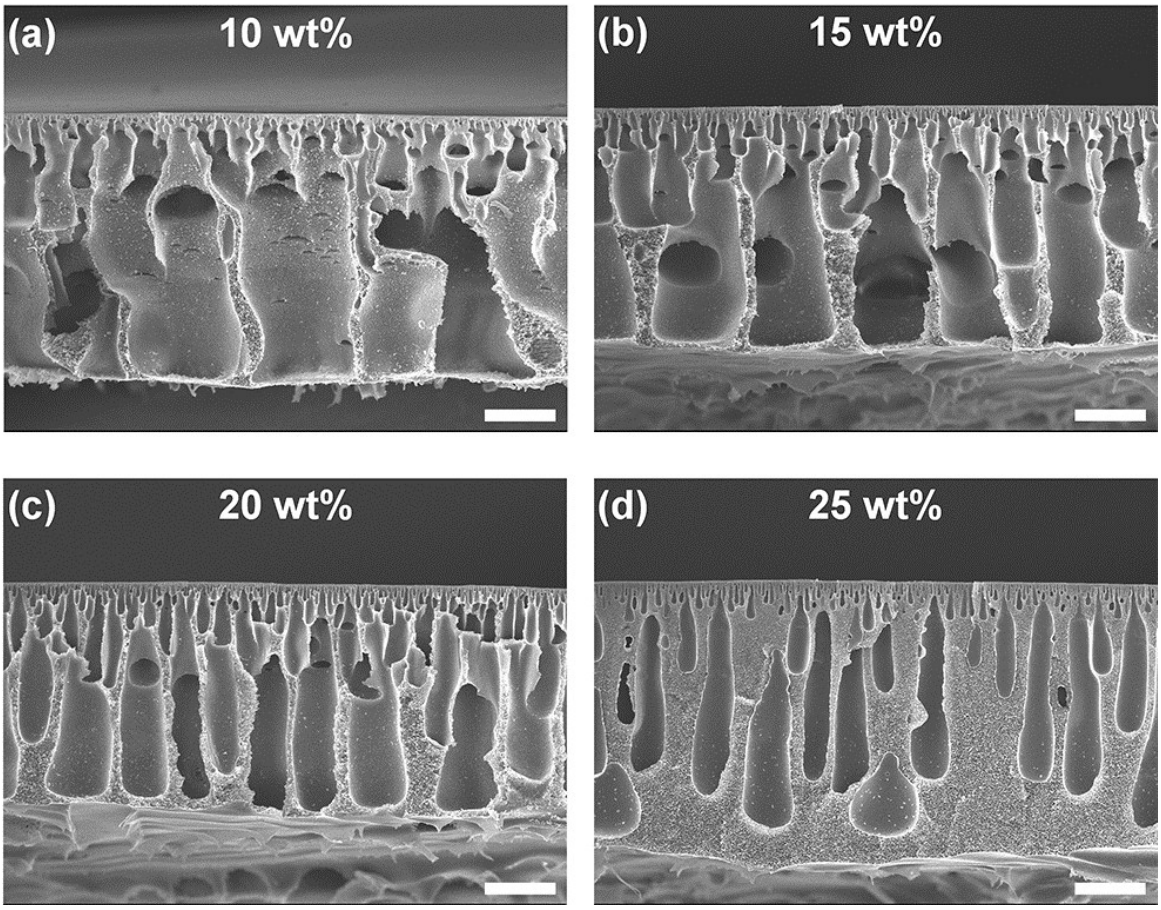

Fig. S3 Cross-sectional SEM images of support layers fabricated with various PSf concentrations (scale bar: 30 μm): (a) 10 wt%, (b) 15 wt%, (c) 20 wt%, and (d) 25 wt%.

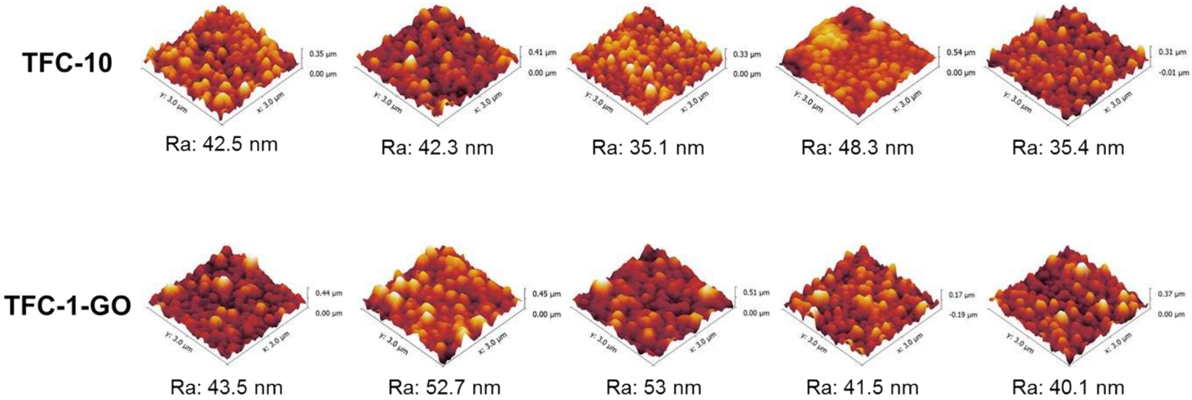

Fig. S4 SPM images of active layers formed on PSf 10 wt% support layer (top) and PSf 10 wt% support layer reinforced with 0.9 wt% 1-GO (bottom).

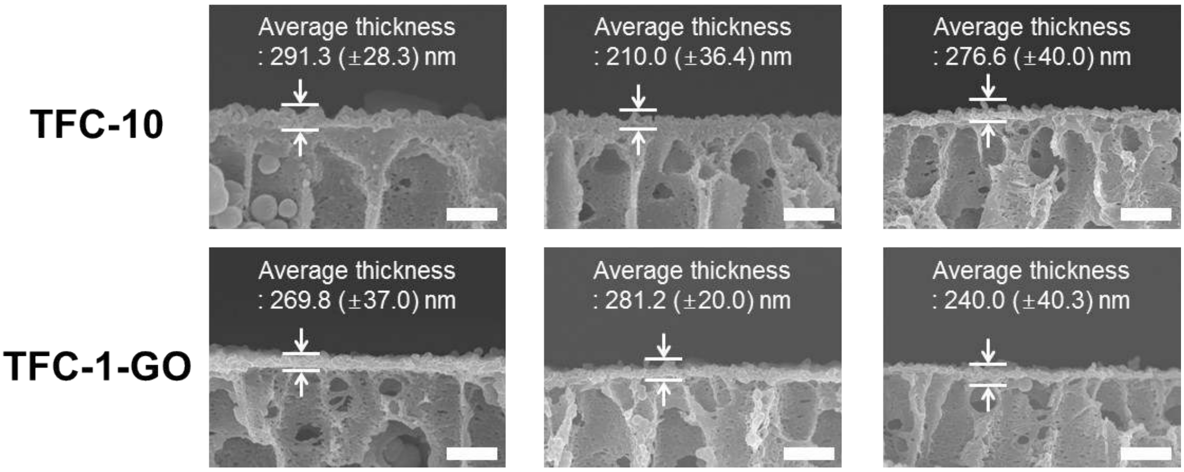

Fig. S5 Cross-sectional SEM images of TFC-10 (Top) and TFC-1-GO (bottom) membranes with the average thicknesses of their active layer (Number in parentheses: standard deviation (n=5)). Scale bar: 1 μm.

Table S1. Comparison of the solid-liquid interfacial free energy of the GO incorporated support layer with that of the support layers prepared with additives in the previous study. Number in parentheses: standard deviation (n=6).

	Membrane sample	$-\Delta G_{SL}$
This study	**PSf**	**92.8 ($\pm$ 3.0)**
	PSf with GO platelets	**99.3 ($\pm$ 1.4)**
Previous study	PSf	89.4
	PSf with polyethylene glycol (MW: 8K)	108.3
	PSf with polyvinylpyrrolidone (MW: 8K)	101.4
	PSf with polyvinylpyrrolidone (MW: 40K)	99.1

To clarify the reason for marginal effect of GO platelets on the characteristics of active layer, we compared the hydrophilicity of the GO incorporated support layer with that of the support layers with additives used in the previous study by estimating their values of solid–liquid interfacial free energy, $-\Delta G_{SL}$. Note that a larger value of $-\Delta G_{SL}$ means a more hydrophilic surface.[S1] As shown in Table S1, $-\Delta G_{SL}$ of the GO incorporated support layer increased only by 7% compared to that of the support layer without GO, whereas the additives used in the previous study increased that of the support layers by as much as 11-21%.

Reference

S1. K. Ghosh, B.-H. Jeong, X. Huang and E. M. Hoek, J. Membr. Sci., 2008, 311, 34-45.