Electronic Supplementary Information

A compact and scalable fabrication method for robust thin film composite membranes†

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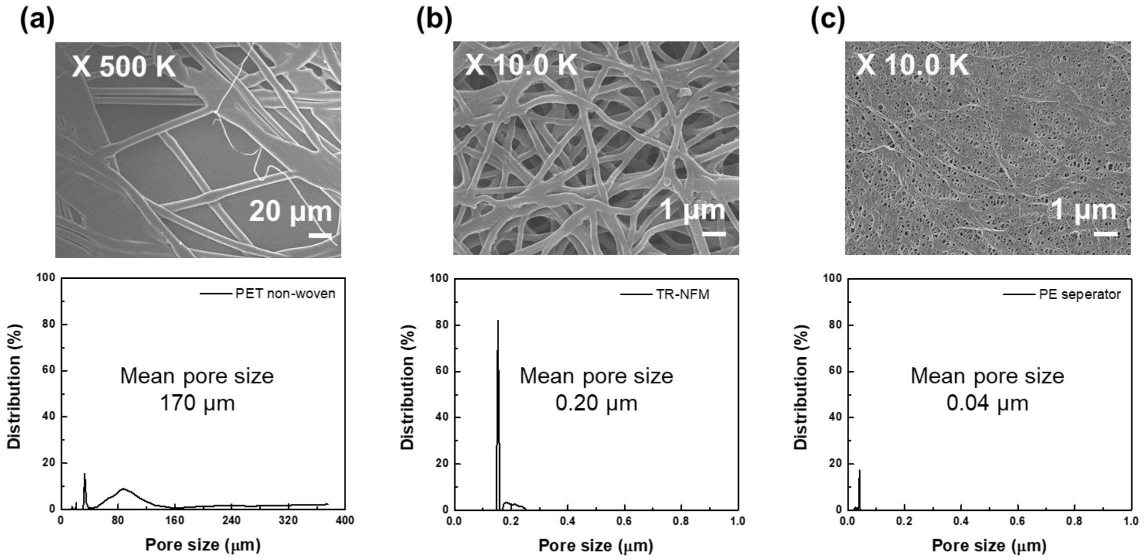

Fig. S1 The surface SEM images and pore size distribution of (a) PET non-woven, (b) TR-NFM, and (c) PE separator.

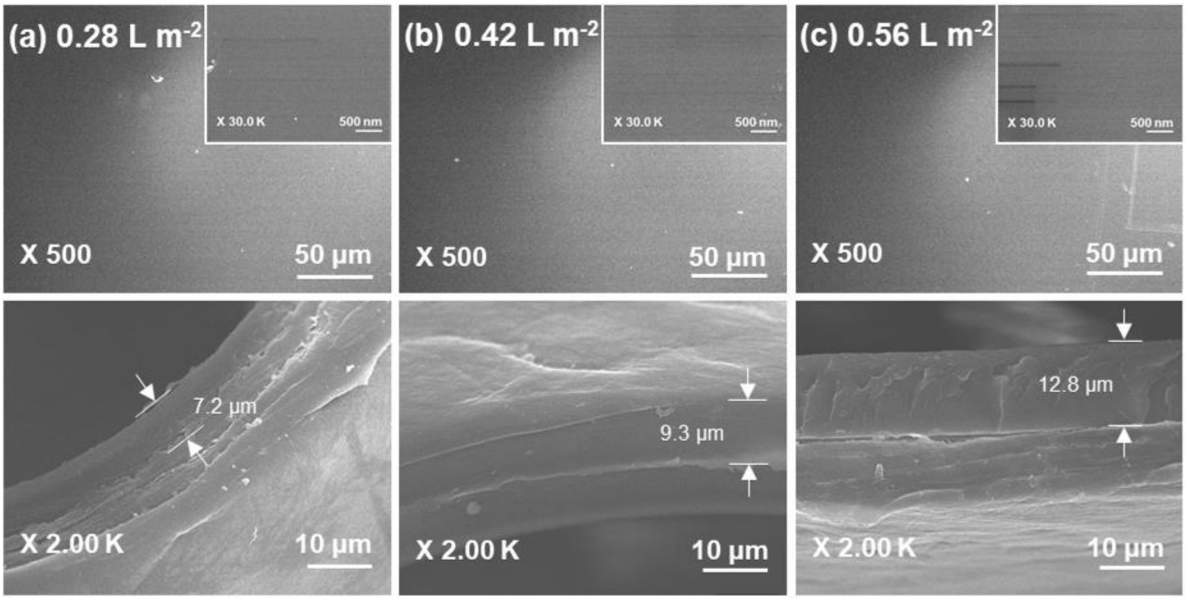

Fig. S2 The SEM images of developed thin film composite membranes on the PE separator which were coated with (a) 1.0 ml (0.28 L m^{-2}), (b) 1.5 ml (0.42 L m^{-2}), and (c) 2.0 ml (0.56 L m^{-2}) of loading volume at fixed membrane area (0.0036 m^{2}).

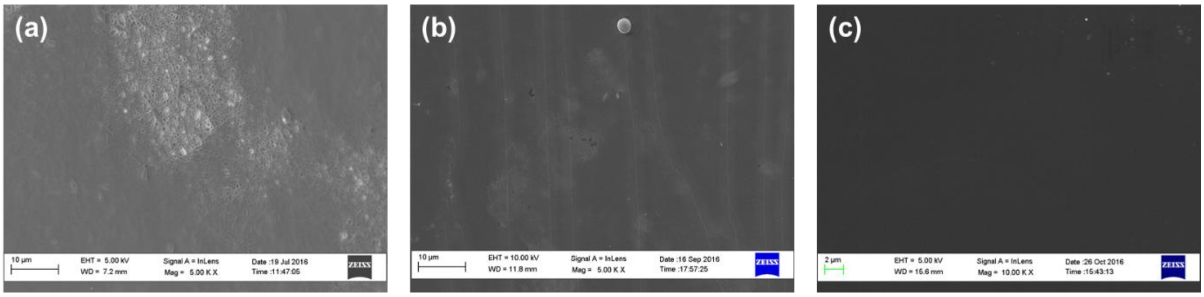

Fig. S3 The surface SEM images of the fabricated S-TFC-TR membranes at 0.56 L m^{-2} loading volumes with different concentration of sulfonated poly(arylene ether sulfone) solution: (a) 4 *wt*%, (b) 6 *wt*%, and (c) 8 *wt*%.

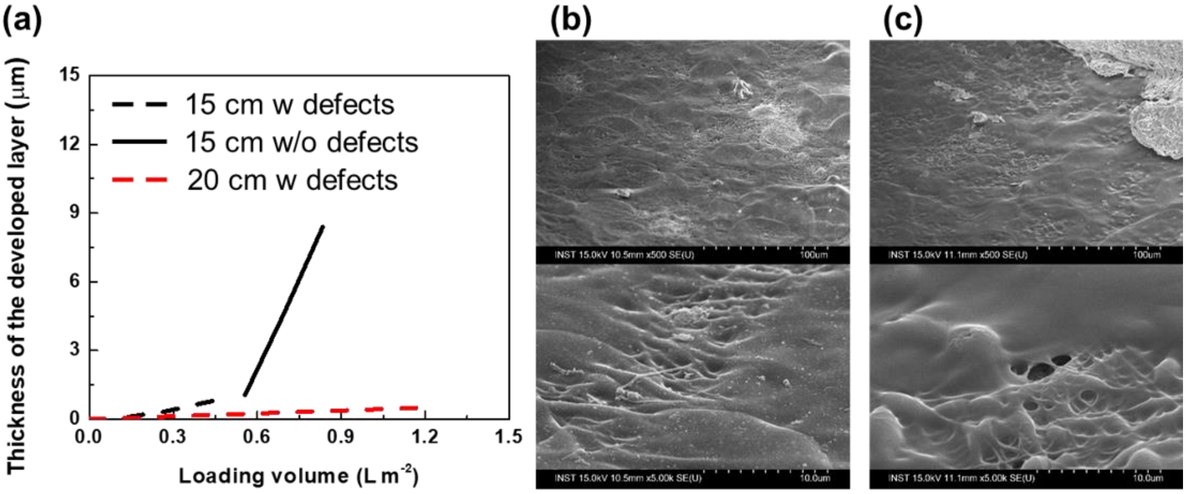

Fig. S4 (a) Schematic diagram of sprayed layer thickness according to loading volumes at different spray gun-to-collector distances (15 cm and 20 cm, respectively). The surface SEM images of the fabricated S-TFC-TR membranes fabricated at 20 cm of spray gun-to-collector distance with (b) 1.11 L m^{-2} and (c) 1.25 L m^{-2} of loading volumes, respectively.

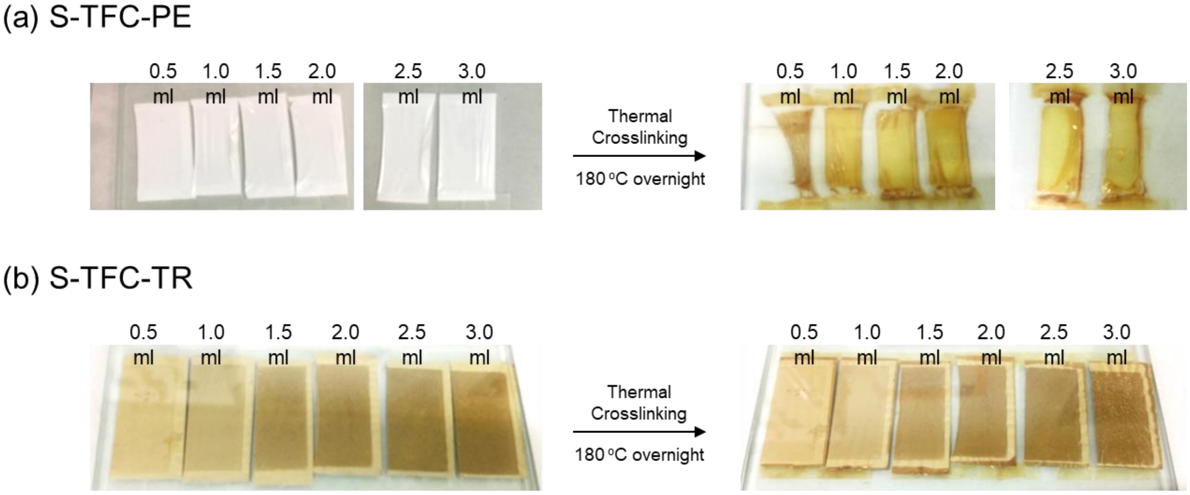

Fig. S5 Digital photographs of developed membranes on (a) PE separator and (b) TR-NFM before and after the thermal crosslinking.

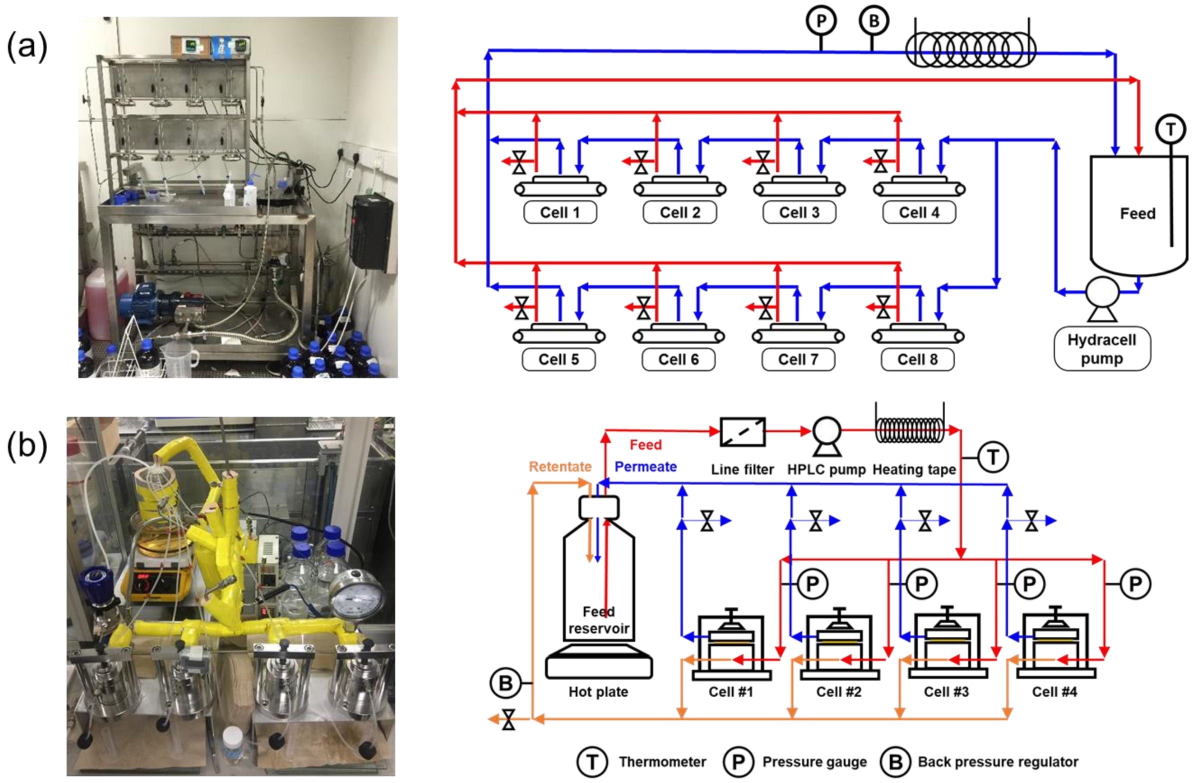

Fig. S6 (a) A cross-flow and (b) alternative high-temperature apparatuses for OSN test.

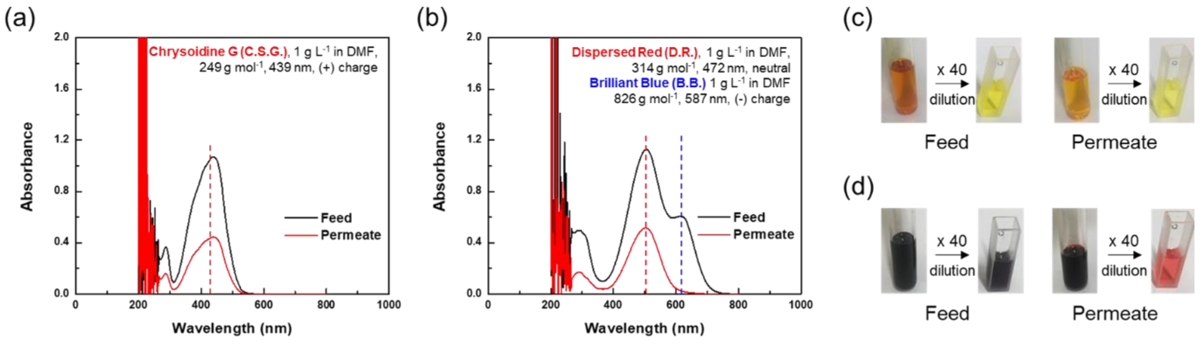

Fig. S7 UV spectra of feed and permeate solutions which were measured after 40 times dilution: (a) 1 g L^{-1} Chrysoidine G (C.S.G.)/DMF solution and (b) 2 g L^{-1} Dispersed Red (D.R.) and Brilliant Blue (B.B.)/DMF solution. Digital photograph of feed and permeate solutions before and after 40 times dilution of (c) 1 g L^{-1} C.S.G./DMF solution and (d) 2 g L^{-1} D.R. & B.B./DMF solution, respectively.

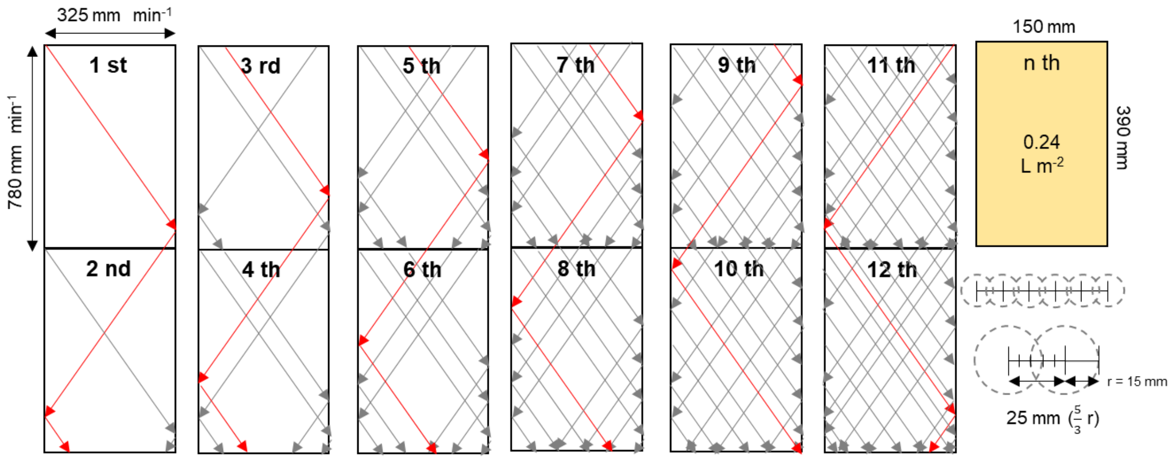

Fig. S8 Illustration for investigating a potential of mass production using the electrospinning machine which attached the spray gun instead of a syringe. The moving speed of traverse and machine direction was designed to overlap 1/3 radius of the sprayed area each other.

Table S1 Information for calculating the carbon footprint from distillation and each fabrication process.

	Unit area (m^2)	Polymer formula	Polymer usage ($kg\ m^{-2}$)	Carbon footprint from polymer ($kg\ m^{-2}$)	Solvent 1 formula	Solvent 1 usage ($kg\ m^{-2}$)	Solvent 2 formula	Solvent 2 usage ($kg\ m^{-2}$)	Carbon footprint from solvent ($kg\ m^{-2}$)	Water bath usage (L)	Carbon footprint from distillation ($kg\ m^{-2}$) [a]
PI conventional fabrication method	0.06	$C_{24}H_{16}N_2O_5$	0.11	3.38	C_5H_9NO	0.29	C_4H_8O	0.10	10.66	20	0.05
PEEK green fabrication method	0.06	$C_{21}H_{18}O_3$	0.06	2.09	CH_4O_3S	0.33	H_2SO_4	0.11	1.82	15	0.04
Proposed fabrication method	0.0585	$C_{26}H_{22}O_{6.4}S_{1.8}$ [b]	0.02	0.56	$(CH_3)_2SO$	0.29	-	-	3.93	-	-

	Unit area (m^2)	Crosslinker formula	Crosslinker usage ($kg\ m^{-2}$)	Solvent 3 formula	Solvent usage ($kg\ m^{-2}$)	Conditioner formula	Conditioner usage ($kg\ m^{-2}$)	Solvent 4 formula	Solvent 4 usage ($kg\ m^{-2}$)	Carbon footprint from coagulation bath ($kg\ m^{-2}$)	Total carbon footprint ($kg\ m^{-2}$)
PI conventional fabrication method	0.06	$C_6H_{16}N_2$	0.8	C_3H_8O	1.2	$C_{18}H_{38}O_{10}$	1.2	C_3H_8O	0.8	102.25	116.29
PEEK green fabrication method	0.06	-	-	-	-	-	-	-	-	0.04	3.95
Proposed fabrication method	0.0585	-	-	-	-	-	-	-	-	-	4.49

[a] Carbon footprint of distillation for water bath was calculated on the based of MSF plant. Liu *et al* reported that MSF plant can process 5,032,133 m^3 of water per day and it generates 13667.27 t of CO_2 per day.[1] Therefore, we assumed that the carbon footprint of distillation for water bath is 0.0025 $kg\ L^{-1}$.

[b] Average polymer formula was calculated from 40 % disulfonated poly(aryelene ether sulfone) and 60% poly(arylene ether sulfone).

Carbon foot print of distillation for DMF was calculated in order to compare with that of membrane fabrication processes from Szekely's work.[2] As followed previous work, DMF is the 10th largest system in OSN field. Annually, DMF was generated 2.79 x 10^6 kg and 2 x 10^6 kg of CO_2 was also generated for 70 % solvent recovery. Based on this relationship, the profile of CO_2 emission in distillation was drawn in **Fig. 11b**. To compare each system intuitively, the CO_2 emission was simply calculated following below assumptions: (a) CO_2 emission from distillation was considered from heating and evaporation to condensing for 70 % solvent recovery, (b) bench-scale membranes after use will be disposed by incineration, and (c) contaminated waste from each fabrication process is distilled.

References

1. J. Liu, S. Chen, H. Wang and X. Chen, *Energy Procedia*, 2015, **75**, 2483-2494.
2. G. Szekely, M. F. Jimenez-Solomon, P. Marchetti, J. F. Kim and A. G. Livingston, *Green Chem.*, 2014, **16**, 4440-4473.